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PreAgri

NEW SKILLS DEVELOPMENT IN PRECISION AGRICULTURE

Precision agriculture handbook for beginners

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PART A – Principles, needs and gains of precision agriculture

A.1. Introduction

With the global population continuing to grow the ever-increasing pressure on farmers to feed the world, demands new ideas, technologies and methods. Additionally, changing consumer patterns, global trends towards preserving nature together with land and water shortages add to the burden on farmers to balance the various demands. Until the development of precision agriculture and digitalization, farmers have had to manually monitor the condition of their livestock, environment or agricultural produce, even on large farms. Precision agriculture allows plants (or animals) to get precisely the treatment they need, determined with great accuracy thanks to the latest technology. To achieve this a range of technologies are used and more are added by the day. Technology can assist in strategic decision-making at farm level as well as with operational actions at plant level. The big difference with classical agriculture is that rather than determining the necessary action for each individual field, precision agriculture allows actions to be determined per square meter or even per plant.

The aim of the project is to help farmers gain knowledge, skills and competences on an innovative agricultural methodology which will support them to redesign their crop production. To accomplish these goals the partnership will construct an E-Learning platform, create this Precision agriculture handbook for beginners and will develop a VET Curriculum on precision agriculture that will contain the necessary information for supporting a VET trainer to educate and train farmers in precision agriculture. Goal of this Handbook is to set up a theoretical framework and knowledge of precision agriculture supported with real life best practices. This handbook presents a framework on precision agriculture starting with the current situation in agriculture of EU and project countries followed by a comprehensive literature review of research and development currently going on in the field of precision agriculture.

Current socio environmental situation
- characteristics of the rural population, gender and demographics related facts

Literature review on precision agriculture
- current research and achievements in the field of precision agriculture

Diagnostic report on skills demand of agricultural sector
- a report on the questionnaire results and presents the results of the questionnaire Workforce Skills Development in Precision Agriculture implementation

Digitalisation of agriculture
- technologies and solutions currently used in production

Policies and founding tools of precision agriculture
- contributions of policy makers in promoting precision and funding of precision agriculture

Future farmer
- challenges and changes predictions for future farmer

Part B

Best practices present the way precision agriculture technologies work in real-time farms, and how they affect the production and quality of life of farmers.

A.2. Current socio environmental situation

A.2.1. EU and global

In this chapter we aim to focus on characteristics of the rural population at large and raise attention to some gender and demographics related facts. It is important to note significant and surprising differences in the socio-economical pattern on global and on EU level. Land use and the environmental characteristics vary on geographical region; this chapter gives an overview on that too. Finally, the scope of the chapter becomes the training level of farmers and landowners in the PreAgri countries.

RURAL POPULATION

Globally known fact that in the last more than two decades the world's population increased by 29%, but a little more surprising that the rural population has only grown by 6%. This underpins the urbanization trends worldwide. In other words, in 1997, 55% of the global population lived in rural areas, while in 2017 only 45% lived in areas where agricultural production is possible at all. This means among others, two main circumstances: once the population in need for food and alimentation seriously increased, secondly, less and less people choose agriculture as profession for way of living and livelihood.

Meanwhile in Europe a much more moderate population growth (3%) is detected in cities, and a serious depopulation in rural areas (11%). In other words, one quarter of the old continent's population lives in the countryside, which means a different lifestyle and absolutely defines the approach to agriculture in Europe.

GENDER

Going further on global livelihood, the 40% of the whole world's population – almost only women (!) – lived on agriculture based production by the end of 20th century, which decreased by approximately 12% until nowadays.

European statistics show that the employment in agriculture dropped from 11% to 5.7% which is in line with the above mentioned population repartition, even though it's somewhat better gender-balanced, as 90% female employment went down to 75% until 2017. All that – globally in Europe as well – can be seen because of mechanization, automation; secondly, the drop in willingness to work in the agriculture sector.

LAND USE

Looking at the environment-related trends globally, we can conclude that the agricultural land area has slightly (0.5%) dropped since 1997 but still is over 37% of total land area – in other words, more than the third of our land on Earth is involved into agricultural production which draws the attention on the manner and quality how sustainably we use these lands. Great achievement, that since 2007 the area of organic farming has doubled but it's still infinitesimal with its 69k hectares compared to our entire land use.

In Europe, as mentioned before, less people live in rural areas, in accordance with this, there is less area involved into agricultural use: only a fifth of the entire continent is used for food or feed production. The proportion of land used for organic farming has almost doubled in the past decade, despite general consumption might tend to be more conscious in Europe than other parts of the world.

ENVIRONMENTAL CHARACTERISTICS[1]

Another important, global-scale impact of agriculture on climate change is expressed in greenhouse gas (CO_2 equivalent) emissions. Shocking to learn that in the past more than two decades - when climate awareness has theoretically grown - greenhouse gas emission related to agriculture has increased by 19%.

However, in Europe, thanks to the direct investment into so-called climate-friendly solutions, this proportion has decreased by 17% since 1997. Important to note, that this is still far away from being enough to (1) balance the world's pollution, (2) stop global temperature rise and keep it under the critical 1.5°C degrees, (3) stop monocultures causing biodiversity loss, extinction and soil degradation.

To conclude, when we talk about precision agriculture, we have to keep in mind these trends and aim for more sustainable solutions and a more socially responsible, balanced structure in agriculture. Precision agriculture should decrease unfavorable impacts of agriculture, such as greenhouse gas emissions, soil erosion, over usage of chemicals, exploitation of natural and human resources while providing healthy and enough food for the world's population.

DEMOGRAPHICS[2]

Some projects already exist for promoting opportunities for youth, generally supported by governments and well-known international NGOs. As an example, Korea International Cooperation Agency (KOICA) leads the Green jobs for rural youth employment project that lasts for more than 4 years and focuses on West-African countries' youth.

Once, the project aims to provide green jobs in rural areas and agricultural sectors for youth through training for young people, and building their capacities to address local. The strategy is to promote youth-led, green employment and entrepreneurship opportunities in rural areas.

Secondly, the project assists governments in their transition to the Green Economy by fully utilizing the developmental potential of rural areas and agricultural sectors by mainstreaming green jobs and youth employment in national policies and strategies, achieving Nationally Determined Contributions (NDCs) for climate change and building sustainable food systems.

The population is ageing in many countries, especially the wealthier ones, but the trend is evident even in developing countries. In South Asia, male outmigration has led to women playing an increasingly important role in the agricultural labor force (often referred to as the feminization of agriculture).

Some of the main constraints to the greater use of drones are the cost of the drone itself and their limited flight range before the power supply is exhausted. The development of rental markets for drones (see the previous subsection) and improved battery storage technologies are likely to alleviate these constraints over time and make the technology affordable to smallholders.

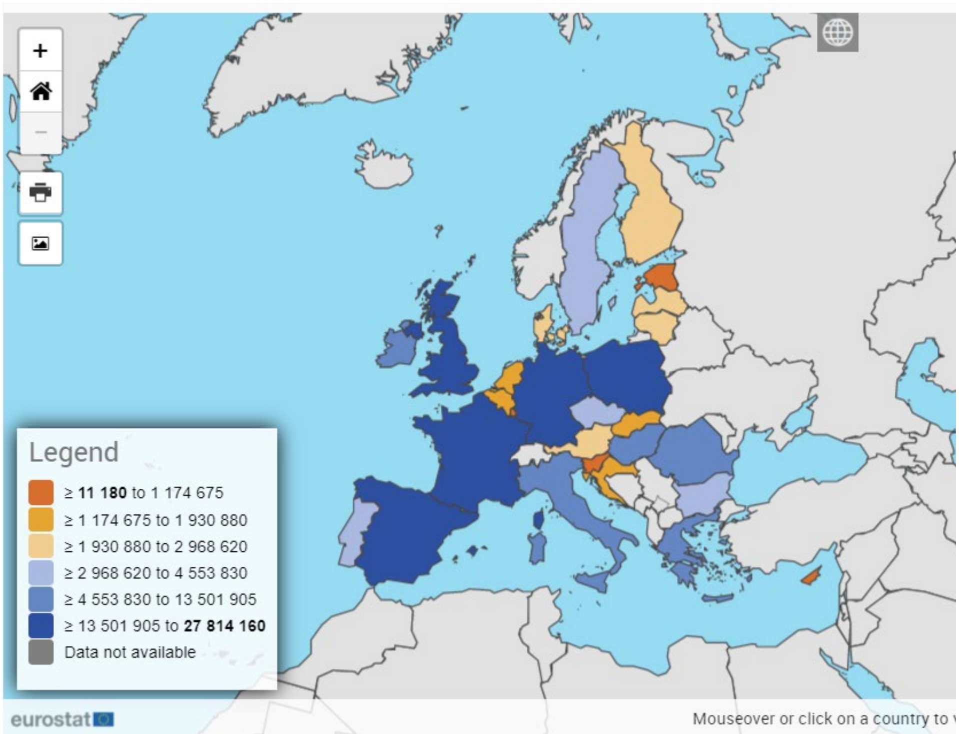
[1] http://faostat.fao.org/static/syb/syb_5000.pdf , http://faostat.fao.org/static/syb/syb_5400.pdf

[2] Green jobs for rural youth employment, http://www.fao.org/publications/card/en/c/CB2356EN
Dynamic development, shifting demographics and changing diets p132, p151
http://www.fao.org/publications/card/en/c/I8499EN

EDUCATION LEVEL OF STAKEHOLDERS

In the next section we will be analyzing the number of farm managers having basic training, practical experience only, full agricultural training; the total of these three meaning training at once. Statistics are available for 2013 and 2016, for all European countries. There is no data available corrected to the population, therefore we are able to analyze only total number of participating farm managers, regardless the entire population of the country.

Therefore, training of farm managers tends to be popular in countries with huge territories and/or areas able to be used for agriculture: first top five countries stayed France, Spain, UK, Germany and Poland in the above-mentioned period of time (Picture 1).



Picture 1. Training of farm managers

Narrowing the filters down to the countries of the PreAgri project, we can conclude that training of farm managers stayed almost unchanged in Hungary, Slovakia and Spain, participants' number dropped by 7% in Greece and increased by 17% in Croatia (Graph 1).

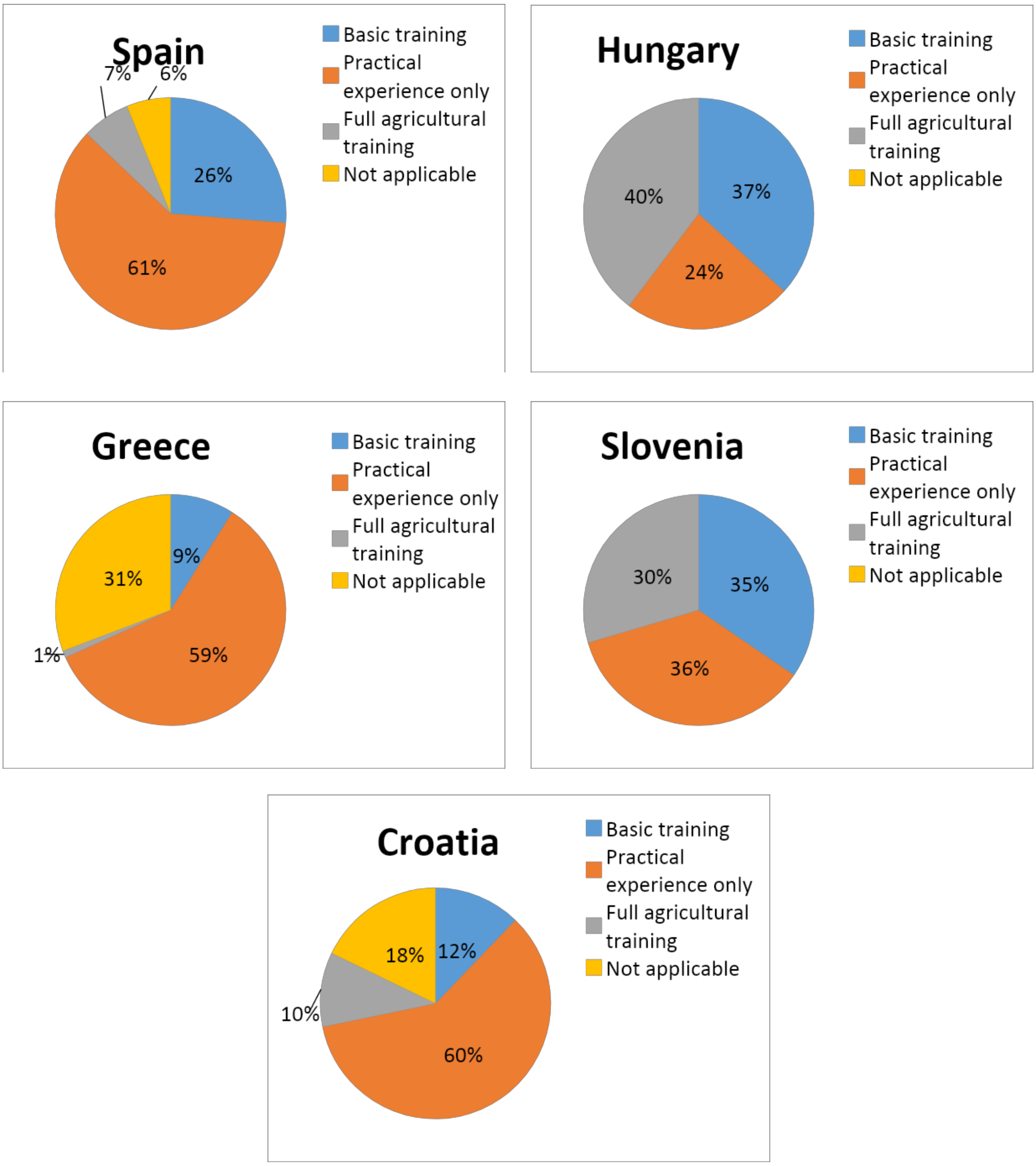
Graph 1. Change in the training of farm managers

Farmers training level[3]

Farm managers' agricultural training is thought to have among others an influence on the environmental impact of farming. The farm manager is the natural person responsible for the normal daily financial and production routines of running an agricultural holding. Per holding, only one person can be identified as the farm manager. Sometimes the farm manager is also the owner of the holding; however, the farm manager can also be a different person than the owner. The highest agricultural education level that was obtained by the manager:

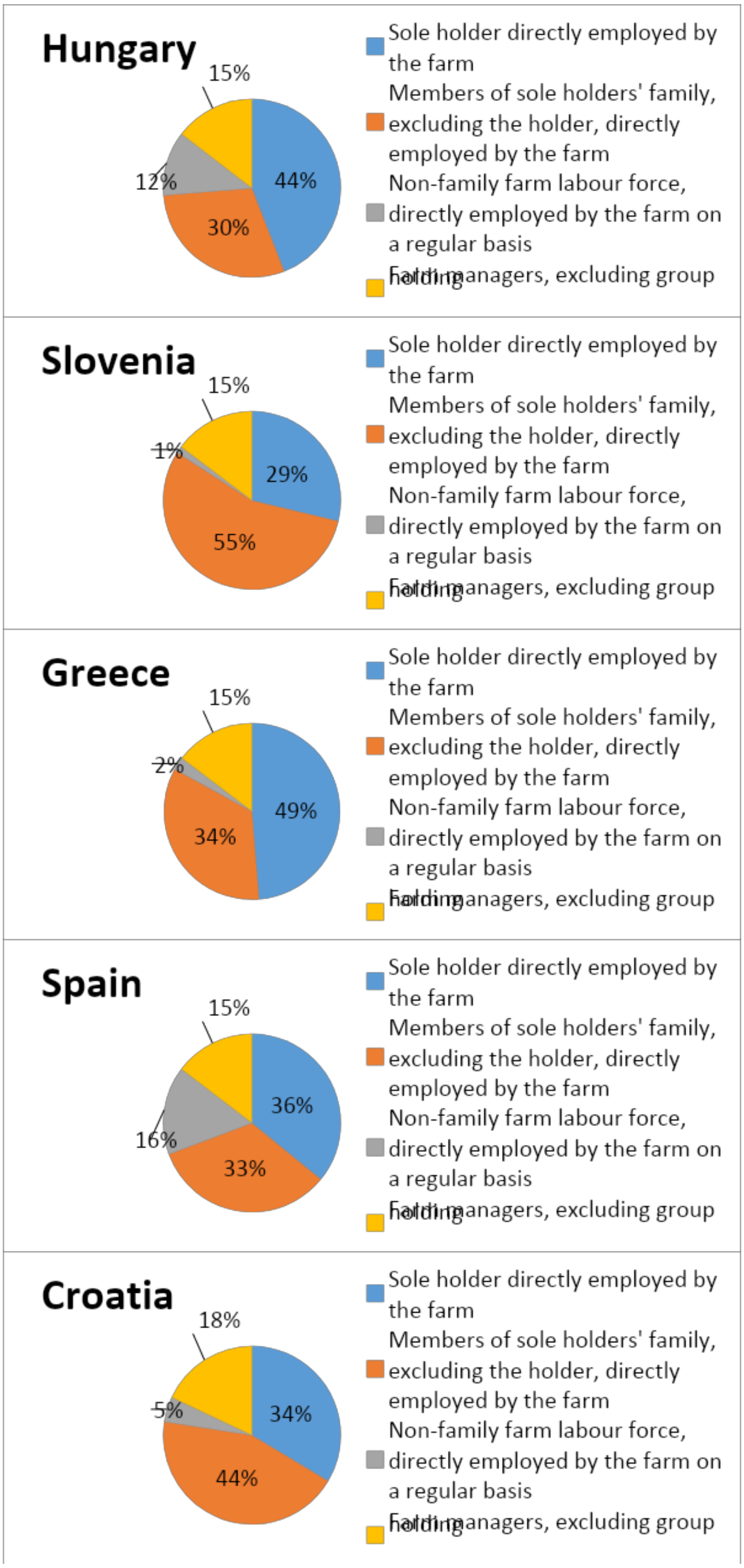
- BASIC - basic agricultural training; if the manager took any training courses completed at a general agricultural college and/or an institution specializing in certain subjects (including horticulture, viticulture, silviculture, pisciculture, veterinary science, agricultural technology and associated subjects); a completed agricultural apprenticeship is regarded as basic training;
- PRACT - only practical agricultural experience; if the manager's experience was acquired through practical work on an agricultural holding;
- FULL - full agricultural training; if the manager took any training course continuously for the equivalent of at least 2 years full-time training after the end of compulsory education and completed at an agricultural college, university or other institute of higher education in agriculture, horticulture, viticulture, silviculture, pisciculture, veterinary science, agricultural technology or an associated subject;
- VET - Farm managers can also undertake vocational training; a training measure or activity provided by a trainer or a training institution which has as its primary objective the acquisition of new skills related to the farm activities or activities related directly to the holding or the development and improvement of existing ones;

[3] https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Farmers_training_level



Graph 2. Training of farm managers[4]

[4] https://ec.europa.eu/eurostat/databrowser/view/EF_MP_TRAINING__custom_528679/default/map?lang=en

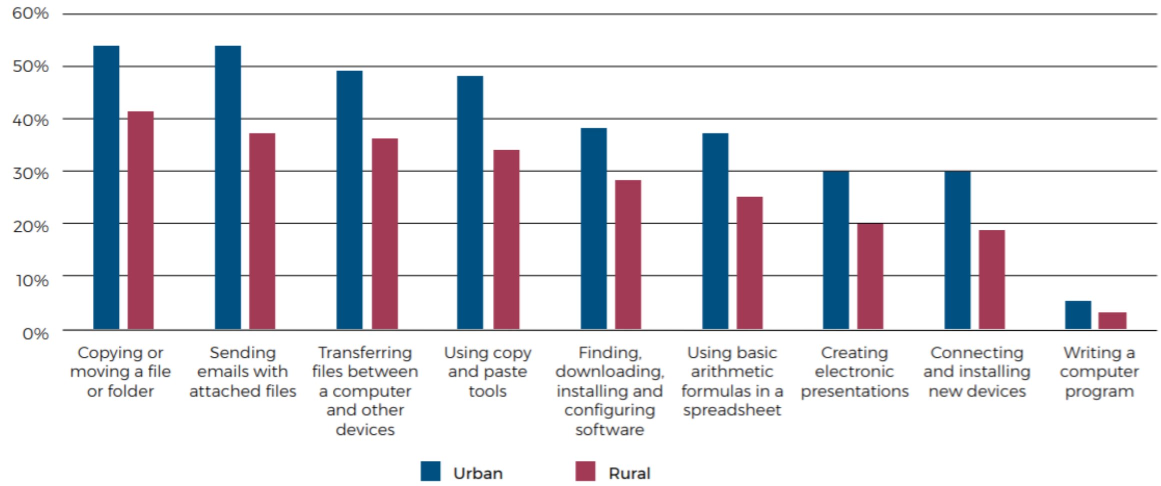


Graph 3. Employment - Labor force – farm[5]

[5] https://ec.europa.eu/eurostat/databrowser/view/ef_lf_size/default/bar?lang=en

DIGITALIZATION IN AGRICULTURE[6]

In the agrifood sector, the digital transformation will change the structure of the labor market and the nature of work. It will redefine the role of farmers and agripreneurs and alter the skill set required in the agrifood sector. It may also transform how and where people work and is likely to affect female and male…" In many LDCs and developing countries, basic computer courses are not integrated in primary or secondary education due to a lack of interest from governments and the private sector to invest in building new digital skills rather than hiring already skilled labor. There is also a lack of relevant skills among teachers.



Graph 4. Average proportion of the population with a specific digital skill, 2017

CLIMATE CHANGE AND EDUCATION - SUSTAINABILITY DEVELOPMENT GOALS

Improved farming practices reduce impacts of **climate change** - but barriers to their adoption remain[7]

SDGs

- 2 Zero Hunger
- 5 gender equality
  - http://www.fao.org/sdg-progress-report/en/#sdg-5
  - Women also make up a substantial share of the agricultural labor force in developing countries, yet relatively fewer women than men have ownership and/or secure tenure rights over agricultural land. Substantial progress is still needed in both legal frameworks and their implementation to realize women's land rights.
- 6 Clean water and sanitation
- 9 industry, innovation and infrastructure
- 12 Responsible consumption and production
- 14 Life below water
- 15 Life on land

[6] http://www.fao.org/3/ca4887en/ca4887en.pdf p10, p14, p4

[7] http://www.fao.org/publications/card/en/c/351573de-de18-41ed-b09a-01ae2c97e100

A.2.2. Countries of the project

HUNGARY

Demography, land use and farm structure

Despite less than a third of the population (29, 85%) live in rural areas, with the exception of the Central Hungary region, all regions of Hungary are among the convergence regions of the EU (NUTS 2 regions with a per capita GDP less than 75% of the EU average). According to the latest data, there were 7,843 farming organizations and 357,257 individual farms in 2016 operating in agricultural areas.[8] Although individual farmers use larger area overall, due to their high number, farms are fragmented, and in Hungary, large farms dominate. Their proportion is also high at the regional level.[9]

Agricultural education

Four-fifths of individual farmers do not have a school-based agricultural education. Most of them (72.91%) have only practical experience.[10] According to Eurostat data, the educational level of Hungarian agricultural managers is unfavorable at the regional level as well.[11] The proportions of students in agricultural education confirm all this. Based on the data the interest of young people is low compared to other fields of education.[12] Although the age distribution of agricultural employees is one of the most favorable in the region, in case of the individual farmers almost four-fifths of them are over 45, of which nearly one-third are of retirement age.[13]

Agriculture and nature conservation

The correct use of arable land, which provides four-fifths of the country, is particularly important not only for agriculture, but also for nature conservation and biodiversity. It is important to be aware of the responsibility of large-scale farmers (e.g. livestock farms or monoculture growers) to protect natural resources, who - as primary toxic pollutants - directly or indirectly pollute our natural resources, reduce species richness and change species distribution. Although purely growth-oriented intensification (without environmental considerations) increases the amount of production per unit area and generates more profit in the short term, the same time, emissions per unit area increase, leading to environmental destruction, soil erosion and long-term yield losses.

Aware of all this, drastic, real "greening" is needed in both European and Hungarian agricultural production. The possibilities of precision farming provide continuous, real-time feedback not only on the state of the stock, but also on the state of the environment. That is why - in addition to increasing yields - ecological and sustainability, considerations must be given at least equal weight when applying

[8] HCSO - Agricultural census: https://www.ksh.hu/agricultural_census_fss_2016
[9] Eurostat [EF_M_FARMLEG]
https://ec.europa.eu/eurostat/databrowser/bookmark/dea13459-9f13-4941-a299-786e2ef36849?lang=en&page=time:2016
[10] HCSO - Agricultural census: https://www.ksh.hu/agricultural_census_fss_2016
[11] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_mptrainman&lang=en
[12] HCSO -
[13] Eurostat [LFSA_EGAN2]
https://ec.europa.eu/eurostat/databrowser/view/LFSA_EGAN2__custom_732638/default/table
HCSO: Number of farmers in individual farms by age group:
https://www.ksh.hu/docs/hun/agrar/gszo2016/gszo2016_10.xls

precision farming. However, all of this requires skilled young farmers who manage our common natural resources responsibly in long-term.

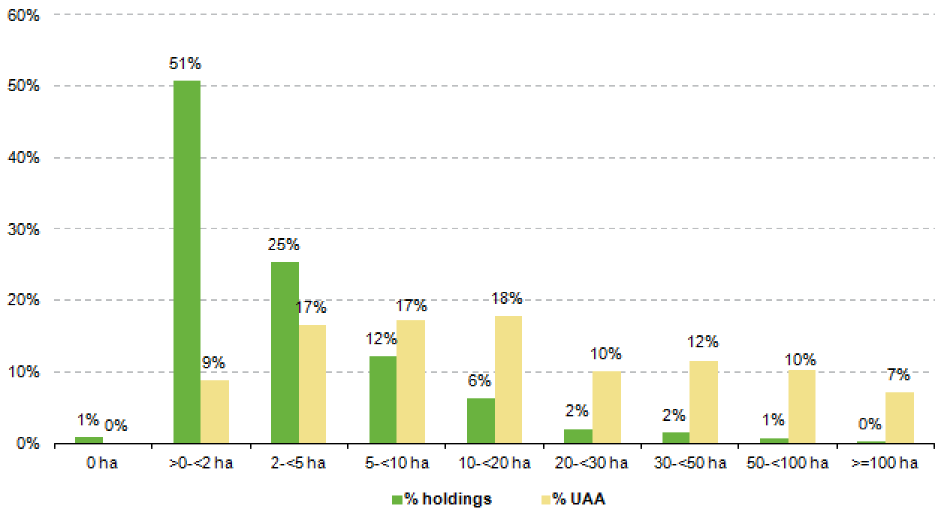
GREECE

Demographics and environmental characteristics

Greece is a country in southeastern Europe with thousands of islands throughout the Aegean and Ionian seas. According to the data of Hellenic Statistical Authority, the population is approximately 10.7 million. Athens its largest and capital city, followed by Thessaloniki. Eighty percent of Greece consists of mountains or hills, making the country one of the most mountainous in Europe. The climate of Greece is primarily Mediterranean featuring mild, wet winters and hot, dry summers.
We can see in the following (table 1) the land use in each region of Greece and (Graph 5) the number of holdings and utilized agriculture area (UAA) by UAA size classes, Greece.

	Total	Farming by owner		Farming by tenant		Shared farming or other modes	
	(ha)	(ha)	(% of total UAA)	(ha)	(% of total UAA)	(ha)	(% of total UAA)
Greece	3 477 930	2 161 580	62.2	1 227 800	35.3	88 540	2.5
Anatoliki Makedonia, Thral	346 760	190 120	54.8	152 520	44.0	4 120	1.2
Kentriki Makedonia	641 670	296 610	46.2	335 770	52.3	9 290	1.4
Dytiki Makedonia	222 760	75 570	33.9	121 940	54.7	25 250	11.3
Thessalia	392 200	249 710	63.7	139 130	35.5	3 370	0.9
Ipeiros	104 140	58 950	56.6	39 830	38.2	5 370	5.2
Ionia Nisia	77 000	63 390	82.3	11 770	15.3	1 840	2.4
Dytiki Ellada	298 450	225 860	75.7	67 860	22.7	4 730	1.6
Sterea Ellada	334 580	226 870	67.8	95 100	28.4	12 610	3.8
Peloponnisos	338 210	270 450	80.0	59 330	17.5	8 430	2.5
Attiki	46 970	38 600	82.2	6 660	14.2	1 720	3.7
Voreio Aigaio	164 870	89 210	54.1	73 720	44.7	1 950	1.2
Notio Aigaio	99 180	64 730	65.3	29 100	29.3	5 350	5.4
Kriti	411 130	311 530	75.8	95 100	23.1	4 510	1.1

Table 1: Land use in each region of Greece



Graph 5: Number of holdings and utilized agriculture area (UAA) by UAA size classes, Greece, 2010 (%)

Key indicators[14]

As shown in Table 2, there were 723 010 agricultural holdings in Greece. Although 94 050 farms ceased their activity between 2000 and 2010 (-12%), Greece was one of the EU Member States with the largest number of holdings in 2010.

Greece	2000	2010	Change (%)
Number of holdings	817 060	723 010	-11.5
Total UAA (ha)	3 583 190	3 477 930	-2.9
Livestock (LSU)	2 540 110	2 406 520	-5.3
Number of persons working on farms (Regular labour Force)	1 431 250	1 212 720	-15.3
Average area per holding (ha)	4.4	4.8	9.7
UAA per Inhabitant (ha/person)	0.33	0.31	-6.4

Table 2: Key indicators

As the fall in the number of holdings was sharper than that of the agricultural land area, the average size of holdings rose between the two reference years, from 4.4 to 4.8 hectares per farm. However, Greece was among the EU Member States with the lowest average area per farm, with only Romania (3.4 ha per farm), Cyprus (3.0 ha) and Malta (0.9 ha) having smaller values.

As widely seen across the EU-2815 the agricultural labor force also decreased in Greece, from 1.4 million in 2000 to 1.2 million in 2010 (-15%). However, the regular agricultural labor force represented a quarter of the active population in 2010, which was one of the highest proportions among the EU Member States.

As presented in Table 2, there were about 2.4 million livestock units (LSU) in Greece, a 5.3% decrease compared to 2000 (-133 590 LSU). Among the other EU-28 countries, Hungary (2.5 million LSU) and Portugal (2.2 million LSU) had similar values.

Education Level

The standards of the educational level have changed significantly: on average, younger people reach higher levels of education than older people do. In 2019 , 80,8% of people aged 25-45 in the EU had completed at least upper secondary education, compared with 66,2% of people aged 55-74.
Education level contributes to the development and modernization of agricultural production.

Agriculture, climate change and sustainability are a high priority

European Commission Rural development policy aims to improve competitiveness in agriculture and forestry, the environment and the countryside, as well as to improve the quality of life in rural areas, and to encourage the diversification of rural economies.

[14] https://www.statistics.gr/
https://en.wikipedia.org/wiki/Greece
[15] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:EU_enlargements

As agriculture has been modernized and the importance of industry and services within the economy has increased, agriculture has become much less important as a source of jobs. Consequently, increasing emphasis is placed on the role farmers can play in rural development, including forestry, biodiversity and the diversification of the rural economy, in order to create alternative jobs and provide environmental protection in rural areas.

Organic agriculture is an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on the minimal use of off-farm inputs and on management practices that restore, maintain or enhance ecological harmony.

In Greece, the number of holdings practicing organic farming increased dramatically between 2000 and 2007 from 1 460 to 27 700. In 2010, however this almost halved to 14 530 farms, accounting for 2.0% of the country's holdings. The agricultural area under organic farming followed the same trend, increasing rapidly from 52 090 to 192 930 hectares between 2000 and 2007, then decreasing sharply to 116 420 hectares in 2010. This area accounted for 3.3% of the country's UAA.

Slovenia

In Slovenia, more than ten years after the 2007-08 food price spike, conditions on world agricultural markets are significantly different. Production of many commodities has increased sharply, reaching record highs in the last periods.

Levels for most cereals, meat, dairy and fish, and cereal stocks climbed to the highest levels in historical highs. At the same time, demand growth has started to slow down. Therefore, agricultural commodity prices are expected to remain low. Similarly, a renewed increase in the next is unlikely in the next few years due to the current high level of stocks.

The weakening in demand growth is expected to persist into the next decade. The population will be the main driver of consumption growth for most commodities, although the growth rate of the population is projected to decline. This is particularly noticeable for staples such as cereals and roots, where consumption levels are close to saturation levels in many countries. On the other hand, growth demand for meat products is slowing down due to regional differences in preferences and constraints of disposable income, while demand for animal products, such as dairy products, is expected to grow and is expected to accelerate in the coming decade.

For cereals and oilseeds, feed will be the most important source of demand growth, followed by nutrition. A large share of the additional demand for feed will continue to come from China. However, the demand for feed is expected to slow down at global level, despite intensified livestock production. Much of the additional demand will come from regions with high population growth, such as sub-Saharan Africa, India and the Middle East and North Africa.

The growth in demand for cereals, vegetable oil and sugar cane as feedstock for biofuels is expected to be much more modest than in the last decade. While growth in the past decade biofuels contributed more than 120 megatons of additional demand for cereals, especially maize, this growth is expected to be virtually zero over the forecast period. In developed countries, existing policies are likely to not support much further growth. Future demand growth will therefore mainly come from developing countries, many of which have introduced policies that favor biofuels.

Exceptions to the general pattern of slowing per capita demand growth are sugar and vegetable oils. Per capita consumption of sugar and vegetable oils is expected to increase in developing countries because urbanization is driving increased demand for processed and (semi-)prepared foods. Changes in food consumption levels and diet composition mean that developing countries will continue to bear the 'triple burden' of undernutrition, over nutrition and inadequate nutrition.

Global agricultural and fisheries production is projected to increase by 20 per cent over the next decade, but with significant regional variations. A high growth is expected to be happening in East Asia, the Middle East and North Africa. In contrast, output growth in the developed world will produce growth that is expected to be achieved mainly through higher output growth in the developed world.

Croatia[16]

Workforce in Croatia

The total number of people employed in agriculture in 2016 is estimated at 36,990, and they account for 2.7% of the total number of employees in the Republic of Croatia. Compared to 2015, the number of persons employed in agriculture decreased by 3.9%

The age profile of farmers and forest owners: 58,8 % of holders of agricultural holdings are over 55 and only 4,1 % under 35 with a lack of generational renewal;

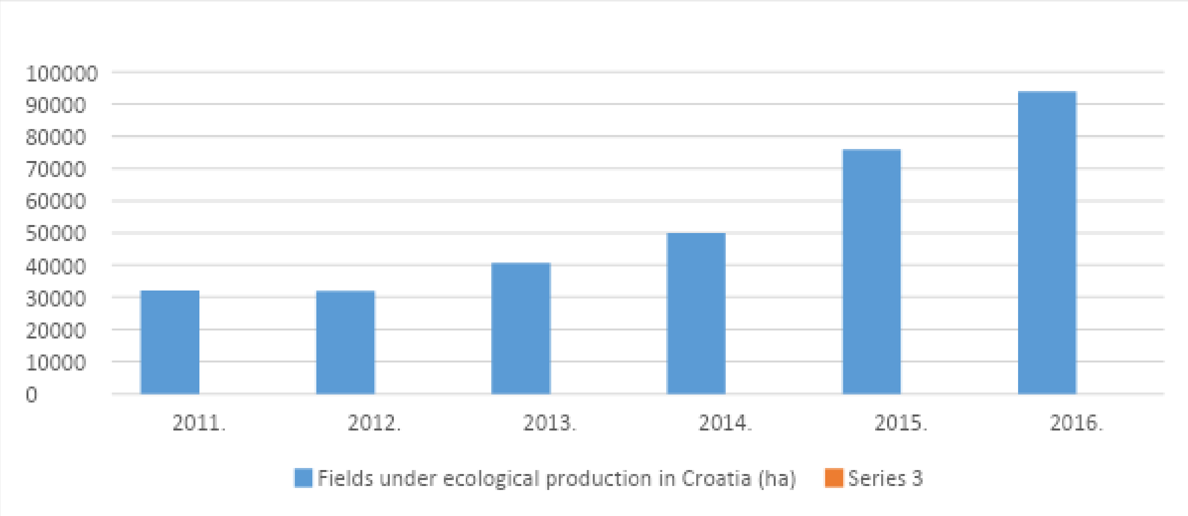
Proportion of adults with only primary education ranges from 20-35 % and 95 % of farmers have no vocational agricultural education whatsoever.

Production of agriculture goods in Croatia

According to the CBS data, in 2016 the physical volume of agricultural gross production, observed compared to the previous year, increased by 9.6%. The growth of the physical volume of agricultural production was enabled by the growth of crop production of 15.1% and the growth of livestock production of 3.1%. In the total gross production in 2016, plant production participated with 56.7%, and livestock production with 43.3%.

In the Republic of Croatia, there is a significant growth trend in areas under organic production. During 2016, 3,546 producers were registered with an area of 93,814 ha, which is 6.1% of the total agricultural area.

[16] Croatian agriculture 2016.
https://poljoprivreda.gov.hr/UserDocsImages/dokumenti/poljoprivredna_politika/poljoprivreda_u_brojkama/Hrvatska_poljoprivreda_2016.pdf



Graph 6. Fields under ecological production in Croatia

Spain

Demography, land use and farm structure

In a study about Structure of Agricultural Holdings realized in Spain in 2016 was concluded the next:

- The number of agricultural holdings decreased 2.1 % between 2013 and 2016.
- The medium agricultural area used by exploitation was situated at 25.06 hectares, increasing 1,6% compared to 2013.
- The number of agricultural exploitations increased by 2.1 % compared to 2013.

The geographical distribution of agricultural areas in Spain is much divided. The autonomous communities Castilla y León (59.71 hectares), Aragón (47,57 hectares) and Comunidad de Madrid (40,91 hectares) had the biggest medium areas by exploitation in 2016. On the other hand, the smallest medium areas were Canarias (4.17 hectares), Comunidad Valenciana (5,53 hectares) and Galicia (8,35 hectares).

Agriculture is a sector with strong roots in the economy, society and territory of Spain that generates wealth in its own activity and in other activities due to its interrelationship with other sectors. In 2017, agricultural sector bill 23.357 millions of euros was in charge of the occupation of 749.700 active persons and 6.555 million of euros of trade balance.

Agro alimentary system is the second industry of Spain with a contribution of 10.6% to Gross Domestic Product (GDP) and 14,2% of the employed, next to the tourism sector.

Agricultural Education

In Spain, the employed population of the agricultural sector tends to have a minor educational level than the national average. Particularly, if the number of exploitations in which owners have received specific higher agricultural education is analyzed, Spain is below of the main European agricultural countries. However, the number of explorations directed by farmers with university education has increased by 16% since 2005, above the majority of European countries. So, highlight that the young Spanish farmers tend to have better educational levels than their older counterparts do.

Besides, new technologies have been more affordable economically and easier to use. For this reason, this sector must introduce people with better qualifications, with technical advanced abilities, and be able to implement and manage productive innovative systems. The future farmer should be a multidisciplinary professional who knows how to operate machinery, computing, robotics, meteorology, chemistry or biology.[17]

[17] Pwc (2019). El futuro del sector agrícola español. https://www.pwc.es/es/publicaciones/assets/informe-sector-agricola-espanol.pdf

Instituto Nacional de Estadística (2017). Encuesta sobre la Estructura de las Explotaciones Agrícolas. https://www.ine.es/prensa/eeea_2016.pdf

A.3. Literature review on precision agriculture

In this chapter, we aim to focus on current research and achievements in the field of precision agriculture. It is important to note that these are examples chosen by the project partnership to cover different topics of the field of precision agriculture. The goal is for the reader to have a general overview of what is being developed and inspire them to further research the topics of interest.

A.3.1. Producer's disposition to adopt Precision Agriculture[18]

Problem: Adaptation of Precision agriculture

Solution: Appropriate training, demonstrations, services, products and support

There are many positions for and against the introduction of innovation and new technologies in the field of farming and agriculture. The adoption of smart, connected, automatized but also complex technologies represent a big change in the traditional operation of farms and croplands. While the economic and technological research on models of precision agriculture has been plenty, analysis on the disposition of farmers and producers, as well as its influence on implementation, seems to be lacking as of yet.

After the study, some results were concluded and grouped under different headings: *The perceived usefulness of PA* did not in fact directly affect the decision to adopt precision agriculture techniques in a significant way. However, it seems to be a great influence on the relationship between Confidence and Perceived Net Benefit, with high confidence bringing higher levels of perceived usefulness and high-perceived usefulness being equated to a high perceived net benefit respectively. *Perceived ease of use of PA* did not affect the adoption of precision agriculture in a straightforward way, but similarly to usefulness, was influenced by Confidence, going up the more motivated a producer is about the new technology.

Confidence in themselves was the most influential perceptive factor, as it directly influenced the decision to use precision agriculture more than any other construct. *Perceived net benefit of PA* and all *Other Variables* results were on par with the original hypotheses, with perceived benefit as well farm size and education directly affecting the decision to utilize innovative farming techniques.

These results indicate that farmers' attitudes toward the relevant technologies are different between those planning on adopting precision agriculture and those who don't. An attitude of confidence can lead to a greater understanding of the technology's usefulness, therefore eventually leading to their adoption. In addition, producers who indicated confidence about using and learning technologies, as well as perceived a net benefit from using these technologies, showed greater interest in adopting innovative farming practices. Thus, it can be said that raising the confidence level of producers can affect the way they view the technology in both its use and its complexity.

The paper concludes by pointing out that the steep learning curve and general investment involved in the adoption of precision agriculture complicates producer's decisions on their inclusion in their

[18] Producers' perceptions and attitudes toward precision agriculture technologies, Adrian A. M., Norwood S. H., and Mask P. L., (2005) https://www.sciencedirect.com/science/article/abs/pii/S0168169905000852

businesses. Understanding the farmer's motivations and concerns on this technology can help relevant agents develop new, more efficient ways to approach producers and demonstrate its innovative aspects. Through appropriate training, demonstrations, services, products and support, they can increase producer confidence in using precision agriculture.

A.3.2. Precision Agriculture and Sustainability[19]

Problem: Sustainability of Precision agriculture

Solution: Economical and environmental level gains of using Precision agriculture

The environmental effects of precision agriculture and their potential as a sustainable farming method have been under discussion since the first time a global positioning system was applied to agricultural equipment. This paper approaches the inextricable connection between sustainability and precision agriculture, exploring its realities by defining these elements, reviewing relevant research and finally, creating proposals for a profitable, as well as environmentally conscious farming practice.

Sustainable agriculture is defined as a practice that in the long-term enhances environmental quality, the resource base on which agriculture itself depends on. Simultaneously, it provides for nutritional needs, is economically viable and increases the quality of life for producers, consumers, and society as a whole. When it comes to precision agriculture, its ties to sustainability come through its role in Site-Specific Management, a concept as old as agriculture that makes sure appropriate care is being used in the correct timeframe and agricultural area depending on their specific demands. Precision agriculture is now re-opening this possibility by utilizing information technology, which allows producers to monitor and tailor their practices to their desired outcomes. The paper also approaches this subject from an ethical standpoint, framing precision farming as less disruptive to natural systems while improving communications and the standard of living in agricultural areas.

In order to pin down the challenges of sustainable precision agriculture, the writers first conclude to three different categories of field variables; *Natural*, such as topography and soil (with its own subcategories), *random*, such as rainfall, and *managed*, such as fertilizer and seed application. The challenge relevant to these elements is the quantification of soil variations, with precision farming now offering promising results through the observation of the many and complicated biological variants, most notably the Nitrogen (N) dynamics of the soil. Additionally, according to previous studies it has been shown that soil quality and fertilization are not uniform, therefore a single approach to soil test calibration cannot exist for fields with different variability.

The main analysis on the topic comes from the writers' reviewing specific aspects of agricultural tools and processes, presenting their environmental influence and the possible effects of utilizing precision agriculture relevant to these aspects. Namely, they note on nutrients and soil organic matter, pest management, soil and water quality, as well as analyzing the economic aspects of those issues and completing overall comparisons between conventional agricultural methods and precision agriculture. In addition, they report on the impact site-specific N management has had on testing fields in Argentina, analyzing their methodology and discussing the subject on both an economical and environmental level.

[19] Precision Agriculture and Sustainability, Bongiovanni R., Lowenberg-DeBoer J., (2004) https://bit.ly/2UdEiyi

The paper concludes by stating that as long as the external element of precision farming is accepted into agriculture, it will be able to assist in more balanced and profitable agriculture. Specifically, the spatial management of Nitrogen offered by precision farming can reduce overall application, both on normal and on sensitive areas, while maintaining profitability by reducing nutrient imbalance-related losses and reducing resistance in pesticide.

At the same time, as studies suggest costs are reduced as overall application of chemicals is reduced, and as proven in the study related to the Argentina case, maintaining profit while reducing Nitrogen applications is a viable option, modestly profitable in the end.

A.3.3. Frost response in wheat and early detection using proximal sensors[20]

Problem: Negative effects of low temperature crops

Solution: Manipulating flowering time in order to avoid seasons with a higher possibility of frost

Frost and occurrences of low temperature have great chances of negatively influencing field crops, especially in Mediterranean-type environments, where this phenomenon causes significant annual economic losses in the production of Australian wheat. This paper reports on a frost treatment methodology tested on wheat under field conditions, as well as the use of canopy reflectance data for detecting all crop damage at an early stage.

The conventional methods of avoiding this predominantly consist of avoidance measures, like manipulating flowering time in order to avoid seasons with a higher possibility of frost, however these techniques also face difficult issues, like the heat stress and drought that a later blooming season can bring.

This is why limiting the impact of frost needs improved strategies including both breeding solutions and revolutionary agricultural management; increasing plant endurance, using crop simulation for targeted cultivation, managing variables such as sowing dates, and finally, using proximal or remote sensing technologies for faster and more efficient management of damaged crops.

Wanting to test the utility of sensors in detecting and categorizing frost damage to wheat the researchers considered a variety of methods, finally implementing purpose-build portable pot-trials and cold chambers. Using these, they were able to apply a variation of condition scenarios on a small percentage of crops, measure their immediate response in a field, and evaluate techniques of crop surveillance as well as link them to specific indicators.

The experimental design consisted of ten-frost scenario treatments repeated four times, where temperatures below 0 degrees Celsius were applied to randomized blocks of wheat. Sample crops were later hand-harvested, processed, and analyzed, resulting in the final statistical analysis of the experiment.

For the wheat grown in natural temperature with no frost or heat events from five days before an thesis to maturity, grain number and yield was accounted to 15890 grains per m2 and 6822 kg/ha,

[20] Frost Response in wheat and early detection using proximal sensors, Nutall G. J., Perry E., O'Learry J. G. (2018) https://cutt.ly/EmaEi8w

respectively. The impact was observed to be cumulative over multiple frost nights, with an almost doubling of impact from one to two consecutive nights.

The paper points out the need for further testing in order for these detection concepts to be marketable on a wider scale, as they need to address the commercial practicalities of the subject. They close on a future proposal, acquiring a series of measurements taken at the whole paddock scale, during the reproductive phase of a field crop and establish a rolling baseline (zero frost).

At a point of natural frost onset, then bracketing between the next and last measurements before the frost event will be used to estimate change in canopy reflectance due to frost. Ground scouting and cross-registering with spatial yield maps would provide the validation of this paddock scale test. Ultimately if such technologies can be utilized they will advance the aim of being able to spatially map frost damage to crops in-season and support timely management to limit economic losses.

Picture 2. Frost chambers (a) performance testing and simulated frost being applied to wheat (b)

A.3.4. Precision researches for sustainable and competitive agriculture in Hungary

Problem: Unused potential on the field

Solution: Research aimed at the ecological application of precision technologies

Although in Hungary precision farming is mainly used in field crop production (targeted large-scale application of pesticides and fertilizers), the use of precision technologies also offers extraordinary opportunities for animal husbandry. Because of the high requirements of precision farming (technology, expertise), most often it is only affordable for large-scale farms. Among the small-scale, organic farmers are still less widespread.

Precision technologies are extremely important in the field of sustainable agriculture. Therefore, in order to present good practices we would like to introduce research aimed at the ecological application of precision technologies.

The Ecological Agricultural Research Institute (ÖMKi) is the only research institute in Hungary specializing in organic farming. It aims to promote the development and wider application of organic farming. The national On-farm network of domestic organic farms has been operating since 2012 and has been a member of the European Network of Living Laboratories (ENoLL) since 2020. ÖMKi is currently conducting three researches on precision agriculture: two on crop production and one on animal husbandry. Researches began in the spring of 2020 and they are currently underway.[21]

A.3.5. Precision solutions in plant protection monitoring[22]

Problem: Plant protection monitoring system for organic farms

Solution: Plant protection via spectral characteristics using hyperspectral scanners on drones

The aim of the research is to develop a small-scale, prevention-focused plant protection system optimized for organic farms, which detects various pathogens and harmful phenomena based on their spectral characteristics.

The research is based on hyperspectral scanners (spectrometers) mounted on drones, which are able to detect different electromagnetic waves coming from a given surface and to record the measurement results. The advantage of this spectral remote sensing technology is that it allows the collection of chemical data, without the necessity of destroying the sample or using reagents, which makes it ideal for the study of organic farms.

Activities

Picture 3. Spectral remote sensing in tomato foil tent

In the research, sensory measurements (spectral remote sensing) are performed at two On-farms and in the experimental areas of ÖMKi (in a foil tent, in a tomato shoots), which are confirmed (validated) with traditional field and laboratory recordings (e.g. pathological bonitation, pathogen culture).

In the research, artificial infection experiments are performed on the most important pathogens (e.g. for the early prediction of phytophthora), aimed at determining the spectral characteristics of adverse phenomena. In this process, laboratory spectral and conventional pathological examinations are performed on the plants examined under controlled conditions at different times. Based on these results, the wavelengths suitable for the earliest possible detection of the given disease are identified.

[21] https://biokutatas.hu/en/page/category/precision_agriculture
[22] https://biokutatas.hu/en/page/show/plant_protecting

Expected results

The research is expected to promise practical results that can be used not only in science, but also in the field of technology and directly for farmers, even in the short and medium term.

- **The development of innovative recording technologies and sets of related tools in order to monitor the growth of tomato seedlings (e.g. using new sensors and automatic, moving cameras).**
- Determining the spectral fingerprint of major plant pathological phenomena. **These results can help not only in prevention but also in the development of cheaper targeting tools.**
- The application of software solutions enabling real-time evaluation of image data.
- Scientific and technical publications on the practical application of these testing and evaluation methods.

For more information, please visit: https://biokutatas.hu/en/page/show/plant_protecting

A.3.6. Variety testing using precision recording methods

Problem: Variety testing in organic farms

Solution: Remote sensing with spectral scanners on drones

With the possibilities provided by the recently introduced techniques and platforms (spectral scanners mounted on drones), new forms of agricultural remote sensing have emerged, which already take into account the special characteristics of production (e.g., large spatial, spectral, and temporal scales within a production cycle). The main aim of the research is to investigate the application possibilities of these modern spectral remote sensing technologies and to renew the methodologies for small-plot and farm-level variety testing. One of the biggest challenges currently facing researchers in remote sensing is to increase the temporal resolution, which can be achieved with the development of automatic and/or remotely controlled platforms.[23]

Activities

During the research in order to develop a precision toolkit for variety testing, small-plot and field sensor measurements are conducted, to examine the agricultural performance of different wheat varieties in on-farm conditions. The results of the sensory instruments extracted here are validated and calibrated by conventional field and laboratory recordings (e.g., soil tests, SPAD, sampling, etc.). They also perform experiments on nutrient supply and artificial infection in culture dishes (in order, for instance, to make early predictions of wheat leaf rust). Under controlled conditions, the plants are subjected to laboratory spectral examination at various times, alongside conventional pathological bonitation, in order to determine the wavelengths suitable for the earliest possible detection of disease.

[23] https://biokutatas.hu/en/page/show/variety_testing

Expected results

- The development of innovative recording technologies and their tool systems, for the implementation of wheat cultivar tests (e.g. using new sensors and drones).
- The determination of the spectral characteristics of major plant pathological phenomena.
- Scientific and technical publications on the practical application of these testing and evaluation methods.

For more information, please visit**:** https://biokutatas.hu/en/page/show/variety_testing

A.3.7. The development of a customized feeding and disease prevention system in free-range dairy farms using precision sensors

Problem: Prevention and monitoring in organic animal husbandry

Solution: Precision sensors

The revolutionary opportunities offered by precision technologies have also opened new avenues in organic animal husbandry. Although in the case of free-range animal husbandry, which is more adapted to the natural needs of the animals, the implementation of continuous monitoring has been difficult in the past, new, individual, non-invasive sensors now make this possible. The aim of the research carried out in the on-farm network is the introduction and further development of precision farming techniques used in organic animal husbandry, and the development of a disease prevention system.

Activities

Picture 4. Implementation of PA in organic animal husbandry

In the field of animal husbandry, they collect sensory and conventional measurement data on the nutritional processes, health status and weight gain of free-range cattle. Based on the data measurements, it should be possible to optimize husbandry technology, as well as ensuring the effective detection of diseases, and the application of individual veterinary procedures adapted to the biological needs of the animals. To disseminate results and share knowledge they organize field days, professional evaluation and planning days for the sharing of experiences and a discussion of results. Thanks to all this, high-quality domestic food products with an outstanding content index can be produced.

Expected results

- The introduction of new sensors into animal husbandry practice, which allow for the discovery of correlations between dietary habits, digestive efficiency, and animal behavior (e.g. based on the length, rhythm, and time of the rumination process).

- Improvements will allow farmers to more accurately monitor their cattle at an individual level, thereby ensuring and documenting excellent animal welfare conditions, and thereby increasing the protection and service of consumer interests.
- The development of new products has already begun, which will stand out from those currently on offer thanks to their favorable content indices.

For more information, please visit**:** https://biokutatas.hu/en/page/show/animal_husbandry

A.3.7. Robotics to optimize irrigation and plan the harvest more efficiently

Problem: Water and irrigation management

Solution: Robotics to optimize irrigation more efficiently

This paper presents a solution for the water management in farming. The aim is to make use of different developments in irrigation technologies, which is vital for the development of the goods of the ground. Water management is one of the main concerns in agriculture, if the right is to deal with too little or too much water. Discovering different methods and tools in order to better manage water is vital for the future success of agriculture. Precision farming technologies are trying to find their way into different facets of agriculture. Recently, there have been some advancements which have made this technology more practical regarding irrigation.

Picture 5. Example of an agricultural robot

Researchers from the Universitat Politècnica of València (UPV) have developed the latest technology; a robot which is able to improve the irrigation efficiency of vine crops and through several sensors. It also enables the state of the vine to be recorded at all times as well as it helps the winegrower to get the most out of the plots. This fully electric robot has the capability to work for at least 2 days. [24]

[24] *Adapted from RETEMA [Image]. RETEMA: Revista Técnica de Medio Ambiente (https://www.retema.es/noticia/robotica-para-optimizar-el-riego-y-planificar-la-vendimia-de-forma-mas-eficiente-ykiAW)*

VineScout measures key parameters of the vineyard that allow vegetative development, estimating its water needs, or anticipating the variation in the degree of maturity within the same plot. It does all this thanks to the combination of a series of radiometric, environmental and spectral sensors.

VineScout has been proven to be robust and reliable, the new agricultural revolution. This robot is a completely new approach to agricultural automation for trellising crops.[25]

A.3.8. Use of drones for the treatment of small areas such as parks, gardens or delicate areas

Problem: Bacteria and insects in green areas

Solution: Make use of the latest robotic technology: Drones

This paper presents a new approach to the maintenance of agricultural areas focused on less waste of discharges and greater cost savings, thus cutting down the environmental impact. The aim is to make use of the latest robotic technologies, which are the key tools in farming nowadays. Human beings no longer carry out reaching hard areas in agriculture. For the grounds maintenance, it is necessary to eliminate bacteria found in the field, where the use of insecticides play an important role.

Garden treatment might be difficult because of the variety of situations that machinery deployment can bring about. Servicing any type of tree with cranes can be slowed down due to different causes such as its height, a variety of obstacles on the ground like areas with difficult access for machinery, streets or even a high density of trees, which avoid access between them.

Garden treatment might be difficult and it can be sorted out by the use of drones. These drones can service and treat every zone, all kinds of trees, being extremely useful in the highest ones and in all growing areas. These drones are able to treat over one hundred specimens in one single day.[26]

Picture 6. Example of a drone for aerial application

[25] *Bibliography:*
Dorsey, N. (October 12, 2017). 4 important ways precision technology is impacting irrigation. Precision Ag. https://www.precisionag.com/in-field-technologies/irrigation/4-important-ways-precision-technology-is-impacting-irrigation/
RETEMA (w.d.). Robótica para optimizar el riego y planificar la vendimia de forma más eficiente. https://www.retema.es/noticia/robotica-para-optimizar-el-riego-y-planificar-la-vendimia-de-forma-mas-eficiente-ykiAW

[26] *Adapted from Drones Hispania [Image]. Drones Hispania (*https://droneshispania.com/*)*

The future of agriculture is already a reality thanks to the arrival of the latest technology as a working tool. This new robotic technology is changing the way of treating and working green spaces in the countryside and cities, which until today have been treated in the same way as many years ago.[27]

A.3.9. Tomato harvester due to the lack of workforce

Problem: Lack of workforce

Solution: Make use of the latest robotic technology: Tomato Harvester

This paper presents a new focus on the solution to combat labor shortages and instead make use of a multifunctional robot. Growers have had to fight against labor shortages for years. Even before COVID impeded workers from going abroad to work, businesses and producers did not always have enough staff. The aim is to implement a fast, accurate and effective technology, which will be a vital element in the collection of products, in this case, the tomato.

While this might seem like a utopia which only rich multinationals can accomplish, multifunctional robots will also be disponible very soon for passive greenhouse growers as well. This robot labor can operate in greenhouses as well as to drive off-road. It is applied to the tomato harvester attachment, which increases reliability, quality of the harvest and availability. Although the main approach has revolved around the tomato sector, the robot can also be applied to other sectors. Since the cost of multiple robots will be expensive, a multifunctional robot would solve this problem, as it contains several robot applications, which will bring more efficiency as well as it, will support the growth cycle of multiple crops.

Dror Erez, manager of Automaton Robotics, has expressed that this robot has been tested in the most complex situations and it is now trained to detect even hidden vegetables. This person has also states: "We hope that our robotic platform will enable other robotic greenhouse applications under development for active greenhouses to be also implemented and used in passive greenhouses as quick as possible." [28]

[27] *Bibliography:*
Drones Hispania (2021). Inicio. https://droneshispania.com/
Drones Hispania (2021). Tratamiento de parques, jardines y áreas delicadas como pistas o campos de golf. https://droneshispania.com/tratamiento-de-parques-jardines-y-areas-delicadas-como-pistas-o-campos-de-golf/

[28] *Bibliography:*
Tips y temas agronómicos (January 14,2021). Se implementa el uso de una cosechadora de tomates debido a la falta constante de mano de obra para el campo. https://www.tipsytemasagronomicos.com/cosechadora-de-tomate-debido-a-la-falta-de-mano-de-obra/

A.3.10. Drone and sensor technology for sustainable weed management: a review[29]

Problem: Weed detection.

Solution: An overview of precision weed control with a focus on the potential and practical use of the most advanced sensors available in the market.

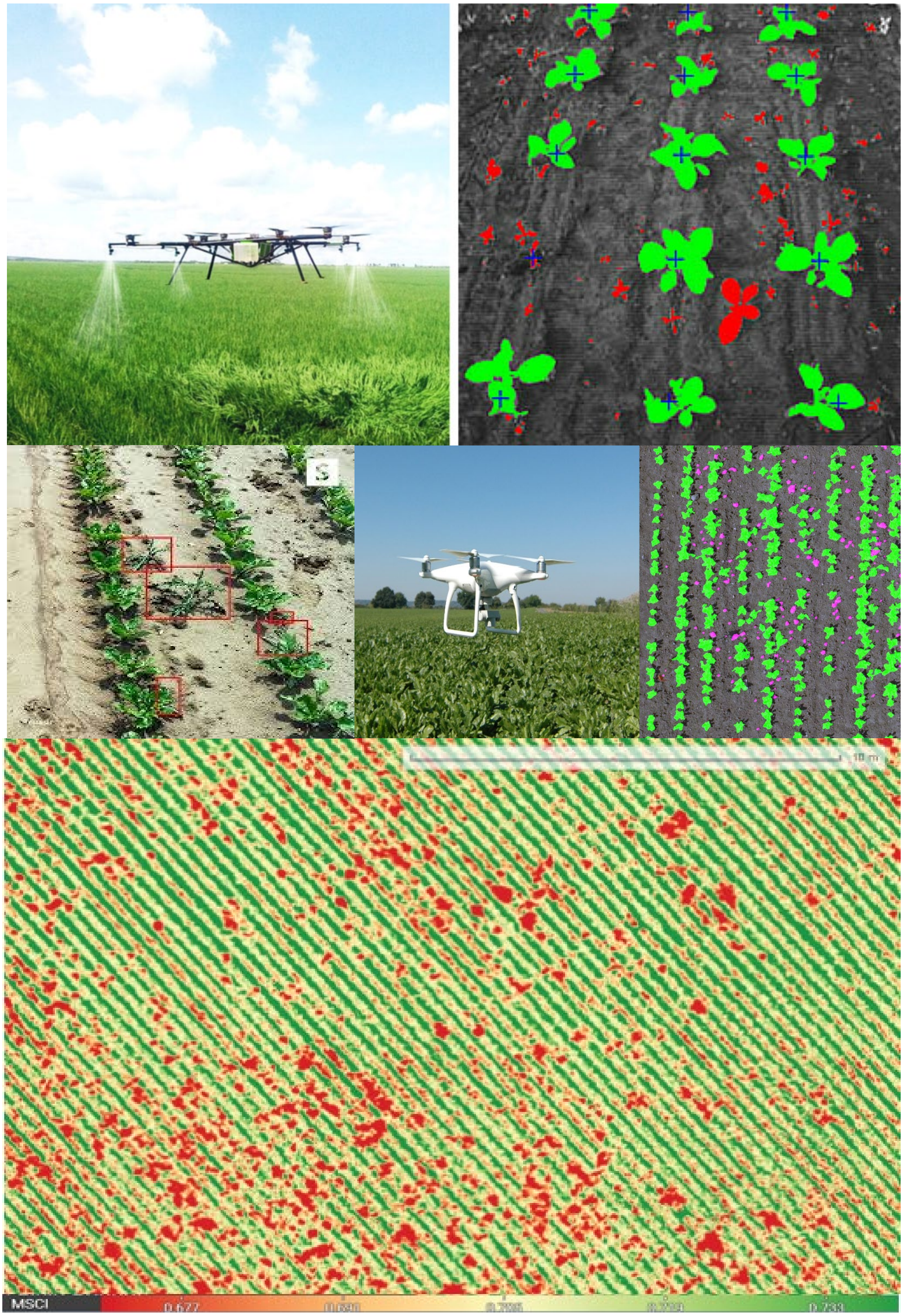
Biotic threats such as insects, weeds, fungi, viruses, and bacteria can broadly affect crop yield and quality. Among these, weeds are the most impacting problem causing remarkable yield loss worldwide. The most characterized effect of weeds is competition for resources such as light, water, space, and nutrients. In addition, specific chemical signals and/or toxic molecules produced by weeds may interfere with a normal crop development. A distinctive trait of wild species, including weeds, is their high physiological, morphological, and anatomical plasticity, which makes them more tolerant than crop species to environmental stressors. Moreover, weeds interact with other biological components of the environment, acting as refuge for plant pests such as insects, fungi, and bacteria that can harm close in crops. Finally, weed infestation may affect fresh and processed products quality such as beer, wine, forage. In this respect, weed residuals may cause accumulation of off-flavors products, or in some cases, can make them harmful to humans and animals. Weeds may also contain high levels of allergens and/or toxic metabolites that, if ingested, can cause asthma, skin rash, and other reactions.

Most weed research aims at developing strategies that can reduce the deleterious impact of the interspecific competition between crops and weeds and recent technological advances may further contribute to this scope, while improving the sustainability of weed control. Worldwide, weed competition causes severe yield reduction in all major crops, such as wheat (23%), soybean (37%), rice (37%), maize (40%), cotton (36%), and potato (30%). The annual global economic loss caused by weeds has been estimated to be more than $100 billion U.S. dollars, despite worldwide annual herbicide sales in the range of $25 billion.

Precision agriculture relies on technologies that combine sensors, information systems, and informed management to optimize crop productivity and to reduce the environmental impact. Nowadays, precision agriculture has a broad range of applications and it is employed in different agricultural contexts including pests control, fertilization, irrigation, sowing and harvesting. Precision agriculture can be effectively applied to integrated weed management (IWM) also. Unmanned aerial vehicles (UAV) are one of the most successful technologies applied in precision agriculture. UAVs can be highly valuable since they allow for Site-Specific Weed Management (SSWM). SSWM is an improved weed management approach for highly efficient and environmentally safe control of weed populations, enabling precise and continuous monitoring and mapping of weed infestation. SSWM consents to optimize weed treatments for each specific agronomical situation. The combination of UAVs with advanced cameras and sensors, able to discern specific weeds, and GPS technologies, that provide geographical information for field mapping, can help in precisely monitoring large areas in a few minutes.

The use of UAVs and machine learning techniques allow for the identification of weed patches in a cultivated field with accuracy and can improve weed management sustainability. In addition, imaging analysis can help in the study of weed dynamics in the field, as well as their interaction with the crop.

[29] Marco Esposito, Mariano Crimaldi, Valerio Cirillo, Fabrizio Sarghini and Albino Maggio (2021).



Picture 7. Examples of drone usage and recived data

A.3.11. HidroMap: A New Tool for Irrigation Monitoring and Management Using Free Satellite Imagery[30]

Problem: Control and planning of water resource use.

Solution: An open source tool for irrigation monitoring and management using free satellite imagery.

Water plays a key role in all natural ecosystems. It is the essential resource for the survival of all living organisms. Irrigation farming consumes around 70% of the total annual withdrawal of fresh water, which contributes to increasing agricultural productivity, mainly in unproductive arid lands. However, irregular water uses and climate change effects involves the overexploitation of a large number of aquifers and the degradation of water quality sources. This unsustainable water balance and the variability of water world cycles turn water to an increasingly scarce and limited resource. Therefore, in order to stop and reverse this process, it is essential to adopt several measures focused on controlling runoff water and groundwater uses in the framework of farming irrigation. The HiroMap tool was developed to support Hydrological Planning Offices (HPOs) as a decision support tool including all actors involved in water management and water policy-makers at field level.

Aerial and satellital remote sensing have been recognized as excellent tools to acquire a large amount of spatial information. This is due to their capability to cover large areas and so monitor crop biophysical parameters and control crop water uses along growing seasons. In this regard, relevant changes related to the policy of National Aeronautics and Space Administration (NASA) and European Space Agency (ESA) have allowed open access to georeferenced Landsat and Sentinel images in near real time.

Regarding data integration in geospatial environments, several decision support systems based on web-GIS technologies have been developed with different aims. However, most of these applications are not open source and they are only available for private uses. Focusing on remote sensing applied to agronomic studies, there are previous experiences in crop assessment development.

Improving the management and monitoring of water uses not only requires farmers respect the legal framework and water consumption limits, but also developing tools that provide accurate information to water users and managers. This research work was mainly focused on developing a multifunctional and open source tool.

The tool offers a combined GIS solution: a desktop-GIS plugin that allowed carrying out tasks of management, control and surveillance of irrigated areas and illegal irrigation; and a web-GIS system that allowed carrying out quickly inspections and irrigated area monitoring, as well as visualizing crops and phenological patterns in a simple and intuitive way.

From a conceptual and application point of view, HidroMap achieved a fourfold objective:

- Immediate and automatic detection of incidents
- Management of illegal irrigation
- Optimization of resources of the RIO
- Temporal monitoring of the irrigated area

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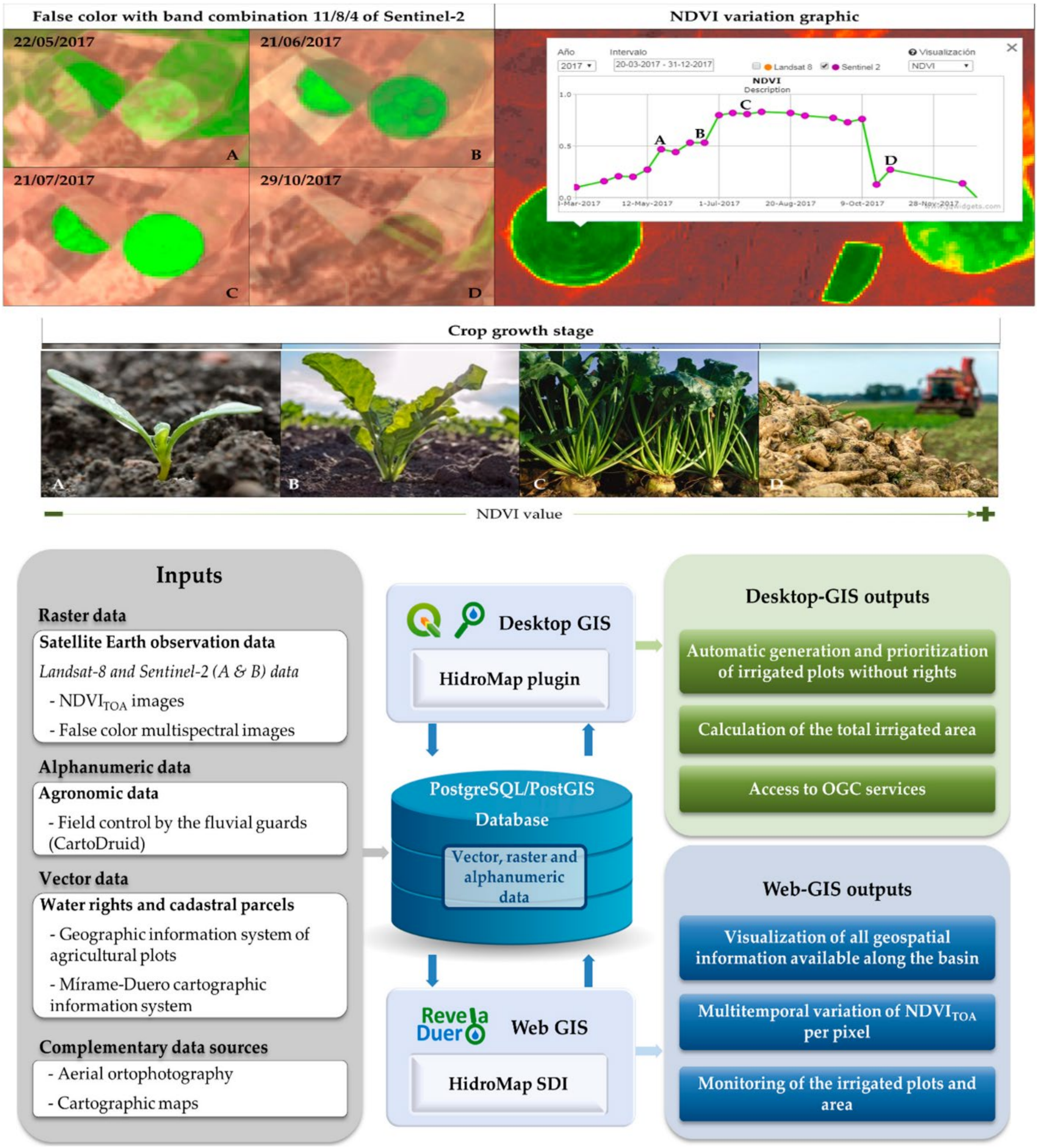
[30] Laura Piedelobo, Damián Ortega-Terol, Susana del Pozo, David Hernández-López,Rocío Ballesteros, Miguel A. Moreno, José-Luis Molina and Diego González-Aguilera (2018).

The dual GIS environment offered by HidroMap was an important challenge for any river basin organization for management and planning of available water resources. In addition, it can be adapted to any type of further requirement.



Picture 8. Irrigation monitoring using hidro maps

A.3.12. Real-Time Detection of Apple Leaf Diseases Using Deep Learning Approach Based on Improved Convolutional Neural Networks[31]

Problem: Real time detection of apple leaf diseases

Solution: Using deep learning approach on improved convolutional neural networks

With a high nutritional and medicinal value, apples are one of the most productive types of fruit in the world. However, various diseases occur frequently on a large scale in apple production, thereby causing substantial economic losses.

Traditionally, visual observation by experts has been conducted to diagnose plant diseases. However, there is a risk for error due to subjective perception. In this context, various spectroscopic and imaging techniques have been studied for detecting plant diseases. However, they require precise instruments and bulky sensors, which lead to high cost and low efficiency. In recent years, with the popularization of digital cameras and other electronic devices, automatic plant disease diagnosis via machine learning has been widely applied as a satisfactory alternative. Inspired by the breakthroughs of CNNs in object detection, research and applications of CNNs are not rare in crop disease detection currently. However, implementing the real-time detection of apple leaf diseases remains difficult because ALDD has the following characteristics: first, multiple diseases may occur on the same leaf. Moreover, the sizes of the disease spots on the leaves vary among diseases and for the same disease. In addition, most spots of apple leaf diseases are very small. Finally, environmental factors such as shadow, illumination, and soil also interfere with apple leaf disease detection.

To overcome these challenges, this paper applies the latest deep learning approach, which is based on improved convolutional neural networks, to perform real-time detection of apple leaf diseases. The main contributions of this paper are summarized as follows:

- The apple leaf disease dataset is built to provide an important guarantee of generalization capability of the proposed model.
- A novel real-time detection model that is based on the single-shot multibox detector (SSD) for apple leaf diseases is proposed.
- A deep convolutional neural network is employed for the real-time detection of apple leaf diseases.

The deep-learning-based approach can automatically extract the discriminative features of the diseased apple images and detect the five common types of apple leaf diseases with high accuracy in real time.

The experimental results demonstrate that the proposed realtime detection approach realizes a mean average precision of 78.80% and a detection speed of 23.13 FPS, which corresponds to an improvement of 2.98% mean average precision over the original SSD. The proposed model also exhibits strong detection performance and robustness. Hence, the proposed model is fully capable of real-time detection of apple leaf diseases.

[31] Peng Jiang, Yuehan Chen, Bin Liu, Dongjian He and Chunquan Liang (2019).

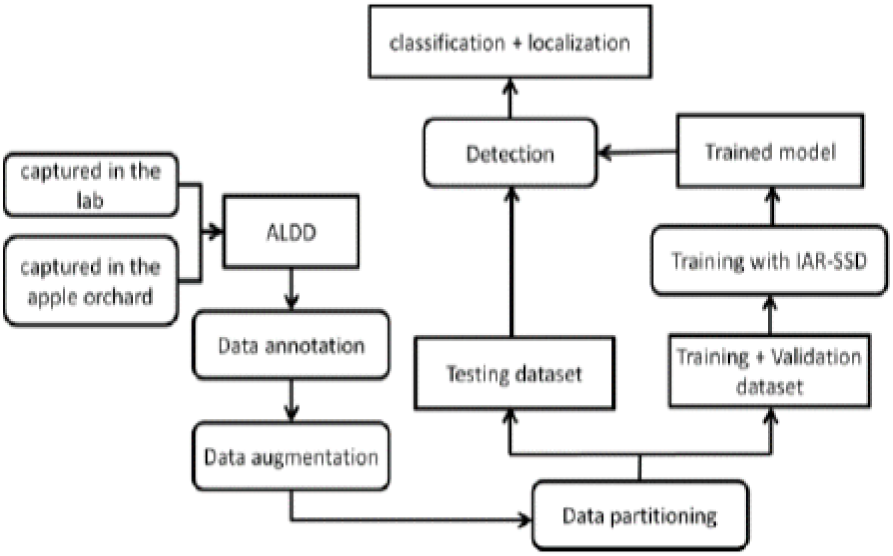
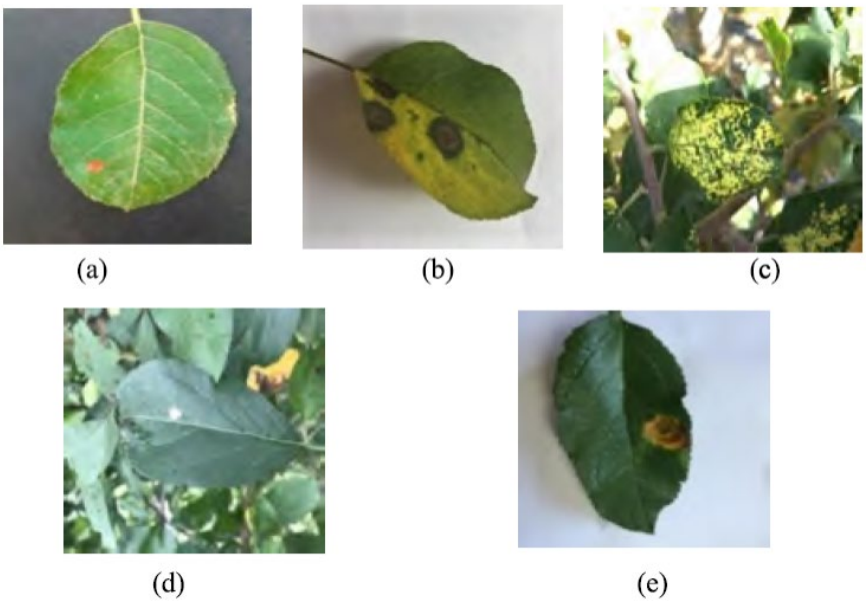


Figure 1. Real-time detection flow chat of apple leaf diseases



Picture 9. Five common types of apple leaf diseases. (a) Alternaria leaf spot, (b) Brown spot, (c) Mosaic, (d) Grey spot, (e) Rust.

A.3.13. DeepFruits: A Fruit Detection System Using Deep Neural Networks[32]

Problem: Fruit detection on the plant

Solution: Using neural networks (Artificial intelligence) for autonomous detection and harvest

This paper presents a novel approach to fruit detection using deep convolutional neural networks. The aim is to build an accurate, fast and reliable fruit detection system, which is a vital element of an autonomous agricultural robotic platform; it is a key element for fruit yield estimation and automated harvesting.

Picture 10. Example images of the detection of fruits

According to sourcing skilled farm labor in the agriculture, industry (especially horticulture) is one of the most cost-demanding factors in that industry. This is due to the rising values of supplies, such as power, water irrigation, agrochemicals, and so on.

Robotic harvesting can provide a potential solution to this problem by reducing the costs of labor (longer endurance and high repeatability) and increasing fruit quality. The development of such platforms includes numerous challenging tasks, such as manipulation and picking. However, the development of an accurate fruit detection system is a crucial step toward fully automated harvesting robots, as this is the front-end perception system before subsequent manipulation and grasping systems; if fruit is not detected or seen, it cannot be picked.

In real outdoor farm settings, a single sensor modality can rarely provide the needed information to detect the target fruits under a wide range of variations in illumination, partial occlusions and different appearances. This makes a great case for the use of multi-modal fruit detection systems. Deep neural networks have already shown great promise when used for multi-modal systems in domains outside agricultural automation,. This work follows the same approach and demonstrates the use of a multi-modal region-based fruit detection system and how it outperforms pixel-level segmentation systems.

[32]DeepFruits: A Fruit Detection System Using Deep Neural Networks, Sa I., Ge Z., Dayoub F., Upcroft B., Perez T., and McCool C. (2016.).
https://www.mdpi.com/1424-8220/16/8/1222

A.3.14. The future of Robotic Agriculture[33]

Problem: Upcoming robotic advances in agriculture,

Solution: Technological focus

The paper covers a variety of aspects that are directly connected to implementation of robotic solutions in agriculture and the general overview of the upcoming advances in agriculture and challenges that come with it.

Robotics and Autonomous Systems (RAS) are set to transform many global industries. These technologies will have greatest impact on large sectors of the economy with relatively low productivity such as Agri-Food (food production from the farm through to and including manufacturing to the retail shelf). As well as delivering economic benefits, such as increasing productivity and reducing waste throughout the food supply chain, developing a new focus for RAS within Agri-Food will have significant societal and environmental benefits.

PRECISION AGRICULTURE

Also known as 'smart farming', precision agriculture has its origins in developments first applied in industrial manufacturing as far back as the 1970s and 80s. It concerns the use of monitoring and intervention techniques to improve efficiency, realized in application through the deployment of sensing technologies and automation. The development of precision agriculture has been driven by the desire to better handle the spatial and temporal variability, e.g. in soil water-content or crop varieties, from farm-scale, down to field-scale, through to sub-field scale. The advent of autonomous system architectures gives us the opportunity to develop a new range of flexible agricultural equipment based on small, smart machines that reduces waste, improves economic.

TECHNOLOGICAL FOCUS

The recent focus of the agri-robotics community has been to identify applications where the automation of repetitive tasks is more efficient or effective than a traditional human or large machine approach. Research is needed into robotic platforms that can operate close to the crop (either on the ground or at elevation) and advanced manipulation. Land management is a specific issue of, given the issues of fertilisation, water management and carbon content in the soil, so the use of advanced sensing and soil management using remote platforms including robotics will be increasingly important. Additionally, the use of robotics for livestock management is a specific opportunity for the deployment of autonomous platforms, as has already begun in automated milking stations, and with potential applications for raising animals in fields, barns, sheds and aquaculture, or fish farms.

[33] The future of Robotic Agriculture,Sa I., Ge Z., Dayoub F., Upcroft B., Perez T., and McCool C. (2016.). https://www.n8agrifood.ac.uk/media/dx-tile/Future-of-robotics-agriculture-1.pdf

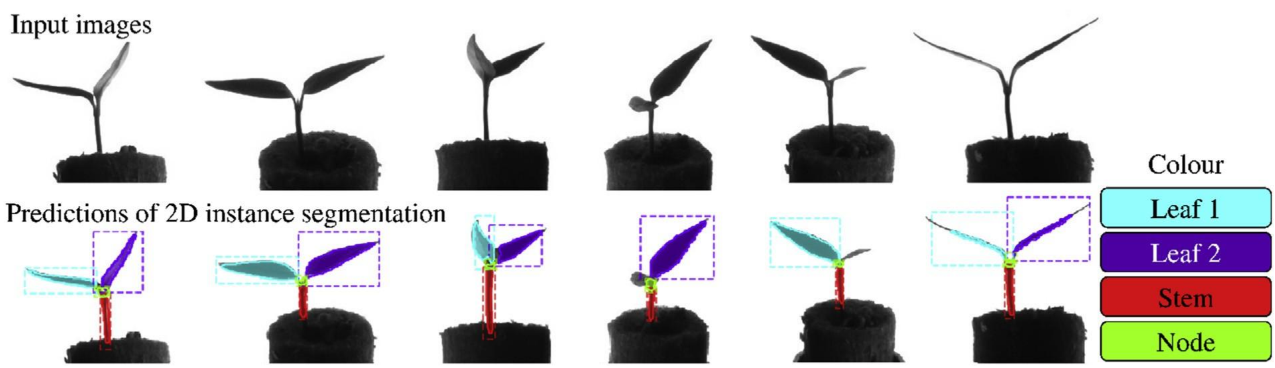
A.3.15. Plant-part segmentation using deep learning and multi-view vision[34]

Problem: Increase the speed of selection in plant breeding

Solution: Using computer vision and deep-learning systems

Plant scientists, geneticists and breeders are interested in having a better understanding of the relationship between a plant's genotype, it's environment and its resulting plant phenotype. The commonly used assessments of a plant's phenotype are mainly based on manual assessment, which is expensive, time-consuming, subjective and error-prone. Lacking a vast amount of complete and accurate phenotypic data, in contrast to the readily available genotypic data, this has been called the phenotyping bottleneck. This research was based on early-growth stage of tomato seedlings. Deep neural networks were used for the segmentation of plant parts in 2D images. Others have shown that these methods can deal with more complex plant structures with dense foliage and with different plant species. Future work needs to show the accuracy of our method on other plant types and in later growth stages.

Imaging techniques have the advantage of non-destructive detection, high-throughput processing and multi-trait measurement. Two-dimensional (2D) image-based phenotyping approaches are common methods to measure morphological plant traits. The disadvantage of these 2D approaches is that the acquired phenotypic traits are not complete, as the methods cannot deal with overlap and occlusion, and not accurate, as size and area measurements are inaccurate, due to the lack of the 3rd dimension. With the rapid development in computing power and sensor technology, plant traits extracted from 3D models can provide researchers with more profound and accurate information. To get detailed phenotypic information, the plant models need to be segmented into the individual organs, such as leaves, stems, and nodes. Many of the hand-crafted segmentation methods have recently been outperformed by deep-learning methods. The segmentation of 3D points clouds using deep learning is a fresh field.



Picture 11. Example of input image and ground-truth instance-annotations

[34] Plant-part segmentation using deep learning and multi-view vision, Shi W., Van de Zedde R., Jiang H. and Kootstra G. (2019.). https://www.researchgate.net/publication/335970199_Plant-part_segmentation_using_deep_learning_and_multi-view_vision

A.4. Diagnostic report on skills demand of agricultural sector

1. Summary.

This diagnostic is a report on the questionnaire results and presents the results of the questionnaire Workforce Skills Development in Precision Agriculture implementation. This questionnaire is part of the Erasmus+ KA202 project "New Skills Development in Precision Agriculture" and includes a range of opinions about technologies used in agriculture and other skills needed to work in this sector from different agriculture profiles in different countries.

2. Questionnaire objectives and participants.

The questionnaire included variety of questions to have a better view from different aspects such as the participants profile, their opinion about the use of technology in agriculture, the skills required by a farmer to manage the technologies in the exploitation, or the preparation of future farmers about precision farming technologies. The specific objectives are the next:

- To know the agriculture situation in different countries.
- To know the opinion from agriculture workers about the use of technology in agriculture.
- To know the opinion from agriculture workers about the future agriculture workers.
- To know the opinion from agriculture workers about the skills needed to work in agriculture.

The total number of participants was 190. These participants are divided into countries as follows:

- Spain: 14 participants.
- Slovenia: 13 participants.
- Greece: 72 participants.
- Hungary: 80 participants.
- Croatia: 11 participants.

3. Methodology and data collection.

The questionnaire was created in Google Drive Form. All the project partners created and designed the questionnaire,

The questions were divided in different sections:

- Section 1: explaining the objectives of the questionnaire and the methodology.
- Section 2: background information to obtain the participant profile (questions 1, 2, 3, 4 and 5).
- Section 3: use of precision agriculture technology in which participants show their opinions about technologies in agriculture (questions 6, 7, 8, 9 and 10).
- Section 4: skill level of the workforce in which participants express their opinions about the preparation of future farmers, the skills they should have and the precision farming training (questions 11, 12, 13, 14, 15, 16, 17 and 18).

These questions were measured in qualitative data selecting the answers between different options.

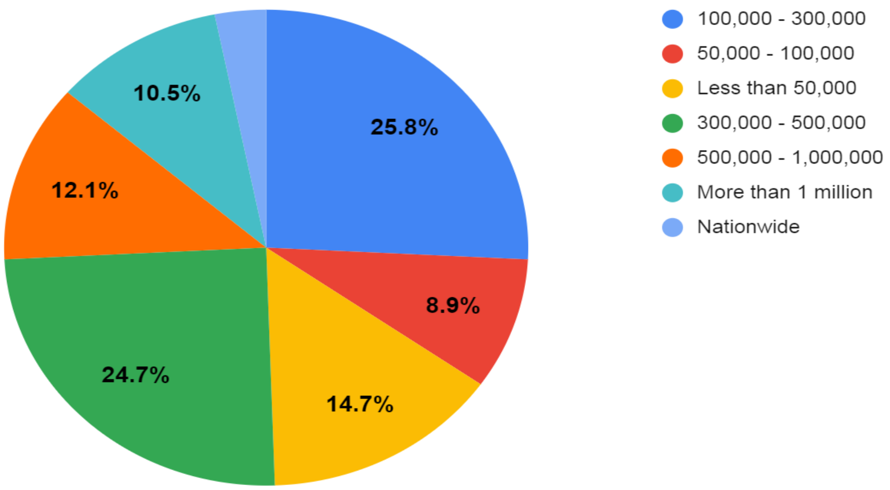
4. Results and discussion.

Section 2. Background information to obtain the participant profile

In this section, the aim was to know the participants' profile to know more about them.

The participants are divided in five different countries: Croatia (5,8%), Spain (7,4%), Hungary (42,1%), Slovenia (6,8%) and Greece (37,9%). The difference in the number of participants in each country can have a negative impact on the results since the participants are not balanced out. This can make it difficult to make conclusions about Europe in general because of the region's particularities. This is especially important to notice in the case of Spain since its geographical, cultural and economic background is quite different from the rest of the countries participating in this research. Hungary, Slovenia and Croatia are all from the same region and have a similar agricultural background. Greece has certain particularities but has enough participants to represent its situation.

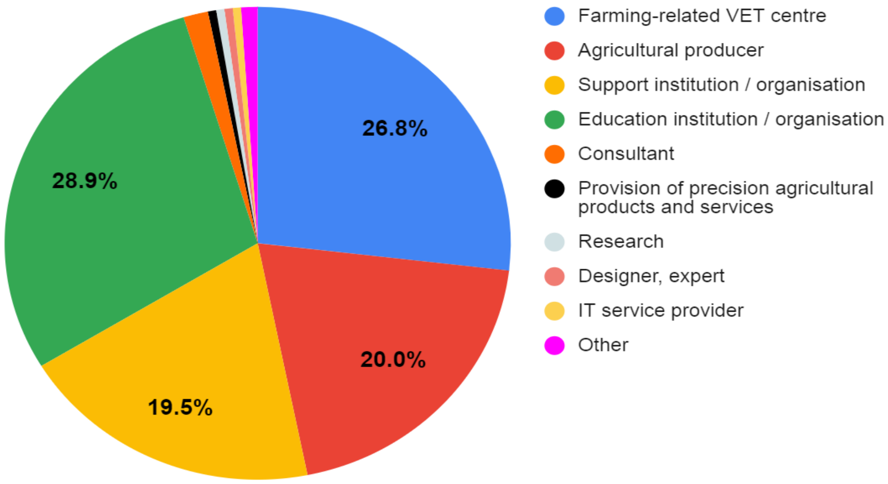
The population of the region where participants work is very divided (Graph 7), but we can affirm that the middle of the participants (50,5%) work in population regions with 100,000 to 500,000 people. This is in direct correlation with agricultural activity being mostly in rural and suburban regions.



Graph 7. Region population of participants

The organizations/companies sizes in terms of number of employees in which the participants work are clearly small and medium. 72% of the participants are working in an organization/company with less than 50 employees, and this data is interesting to analyze with the rest of responses. Having the majority of participants from small to medium organizations is beneficial since it will give a better insight into the most common problem of lack of funding for implementing precision agriculture technologies.

The primary activities of the companies/organizations (Graph 8.) are very different, but the most of them are Farming-related VET center, Agricultural producer, Support institution/organization, and Education institution/organization.



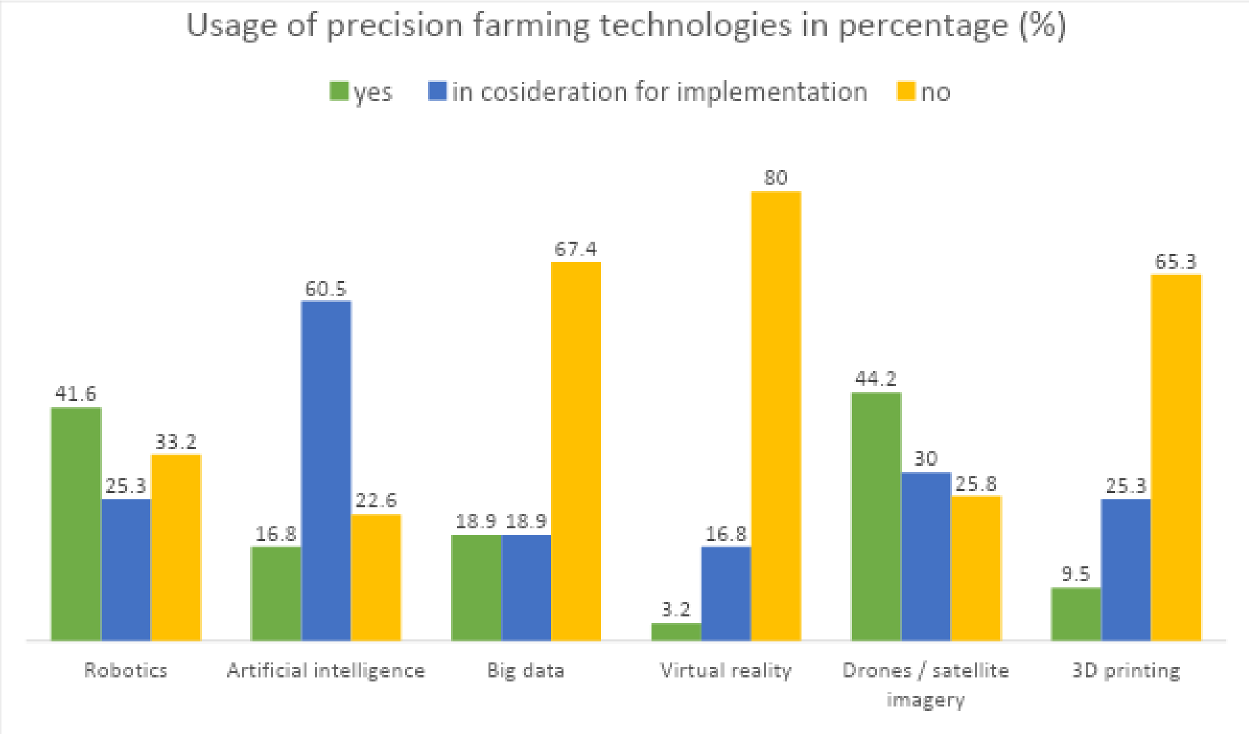
Graph 8. Primary activities of participant organizations

People that participated in the questionnaire have very different positions in their companies/organizations, but the most of them (65.3%) are working like Management – decision maker (owner, CEO, director, etc.) or like Professor/teacher/trainer. The other categories more selected are Head of IT or Technology department (10.5%), Researcher (10%), Department manager (4,7%) and Advisor (3,7%). Having decision makers as the primary group is vital to understand the stage of implementation of precision agriculture technologies and problems that come with it.

Section 3. Use of precision agriculture technology

The objective of this section is to know the participants' opinions about the actual education/training/support of precision farming technologies, the difficulties to implement it and the skills that they think farmer lever must have for technology management. Furthermore, they express what skills and knowledge they have about technology management and what precision farming technologies they use in their activities/actions.

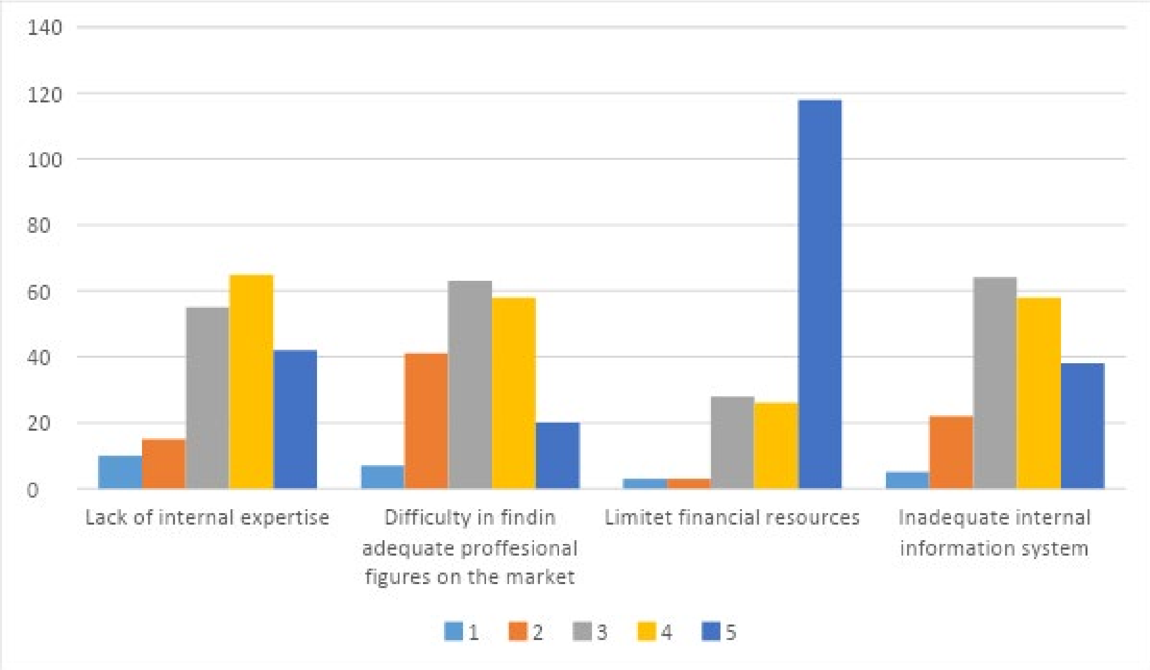
About what precision farming technologies are used or educate/train/support, participants have to indicate it in different categories represented in Graph 9.



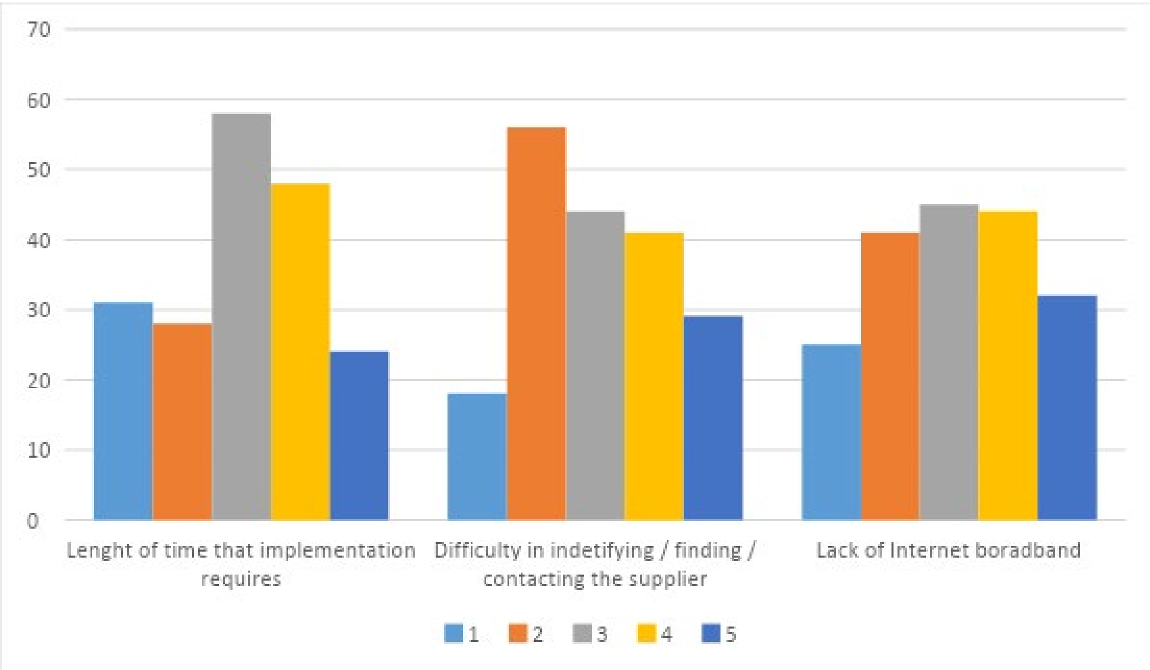
Graph 9. Usage of precision farming technologies

Robotics and drones / satellite imagery are the most commonly used technologies of precision farming. This is in line with the development and availability of these tools. Satellite imagery is available free for farmers to use, while drone capabilities have drastically increased while their prices are becoming more affordable by the day. Robotics are necessary in food processing while the implementation on fields is still in development. Important to notice is a clear interest in implementation of artificial intelligence. This is an indicator that this technology could be next in line for implementation in production processes. For big data, virtual reality and 3D printing participants show the lowest interest for implementation.

About what difficulties or constraints find participants when implementing farming, participants have to express their opinion in different items and measured on scale (1 indicates lowest difficulty and 5 indicates the biggest difficulty). The results are represented in Graph 10 and Graph 11.



Graph 10. Difficulties or constrains when implementing precision farming. 1- lowest, 5 highest difficulty



Graph 11. Difficulties or constrains when implementing precision farming. 1- lowest, 5 highest difficulty

- Difficulty in finding adequate professional figures in the market: participants do not agree on this difficulty. Most of their responses are between 2 and 4, and it indicates that the availability of professionals is not consistent. Furthermore, this variety of responses can be due to the participants' countries, depending on where they live and the affordability of the professionals.

- Difficulty about limited financial resources: most of the participants have answered this as the highest difficulty and it indicates a clear economical problem.
- Difficulty about inadequate internal information systems, length of time that implementation requires, difficulty in identifying the supplier and lack of internet broadband: all of this difficulties follow a scattered pattern that can be related to the differences between the participants' profiles. It is not possible to make a clear conclusion, except that for half of the participants it is a problem and as such needs to be addressed.
- Other difficulties: participants were asked about other difficulties that they find about implementing Precision Farming Technologies. There were many different answers about it and some examples are “information about equipment”, “lack of competence”, “lack of scientific background”, “lack of equipped / prepared training places” or “money”.

The next part of the questionnaire is about the skills required and available at farmer lever for technology management. About this question, participants had to select the skills that in their opinion are necessary, selecting “Yes” or “No”. Results are shown in Table 1.

Regarding the responses, it is possible to affirm that participants think personal development skills and advanced digital skills are the competences most necessary for technology management.

Furthermore, participants were asked about other skills that they think are necessary for technology management, and some or their responses were “professional skills (eg agricultural)”, “precise, careful and detailed attitude” or “joint environmental development”.

On the other hand, participants were asked about what of the previous skills they consider to have. Results are shown in Table 1.

In addition, participants had to say if they have other skills, and although 96,3% answered “No”, the rest expressed some such as “precise attitude”, “the intention to embrace new technologies” or “test”.

With these responses, it is possible to make a comparison: even if participants consider farmer lever needs all the skills described, not all of them have them. To show it clearly, in Table 1. you can see a comparative between what skills participants consider farmer lever should have and what skills participants have.

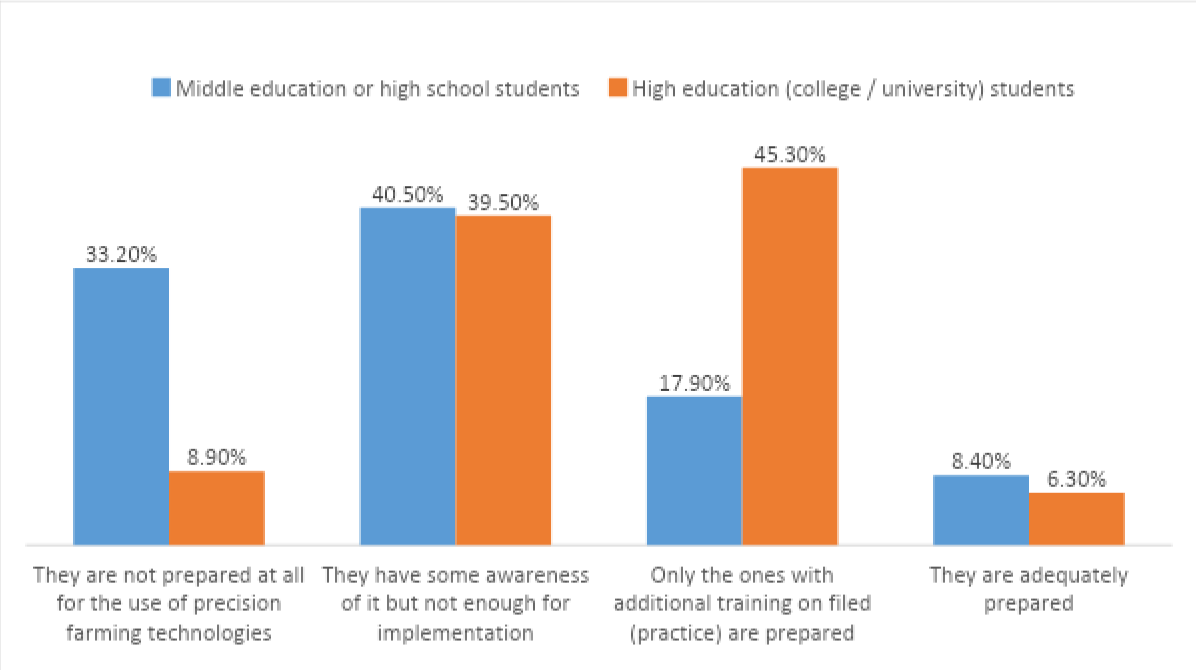
	Percentage of participants Consider necessity of skills at farmer lever	Percentage of participants Consider they have these skills
Personal development skills	87,9%	81,1%
Management skills	58,9%	48,4%
Basic digital skills	67,4%	79,5%
Advanced digital skills	86,3%	34,7%

Table 3. Comparison between what skills participants consider farmer lever should have and what skills participants have.

Section 4. Skill level of the workforce.

The aim of this section is to know the opinion of the participants about the preparedness of fresh graduates, availability of workforce and training, the usefulness of the training, interest of the people in this type of training, foundation of the training and training repercussions in their organizations.

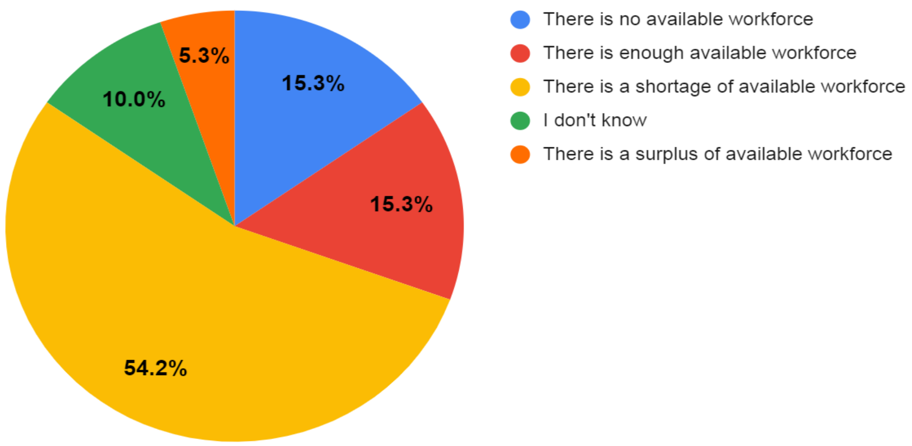
First, in line with the skills considered by participants, they had to express their opinion about the preparedness of freshly graduated students from middle education and high education to use precision farming technologies. Results are shown in Graph 12.



Graph 12. Preparedness of fresh graduates to use precision farming technologies

Comparing both results, there are two clear differences between students. Most participants (73.5 %) think that students from high school or middle education are mostly not prepared at all for the use of precision farming or that they only have awareness of it. For students from college or university, most participants (84,8 %) think that they only have the awareness (39.5 %) or that they are ready after additional training on field (practice) (45.3 %). With these opinions, it can be understood that students from college or university have better training than students from middle education or high school and therefore better preparedness to use precision farming technologies.

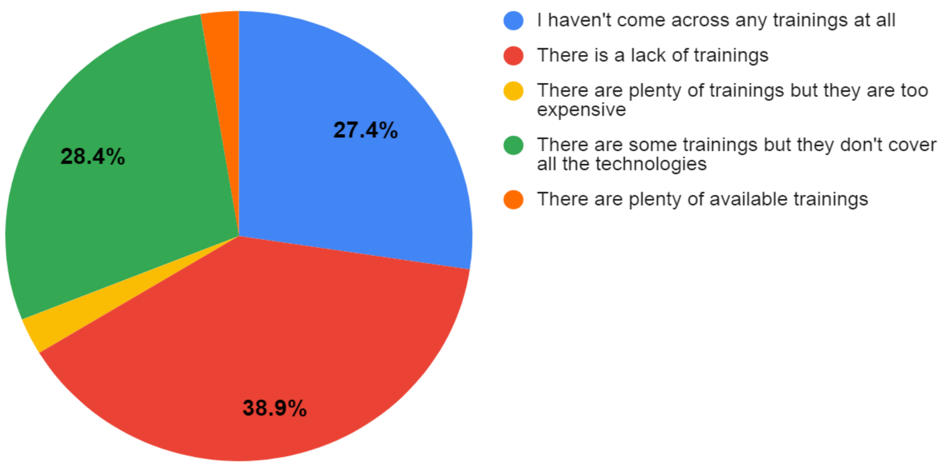
Directly related to the preparedness of the freshly graduated students, participants were asked about availability of the workforce that is prepared for adaptation of precision farming technologies, the training for the precision farming and their foundation. The results are shown in Graph 13.



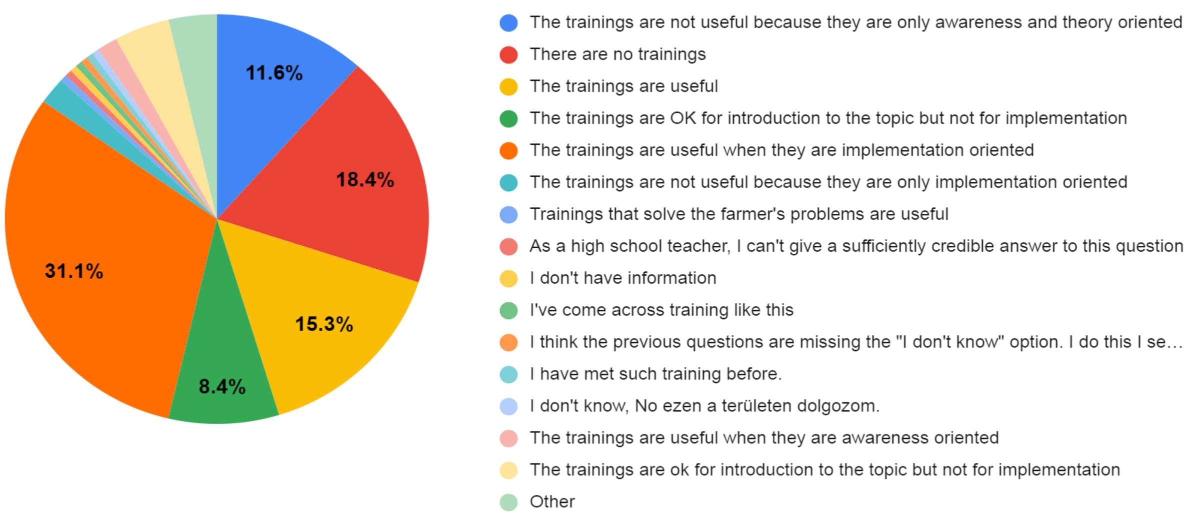
Graph 13. Availability of prepared workforce for adaptation of precision farming technologies.

Results for the questioner about the availability of the adequate workforce clearly show a lack of competent workforce since only 20% of participants think there is either enough of a surplus of available workforce. The lack or surplus could be related to participants' profile (location, field of work).

Participants were additionally asked about the availability and usefulness of additional training for the workforce concerning precision farming. The availability of additional training is shown in Graph 14. which shows a clear lack of training or a lack of technology specific training. Most concerning is that 27.4% or participants have not even come across any training. Considering the usefulness of the training, participants agree that the training is useful only if it is implementation oriented. This can be concluded for the percentage of participants (31.1%) that choose that exact answer, 11.6 % that said that training is not useful because they are only awareness and theory oriented and 8.4% that say the training is ok for interdiction but not for implementation. Results are shown in Graph 15.



Graph 14. Availability of additional training for the workforce concerning precision farming.

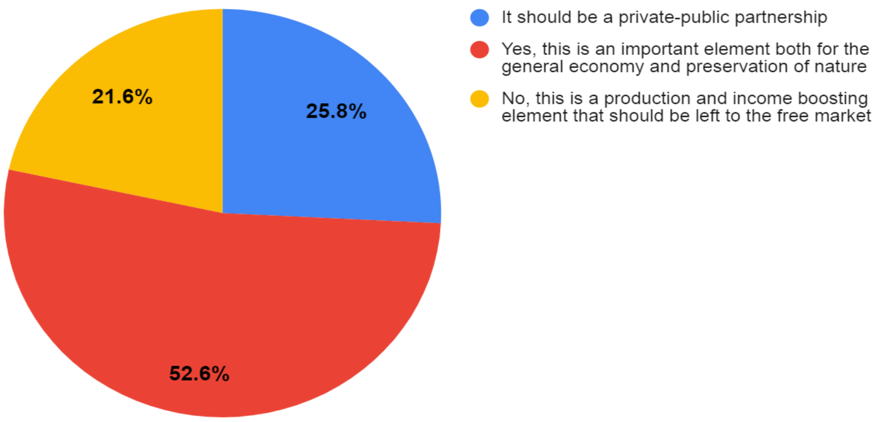


Graph 15. Usefulness of the training concerning implementation of precision farming technologies.

There are other responses from participants' opinions such as “I don’t know”, “As a high school teacher, I can’t give a sufficiently credible answer to this question” or “I have met such training before”.

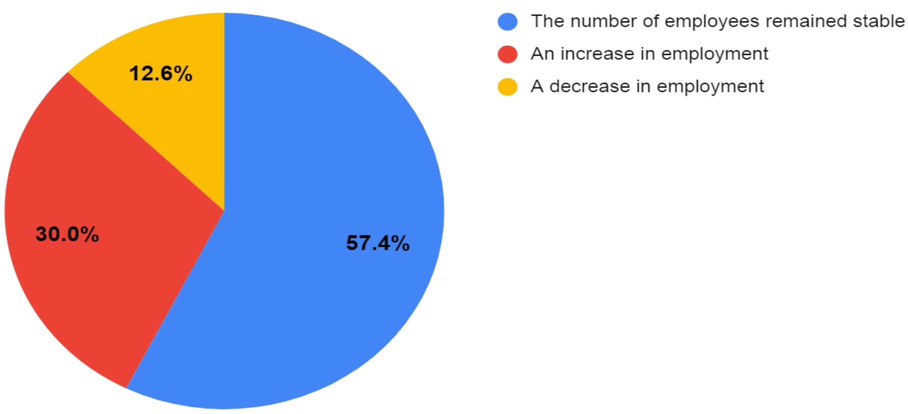
About the training sessions, participants were asked about if they have ever organized a training/education on precision farming, what was the level of interest from participants. Most participants (80%) never organized any training / education on the topic. Also, 6,8% say that the amount of participants was as expected and 5,3% affirm that some spots for the training were not filled. About the remaining percentage, they are divided into “the interest for the training/education was low”, “there were more applicants than available spots” and “there was no interest for the training/education at all”.

Regarding the founding of the training for the implementation of precision farming, participants were asked about whether it should be funded from public, private or mixed sources. Half of the participants agree that training should be publicly funded. Results are shown in Graph 16.



Graph 16. Founding of trainings for the implementation of precision farming

Finally, participants express their opinion about if the investment in Smart Farming technologies had an impact on employment in their organizations. The results shown in Graph 17. show that implementation of smart farming technologies has a positive effect on the workforce since in most cases it didn’t not affect the number of employees but when it did it resulted in additional employment more often the in decrease in employment.



Graph 17. Impact of smart farming technologies on employment.

5. Conclusion and future farmer predictions

The questionnaire addressed various topics that enable or inhibit the implementation of precision agriculture technologies. Although the results would have been better if more respondents had participated, they are still relevant because the project partners that conducted the survey sent the questionnaire only to relevant organizations and participants, as can be seen from the fact that most respondents are decision makers in their organization. Specific economic and geographical characteristics can by no means be ignored, however, from the results of the questionnaire clear trends can be concluded regarding the development and implementation of precision farming technologies.

The results on the usage of technologies clearly indicate that the implementation of technologies such as drone and satellite monitoring and the use of robotic solutions are already being implemented. The implementation of technologies is directly related to its readiness for the market, but the results also show a tendency for certain upcoming technologies. For instance, one of the upcoming technologies, artificial intelligence, is a technology that most respondents monitor and consider for introduction into their processes, while virtual reality, big data and 3D printing are less represented. This result is interesting because respondents are more interested in artificial intelligence technology, which is still in its infancy in terms of implementation, while showing less interest in big data and 3D printing technologies that have already been successfully used in agriculture and other sectors in recent years.

The main factor hindering the implementation of precision agriculture technologies is the lack of financial resources. This result is expected given that these are newer technologies, and therefore more expensive. Additionally, most of the technologies still have to prove the profitability of the investment and a reasonable time of investment return. Other limitations for implementation apart form cost and investment return are evenly distributed and it cannot be concluded that they are inhibitory for the implementation of technologies in general. They are more individual situation based.

Personal development skills and advanced digital skills are recognized as the most important traits needed to implement precision farming technologies. The vast majority of respondents believe that they have the necessary personal development skills but clearly indicate that they do not have advanced digital skills. Regardless of what the respondents consider to be basic or advanced digital skill, these results indicate that respondents consider that they do not have sufficient digital competencies. Whether this is true or whether fear of the unknown prevails, would need to be investigated in more detail.

Labor availability has proved inadequate. The results clearly indicate that students regardless of their level of education are not ready to use these technologies without additional training. High education students (college, university) have a clear advantage, but their readiness for implementation is assessed as not adequate without additional training. This assessment of the education of the new generations directly correlates with the lack of adequate workforce that the respondents also recognized. Agricultural precision technologies, like all other digital technologies, are evolving very rapidly and it is difficult to expect that standard education systems will be able to keep up with the constant change. For this reason, a significant increase in training is needed to train the workforce. Participants expressed the lack of availability of such training and the need for training focused on the implementation of the technologies. Most agree that this topic is important for the general economy and environmental protection and as such, the training should be funded from public funds. This opinion confirms the need and justification of projects like this.

A4.1. Future prediction

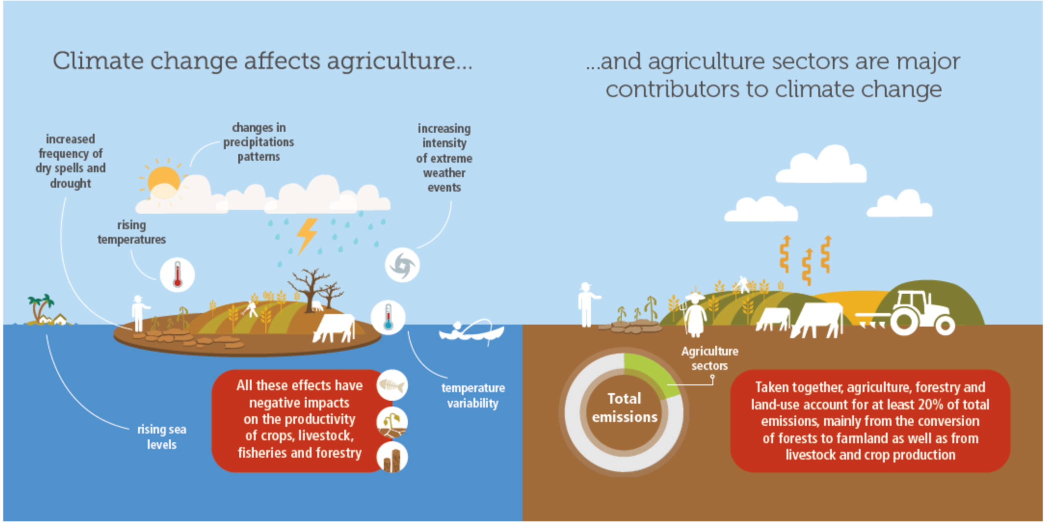
The tendency to implement and increase interest in precision farming technologies is continuously growing. In order to monitor this trend in the field, a significant increase in implementation-oriented education and training is needed. Education systems build basic knowledge; however, they cannot keep up with the pace of technology change in the field. This role should be taken over by facilitators and trainers. Given the speed of technology change and the already busy working day of farmers, it is to be expected that in the future the farmer will need continuous help and advice from experts. This whole process will require significant financial investment, which the EU has already recognized to some extent through the funding of knowledge transfer projects and the creation of digital innovation hubs that should become the main driver of knowledge transfer to farmers. Such and similar initiatives will be the bearers of changes that will enable small farmers to cope with advancements, even though they have limited financial resources which is the main inhibitor of implementation because of expensive equipment, but also the need for education.

Technologies of precision agriculture and digitalization of agriculture are also recognized as a factor in achieving sustainable development and nature conservation. This feature will significantly increase the availability of finance in the coming periods given the EU's goals in this area, which will not be possible without changes in the agricultural sector.

A.5. Digitalisation of agriculture

In this chapter, we aim to focus on technologies and solutions currently used in production. It is important to note that these are examples chosen by the project partnership to cover different topics of the field of precision agriculture. The goal is for the reader to have a general overview of what is being developed and inspire them to further research the topics of interest.

A.5.1. Impact on sustainability



Picture 12. Climate change's effects on agriculture

4.2.1 Agriculture's impact on climate change[35]

In human history, we always affected, changed and adjusted our environment to our needs. The question is on what scale and for what price.

No doubt, we need to produce enough food for our own survival, but we need to take into consideration besides that agriculture's contribution to global warming, it has other harmful effects on the environment. Agriculture is often the reason for deforestation and change in land use. Natural ecosystems are more rich and complex; therefore, they can take up and store much more carbon dioxide (CO_2) than farmlands can.

[35] http://www.fao.org/3/i3671e/i3671e.pdf
https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_full.pdf
https://www.futurelearn.com/info/courses/climate-smart-agriculture/0/steps/26564
https://ec.europa.eu/eurostat/databrowser/view/env_air_gge/default/table?lang=en

Globally, 25% of our greenhouse gas (GHG) emission originates from agriculture that makes it an important sector among other human activities. Between 2000-2009, mostly

- Land use and change in forestry,
- Drained peat and peat fires, and
- Enteric fermentation were the main resources of climate change causing gases.

Changing the function of uncultivated land from being a carbon sink and store (forest and natural ecosystems) to being a source of GHG emissions due to burning plant material or farming, has a negative impact on the emission balance. Likewise, maintaining and increasing plant biomass contributes to carbon sequestration and reduces the concentration of CO_2, so forestry and the management of woodland, both impact on the amount of GHGs in our atmosphere.

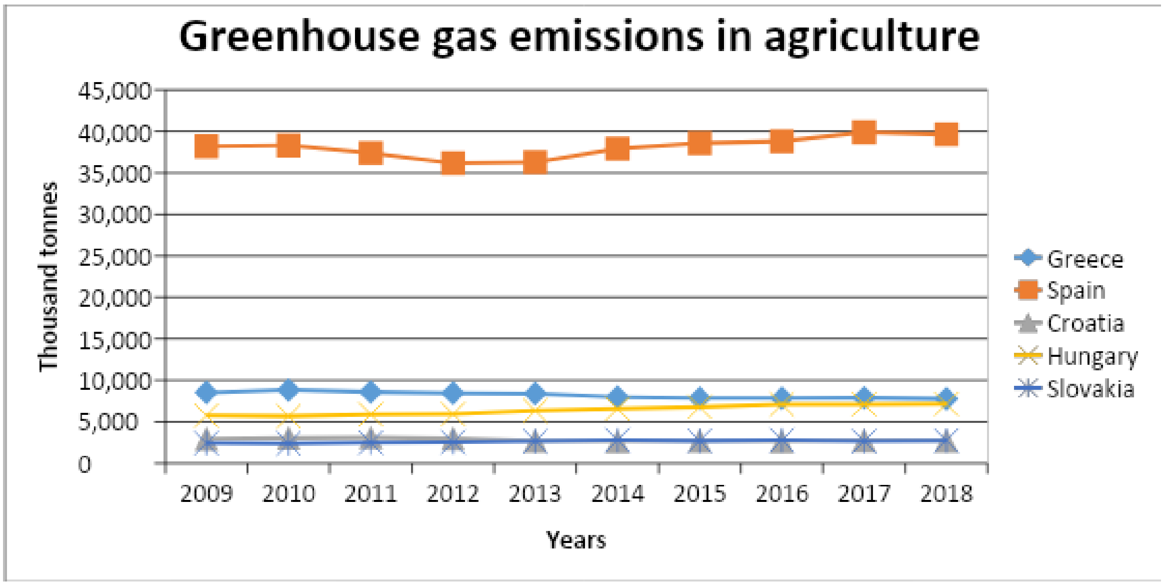
Peat fires and drained peat cause mainly emission of N_2O and CH_4 (beside CO_2).

Nitrous oxides originate from livestock sector, but are also formed during the application of fertilizers rich in nitrogen to fields. Moreover, they also originate from manure or engines burning fossil fuels. Fertilizers rich in nitrogen can pollute water and threaten aquatic ecosystems.

Methane (CH_4) has two main sources, once the digestive processes in cattle and similar fermentative processes in manure, secondly the rice paddies; where constant flooding of the fields creates similar, anaerobic conditions, which favors methane production.

It is complicated to estimate the concrete steps that will happen through biodiversity loss to a Planet-wide collapse of ecosystems. What we know now is that pesticides, herbicides, and monocultures are pushing humanity into this direction.

Regarding the PreAgri countries, GHG emission in agriculture in the past 10 years did not go under significant change. Total emissions vary on country profile and size of course. Compared to global trends, agriculture as a sector is responsible for approximately 10% of total emissions – keeping in mind the fact that a huge percentage of our consumption (exotic fruits, tea, coffee, etc.) is not produced locally, but more and more often is imported from other continents.



Graph 18. Greenhouse gas emissions in agriculture

4.2.2. Climate change's impact on agriculture[36]

Climate change has already serious negative effects on agriculture, food security and right on the farmers living on agriculture. Immediate images of flood, drought, frost, or baking heat are linked in the public's eye and in reality with the weather dependence of food production and with the populations who may suffer deprivation if crops fail. Therefore, farmers are particularly at risk, especially in countries of the Global South. Since ever, agriculture depends directly on climatic conditions and natural resources, and is affected more than - ever - any other sector by the impacts of climate change.

The majority of studies conducted in the topic, point to mostly negative impacts, which will worsen over time. They also show that negative impacts are likely to be much more pronounced at lower latitudes. Most of the cost – in particular lost production and productivity - will be suffered by developing countries and countries with already high levels of poverty and food insecurity.

Agriculture has to both adapt to climate change and contribute to mitigation. This requires changes in agricultural practices as well as improvements in livelihood options for poor farm households.

Adaptation can happen in several ways, ranging from flood prevention, adaptation of crops (drought resilient species) up to population-wide dietary changes (conscious consumption) and more. Remotely sensed images of land use, crop cover, and soil properties over large landscapes such as watersheds and river basins are powerful tools to analyze physical constraints on crop yields. Research is needed to develop analytical tools using precision agriculture models, which can interpret large quantities of geospatial data, and which can be applied to make recommendations on crop cultivar selection and water and fertilizer requirements, therefore optimizing crop yield as well as farmers' economic returns.

Precision agriculture can provide solutions to farmers to become more resilient to effects of climate change, through electronic, digital, online systems usage such as drones, satellites, databases and software that allow farmers to better regulate their water, energy consumption and give a more adequate answer to their field's and crop's needs. A few examples listed below show how smart farming techniques can support mitigation and adaptation to climate change.

- Conscious usage of chemicals can facilitate the more efficient use of nitrogen fertilizers and thus reduce greenhouse gas emissions associated with excess application
- Tillage scheduling can avoid soil degradation and save energy
- Right amount of water avoids over-irrigation and appearance of locally dry areas
- Mainstreaming science and data based decision making results avoiding ad-hoc and short term solutions
- Satellite pictures may help in choosing the most adequate crop for the field
- Optimization of overall energy usage (for example trajectory of vehicles and machines)

[36] FAO, The State of Food and Agriculture 2016, Climate change, agriculture and food security
CLIMATE CHANGE: WHAT DOES IT MEAN FOR AGRICULTURE AND FOOD SECURITY?
https://jwafs.mit.edu/sites/default/files/imce/publications/Climate_Ag_Report_New.pdf

- On-site cameras help decide whether the farmer has to travel to the field or not.

Moreover, climate change caused havaria and extreme weather events happen more often, therefore strengthening agriculture in sustainable manners is a way forward. Precision agriculture techniques can enhance farmers' efficiency in production by

- predicting extreme weather conditions
- providing live data that supports immediate decision making
- helping pest prevention.

Other than this, changes in the broader food system are also needed, including reductions in food waste and losses and changes in dietary patterns to reduce their carbon footprint.

A.5.2. Small-scale farmers' opportunities in self marketing on digital platforms[37]

However, large-scale farming has its short-term benefits, mainly on the income side but as several times the attention was drawn on concerns from sustainability point of view. Thus we feel urged to point on small-holders' opportunities and advantages from digitalization perspective in this chapter.

The pandemic situation brought important changes to the everyday life of everyone. Many of our personal interactions moved online and so did farmer-customer relations. Clients tend to order online and instead of going to the market, home delivery became frequent in our reality. In this chapter we would like to collect the platforms through small-scale farmers can still reach their buyers – in such an extraordinary situation now, as later on for an extended pool of customers.

Picture 13. Fresh and healthy vegetables

[37] http://www.fao.org/3/ca4887en/ca4887en.pdf
https://tudatosvasarlo.hu/a-covid-jarvany-alatt-keresett-a-helyi-elelmiszer-bevasarlokozossegek/
https://en.wikipedia.org/wiki/Community-supported_agriculture

Box-system

Community-supported agriculture (CSA model) or crop-sharing is a system that connects the farmer / producer and consumers within the food system more closely by allowing the consumer to subscribe to the harvest of a certain farm. It is an alternative socioeconomic model of agriculture and food distribution that allows the producer and consumer to share the risks of farming. This model strengthens the sense of community through local markets. In return for subscribing to a harvest, consumers receive a weekly box of product or other farm goods. This includes in-season fruits and vegetables and can be topped up with eggs, milk, meat, dried goods, etc.

"What we like the most is not even the veggies, but the community." – says one of the oldest customers. Recent studies show that since the beginning of the pandemic, shopping communities tend to increase in number of subscribers and in size of orders too, placed throughout the year.

Europe-wide, in 16 countries, 6300 farmers work on at least 4000 community farms, providing fresh food to more than 465 000 consumers. In Hungary, more than 1000 families are signed up for their weekly boxes – this way of trading is the most widely spread system in Hungary. In most of the cases, farmers and consumers sign an agreement of a yearly commitment, but organic product retailers and some larger farms opened the possibility for placing individual orders too.

Organizing orders, logistics, administration and billing, all need some IT background, therefore these farms or retailers developed their own system where buyers can place their orders and producers can easily follow and administrate them. These are usually user-friendly websites, with several online paying systems.

Webshop

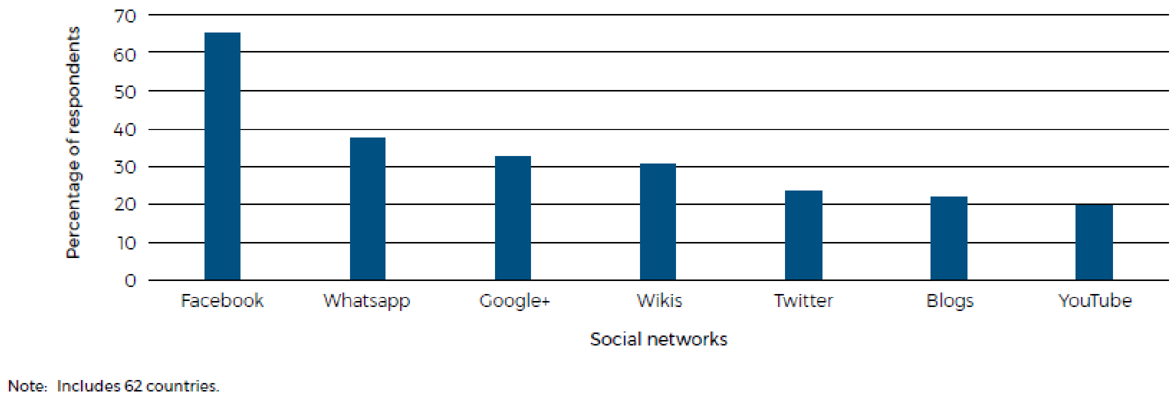
There is more sense to sell longer lasting products in a Webshop – typically not fresh veggies and fruits, but rather – honey, marmalade, syrup, creams and dips, sauces or wine. A webshop opening require some technological knowledge, but as a new trend, freelancers tend to specialize on web marketing, social media marketing that often include webshop building as well. Webshops have their own regulation from taxation point of view; this is something worth checking with the accountant to ensure our business complies with the actual regulations.
One of the most recent businesses is Crowdfarming that provides a platform that directly connects producers and clients: https://www.crowdfarming.com/en

Facebook

It is getting easier to buy and sell products in general on social media. Facebook is popular because it is widespread, and has more and more features that allow users promoting the things they want to sell. It is also results quicker sales than traditional ways.

- Marketplace function allows us to search for specific products. Is it the strawberry season? So producers post their fruits on Marketplace, buyers look for the great deals.
- Buying-selling groups are often organized by location that makes it easy for locals to exchange their goods.

Nevertheless, we have to mention that the above-mentioned techniques work only in specific settings. Selling agricultural products online, right to the consumer works only in case of small-scale farms. Farm owners and their buyers are typically intellectuals – it is more likely they have some basic computer literacy. This is not the case on a global scale. The below graph shows social media preferences among agricultural stakeholders in 2016.



Graph 19. Social media preferences among agricultural stakeholders, 2016[38]

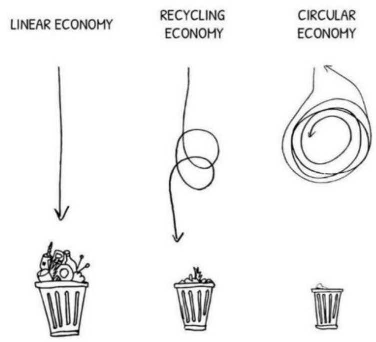
Digital skills and e-literacy remain a significant constraint to the use of new technologies and are particularly lacking in rural areas, especially in developing countries. The diversity of available digital technologies and a lack of standardisation also present a barrier to adoption. The choice of which technology to use is complex and there is a lack of advisory services to support farmers in these decisions. Education and supporting services must be improved to support the adoption of digital technologies.

Sources:
http://www.fao.org/3/ca4887en/ca4887en.pdf
https://tudatosvasarlo.hu/a-covid-jarvany-alatt-keresett-a-helyi-elelmiszer-bevasarlokozossegek/
https://en.wikipedia.org/wiki/Community-supported_agriculture

A.5.3. Sustainable food packaging

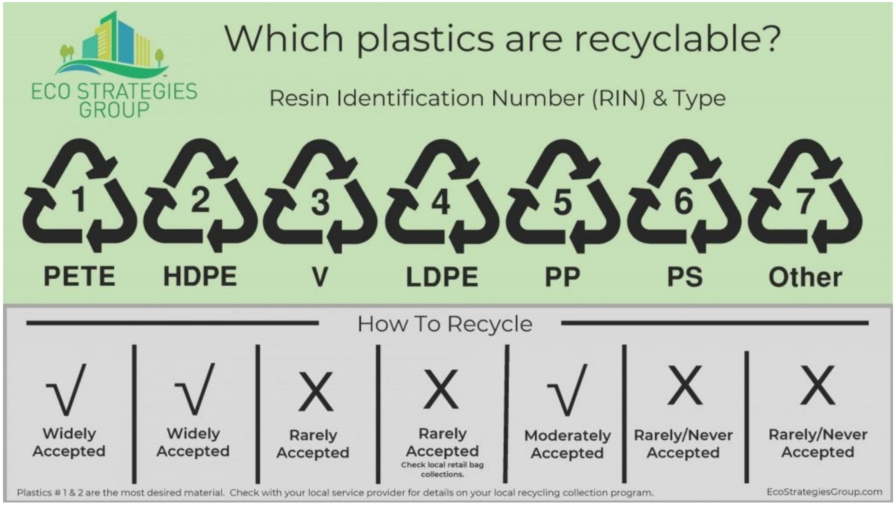
It’s now a well-known, yet increasingly burning, problem of the health and environmental damage caused by the accumulation of plastic waste in the world. The solution definitely requires the change of attitudes, in which single-use packaging solutions are replaced by environmentally friendly, reusable or even packaging-free, long-term truly sustainable packaging technologies based on a circular economic model.

[38] Bhattacharjee and Saravana, 2016.



Although the range of alternatives is expanding as the packaging-free and zerowaste movement becomes more popular, for many food products proper packaging is essential from a food safety perspective.

Unfortunately, there are a lot of misconceptions and misunderstandings about the various “green” solutions in the public. One of them is that recycling alone solves the waste problem. Unfortunately, the reality is much more complicated, because selective collection in itself is not a solution**.** In fact, there are a wide variety of plastics, which are usually classified in 6 + 1 other categories, of which only 4 are recyclable. In the case of food packaging, it is particularly common for manufacturers to combine different types of materials with different properties in order to increase their shelf life, but it makes recycling often impossible, or at least more expensive.



Picture 14. Recyclable plastics

The so-called “bioplastics” are also becoming more and more common. The term includes bio-based and biodegradable plastics. Although they are made from renewable raw materials, it does not follow that they degrade naturally. Most bio-based plastics are non-degradable, non-compostable (bio-polyethylene, bio-PET) or degrade only under industrial circumstances (PLA) which requires a separate collection and sorting system, which makes selection extremely difficult. Not to mention oxo-degradable plastics, which are fragmented into micro plastics by light due to the metal salt additives, which is particularly harmful to wildlife and thus to humans. The name „bio” is therefore extremely misleading, as it suggests that they are naturally degradable, environmentally friendly packaging materials.

On the way to the solution, microbiologically degradable polymers e.g. from agri-food waste residues, crop residues, sewage sludge seem to be a promising way to create an innovative, more flexible and productive waste-based food packaging economy. Such as food packaging made from milk protein (dairy by-products), which used as the inner layer of the entire package, is also edible. Another example is plastic developed from municipal plastic waste and agricultural by-product (rice husk), which greatly reduces the energy and CO2 emissions required for production.[39]

It is important to underline, that with our current consumption patterns and economic structure, these innovations in themselves are not real sustainable solutions to the problem of plastic pollution. Waste

[39] http://www.miniwiz.com/

prevention and the rediscovery of refundable and redeemable products are also important steps. Real change requires the cooperation of conscious consumers, manufacturers and decision-makers.

A.5.4. Drones in Agriculture

The usage of drones in agriculture is an innovative tool that allows farmers and landowners to speed up the process of monitoring their fields and cropland in a unique manner. Their applications in agriculture are varied and can serve for a potential improvement in the final product and its cost-effectiveness.

The technology behind drones has been evolving greatly in the last years and both the consumer and professional offers have improved and prices are lower at the present time.

Usage varies; the affordability of drones, as well as rapid advances in the scope of the technology, are fueling an ever-expanding range of current applications. These include aerial mapping, plant health monitoring, weed detection, and crop spraying, where it’s permitted by law:

- Precision fertilizer programmer planning - Drones begin flying operations by taking hundreds of images of the crop's developing canopy. The images are then stitched together to form a map, and early growth patterns are identified using software.
- Weed and disease control programs - The photos are then stitched together to create a map, which is subsequently utilized to determine early growth trends using software. The drone collects data that identifies the different reflective qualities of distinct plant varieties as well as diseased parts of the crop.
- Tree and land mapping - The capacity to cover enormous regions of ground is a significant advantage for mapping in general. Hundreds of hectares can be mapped in a single day using the most advanced systems, which can pinpoint changes in terrain and boundary features to within 10cm. The information gathered is then used to generate a three-dimensional computer model that highlights ground characteristics and any changes that have happened.

Ongoing future technology development for drones in agriculture include:

Drone swarms

While the majority of spraying is done using single drone units to patch, strip, or spot spray, fast improving drone technology may allow far greater regions to be sprayed in the future. Drones can already communicate with one another in order to avoid collisions and fly in formation. In the future, this might allow a string or swarm of drones to spray insecticide across entire fields. While trials are still ongoing, the major roadblock to success may be legislation, since governments and military leaders are concerned about the threat posed by a swarm of autonomous aircraft.

Plant Pollination

The decline in bees has sparked global anxiety about the future of plant pollination, which is essential for horticultural and agricultural production. Researchers in Japan have looked into using drones to complete the task. The drone, which is only four centimeters across and weighs 15 grams, has proven that it is capable of pollinating flowers without harming the plant. The research team is now working on an auto-piloted version that the grower may use to complete the task on its own.

Beyond Visual Line Of Sight flying

A safety restriction, limiting maximum operating distances to 500 meters, is a typical feature of drone law. Within that distance, the pilot must always maintain a Visual Line Of Sight. Pilots, on the other hand, say that these limitations drastically limit the technology's potential. If a field border is more than 500 meters away, or if undulating fields or trees obscure the line of sight, the operator must assemble his or her equipment and move.

Operators and producers are pleading with the government to abolish the limitations. They claim that BVLOS flying will revolutionize the drone market and that it is safe due to advancements in on-board safety systems. Drones can be securely flown in rural regions thanks to sense-and-avoid systems, remote viewing using imaging devices, and pre-programmed return-to-base mechanisms that are triggered if the drone loses touch. More testing is being done on this technology with the goal of establishing that BVLOS flying is safe and could become a reality in the near future.

A.5.5. Technologies in food processing

Food processing allows consumers to have a wider variety of foods available to them, resulting in a more varied and balanced diet. Perhaps the most significant advantage of food processing is that processed foods are microbiologically safer than fresh or unprocessed foods.

People refer to Industry 4.0 as the "future industry," in which devices are interconnected, communicate, and control processes autonomously. The food industry must use new tools and be more adaptable in order to better adapt to consumption niches and consumer specific demands."

Because processed foods are perceived to be harmful to health, consumers are increasingly choosing fresher and less processed products. The main advantage of novel technologies is that they allow for the extension of shelf-life and assurance of fresh food safety without affecting taste, appearance, or nutritional properties.

Improve heating or avoid temperature rise:

Throughout history, heating has been used for a variety of food processing purposes. Novel food processing technologies are divided into two categories: those that reduce the negative impact of thermal processing by improving heating (microwave, ohmic heating) and those that do not. (HHP, PEF and irradiation) that prevents temperature rise during processing. HPP stands for High Pressure Processing, using pressure to preserve the food and PEF stands for Pulsed Electric Field, using electricity pulses. These technologies have many different applications in the food industry.

Non-thermal processing

Non-thermal processing takes place at lower temperatures than thermal processing, avoiding the negative effects of heat on taste and nutrition. Furthermore, reducing energy inputs with these new technologies may help to reduce the environmental impact of food processing. PEF and HHP are widely used in the food industry.

Preservation

High hydrostatic pressure processing (HHP) is a very useful technology for pasteurizing solid foods after packaging and preventing contamination during processing. The main issue with HHP is that it is a batch process, so the facilities' production capacity is limited. The pulsed electric field (PEF) is better suited for pasteurization of liquid foods because it allows continuous lines to meet the food industry's processing requirements. PEF cannot be used to preserve solid foods. Both technologies have the ability to inactivate bacteria but not bacterial spores, so applications must be focused on food pasteurization rather than sterilization.

Other applications

PEF and HHP can both be used for purposes other than food preservation. For example, HHP can be used to easily and cleanly remove meat from shellfish including oysters, lobsters and crabs and PEF can be used to improve extraction of intracellular compounds in different operation of the food industry such extraction of polyphenols during red winemaking or to modify food structure facilitating cutting operations of peeling of fruits and vegetables.

A scarcity of dependable and viable industrial-scale equipment capable of meeting the needs of the food industry i.e. high processing capacity, low energetic requirements and easy implementation in existing processing lines has limited the commercial exploitation of novel technologies in the food industry for many years. The successful transfer of PEF and HPP technology for industrial applications has been fueled by technological advancements in recent years. It is still difficult to find equipment that meets the needs of the food industry for other new processing technologies such as pulsed light applications, cold plasma treatment, ultrasound, and so on.

A.5.6. Smart Machinery

"Smart farming" is a new idea that refers to managing farms utilizing the Internet of Things (IoT), robots, drones, and artificial intelligence (AI) to boost product quantity and quality while reducing the amount of human labor necessary for production.

Sensors (soil, water, light, humidity, and temperature management), software (specialized software solutions that target specific farm types or use case agnostic IoT platforms), and connectivity (cellular, LoRa, etc.), location (GPS, Satellite, etc.), robotics (autonomous tractors, processing facilities, etc.), and data analytics: standalone analytic platforms are among the technologies available to today's farmers.

Agriculture advances in tandem with science and technology, and it will only be a matter of time until the Internet of Things (IoT) is widely used in farmscapes. Technical advancements in new agricultural technology should increase production efficiency and quality while also reducing environmental effect and production-related dangers.

Precision farming, blockchain adoption in value chains (e.g. transportation, storage, washing, grading, packaging, labeling, or processing), AI for pest and disease diagnostics and management options, remote sensing (satellite and aforementioned drone imagery), and deployment of ground sensors (soil, crop, or meteorological stations) or automated equipment are all examples of such improvements.

- *Autonomous Robotic Labor and Driverless Tractors* - An agrobot (as of yet, not an officially established term) may perform a wide range of functions in the field of agricultural robotics. The first commercially accessible robots are capable of removing weeds, monitoring pests and illnesses, and harvesting specific crops, among other things (berries or vegetables). An agrobot decreases labor needs (weeding and harvesting), restricts the use of inputs (pesticides), and lowers crop losses due to late identification of pests and illnesses, all of which save money.
- *Automatic Watering and Irrigation, also known as Smart Irrigation* - Smart irrigation controllers monitor weather, soil conditions, evaporation, and plant water usage to automatically modify the watering schedule to the real conditions of the site, unlike standard irrigation controllers that function on a preset programmed schedule and timers.
- Sensors and the IoT - Many people feel that IoT may benefit all aspects of farming, from grain production to forestry. In this post, we'll discuss how IoT can change two important sectors of agriculture: precision farming and agricultural robotization or automation.

Smart farming techniques, like precision agriculture, allow farmers to better monitor the requirements of individual animals and change their feed as needed, reducing sickness and improving herd health. Wireless IoT apps may be used by large farm owners to track the location, well-being, and health of their livestock. They can use this information to identify unwell animals and separate them from the herd to avoid disease transmission.

Traditional greenhouses employ manual intervention or a proportional control system to adjust environmental factors, which often results in output loss, energy loss, and higher labor costs. Smart greenhouses powered by the Internet of Things can autonomously monitor and adjust the environment, removing the need for physical intervention. Various sensors are used to detect environmental factors in accordance with the crop's individual needs. This information is saved on a cloud-based platform for processing and control with little human participation.

The Internet of Things has fueled the belief that a smart network of sensors, actuators, cameras, robots, drones, and other connected devices will bring agriculture an unprecedented level of control and automated decision-making, paving the way for a long-term ecosystem of innovation in the oldest of industries.

Smart farming and IoT-driven agriculture are laying the groundwork for a Third Green Revolution. The Third Green Revolution is taking over agriculture after the plant breeding and genetics revolutions. Precision farming equipment, IoT, "big data" analytics, Unmanned Aerial Vehicles (UAVs or drones), robotics, and other data-driven analytics technologies are all part of this revolution.

Pesticide and fertilizer consumption will decrease in the future, but overall efficiency will increase, according to this smart agricultural revolution. Food traceability will be improved thanks to IoT technology, which will lead to higher food safety. It will also be good for the environment, thanks to more effective water usage and treatment and input optimization, for example.

As a result, smart farming has the promise of delivering a more productive and sustainable kind of agricultural production based on a more accurate and resource-efficient method.

A.5.7. Automation in Smart Greenhouses

Greenhouse cultivation allows for quality production and higher yields at any time of the year. In turn, they allow extending the growing cycle and being able to produce at the most difficult times of the year and, consequently, obtaining better prices.

The increase in the value of the products allows the farmer to invest in technology for their exploitation, improving their yield and the quality of the final product. The use of technology in greenhouses to control the different environmental variables affecting cultivation is called a smart greenhouse.

Nowadays there are many automation systems that allow to control the climatic parameters of greenhouses: automation of ventilations, radiometers, heating equipment, etc. The most important parameters for controlling the greenhouse are those related to climate, irrigation, CO2 or humidity.

The operation of these automation systems consists of the use of a central computer to which sensors are connected and collecting the different parameters with respect to default values. This central computer collects the information captured by the sensors, coordinates the actions and sends the orders to the different sectors.

That is, the operation of the control parameters are managed by sensors. Sensors allow variables to be quantified and provide qualitative guidance regarding the environmental conditions that our crop has. Thanks to these sensors we can have control of climate, irrigation and nutrient, temperature, moisture, lighting, CO2 application, etc.

In conclusion, the automation in smart greenhouses has some advantages that benefit the farmer job and help to take care of the farming.[40]

A.5.8. Precision Livestock Farming

In the last years, precision livestock farming has been one of the sectors in which more innovations are added thanks to the technologies with the aim to improve livestock farming and the products quality. With this technology we can obtain a better resources optimization, and it improves the farm yields and allows improve the ambient impact and the animal bienestar. Replacing the farmer is not the objective of this technology; it is to give support tools to benefiting profitability, efficiency and sustainability of farms.

Monitoring the ranching and production with biometric indicators of physiological and morphological character is to carry out the use of resources. The collected data are used to analyse objectively the production process, which allows to make a responsible resource's use to reduce the ambient impact and improve the feed use. This improvement in the optimization of the resources used in livestock farms is in line with some of the Agenda 2030 for the sustainable development objectives: zero hunger, responsible consumption and production, and climate action.

[40] DecorexPro (w.d.). Invernadero Inteligente: automatización para invernaderos.
https://es.decorexpro.com/teplica/umnaya-avtomatika-dlya-sooruzhenij/
Novagric (January 16, 2015). ¿En qué consiste un invernadero inteligente?
https://www.novagric.com/es/blog/articulos/que-es-un-invernadero-inteligente

Furthermore, with the technologies implementation the animal bienestar is improved. Animal health problems such as skin conditions or body discomfort can be detected in real time and it indicates the actual animal health.

About the technologies applied in this sector, some of the most important are:

- Visual estimation systems for the weight of cows and pigs.
- Thermal control systems in pig hatcheries.
- Accurate feeding in pigs.
- Administration of milk-producing livestock.
- Temperature sensors for pigs and cows.
- Udder monitoring systems in dairy cows.
- Visual inspection systems for birds.
- Automated egg identification and counting.
- Prediction of pig growth.
- Automated fish size and separation determination.
- Egg incubators synchronized with laying.
- Intelligent ventilation, mobile apps and thermal control systems.

In the livestock farm, implementation we can find some steps related to the application:

1. Data capture and digitization: data is captured with sensors or drones, while watching the farmer.
2. Data encoding and processing all the data obtained in the first phase is analyzed, allowing them to be worked out of the operation.
3. Solution search: For analyzed variables, analysis techniques and tools are implemented.
4. Implementation: based on the previous phases, appropriate measures are taken.

Regarding to animal welfare, some objectives are also set in order to improve the production and quality of the holding:

- Prevent or reduce stress with strict animal hygiene controls, the quality of the food they receive and the environmental conditions in which they are located.
- Optimize the nutrition of animals so that their immune status is improved.
- Eradicate some diseases.
- Genetically select disease-resistant animals.

Nowadays, precision livestock farming is just part of the farmer sector with the aim to catch the best livestock farm efficacy and efficiency.[41]

[41] *Repuestos Fuster (November 20, 2020). ¿Qué es la ganadería de precisión?*
http://www.repuestosfuster.com/blog/ganaderia-de-precision-que-es/
Innovation AgroFood Design (March 30, 2020). Ganadería de precisión.
https://innovatione.eu/2020/03/30/ganaderia-de-precision/

A.5.9. Categories of sensors and their application in Precision Agriculture[42]

Nowadays, the evolution of technology and the application of sensors in agriculture, gives the opportunity to farmers to constantly monitor the needs and potential problems in their crops, in order to immediately solve and meet their requirements.

Sensor categories

1. Production mapping sensors for machine-harvested crops.

- Combine sensors (measuring seed flow and moisture)
- Production mapping sensors in cotton harvesting machines (seed flow measurement)
- Production mapping sensors in grape harvesters

2. Production mapping sensors in silo cutters

3. Production mapping sensors in non-mechanically harvested products

4. Sensors of quality characteristics of the seed

5. Ambient sensors

- Ambient humidity sensors
- Ambient temperature measuring sensors

6. Field sensors

- Moisture and soil temperature sensors
- Irrigation management system sensors
- Soil electrical conductivity measuring sensors
- Non-contact electrical conductivity measuring sensors
- Variable dose range lubrication sensors N
- Plant and weed sensors

7. Electrical conductivity mapping sensors

- Electrical conductivity and ground sampling sensors
- Electrical conductivity and soil moisture
- Electrical conductivity and salinity
- Electrical conductivity and nematodes
- Electrical conductivity and production

8. Remote Sensing Sensors

- Active sensors

[42] https://blog.farmacon.gr/katigories/texniki-arthrografia/georgia-akriveias/item/2863-katigories-ton-aisthitiron-kai-efarmogi-tous-stin-georgia-akriveias

- Passive sensors

WSN sensors

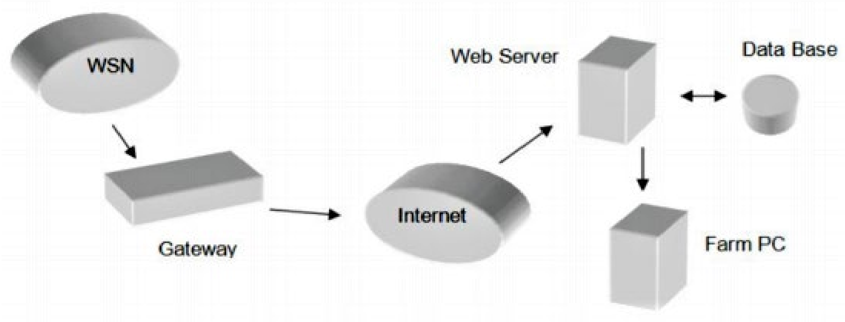


Figure 2. WSN sensor workflow

Agricultural production systems with WSN provide real-time information by creating a decision-making model for farmers. The model allows the farmer user to adjust the strategy whenever the need arises.

Advances in wireless communications have led to the development of low power, low-cost multifunction sensors. They are small in size and energy autonomous, consist of individual sensing parts of data and communication processing, and are able to react to environmental changes.

WSN wireless networks are mainly used for observations and controls of the natural environment in cases where the location is not easily accessible.

Ambient humidity measurement sensors

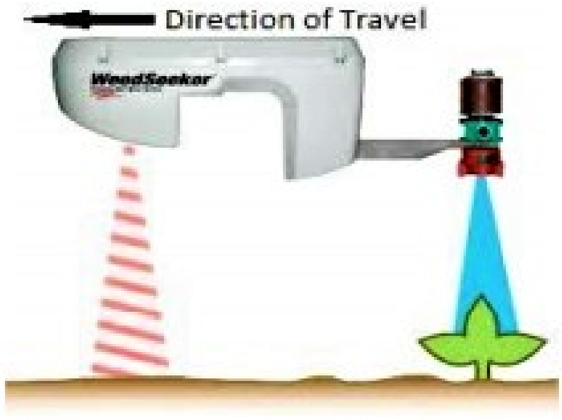
They are applied in Precision Agriculture in automatic meteorological stations and in agro-meteorological stations.

Irrigation system management sensors

This system compares expert data with real-time humidity data to determine if crops should be irrigated and to decide the amount of irrigation per unit area. Irrigation instructions are sent to the base station to determine the location and amount of irrigation.

Plant and weed sensors

Weeds, diseases and insects are detected with sensors and actuators that are either connected to the tractor or are independent autonomous machines. The Weedseeker system detects the difference between weeds and soil by spraying only the weeds as it progresses into the field.



Picture 15. Weed detection and spraying

Nitrogen Dose Variable Fertilisation Sensors

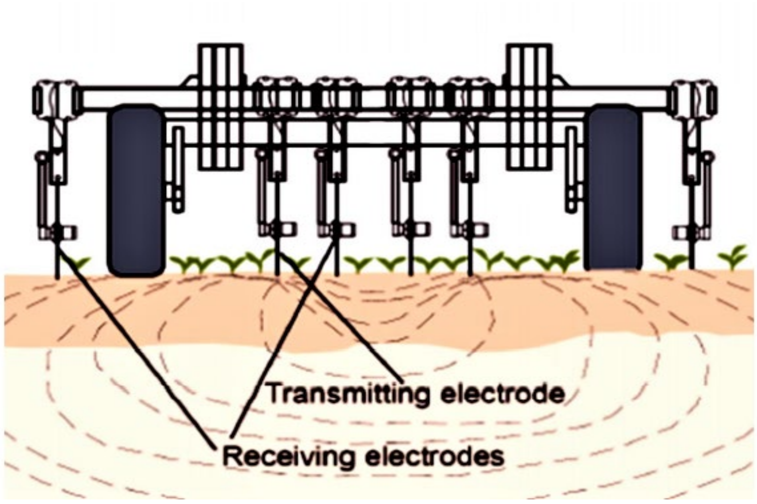
The first and basic step in estimating the culture requirements in N is the production of a map of the chlorophyll index. The most modern method of using foliage sensors for fertilization is their use in N variable supply systems for real-time fertilization.

Ambient temperature measurement sensors

With the development of sensors, the ambient temperature can be predicted and potential damage to crops can be avoided.

Measurement of electrical conductivity with sensors

The systems developed by Veris for measuring electrical conductivity are 3100, 3150, 2000XA, QuandEC1000 and Quand 2800. Specially adapted machine for heavy cohesive soils with very durable construction and very good electric field transmission. The principle of operation in the middle are the two sensors of absorption of the electric field and at the ends and internally the sources of electric current and the corresponding electric fields that are created in depth.



Picture 16. Measurement of electrical conductivity

GPS is necessary to determine the position at any time that corresponds to a measurement of electrical conductivity. It is good to be placed on top of the agricultural tractor, while an RTKGPS is always useful to have more accurate measurements. Speed measurement can be done either via GPS or radar. The data processing and recording system is essentially a software and a console that allows us to intervene in the resulting data. Most conductivity measurement systems now have adapted systems for simultaneous storage, processing and recording of data that are adapted to the cabin of the agricultural tractor.

According to a study, for the creation of electrical conductivity maps and the calculation of the runoff of salts, the conductivity was correlated with the leaching of the elements. A strong correlation was found between electrical conductivity and runoff of salts (elements). Thus, according to the above, a double reading map was created, ie depending on the values of electrical conductivity, to translate data losses due to leaching. In practice, zones of management and application of variable doses of fertilizers were created spatially depending on the electrical conductivity map of a field. Specifically, less dose is needed in areas of high electrical conductivity above> 4 ds / m (safer above 8 ds / m), as we have less data losses due to leaching.

In addition, another study on spatial and temporal variability was conducted in which a high salinity concentration was observed in soil. For this purpose, electrical conductivity maps were created at various time intervals and it was observed that salt concentrations remained both spatially and temporally constant. However, these prices in a field may change significantly over a year.

Remote Sensing Sensors

The sensors used in remote sensing are divided into 2 categories. These are the active sensors and the passive sensors. The difference is that active sensors emit radiation to make their measurements, while passive sensors use the existing radiation from the sun to make their own measurements.

Passive sensors

- Radiometer
- Spectral cameras
- Spectral radiometer
- Spectrometer

Active sensors

- RADAR (Radio Detection and Ranging)
- Scatterometer
- Lidar (Light Detection and Ranging)
- Altitude laser

A.5.10. Irrigation management[43]

[43] https://agriculture.vic.gov.au/farm-management/water/irrigation/irrigation-management
https://edis.ifas.ufl.edu/pdf/CV/CV10700.pdf

Irrigation allows you to:

- grow more pastures and crops
- have more flexibility in your systems and operations
- produce higher quality crops/pastures as water stress can dramatically impact on the quality of farm produce
- lengthen the growing season (or start the season at an earlier time)
- have 'insurance' against seasonal variability and drought
- stock more animals per hectare and practice tighter grazing management due to the reliability of pasture supply throughout the season
- maximize benefits of fertilizer applications
- use areas that would otherwise be less productive
- take advantage of market incentives for unseasonal production
- have less reliance on supplementary feeding (grain, hay) in grazing operations due to the more consistent supply and quality of pastures grown under irrigation
- improve the capital value of their property
- cost save or get greater returns.

Types of irrigation

Furrow systems

This system comprises a series of small, shallow channels used to guide water down a slope across a paddock. Furrows are generally straight, but may also be curved to follow the contour of the land, especially on steeply sloping land. Row crops are typically grown on the ridge or bed between the furrows, spaced from 1 meter apart.

Flood or border check systems

These systems divide the paddock into bays, separated by parallel ridges or border checks. Water flows down the paddock's slope as a sheet guided by ridges. On steeply sloping lands, ridges are more closely spaced and may be curved to follow the contour of the land. Border systems are suited to orchards and vineyards, and for pastures and grain crops.

Level basin systems

These systems differ from traditional border check or flood systems in that slope of the land is level and area's ends are closed. Water is applied at high volumes to achieve an even, rapid ponding of the desired application depth within basins.

Center-pivot sprinkler systems

A center-pivot sprinkler is a self-propelled system in which a single pipeline supported by a row of mobile towers is suspended 2 to 4 meters above ground. Water is pumped into the central pipe. As the towers rotate slowly around the pivot point, a large circular area is irrigated. Sprinkler nozzles

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https://www.google.gr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwjqmY_w1-nwAhXbhv0HHfFoAMcQFnoECAcQAA&url=https%3A%2F%2Fwww.naturalresources.sa.gov.au%2Ffiles%2Fsharedassets%2Fsouth_east%2Fwater%2Firrigation%2F150629-irrigation_best

mounted on or suspended from the pipeline distribute water under pressure as the pipeline rotates. The nozzles are graduated small to large so that the faster moving outer circle receives the same amount of water as the slower moving inside.

Hand move sprinkler systems

Hand move sprinkler systems are a series of lightweight pipeline sections that are moved manually for successive irrigations. Lateral pipelines are connected to a mainline, which may be portable or buried. Hand move systems are often used for small, irregular areas. Hand move systems are not suited to tall-growing field crops due to difficulty in repositioning laterals. Labor requirements are higher than for all other sprinklers.

Solid set and fixed sprinkler systems

Solid set or fixed refer to a stationary sprinkler system. Water-supply pipelines are generally fixed (usually below the soil surface) and sprinkler nozzles are elevated above the surface. Solid-set systems are commonly used in orchards and vineyards for frost protection and crop cooling. Solid-set systems are also widely used on turf and in landscaping.

Travelling gun sprinkler systems

Travelling gun systems use a large sprinkler mounted on a wheel or trailer, fed by a flexible rubber hose. The sprinkler is self-propelled while applying water — travelling in a lane guided by a cable. The system requires high operating pressures, 100psi is not uncommon.

Side-roll wheel-move systems

Side-roll wheel-move systems have large-diameter wheels mounted on a pipeline. This enables the line to be rolled as a unit to successive positions across the field. Crop type is an important consideration for this system since the pipeline is roughly 1 meter above the ground.

Linear or lateral-move systems

Linear or lateral-move systems are similar to center-pivot systems, except that the lateral line and towers move in a continuous straight path across a rectangular field. Water may be supplied by a flexible hose or pressurized from a concrete-lined ditch along the field's edge.

Low-flow irrigation systems (including drip and trickle)

Low-flow irrigation systems (including drip and trickle) use small-diameter tubes placed above or below the soil's surface. Frequent, slow applications of water are applied to the soil through small holes or emitters. The emitters are supplied by a network of main, sub-main and lateral lines. Water is dispensed directly to the root zone, avoiding runoff or deep percolation and minimising evaporation. These systems are generally used in orchards, vineyards, or high-valued vegetable crops.

Irrigation scheduling

Irrigation scheduling is the process by which an irrigator determines the timing and quantity of water to be applied to the crop or pasture. The challenge is to estimate crop water requirements for different growth stages and climatic conditions. To avoid over or under watering, it is important to know how much water is available to the plant, and how efficiently the plant can use it. The methods available to measure this include:

- plant observation

- feel and appearance of the soil
- soil moisture monitoring devices
- available water from weather data.

Over or under watering problems

While irrigation has provided a number of important benefits there can be potential drawbacks of over or under watering.

Under-watering can cause:

- loss in market value through yield reduction
- reduction in fruit size and quality.

Over-watering can cause:

- unwanted vegetative growth
- losses of valuable water to the water-table
- erosion
- pesticides, pathogens and weeds to spread during irrigation
- runoff
- increased operational costs (labour, pumping, cost of water)
- leaching of nutrients
- downgraded product quality and reduced yield
- higher operational costs for the producer
- pressure on water resources.

The best management practices outlined below are deliberately non-prescriptive, that is they do not set out to tell irrigators exactly how they should go about managing irrigation, or exactly what tools they need to use. These decisions are for individual irrigators to make, and will vary according to a whole range of site and irrigator specific factors.Instead the best management practices provide guidance on what are the important principles that make for best practice in irrigation, as follows:

1: Rate irrigation highly within the management system.

All case study irrigators cited irrigation as either one of the most important factors in their production system, or the single most important factor. For example, for one of the case study irrigators, "Irrigation is always number one". When irrigation is seen as a low priority it is no surprise if irrigation performance is low, and likewise it is not surprising that the best irrigators all place irrigation as a high priority in their growing system.

2: Get to know the soils on the property.

Efficient irrigation is very difficult without good information about the capacity of soil to hold water, and where in the soil profile the roots of the crop are.

3: Design And Maintain Irrigation Systems Correctly.

Poor irrigation system operation can make good irrigation management almost impossible. A number of the case study irrigators cited irrigation system setup, age, and maintenance as limiting factors in their ability to manage irrigation as well as they would like. Existing irrigation systems should undergo regular checking and be maintained to these same guidelines.

4: Monitor all aspects of each irrigation event.

The simple decision of when to irrigate is only part of the whole story. Monitoring of where water is going, both during the irrigation, by measuring system performance and uniformity of application, and after the irrigation, by assessing under-and over-irrigation, is vital to efficient irrigation.

5: Use objective monitoring tools to schedule irrigation.

An important point about scheduling tools is that they must be appropriate, both to the crop and irrigation system they are used with, and also to the irrigators who must maintain them and interpret the data provided by the tool.

6: Use more than one tool for scheduling irrigation.

All of the case study irrigators used a range of information sources in making the decision on when to irrigate and how much to apply. Typically, much of the decision relied on one particular tool, but other factors were taken into account. The most common and simplest included digging holes to check soil water, observation of the appearance of plants, and the checking of testwells or drain flows after irrigation and subsequent adjustment in practice at thenext irrigation.

7: Retain control of irrigation scheduling.

With modern technology, it is possible to set up irrigation systems to operate entirely automatically, based on the readings from a probe or a set of probes. Along the same lines, it is easy to allow a consultant to dictate the irrigation schedule, based on his or her measurements, or to blindly irrigate because the tool being used indicates that it is time to. The case study irrigators all firmly held onto control of irrigation scheduling, that is, they took into account the data from the scheduling tool or the recommendation of the consultant, but retained the power to vary the schedule using their own judgement and the use of other tools.

8: Remain open to new information.

The case study irrigators cited a range of different ways in which they obtained access to information about irrigation. All of them saw this process as important, and were willing to talk to anyone with something to offer, even if they later discarded it as not applicable to their situation. In the case of larger, corporate operations, employee education was seen as important, as was encouraging the employees to make a meaningful contribution toward management decisions.

A.5.11. Satellite Earth Observation For Smart Agriculture[44]

[44] https://www.decipher.com.au/blog/agriculture/how-are-satellites-used-in-farming,
Rajendra P. Sishodia, Ram L. Ray and Sudhir K. Singh, Applications of Remote Sensing in Precision Agriculture: A Review, Remote Sens. 2020, 12, 3136 [
https://www.google.gr/url?sa=t&rct=j&q=&esrc=s&source=web&cd=&cad=rja&uact=8&ved=2ahUKEwiq6bXHvenwAhV4gP0HHX_6DoAQFnoECAgQAA&url=https%3A%2F%2Fwww.mdpi.com%2F2072-4292%2F12%2F19%2F3136%2Fpdf&usg=AOvVaw1Z1ZkD8zvhP9-Xp9yzCQRk]

When the first satellite was launched in 1957, not many would have known quite what an impact this technology would start to have on the way so many of us interact with the world around us.

Fast forward more than half a century, and few industries benefit more from satellite technology than agriculture. From the day they helped improving weather forecasts, farmers have been fans of those orbiting objects in the atmosphere. But these days, satellites are impacting farming in far bigger ways.

Here are some of the most significant ways that satellites are used in farming today:

Weather predictability

Floods, draughts, rainfall and serious weather events have significant impact on crops and livestock. For farmers, the earlier they have knowledge about upcoming weather patterns, the better. It allows them to prepare or react in a way that gives their yield the best chance of survival.

Monitoring crop health / Disease and weed management

Satellites have the ability to detect crop conditions over thousands of square metres. Farmers can use satellite data to identify soil and crop conditions and characteristics, monitor growth, assess soil and irrigation requirements.

-Water management / Soil moisture

Information from satellite technology can tell farmers where water needs to be distributed, helping to prevent over- or under irrigation and potentially making huge savings to the farm's water supply. Water conservation is an important issue, and inefficient use of water can be not only costly to a farmer, but also to the wider community, and the environment.

-Fertiliser application / Nutrient management

Not all crops have the same requirements, so blanket distribution of fertiliser won't always result in the best yield. Satellite data helps farmers apply accurate amounts of fertiliser to best suit the requirements of particular parts of a field.

Autonomous tractors

Tractors and machinery equipped with tracking and sensor technology use satellite data to calculate optimal routes. This level of autonomy maximises efficiency and frees farmers up to focus on other necessary tasks. Autonomous machinery also results in less waste – tractors only go where it's essential.

Biomass mapping

Using satellite imagery, farmers can accurately visualize what is happening on their land, and track changes by day, month, or season to quickly understand the impacts of growth, change or weather.

Collaborating with drone technology

There are instances where drones (or UAVs) don't necessarily compete with satellite technology, but complement them. For example, issues identified on a satellite can be tackled by sending a drone to the area for hyper-local evaluation.

Although most of the satellite data are available for free, it may require a significant amount of technical knowledge and expertise to process them for real-world applications. For example, image pre-processing and post-processing require expert knowledge and software. In addition, many precision agriculture (PA) operations such as disease and weed management require fine spatial resolution (cm-scale) data with high spectral and temporal (e.g., daily) resolution. Most of the publicly available satellite data do not meet such requirements. Furthermore, cloudy days and variable or inconsistent irradiance or sunlight may render many satellite images unsuitable for use.

Users/farmers may need to purchase high resolution (spatial, temporal and spectral) satellite data, which can be cost-prohibitive, especially for small farms. However, images acquired from UAVs are likely to offer a low-cost alternative for small farm operations. Use of UAVs and tractor-mounted sensors also involve the use of special software for data analysis and need professional operators (e.g., drone licensing). Hyperspectral images acquired from the state of the art sensors mounted on some of the recently launched satellites and UAVs provide a large amount of information on crop biophysical parameters. However, these sensors are expensive (UAVs), and the processing of imageries is complex.

Despite a large number of studies on remote sensing applications in PA, there is a general lack of established techniques and/or framework that are accurate, reproducible, and applicable under a wide variety of climatic, soil, crop, and management conditions. Accuracies of methods using remote sensing (satellite, aerial, and UAV) data depends on a variety of factors including image resolution (spatial, spectral, and temporal); atmospheric, climatic, and weather conditions; crop and field conditions (e.g., growth stage, land cover); and the analyses technique (e.g., regression-based, machine learning, physically based modeling). More studies are needed to understand the spatio-temporal structure of uncertainty in estimating ET, soil moisture, disease stress, and other crop parameters. Spectral signature from a crop is a reflection of crop status/response to site characteristics (e.g., soil, topography), management, and simultaneously acting multiple biotic and abiotic stressors (e.g., diseases, weeds, nutrient and water stress, etc.). A disease detection method found suitable under controlled experimental conditions may not perform similarly well in real-world conditions where multiple biotic and biotic stressors govern crop response or conditions. Given the complexity of image processing methods and the amount of technical knowledge and expertise it requires for application, there is a need to explore and develop a simple and reliable workflow for image pre-processing, analysis and application in real time. Major challenges and gaps remain in the development of tools and frameworks that can facilitate the use of satellite data for real-time applications by the end-users. Development of accurate, user-friendly systems is likely to result in wider adoption of remote sensing data in commercial and non-commercial PA operations.

A.5.12. Satellite Earth Observation For Smart Agriculture

European project "Internet of Food and Farm" (IoF), which was launched in January 2017 with a duration of four years, seeks to develop solutions for the agricultural sector. It has a budget of 30 million euros and with the participation of 71 European organizations, among which are several Spanish companies and entities. “The objective of this project is that the information generated by all agricultural or livestock activities is stored, either to generate knowledge or to create applications that help the farmer or any other agent in the production chain (cooperative operator, of the transport company, etc.) in decision-making ”, explains Jorge Antonio Sánchez, member of the Automation, Robotics and Mechatronics Group of the University of Almería, one of the project partners. "In this project there are cows that have sensors connected that detect from their location at all times to what they have eaten." The project consists of 5 types of tests (Extensive, Fruit, Meat, Milk and Vegetables) and a total of 19 experimental tests, framed within each type of test.

According to this Doctor in Computer Science and Agronomist Engineer, an attempt is made to collect information throughout the production process, from the moment the plant reaches the greenhouse to transport to the final destination. In the greenhouse, it is a matter of getting all the possible information through sensors on actuators (heating, humidity, opening windows, etc.) and field notebooks. In the cooperative, all the information is collected on the entry of the product, weight, quality, quality standard criteria, destination, etc., and in the transport, the temperature, location, distance and even the times it is opened or closed. the truck to its destination. All information is stored on a platform, based on the European FiWare standard, linked to the development of Internet of Things (IoT) and SmartAgriFood applications and services.[45]

A.5.13. Artificial intelligence

„Artificial intelligence (AI), the ability of a digital computer or computer-controlled robot to perform tasks commonly associated with intelligent beings."[46]

„The use of computer programs that have some of the qualities of the human mind, such as the ability to understand language, recognize pictures, and learn from experience"[47]

As quoted above, artificial intelligence enables computers or machines to make decisions based on previous results. In simple terms to learn from mistakes and successes. This process where a computer system is feed large amounts of dana which it then uses to learn how to carry out a specific task is called Machine learning. The way a computer learns is trough neural networks, brain-inspired networks of interconnected layers of algorithms, called neurons. They feed data into each other, which can be trained to carry out specific tasks by modifying the importance attributed to input data as it passes between the layers. During training of these neural networks, the weights attached to different inputs will continue to be varied until the output from the neural network is very close to what is desired, at which point the network will have 'learned' how to carry out a particular task. Simply put, machine-learning using neural network is a "trial and error process" of learning.

There are two main types of AI:

- **Narrow AI**
    - Intelligent systems that have learned how to do a **specific task**
    - Already all around us
    - Virtual assistants (Siri), self-driving cars, detection of damages on machinery, prediction of interests (YouTube, Netflix..), etc.

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[45] *Caballero, I. (March 27, 2021). La era de la digitalización en el sector agrario. https://isabelcaballero.com/la-era-de-la-digitalizacion-en-el-sector-agrario/*
[46] *Encyclopaedia Britannica, https://www.britannica.com/technology/artificial-intelligence*
[47] *Cambridge Academic Content Dictionary, https://dictionary.cambridge.org/dictionary/english/artificial-intelligence*

- **General AI**
    - General impression of AI
    - Type of intelligence found in humans
    - Flexible intelligence that can learn various tasks

With the help of AI, farmers can now analyze a variety of things in real time to better inform their decisions on weather conditions, temperature, water usage, soil conditions, etc. Farmers are also using AI to create seasonal forecasting models to improve agricultural accuracy and increase productivity. These models are able to predict upcoming weather patterns months ahead to assist decisions of farmers. Seasonal forecasting is particularly valuable for small farms in developing countries as their data and knowledge can be limited.

With more quality AI and machine learning training data for agriculture, the agricultural sector is going to be revolutionized by the large scale use of autonomous machinery, crop protecting systems and planning systems. Even though AI technologies are still at their infant stage more are more forms of applications are becoming real.

- **Agricultural Robotics**
    - Robots that can easily perform multiple tasks in the farming field. Such robotics machines are trained to control weeds and harvest the crops at a much faster pace with higher volume compare to humans.
    - An accurate fruit detection system is a crucial step toward fully-automated harvesting robots, as this is the front-end perception system before subsequent manipulation and grasping systems.
- **Controlling Pest Infestations**
    - AI allows smart systems to recognize pest and forecast the time and extent when the economically important infestation will take place.
- **Soil and Crops Health Monitoring**
    - Deep learning based applications that can detect and predict soil or crop related problems
- **Precision agriculture**
    - Precision agriculture uses AI technology to aid in detecting diseases in plants, pests, and poor plant nutrition on farms.

A.5.13. Robotics in agriculture

The growing need for timesaving autonomous solutions has led to a significant role for the robot in agricultural production and management. The main characteristic that brings revolution to agricultural robotics is autonomy. Robots are the perfect replacement for human labor and for jobs that pose a risk to human health and well-being. The main benefits of developing autonomous and intelligent robotics are increased precision in repetitive processes, increased efficiency and minimized soil compaction. The ability of robots for multitasking additionally increases the stated benefits because they can perform a spectacle of actions in one pass.

Agricultural automation is a necessity of modern production and market demand. The development of autonomous robots and vehicles in recent years has seen a significant increase in the interest of researchers. Many researchers have switched from creating new solutions to minimizing and streamlining existing robotic solutions to make them accessible and affordable to the market. That is why back in 2004 a concept was adopted to use multiple small efficient autonomous machines in place of traditional large tractors. Such systems, in addition to the flexibility of the number of units depending on the area they cultivate, also have a smaller negative impact on the environment due to the precise dosing and application of plant protection products, fertilizers and less soil compaction.

Autonomous vehicles have proven to be an ideal solution in the field of precision agriculture. The solutions are based on three premises: 1. Mobile robot navigation 2. Implements (Framework & Applications) 3.sensor modules. Specialized navigation techniques like an odometer, vision based, sensor based, inertial, active beacon, GPS, map-based, landmark navigation techniques allow robots to operate under unified control space for farming. This technique is used for application like seed-bed preparation, seed mapping, seed placement, reseeding, crop scouting, weed mapping, robotic weeding control, micro-spraying, robotics gantry, robotic irrigation, etc.[48]

Most agricultural autonomous robotics research has been performed in controlled environments such as robotic picking of cherry tomatoes, cucumbers, apples and other fruits. Probably the biggest advancement in robotics in agriculture is seen on milking robots, which have completely changed the sector of milk production. Milking robots have become a necessity for profitability and not a luxury.

Examples of application

MF-Scamp Robots Designed by Blackmore[49] MF-Scamp robots are designed for scouting, weeding and harvesting. It is designed either four wheel or six wheel drive weed seeking robot to perform weed removing or destroy the weed. This intelligent hoe tools uses vision sensor to locate and identify the crops in rows and column and steers itself accurately, to a larger extend reducing the usage of herbicides. It also uses color sensor to identity weeds between the crops by producing weed maps identifying plans. This robot designed not only reduce the labor time but also the economic feasible with slight reductions in prices of navigation systems. This kind of design not only reduce the cost of spraying but also decrease the usage of tractor. The negative effects of the robot is the higher costs for small farmers and additional costs used for electronics devices like GPS-system.

[48] Blackmore, B.s., Fountas S. , Vougioukas S. , Tang, L.,sørensen, C. G., and Jørgensen, R. 2004b, Decomposition of agricultural tasks into robotic behaviors. The CIGR Journal of AEscientific Research and Development in Press.
[49] https://www.researchgate.net/figure/MF-Scamp-Robots-Designed-by-Blackmore-27-Fig-2-API-Platform-27_fig1_312589560

Picture 17. API Platform

AgBot II[50] is a robot designed to help farmers to take decisions on the use of herbicides, pesticides, fertilizers and watering. It is developed at the Queensland University of Technology (QUT) in Australia, using sensor networks, drones, weather, satellite and historical data to help "farmers" run mathematical models and statistical programs to help and guide them in farm management decisions such as whether to use herbicides, pesticides, fertilizers and how much water plants should be given as shown in Fig. 9. The bot is still a prototype equipped with sensors and operated using software and can work individually or in groups. Vision sensors, for example, allow robots to "see" whether a plant is a weed or a rose and chemically or mechanically take action in support of or against the plan.

Picture 18. AgBot II

A.6. Policies and founding tools of precision agriculture

[50] https://research.qut.edu.au/future-farming/projects/robot-platform-design-agbot-ii-a-new-generation-tool-for-robotic-site-specific-crop-and-weed-management/

In this part of the handbook, we are going to explore the different contributions of policy makers in promoting precision agriculture and funding opportunities for precision agriculture. Our focus will be on the farmer and their gains, covering both a global review that focuses on those that are accessible to EU professionals and local/regional specific ones.

A.6.1. European scale

European Common agricultural policy

The EU's common agricultural policy (CAP), which was established in 1962, is a cooperation between agriculture and society, as well as between Europe and its farmers. Its goals are to:

- Maintain rural areas and landscapes across the EU
- Support farmers and improve agricultural productivity, ensuring a stable supply of affordable food
- Help European Union farmers make a reasonable living
- Help combat climate change and the sustainable management of natural resources
- Keep the rural economy alive by promoting jobs in farming, agri-food industries, and related sectors.

The Common Agricultural Policy (CAP) is a policy that applies to all EU countries. It is controlled and supported at the European level using EU budgetary resources.

Farming differs from most other industries in that it requires particular considerations:

- Despite the significance of food production, farmers' earnings are around 40% lower than non-agricultural earnings
- Agriculture is more dependent on the weather and environment than many other industries
- The time gap between consumer demand and producers' ability to supply is unavoidable — growing more wheat or making more milk takes time

Farmers should labor in a sustainable and ecologically friendly manner, maintaining our soils and biodiversity, while being cost-effective.

The important role that the public sector plays for our farmers is justified by business uncertainty and the environmental effect of farming. The CAP takes action in the following areas:

- Market measures to deal with difficult market situations such as a sudden drop in demand due to a health scare, or a fall in prices as a result of a temporary oversupply;
- income support through direct payments ensures income stability and remunerates farmers for environmentally friendly farming and delivering public goods not normally paid for by markets, such as taking care of the countryside;
- income support through direct payments ensures income stability and remunerates farmers for environmentally friendly farming and delivering public goods not normally paid for

The CAP's goals

Promote agriculture that is environmentally friendly

- Farmers face a dual challenge: they must produce food while also protecting the environment and biodiversity.
- For our food production and quality of life – today, tomorrow, and for future generations – it is critical to use natural resources wisely.

Community development in rural areas

- Many jobs are linked to farming in our countryside and its valuable natural resources. Farmers require ‘upstream' sectors such as machinery, buildings, fuel, fertilizers, and animal health care.
- Others are working in ‘downstream' operations, such as food preparation, processing, and packaging, as well as food storage, transportation, and retailing. In the EU, the agriculture and food sectors employ nearly 40 million people.
- Farmers, upstream and downstream sectors all require immediate access to the most up-to-date information on agricultural issues, farming methods, and market developments in order to operate efficiently and remain modern and productive. The CAP's resources were directed toward providing high-speed technologies, improved internet services, and infrastructure to 18 million rural citizens, or 6.4 percent of the EU's rural population, between 2014 and 20.

European Network for Rural Development (ENRD)

The European Network for Rural Development (ENRD) serves as a center for information on how rural development policies, programs, projects, and other initiatives are performing in practice and how they might be improved to achieve greater results.

Stakeholders

The ENRD does not have a membership. Its mission is to engage and reach out to anyone in Europe who is interested in and committed to rural development.

The main stakeholders of the ENRD include:

- National Rural Networks (NRNs);
- RDP Managing Authorities and Paying Agencies;
- Local Action Groups (LAGs);
- European organizations;
- Agricultural advisory services;
- Agricultural and rural researchers; and
- Other interested rural development organizations and individuals.

Objectives

In the current programming period 2014-2020, the ENRD has four key objectives:

1. Increase the involvement of stakeholders in rural development;
2. Improve the quality of Rural Development Programmes (RDPs);
3. Better inform on the benefits of Rural Development policy;
4. Support the evaluation of the RDPs.

Activities

By producing and sharing knowledge, as well as facilitating information exchange and cooperation across rural Europe, the ENRD aids the effective implementation of EU Member States' Rural Development Programmes (RDPs). Two support units, the ENRD Contact Point and the European Evaluation Helpdesk for Rural Development, help to facilitate these operations.

EIP-Agri

The European Innovation Partnership for Agriculture (EIP-AGRI) promotes competitive and sustainable agriculture and forestry that "achieves more and better with less." It helps to provide a consistent supply of food, feed, and biomaterials by working in harmony with the natural resources that agriculture relies on.

Partnership generation

At EU level, the EIP-AGRI brings together innovation actors in agriculture and forestry (farmers, consultants, researchers, corporations, NGOs, and others). They establish an EU-wide EIP network when they function together. Operational Groups, Multi-actor initiatives, and Thematic Networks are all important components of this network. While the Rural Development Programmes fund Operational Groups, the H2020 Programme funds Multi-Actor Projects and Thematic Networks.

Project-based EIP-AGRI Operational Groups address a specific (practical) challenge or opportunity that could lead to an invention. The Operational Group method makes the most of various types of knowledge (practical, scientific, technological, organizational, and so on) in a collaborative manner. An Operational Group is made up of the essential players who are best positioned to achieve the project's objectives, discuss implementation lessons learned, and communicate the results widely. Operational Groups are being formed in a number of EU nations and regions.

EIP-AGRI funding

It's one thing to have an idea; it's quite another to transform it into an innovation activity. Different sorts of available funding sources, such as the European Rural Development Policy or the EU's research and innovation initiative Horizon 2020, can assist get an agricultural innovation project off the ground. The EIP-AGRI helps to integrate multiple funding streams so that they all work toward the same goal and don't produce duplicate outcomes.

Within a country or region, Rural Development will assist Operational Groups and Innovation Support Services in particular. Horizon 2020 will support multi-actor initiatives and thematic networks comprising at least three EU countries as partners. Additional chances may be available through other policies.

EIP-AGRI Operational Groups are project-based and can be supported through RDPs. They address a specific (practical) challenge or opportunity that could lead to an innovation and help the program achieve its goals. Through their Rural Development Programmes, which operate in a specific region or country, EU member states or regions decide on the specific requirements for supporting innovation projects. Operational Groups in the EIP can benefit from a higher EU co-financing rate.

In the agriculture, food, and forestry industries, Operational Groups can get help developing innovative products, methods, processes, and technology. Cooperative labor processes, short supply chains, joint climate change initiatives, communal environmental initiatives, and other conceivable areas of action are also possibilities.

Support can be used to not only fund the Operational Group project, but also to assist in the formation of operational group projects. Innovation brokers can assist in the development of a rough new idea into a project-ready innovation group. The future success of Operational group projects depends on bringing the right partners together and reaching clear agreements on a concrete work plan and cooperation arrangements.

You can find more information in this link: https://ec.europa.eu/eip/agriculture/en

The European Agricultural Fund for Rural Development

The European Agricultural Fund for Rural Development (EAFRD) is a European Structural and Investment Fund that finances the second pillar of the EU's Common Agricultural Policy (CAP) (ESIF). The EAFRD intends to develop the agricultural, agro-food, and forestry sectors, as well as rural areas in general, in the EU.

Most of the established EU priorities for rural development can be achieved with the use of financial instruments backed by the EAFRD, for example:

- Promoting knowledge transfer and innovation in agriculture, forestry, and rural areas
- Improving the competitiveness of all forms of agriculture and farm viability
- Encouraging the organization of the food chain
- Increasing resource efficiency in agriculture, food, and forestry, as well as helping the transition to a low-carbon, climate-resilient economy
- Encouraging social inclusion, poverty reduction, and economic development in rural areas, particularly in terms of small business establishment and development, as well as job creation

All eligible receivers in agriculture, forestry, and rural areas who are implementing financially viable investment projects can access financial instruments through the EAFRD

EAFRD under the 2021-2027 Multiannual financial framework

Financial instruments based on EAFRD funds are expected to help the agriculture and agri-food sectors make the necessary progress toward the European Green Deal and meet the ambitious targets set forth in the new Biodiversity and Farm to Fork initiatives. They can also contribute to the new rural vision by assisting rural non-agricultural SMEs in starting or expanding their businesses.

The recent fi-compass (a platform for advisory services on financial instruments under the European Structural and Investment Funds (ESIF)) study reports on the financing needs of the agriculture and agri-food sectors in 24 Member States emphasize the potential to employ EAFRD resources to close the financing gap and are a suitable starting point for any Member State seeking to establish a financing mechanism.

A.6.2. Hungary

Although applications and funding specifically aimed at the development of precision agriculture are not yet available, the most important strategic document in the field is Hungary's Digital Agricultural Strategy (DAS). It aims to contribute to increasing the profitability of agricultural production by collecting and processing information, automating and robotizing technological operations, and making efficient use of available environmental resources.

The steps required for implementation are formulated in four main target areas:

1. Development of digital competences

As Agriculture 4.0 increases the demand for PA farmers, technicians and machine operators with IT skills, the aim of Hungary's Digital Agricultural Strategy is to ensure the acquisition of the necessary competencies and knowledge from trainings to higher education, and make digital agricultural advisory services available to producers.

2. Digital Agricultural Overhead Reduction:

It includes the development of public administration, where the administrative and other state-influenced costs of the digital transformation of the agricultural economy will be reduced by significantly reducing the costs of digital accessibility of data produced and collected by public organizations.

3. Development of agricultural data management

It aims to collect and process data, reduce the cost of accessing data and make the necessary changes to the legal environment. Within this, in order to achieve the social utilization of the data set generated in agriculture and to achieve the desired degree of sectoral data integration, it supports the digital traceability of agricultural and food products, the collection and processing of related data, and the establishment of a National Food Chain Data Center within the National Food Chain Safety Office (NÉBIH) to ensure the operation of the knowledge base.

4. Development of the innovation environment

The revolution of digital technologies in agriculture has also brought with it the continuous development of digital innovations, for which a "Smart Test Farm System" is being set up under the auspices of the Ministry of Innovation and Technology (ITM) to study the competitive effects of the digital switchover.

A.6.3 Slovenia[51]

Among the different organisations and private tenders that occur in Slovenia, we find that there exist some policies and entities which coordinate and provide for the interest and priorities of farmers. They are represented by the Chamber of Agriculture in Slovenia and the priorities and guidelines are

[51]https://ec.europa.eu/info/food-farming-fisheries/key-policies/common-agricultural-policy/cap-glance_en#:~:text=safeguard%20European%20Union%20farmers%20to,foods%20industries%20and%20associated%20sectors.
https://enrd.ec.europa.eu/sites/default/files/project/attachments/gp_si_poharcifarm_modern_428_web-jto_0.pdf
https://www.fi-compass.eu/esif/eafrd
https://i2connect-h2020.eu/
https://www.kgzs.si/

established and adapted from the CAP (Common Agricultural Policy of the EU) in the Slovenian Rural Development Programme.

The Chamber of Agriculture in Slovenia

The Chamber of Agriculture in Slovenia mission is to represent the public interest, the interests of the industry and members of the Chamber of Commerce and Industry of Slovenia to ensure the development of agriculture, forestry and rural areas, as well as a healthy environment and healthy safe food for the entire population.

The goals for which the Chamber was established and operate are:

- The protection and representation of the interests of agriculture, forestry and fisheries
- Advising individuals and legal entities engaged in agricultural, forestry and fishing activities
- Promoting economical and environmentally friendly farming, forestry and fisheries

The Slovenian Rural Development Programme 2014–2020

The RDP of Slovenia was funding actions under five out of six Rural Development Priorities. Its focus is to assist with the:

- Knowledge transfer and innovation in agriculture, forestry and rural areas
- Competitiveness of agri-sector and sustainable forestry
- Food chain organization, including processing and marketing of agricultural products and animal welfare
- Restoring, preserving and enhancing ecosystems related to agriculture and forestry
- Local development and job creation in rural areas

A.6.4. Croatia

Policies supporting Smart Farming investments

Through the implementation of the common agriculture policy Croatia has formed an document “Program for rural development 2014. – 2020.”

> ***Measure 4 Investments in physical assets -*** This measure is the most important investment program for farmers.
>
> **Measure 16 Cooperation** - is the most important governmental investment program in research and development for smart agriculture. (but not exclusively for smart agriculture)

Public or private initiatives/programs supporting Smart Farming investments

There are a number of initiatives for the implementation of digital farm management software in everyday farmer life. These applications are made by private companies, but some are linked to governmental programs. Public investments/programs are also mainly being implemented trough formation of certain innovation and incubation centers that offer free or cheap working space for new startups. NGO sector is getting more involved in the matter of supporting programs in general and as such in smart agriculture as well. Our own record at ACT Group shows that in Croatia in 2017. there were around 24 support organizations, around 20 technology parks and incubators (if needed I can send you the list on request). Most of them have supportive and/or investment programs that are meant for all sector of the industry/economics. **Issue of smart farming is not yet recognized as a sector for it own programs**.

Digital innovation hubs (DIH)

Digital Innovation hubs in Croatia are in the process of development and positioning on the market and research circles. Concerning agriculture, the situation is not bright as only a few of them are fully operational. Looking at the services the DIHs have pointed they provide or will provide, the lack of specialization is evident. Most of them have all the “main stream / trendy” services on the list. Even though the lack of specialization could be a problem, it is a huge step forward in progress of digitalization and bringing it closer to real production and industry. Will the DIH be able to provide all the services they listed or will they have to get more specialized, is yet to be seen.

A.6.5. Spain

The European Innovation Associations (AEI) in the European Union

The European Union's growth strategy "Europe 2020" gives research and innovation an essential role in meeting the challenges of the present and the future. The Innovation Union is one of the seven flagship initiatives framed in this strategy, and aims to improve conditions and access to funding for research and innovation, in order to ensure that innovative ideas can be turned into products and services that generate growth and employment.

The European Innovation Association for productive and sustainable agriculture

European Association for the Innovation of Productive and Sustainable Agriculture (AEI-AGRI) aims to accelerate innovation in the agricultural sector, to achieve a competitive agriculture that produces more with fewer resources and less environmental impact. The objective is to achieve a more competitive, efficient and environmentally friendly agriculture, helping to guarantee a stable supply of food, feed and biomaterials.

The European Innovation Association for productive and sustainable agriculture in the National Rural Development Program 2014-2020

The National Rural Development Program (NRDP) 2014-2020 offers two sub-measures to promote innovation in the agri-food and forestry sector within the framework of the AEI-AGRI: aid for the creation Supra-autonomous Operational Groups and aid for the execution of innovative projects of general interest or non-territorial disable developed by supra-autonomous Operational Groups. A total of 57 million euros will be allocated for the two sub-measures for the 2014-2020 period.

National and European focus groups

The Focus Groups are temporary groups of experts and users that are constituted around a certain aspect that is important for the agri-food or forestry activity, with the aim of studying or discussing the main existing problems, as well as seeking and prioritizing innovative practices to your resolution. In this way, Spain is being a pioneer in the implementation of national focus groups for innovation. Specifically, these focus groups have been carried out so far, the information of which can be found on the website of the National Rural Network: irrigation, energy and environment, innovation in the forestry sector, digitization and Big Data in the agri-food, forestry and rural sectors, advice at AKIS.[52]

A.6.6. Greece[53]

The Research and Innovation Strategies for Smart Specialization in Greece

The agricultural sector, in order to be able to face the challenges of the time, is called to be ready, to modernize and become more competitive. To adopt solutions, such as intelligent agriculture, the rational use of agricultural inputs, the rational choice of machinery, the useful use of capital, the full utilization of arable land. At the same time, to conserve land resources and utilize renewable energy sources. Modern agriculture is required to be economically viable and environmentally safe, as required by the international consumer community and as enshrined in the European Green Agreement.

One national and 13 regional research and innovation strategies for smart specialization were developed in Greece. As part of the development of these strategies, the country and its Regions were called upon to identify those activities in which they present or are able to build, competitive advantages and to focus the available resources and efforts on them, in order to achieve significant development results.

The Ministry of Rural Development and Food, in the context of the development and provision of new services of optimal information - information and service systems for the rural population, implemented an innovative mobile platform for "smart" devices (smartphones).
The new application "i-AGRIC" provides to the factors of agricultural production and the citizens services of general information, personalized notifications, personalized information and personalized service / consulting:

- Information services (press releases, announcements of the Ministry, etc.)
- Personalized alert services
- Personalized information services – Citizens, after authentication through taxisnet, have access to personalized information services regarding their requests and cases.
- Personalized services – consulting- Citizens' requests may be accompanied by photographs and a geographical representation of the area or geographical location for which they are requesting at that time.

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[52]*Ministerio de Agricultura, Pesca y Alimentación. La AEI o EIP de agricultura productiva y sostenible en España.* *https://www.mapa.gob.es/es/desarrollo-rural/temas/innovacion-medio-rural/EIP-agricultura-productiva-sostenible/*

[53] *https://ead.gr/innovation/kainotomia/*
http://www.minagric.gr/
https://geolabinstitute.org/

Specific technological categories

The main technological categories of precision technologies in rural production are initially classified into three broad sections:

- Hardware and sensors,
- Data analysis and software applications,
- Related products that apply to all productive activities

Similarly, the use of large volume big data from different sources (e.g. satellite data, geographical

- Information systems,
- Electrical ground conductivity,
- Mechanical vision
- Digital crop status recording) can help accurate
- Monitoring of work and data in agricultural production and in turn this can be useful in saving seeds, fertilizers and irrigation

Is based on real-time data analysis for factors such as climatic conditions, water, air quality and diseases. For this purpose, special tools are required and systems and design of variable dose methods according to specialized needs that will arise from the observed results (e.g. measurement of soil electrical conductivity, data from humidity sensors, satellite image analysis).

National funding actions

The Rural Development Program - RDP co-finances a significant number of projects that contribute to achieving the objectives of agricultural policy.

- National Rural Network of the Greek Rural Development Programme
- Farmers, agricultural collectives and private agri-food companies have the opportunity to modernize in order to become more competitive in the international market. The implementation of their investments is done through the Rural Development Guarantee Fund, in which Piraeus Bank participates
- It is noted that the Rural Development Guarantee Fund is co-financed by the Hellenic Republic and the European Union, under the European Agricultural Fund for Rural Development (EAFRD) and by the European Strategic Investment Fund (EFSI).
- ESPA funding in areas such as agriculture, fisheries, animal husbandry, nanotechnology, nanoscience and energy projects
- Also many private companies are currently active in the field of precision agriculture providing valuable advice to our farmers.

A.7. Future farmer

Farmers are already going through a significant change in production and consumption habits i the last decades. In the last more than two decades the world's population increased by 29%, but in that time the rural population has only grown by 6%. Additionally, European statistics show that employment in agriculture dropped from 11% to 5.7% This means among others, two main circumstances: once the population in need for food and alimentation seriously increased, secondly, less and less people choose agriculture as profession for way of living and livelihood.

Great pressure is being put on farmers to increase production while reducing their ecological footprint. Continuous new bans on the active substances of plant protection products and various mineral fertilizers, forces farmers to seek new solutions. The farmer of tomorrow will no longer be able to devote himself only to production with the aim of a higher and higher quality harvest, but will have to actively deal with the socio-demographic and environmental issues of tomorrow. To achieve this this precision agriculture and digitalization in general will have a huge role. Precision agriculture allows plants (or animals) to get precisely the treatment they need, determined with great accuracy thanks to the latest technology. Using such technologies will give the farmers an edge to increase their productions, reduce costs and lower the negative ecological footprint of agriculture. To achieve this a range of technologies are used and more are added by the day. Technology can assist in strategic decision-making at farm level as well increasing the overall productivity of the workforce in agriculture.

As seen in the Diagnostic report, technologies of precision agriculture and digitalization of agriculture are recognized by the farmers and experts, as a factor in achieving sustainable development and nature conservation. This feature will significantly increase the availability of finance in the coming periods given the EU's goals in this area. EU goals will not be possible without changes in the agricultural sector, and these changes will not be possible without investments. Various institutions of the EU have already recognized this and more founding will be available for digital transformation of farmers in the upcoming common agricultural policy (CAP) of the EU.

The tendency to implement and increase interest in precision farming technologies is continuously growing among famers. Given the speed of technology change and the already busy working day of farmers, it is expected that in the future the farmer will need continuous help and guidance from experts. This whole process will require knowledge transfer projects and the creation of digital innovation hubs that should become the main driver of knowledge transfer to farmers. Such and similar initiatives will be the bearers of changes that will enable small farmers to cope with advancements.

Precision agriculture should decrease unfavorable impacts of agriculture, such as greenhouse gas emissions, soil erosion, over usage of chemicals, exploitation of natural and human resources while providing healthy and enough food for the world's population. In the agrifood sector, the digital transformation will change the structure of the labor market and the nature of work. It will redefine the role of farmers and agripreneurs and alter the skill set required in the agrifood sector.

PART B – Case studies on precision agriculture

B.1. Introduction

Goal of this Handbook is to set up a theoretical framework and knowledge of precision agriculture supported with real life best practices. Collection of case studies on precision agriculture applications as best practice presents the way precision agriculture solutions work in real-time farms. Case studies are of varied applications and combinations to cover a wider specter of agricultural production and topics. Case studies promote learning from real life practices in the area of precision agriculture that can support end users (mainly farmers) in real time as they seek solutions to emerging problems in their fields and farms.

The case studies give a general overview of what is currently being used or is in the final steps of development. Depending on the interest of the reader, they are here to inspire them to further research the topics of interest and find the needed solutions.

Co-funded by the
Erasmus+ Programme
of the European Union

B.2. Selection of case studies

B.2.1. BeeBox

Best practice type: Successful implementation
Location: Hungary

Summary

BeeBox is the intelligent beehive solution. BeeBox is a service package targeting stakeholders in the apiary sector.

Picture 19. Beebox services

Description

BeeBox is a monitoring solution based on Internet of Things (IoT) and Remote Sensing data, that connects farmers and the onsite measured data on a user friendly platform. Measured data supports beekeepers with reliable information about the hives. Sensors measure weight, humidity, temperaturein hives supported by a GPS. Special camera modules record photo and video, sound and are able to count bees entering and exiting the hive.

Information is collected at the server that allows farmers to access up-to-date information through a web application that shows trends and important data in an easy to digest way. Using BeeBox enables beekeepers to manage more hives, take prompt decisions and above all, spare fuel, time and energy for further development.

Picture 20. Digital hive scale

Hardware and software

- **Digital hive scale**

  Digital scales provide the beekeeper with data on weight, so he can conclude on the health status of the bee family, moreover he gains important information on the performance of the hive.
- **In-hive sensors**

  Accurate data on temperature helps beekeepers when bee brood happens, especially in springtime, when they cannot open the hives yet.

  In-hive sounds are recorded and analysed to make estimation on the bee family’s actual status.

Picture 21. Bees

- **Camera**
  A camera is placed right above the entry of the hive. The software recognizes bees, county them so the beekeeper gains information on the intensity of the bee work. In case something unexpected happens, the system immediately sends an alarm signal through the application, so the owner knows once action is required.
- **Hive inspection notes**
  The user can fill out the digital version of the hive inspection notes. The digital version allows the user to track biological changes. This creates use full information to track issues and see strength of the hive. As it is digital, remote processing and large-scale research activity is possible based on the notes.
- **Apiarist map**
  Based on remote sensing data (satellite and IoT) the apiary's environment can be discovered. For example, information on the quality and quantity of vegetation cover in the surroundings. Such a map helps the apiarist to choose the right place for the hives.
- **GPS and mobile web**
  Location coordinates earned from GPS and mobile web connection support the accuracy of the map.

- **Solar panels**
  Such digital tools need energy. Batteries are difficult, old-school and definitely not environmentally conscious. But solar panels with accumulators are sustainable and allow hives working remotely even in island mode.

User experience

On the online platform, a beekeeper can add notes and photos for each hive. There are special alerts in case of havaria or removal of a hive. For instance, an unusual drop in temperature is the sign of loss of the bee population, so the farmer can react immediately. Therefore beekeeping is done, based on reliable data shown in the BeeBox application.

More info:
bee-box.io
www.okosmeheszet.hu

B.2.2. WineData[54]

Best practice type: Successful implementation
Location: Hungary

Summary

WineData is a best practice case of precision agriculture in viticulture, in Hungary. WineData is an intelligent production monitoring for vineyards that provides real-time, high-precision monitoring and makes processed information available to the farmer. WineData assists producers improve grape quality while significantly reducing production costs and helps wineries in more environmentally conscious decision making.

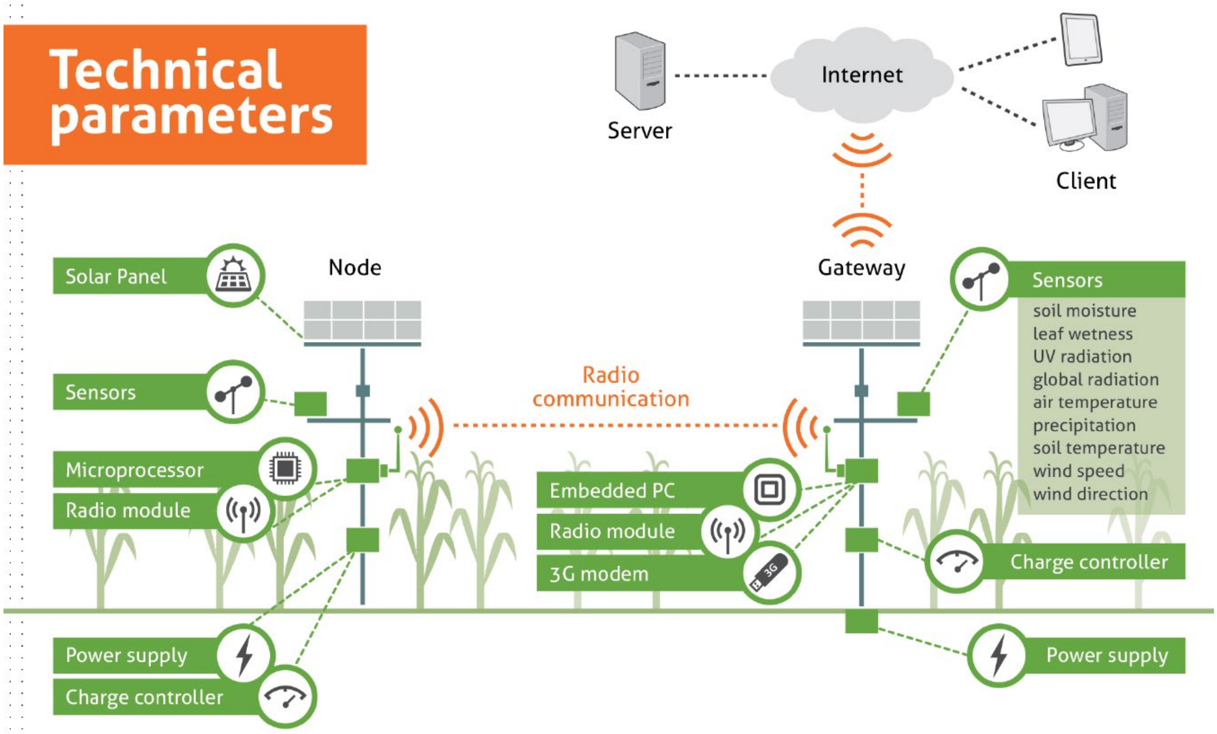
Description of used technology

The main elements of the complex system are the (1) Data collection node, the (2) Communication gateway and the (3) High-precision sensors. On site modules are supported by solar panels, that provide sustainable green energy. Global Navigation Satellite System (GNSS) uses GPS, GLONASS, BeiDou, Galileo data to enhance accuracy in determination of location. Sensors measure precipitation, wind speed and direction, leaf wetness, temperature, humidity, soil moisture and temperature and global / UV-B radiation.

User experience

Producer can access processed information (such as charts and graphs) on PC and smartphones, that results for example that plant protection activities can be scheduled and optimized based on the measured environmental parameters. Moreover, it enables fast, preventive and targeted intervention in case of extreme weather events or spread of pests (powdery-mildew, downy mildew, botrytis).

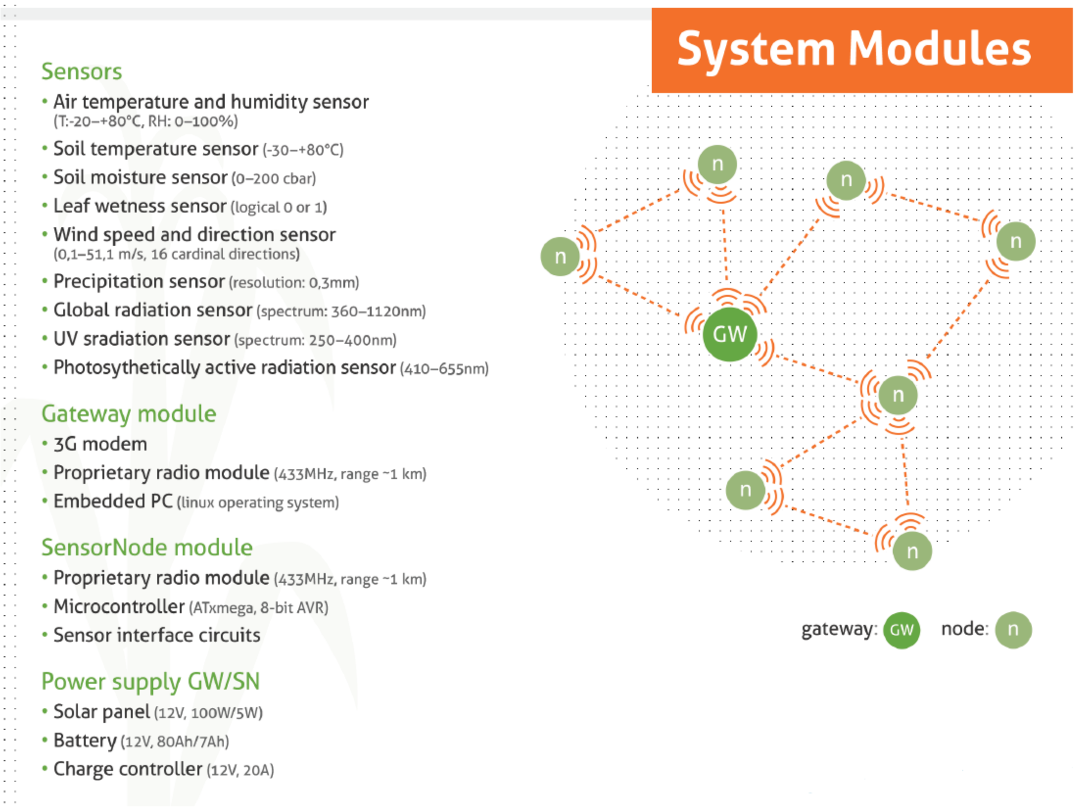
[54] http://winedata.hu/



Picture 22. Technical parameters of WindeData

Monitoring workflow

WineData platform real time shows workers' location and activity based on GPS based tools. For example, a tractor driver picks the smart tool up in the morning, the gateways are installed on his tractor, so his entire day activity can be followed, and administered. Machines are supplied with BTN-s (a custom developed tracking device) that allows us to recognize the actual, concrete work being done, such as harvesting, spraying, dialling. In the meantime, collected data not only gives live information on the work, but also can easily be logged, saved, filtered and systematized for further analysis – either on the workflow, or the crop itself. This data helps in workflow monitoring and optimization, allowing farm owners to draw a lesson and adjust decision making procedure in the future. Same for the harvested crop: quality assurance now can be supported by exact location, origin that can enhance customers' trust towards the product.



Picture 23. System Modules of WineData

Spraying monitoring

Spraying machines’ activity and used chemicals can be followed, tracked and continuously documented. A digital flow-meter records actual consumption of chemicals and there is an alarm possibility if any deviation occurs from the planned amounts. This way, severe losses can be prevented such as under- or over-spraying, or the monetary value of input materials (chemicals). Line-level accuracy is essential for doing the right quality of work, which can also be tracked on an online heat map. The application fully documents plant protection tasks from planning and design, through control to automatic spray logging. All this is provided with an integrated design interface to help plant doctors’ work.

Regional context

WineData systems are used in the biggest Hungarian Wineries, such as Csányi, Bock, Nyakas, Sziget Hegyközség, Tokaji Közösségi Infrastruktúra Központ Nonprofit Kft., on more than 1000 hectares. Right now, WineData provides the most comprehensive data collection and management system on the market, which is underpinned by the positive feedback of the farmers, producers and workers. Hands-on experiences show that 5-10% of spraying, 5-10% of logistics can be spared by using this system. Moreover, ad-hoc and gut-instinct decisions can be avoided - or affirmed - by real data. That can result thousands of euros savings yearly.

B.2.3. APPVID – Grapevine diseases management[55]

Best practice type: New technology and successful case
Date: Project duration 2016 – 2018
Country: Spain

Summary

The control of grapevine diseases is traditionally carried out with phytosanitary treatments either applied at specific times every year, or based on the phenological state of the crop, without taking into account the environmental parameters that affect the disease.

The project aims to develop a collaborative system of precision viticulture. Small wineries and vine growers will have a real time on-line tool that will help them make decisions regarding the management of diseases. The remote sensors and mobile App will provide beneficiaries detailed information about the vineyards health in real time, thus facilitating the planning of phytosanitary treatments.

Context

The winemakers of Álava area, Spain, were aware that a change was necessary in the way grapevine diseases are treated. Mildew, powdery mildew and botrytis, etc., are traditionally controlled with phytosanitary treatments which are repeated systematically throughout the season. Usually the treatment is applied at specific times of the year, or according to the phenological state of the crop, without however considering the environmental parameters that condition the development of the disease. The optimization of the use of phytosanitary products is a complex process since different variables must be taken into account, including weather conditions, grape variety, planting pattern, plot location or cultural practices, etc.

At the same time, Álava is characterized by small wineries with scattered farms, which complicates even further the decision-making process of the growers regarding when to apply treatments since it is not possible to carry out a homogeneous management of the vineyard. Overall, they needed a more sustainable and efficient use of phytosanitary products as it is required by legislation and because it can help reduce costs and improve the quality of the grapes.

Objectives

The objective of the project is to develop an easy-to-use system to monitor the health of the vineyards and inform/guide winegrowers on the optimal timing of treatment for control-disease in each plot.

Description

Given the farm structure in the area, a collaborative use of precision farming tools seems to be the most efficient approach. The basic tool will be a mobile application that will analyze data provided by meteorological sensors implanted in certain selected plots (characteristics of each farming plot will also be available). The App will indicate to the grower the risk of occurrence of the different diseases

[55] https://enrd.ec.europa.eu/sites/enrd/files/project/attachments/gp_pt_diseases_mang_vineyards_web.pdf

in each one of the farms. Once the risk of illness is known, the grower can apply a treatment, if necessary.

The challenge to develop this project is two fold:

- Collaborative: Wineries/winegrowers are used to manage their own farms, and the cooperation among them hasn´t been sufficiently stimulated in the past. In order to monitor all fields they would have to have sensors in each plot, which is economically impossible. Collaborating among them, and putting each of their sensors available to the rest, creates a network of sensors that allows monitoring all plots.
- Technological: Develop a network of communications and unified management of all data (through Big Data, precision farming and artificial intelligence), makes available to the winegrower a mobile APP that reliably estimates the risk of disease and helps in the optimal application of phytosanitary products.
- In a first phase the needs of the winegrowers were studied. To this end, farmers provided the necessary information about their farms, including:
  - registering the plots: the location of the plots and characteristics (common to others or particular) of each farm.
  - reviewing of each participating farmer´s “management notebooks”: get to know the treatments applied (kind and number) for each disease in previous campaigns.

Field sensors were installed at the plots to monitor the climatic parameters. As it was not possible to monitor all the plots, vine growers selected those plots most vulnerable to diseases. The weather data are transferred to a web server for processing. Throughout the project winemakers track the condition of each disease, and this data is also sent to the Web server.

The climatic and vineyard information are used to develop the estimation risk-of-disease model. Mathematical models commonly used to calculate disease risk in vineyards only use meteorological information in their calculations and are unreliable. This project takes advantage of relevant data related to the specific characteristics of the plot, management, plot history, etc., with the aim of improving these models and make them more suitable for decision making.

An innovative aspect of the project is that the sensors work in a network. The farmers with scattered plots will select the most sensitive ones to be monitored. In this way, a network of intelligent parcels will cover the entire region. The estimation of disease risk of a particular plot is not determined by the data of the station owned by the winegrower, but by the station closest to the plot in question. This station may have been incorporated into the system by another farmer. The project requires, therefore, the collaboration between the winegrowers, without which the project can´t work. Once the pilot project demonstrates the viability of the system, other winegrowers will be able to join it.

Another important activity is the development of the computer architecture and communication flow systems to ensure the data arrives to the server.

Finally, the tool that will be mostly used is a mobile phone application. All the information collected by the webserver in the previous phases is reordered and analyzed, in order to obtain answers regarding disease risks and treatment recommendations through the app. In addition the system will be able to introduce the treatments applied in the farmer´s “management notebooks” in a computerized way.

Main Results

It is expected that the system will allow the reduction of the number of phytosanitarity treatments, which will mean:

- An improvement in the profitability of farms due to the reduction of costs involved.
- A reduction of the environmental impact of the activity.
- Improvement of the quality of the grapes. Grapes are healthier and with less phytosanitary residues, which affects positively the fermentation process.

In addition, the creation of the Operational Group aims to generate a framework of trust and a work dynamic that will allow all partners involved addressing new challenges in the future.

B.2.4. BOSOLA – a demonstration project on photovoltaic irrigation[56]

Best practice type: New technology and successful case
Date: Project duration 2017 – 2019
Country: Spain

Summary

In recent years in Spain, the price of electricity for irrigation communities has dramatically increased, e.g. by 1 250 % between 2008 and 2013. This has reduced the competitiveness of many farms. Additionally, it is estimated that conventional irrigation systems release more than 16 million tons of carbon dioxide per year due to the consumption of electricity produced from fossil fuels.

The Las Planas Irrigation Community, in Alfaro, La Rioja, located in northern Spain, set up a multidisciplinary innovation team to convert their old irrigation infrastructure into a hybrid system that would operate using energy from photovoltaic panels. The project involved technical activities to set up the hybrid irrigation system, testing and collecting data, as well as information dissemination and promotion activities.

Objectives

The objective of BOSOLA was to create a renewable and clean energy system for agricultural irrigation that would reduce the dependence on fossil fuels and the high associated costs.

Description

BOSOLA was the first high power photovoltaic irrigation project in the region. Initiated by the Irrigation Community in La Rioja, the project was developed by the innovation team with support from the La Rioja Rural Development Programme 2014–2020. It was focused on the generation of electricity from photovoltaic panels to pump water for irrigation of agricultural crops.

56 https://enrd.ec.europa.eu/sites/enrd/files/project/attachments/gp_es_bosola_hybrid_irrigation_587_web_fin.pdf

Prior to the project, water was pumped from the main reservoirs that are fed by the Lodosa canal. They irrigated 246.24 hectares of vineyards, which are mostly drip irrigated. The Irrigation Community had high energy costs since it needed water to be supplied 24 hours a day in the months of maximum demand for irrigation. To reduce their energy costs, they opted to develop a hydraulically and electrically isolated hybrid system using photovoltaic panels for energy.

During the project, the hydraulic installations were adjusted by setting up a twin system to isolate the photovoltaic pumping and the hydraulic connections to the existing intake and impulse network. In addition, the electrical systems of the pumping station were updated.

The photovoltaic installation consists of 600 solar panels with a total power of 213 kWp, and they are distributed in ten rows with east-west orientation. A booth has been set up to control the photovoltaic system and other infrastructure.

The generated energy enables two pumps to drive 30 litres of water per second to an elevate draft of 70000 m3 with a geometric drop of 225.6 metres. From there, the water is distributed by natural pressure to the 246 hectares of connected vineyards.

The project duration was 25 months. Applying for permits and completing all the necessary paper work with the administration (basic projects, execution projects, productivity studies, trials) took six months. Another six months were dedicated to the installation and civil engineering of the photovoltaic and hydraulic systems. Data were collected for a 12-month period and the dissemination of results lasted one month.

Main Results

After four months of operation, 84981m3 of water had been pumped using renewable energy. That was approximately 30% of the total annual water consumption.

In the same period, the economic savings for the Irrigation Community were also substantial. Comparing the irrigation data after the project to those of the previous three years, it appears that the installation reduced energy consumption by 50% during the irrigation months and by 18 times during the non-irrigation months.

The data collected show that the installation will be amortised in less than five years.

It is estimated that there will be 117 tonnes of CO_2 emissions mitigated per year.

This project will improve the competitiveness of many farmers due to reduced energy costs and will encourage new productive investments with a positive environmental impact.

B.2.5. Integrated Pest Control System using Aerodynamic-Spectrometric Methods[57]

Best practice type: New technology and successful case
Date: Project duration 2018 – 2019
Country: Lithuania

Summary

Conventional farming practices are largely based on the preventive application of protective measures for plants. This includes spraying plants with pesticides within a pre-set frequency. However, this method means pesticides are often applied even when the plants are not affected by pests. During the implementation of this EIP-AGRI project, the Operational Group (OG) scanned the fields with the help of drones and spectral cameras – a process that provides more information than a standard camera. The consultants and researchers used the spectral data to identify the degree of damage to the plants (diseases, pests) and provided recommendations to the farmers, on how the damaged plants should be treated. The OG created an online platform with maps showing the damage caused by diseases and/or pests, in a visual format, using the results of previous scanning and offering recommendations for each case.

Context

Based on traditional agricultural practices to prevent the spread of diseases and pests, wheat is sprayed on average five times per year. Apple trees are sprayed between eight and ten times, blackcurrant is sprayed two to three times and potatoes six to seven times per year. The plant protection products are usually sprayed evenly on the entire field. This practice, however, leads to an increased use of fungicides and pesticides which is not always necessary.

Objectives

The objective of this EIP-AGRI project is to encourage farms to introduce technological innovations that ensure an effective control of pests in an environmentally friendly way.

Description

The project was carried out in three stages. The first stage involved organizing the OG and assigning the staff responsible for the project's implementation. An information stand was set up and a briefing article was published. The OG also selected the trial fields.

The second phase of the project consisted of scientific trials and tests. Tests were carried out using crop hyperspectral imaging, unmanned aerial vehicles with hyperspectral cameras and software for image processing. Hyperspectral imaging (HSI) is a technique that analyses a wide spectrum of light instead of just assigning primary colors (red, green, blue) to each pixel. The light striking each pixel is broken down into many different spectral bands in order to provide more information on what is imaged. Furthermore, plant chemical composition analyses (laboratory studies) were carried out. Other surveys that took place included a survey of the characteristics of the light reflected by healthy

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57 https://enrd.ec.europa.eu/sites/enrd/files/project/attachments/gp_lv_integrated_pest_managment_523_web_fin_0.pdf

plant surfaces and plant surfaces damaged by pests and diseases. Based on these findings, the OG created a model of an Integrated Pest Identification and Control System.

The functionality of the system was trailed in farms growing cereals, vegetables and berries and in market gardens/ kitchen gardens. The system was then finalized and made ready for demonstration.

Main Results

The system allows the detection of pests in fields, gardens and kitchen-gardens and determines the optimal time to implement protective measures. The farmer does not need to apply preventive spraying. Only areas of potential risk are sprayed and only when it is necessary. In this way, expenses like labour and fuel costs are reduced.

The software developed uses the data collected by the hyperspectral cameras to generate vector digital maps. The data are used as the basis for developing an agrochemical model of the farm providing information on the best methods of tillage, sowing, fertilisation and spraying, accompanied with a map of the farm's fields. It also uses geographic information system (GIS) spatial data filtering functions, computer aided design (CAD) and other types of map layers.

The system's website/data visualisation platform includes the methodology describing the fundamentals of the system's operation, guidelines on the data preparation and procedure for downloading the system, as well as images of the project partners' farms showing the spread of pests on them. After testing, the economic benefits of timely fertilisation and appropriate fertiliser rates were estimated. The profit of the pilot farms increased from 9 to 34 EUR/ha.

B.2.6. Performance monitor and fleet management

Best practice type: New technology to check the agriculture machinery
Date: 2021
Country: Spain

Description

When harvest season arrives, it is necessary to check and tune all the machinery used as well as to update the equipment in order to improve its efficiency. For this reason, for several years, it is possible to find performance monitoring systems on combines. This monitoring is based on devices which provide information about the behavior of the plots and which enable us to enter precision agriculture.

Performance monitors are devices which are installed in the harvesters, which allow us to know in real time the data about the production collected as well as the exploitation area that we are working on. In addition, it can provide us with other types of data, such as the degree of humidity of our production.

Thanks to the precision of the current GPS systems, it is possible to generate data with great precision where the margin of error is a few centimeters.

The data obtained by monitors allows us to create a map which points out which are the zones which better produce our exploitation and which ones give the worst outcomes. The map created with the data can be edited and be loaded into smart spreaders that allow to make a variable application. In other words, the map is introduced to the smart spreader indicating how much fertilizer must be applied in the different zones depending on the data previously obtained. This way, we can save on a product in certain areas, which allows us to cut down our treatment costs.

Another novelty is the use of vehicle monitoring and management systems in the fields. This allows us to know the status and position of the machinery at all times, and thanks to the Agroplanning web application, we can manage the entire fleet of agricultural vehicles online.

Results

For these reasons, both technologies have been unified: the performance monitors together with the Agroplanning online platform in order to have the data of the harvesters available, in real time and anywhere. This way, maps of previous harvests can also be archived in order to make comparisons or share them. The combination of performance monitors and online farm management platforms is a useful and easy-to-use solution for everyone.[58]

B.2.7. SGS Precision Agriculture

Best practice type: New technology using SGS precision agriculture
Date: 2021
Country: Spain

Description

Both the importance and the need for sustainability in agriculture is hiking up as the agricultural sector is subject to increases in production costs, fluctuation of product prices and food safety requirements as well as consumers demand for healthier products and with better quality. To do this, farmers have to reduce their expenses while increasing their production.

For this, the company SGS S.A. offers a SGS detailed precision agriculture. These services equip farm managers with the necessary information to make better decisions and maximize productivity. The data they collect and analyze are:

- Chemical mapping of soils - application of variable rate of lime / gypsum.
- Taking leaf samples.
- Crop inspections.
- Interpretation of harvest data.
- Analysis of macro elements and traceability.
- Water analysis.
- Satellite images - NDVI.
- Potential of soils (different crops) for the management of variability in the fields.
- Tillage cultivation methods (depth and type).
- Fertilizer recommendations (variable rate application).

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[58] Agrosap (2021). Monitor de rendimiento y gestión de flotas: una combinación ganadora para tu cosechadora. https://agrosap.es/blog/monitor-de-rendimiento-y-gestion-de-flotas-una-combinacion-ganadora-para-tu-cosechadora/

- Project development (irrigation, orchards and feasibility studies).
- Drainage evaluation.
- Effective root depth and water capacity.

Results

With all this data it is ensured that the farmer has all the necessary information about the exploitation to make effective decisions about the production and sustainability of the crops.[59]

B.2.8. The mosquito problem

Best practice type: new technology using spraying drones
Date: 2021
Country: Spain

Description

When certain dates arrive, mosquitos appear in certain areas such as wetlands. These mosquitos can affect both people and agricultural crops. In order to combat this situation, insecticides have been applied, which have been efficient as they have finished with mosquitos threats and their diseases. The application method used is through a spraying equipment controlled by an operator.

This technique is the traditional one, but Drones Hispania business is developing new and more efficient techniques in which new technologies are implanted, as it is the case of the use of spraying drones.

Picture 24. Arial drone application of chemicals

Results

Fumigation drones are highly advanced equipment controlled by a software capable of carrying out the work that is programmed independently, which facilitates the use of the product in any area of the crop and that perhaps an operator could not reach. Drones Hispania manufactures and programs

[59] SGS (2021). Agricultura de precisión. https://www.sgs.es/es-es/agriculture-food/seed-and-crop/soil-leaf-and-water-services/precision-farming

these drones in order to improve the application of the product as well as the treatment of crops, since all areas will be treated equally.[60]

B.2.9. BeeScanning - an app for protecting bee colonies[61]

Best practice type: Innovative app
Date: Project duration 2017 – 2020
Country: Sweden

Description

BeeScanning app combines the use of artificial intelligence and smartphones, enabling beekeepers to easily detect Varroa mites and reduce the risk of death in their bee communities.

To reduce bee mortality and improve the health of bee communities, the BeeScanning app was developed by an EIP-AGRI Operational Group. BeeScanning uses Artificial Intelligence (AI) image analysis to detect Varroa mites. Beekeepers get infestation results together with recommended actions in a fast and user-friendly way using their smartphones.

Results

- The app offers a fast and user-friendly way of detecting Varroa mites in bee communities, without having to use the traditional methods that involve killing bees.
- No sophisticated equipment is needed since the technique is adapted for smartphones. The app is available for both iPhones and Androids and can be downloaded in 155 countries all over the world.
- In April 2019, the app had been downloaded 3 000 times with an average of 50 new users every week.

B.2.10. Sustainable cultivation of olive trees and innovative extraction of olive oil[62]

Best practice type: New technology and successful case
Date: Project duration 2015 – 2019
Country: Slovenia

Description

The organic farm owned by Beno Bajda has over 1 000 olive trees across a 3.7 ha area in the Municipality of Izola. The firm is helped by advisory services to protect the groves against olive fruit fly attacks. Prior to the project, it incurred significant costs for plant protection products.

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[60] Drones Hispania (2021). El problema del mosquito. https://droneshispania.com/el-problema-del-mosquito/
[61] https://enrd.ec.europa.eu/sites/enrd/files/project/attachments/gp_se_beescanning_531_web.pdf
[62] https://enrd.ec.europa.eu/sites/enrd/files/project/attachments/gp_si_olive_oil_434_web-jto_0.pdf

Entering the RDP Agri-environment-climate measure (AEC measure), allows the farmer to apply sexual confusion and disorientation methods to control the population of pest flies, using pheromones and sticky traps. The farmer also monitors the fly population on a daily basis, enabling preventive actions to be taken as needed. This approach has reduced expenditure on protection products, as well as cutting time and effort needed to control fruit flies. It has also improved product quality.

Results

- The farm has and patented (in Slovenia) a new oil extraction technology without thermal treatment. This method, using ultrasound, means extremely cold extraction – the pulp is not heated at all. This has several benefits in comparison with conventional cold pressed olive oil (in which the olive pulp is heated to 27°C):
    - Processing time is reduced by 20 minutes;
    - 20% energy saving;
    - Up to 30% more antioxidants in the olive oil

B.2.11. Modernisation of the Poharci dairy farm[63]

Best practice type: Successful case
Date: Project duration 2015 – 2019
Country: Slovenia

Description

The beneficiary Matjaž Vrhovšek combined three RDP-supported operations to increase and modernise milk production on his farm and secure one full-time job.

The project supported the construction of a cattle shed, purchase of a breeding heifer, and acquisition of agricultural machinery through a collective investment that was made in cooperation with a neighboring farm.

Results

- A milking robot reduced physical work and gave the cows more freedom to determine when they are milked. New ICT gives the farmer data on the condition and performance of each cow, e.g. on how much milk they produce, their movements, their nutrition,, etc.
- The investment in specialised agricultural machinery helped to make work in fields and meadows more efficient and better quality. This has improved the standard of fodder produced. Finally, the shared investment helped to reduce running costs and meant more used for the new machinery was used more
- The new, larger cattle shed enables the farmer to breed 58 dairy cows and 51 heifers and weanlings. It has significantly improved animal welfare. Modern placing equipment, feeding

[63] https://enrd.ec.europa.eu/sites/enrd/files/project/attachments/gp_si_poharcifarm_modern_428_web-jto_0.pdf

technology and improved ventilation resulted in less stress for the animals and increased the quality and amount of milk produced;

- The farm owner is cooperating closely with an animal nutrition specialist who provides advice and support

B.2.12. PinovaMeteo - agrometeorological station

Best practice type: Successful implementation
Location: Croatia

Timely agricultural work with high productivity, reduced number of operations and minimal labor costs are the characteristics of precision agriculture. According to the above definition, the agrometeorological station fits perfectly into this segment of agriculture. In essence, these are devices that use their sensors to measure weather conditions and some of the values related to the soil and the sun.

The main differences between agrometeorological and classical meteorological stations are in sensors, location of weather measurement and additional algorithms that facilitate agricultural production.

Picture 25. Installed agrometeorological station

It is common for meteorological stations to measure:

- Air temperature (° C)
- Relative humidity (%)
- Precipitation amounts (mm / m2)
- Wind speeds (m / s)
- Wind direction (0-360 °)
- Air pressure (hPA)

What the agrometeorological station must measure in addition to the above is also:

- Presence of moisture on the leaf (%)

- Temperature in the plant zone (° C)
- Soil temperature (° C)
- Global radiation (W / m2)
- Soil moisture (cb or vol%)

Since the device is mounted directly on production areas, the measurements are far more accurate and meaningful than when the device measures parameters 3 km or more from the production area, which can be the case when farmers rely on existing networks of state hydro meteorological PC applications that display measured data and automatically calculate algorithms such as: sums of effective temperatures, models for plant diseases, evapotranspiration, etc.

Practical application agrometeorological station

It helps us set irrigation deadlines and installments! Whether the orientation for irrigation are soil moisture sensors or the calculation of evapotranspiration is in any case better than randomly irrigating according to your own feeling.

It helps us determine when and with what type of means to go for protection! The development of plant disease usually requires leaf moisture and optimal temperature. Plant disease models precisely combine meteorological parameters to obtain information on the time and severity of infection, incubation length, hazard index, or fructification time (depending on the model). With information about the above, plant protection can be made more accurate in time, which leads to better results.

The quality of plant protection application also depends on the weather conditions under which the protection is carried out, which means that it is not convenient to spray during too high or too low temperatures because the agent evaporates too quickly or phytotoxicity (each agent has its minimum and maximum application values). Relative humidity if too low can also reduce the effectiveness of the agent. The wind speed must not be faster than 3-5 m / s because there is too much drift. All these values that are important in plant protection are available in real time to the farmer who can then make the right decision to maximize the effect of the product.

Producer:

- Pinova d.o.o.
- Dr. Ivana Novaka 1, 40000 Čakovec
- pinova@pinova.hr +385976499425

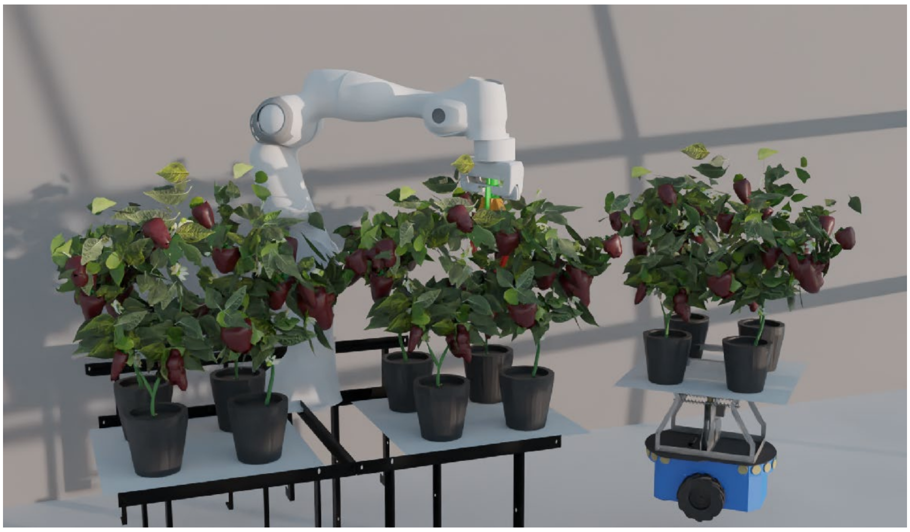
B.2.13. SpECULARIA

Best practice type: Successful research case
Country: Croatia

SpECULARIA (Structured Ecological CULtivation with Autonomous Robots In Agriculture) is a Croatian Science Foundation project that aims to help farmers in indoor organic agriculture using concepts of compliant robot control, soft robotics, and heterogeneous robotic systems. The research is done by UNIZG-FER research group under assist. prof. Matko Orsag, within LARICS - Laboratory for Robotics and Intelligent Control Systems.

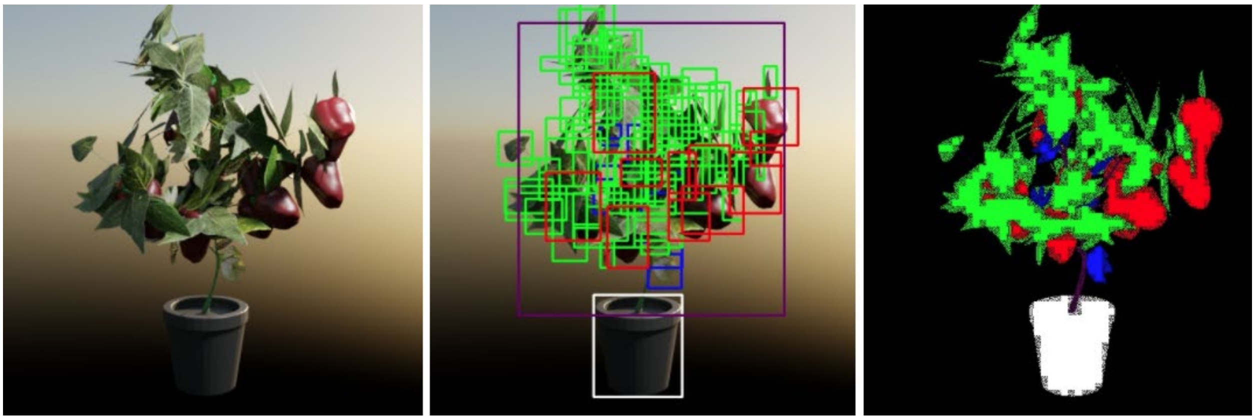
Deploying robots on big farms is not a new concept, but a fast growing industry that focuses on big machines applied for specific crops and use cases. The system proposed in the project is intended for small family run organic farms instead, and is composed of small robots with specific abilities that can execute certain tasks only when they are introduced to work together. This way, in addition to financial advantages, the system has higher scalability and versatility.

The main components of the multi robot system are an Unmanned Aerial Vehicle (UAV), an Unmanned Ground Vehicle (UGV), and a compliant robot arm. The UAV primarily plays a surveillance role, carrying sensors for monitoring crop state. The role of the UGV is to transport plants in their growth unit containers with a custom designed mechanism. The plants are carried from their growing positions to a manipulator station, where the robot arm performs plant treatment procedures. The robot manipulator dealing with sensitive plants needs to be compliant in order to properly execute given tasks, while being harmless to the plants. The responsibilities of the manipulator range from simple watering to physical flower and fruit manipulation, plant pruning, and other mechanical interventions at the plant’s structure.



Picture 26. Collaboration of a robot team in plant treatment

The first step towards creating an artificial farming expert is to enable the system to recognize and perceive plant's parts (i.e. differentiate stems, fruit, flowers, leaves, root, soil, etc). To this end, the project has recently focused on **sweet pepper** as a testing crop for development of perception methods. The perception is based on **RGB-D** cameras and **deep learning**. RGB-D cameras are a fast growing industry that enable perception in 3D space thanks to their depth channel. To this end, a **synthetic dataset** is generated for object detection and semantic segmentation tasks, by scanning all plant parts to create their 3D model representations. These models are then manipulated to increase variations in the dataset. We build plant specific randomized 3D models of the full plant using scanned parts like leaves, fruit, flowers and stems. Finally, annotation of these 3D models is procedural, meaning that it generates annotated images which can be directly used to train the system.



Picture 27. Synthetic dataset for neural network training.

Using **transfer learning** on existing networks we train our system to plan operations such as: sweet pepper yield estimation, detection and harvesting, watering plants, plant hygiene, and many more. Among our recent results is the experimental validation of our **robotic harvesting** solution, where our perception and robot control algorithms achieved a success rate of 75% over three pepper varieties. Most of the failed attempts were due to errors in perception. Currently, our perception method is being further developed both in terms of 2D segmentation, as well as in better estimation of fruit position in 3D space.

Picture 28. Robotic harvesting

B.2.14. VeeMee

Best practice type: Successful implementation
Location: Croatia

VeeMee was established in Croatia with the aim of increasing and improving the agricultural market in the country with an emphasis on strengthening the competitiveness of food products grown on family farms.

VeeMee is currently the only platform that is produced on the market and provides traceability for more than 20,000 tons of food in almost all shopping centers and other retail measures.

We provide family farms with a separate micro website that is updated as desired, brand promotion and a QR code that defines and represents it through the PID - the identity of the manufacturer. QR code with a recognizable message "Do you think you know what you're eating?" It is placed on a product that is readable with a single click on all mobile phones, and the family farm is automatically completed in the first, open search engine of farmers and products. PID profiles are located on the VeeMee platform and contain all relevant information about the origin of the product, its manufacturer and distributors.

Picture 29. Real life and digital application

The goal is food traceability and transparency available to everyone, without raising product prices. We use the same principle on the platform, enabling the availability of data to everyone. The data can be used for the development of individual regions in which there are measurable surpluses or deficits of individual production.

All our services form a closed circle through which food comes from the field to the table. So far, we have saved more than 750 tons of goods from dumping, reduced 40 tons of CO2 emissions, and gathered more than 1,900 active users through the VeeMee platform.

What does veemee do?

- Traceability of food from producers through purchasers / distributors to the end consumer, we achieved through a neutral designation of origin with a QR code that indicates a unique

PID profile on the VeeMee platform. Our labels contain the recognizable message "Do you think you know what you are eating?" Encouraging consumers to learn about the individuals and companies behind the product and creating awareness of the food they consume. Knowing the origin of food and products to the shelves strengthens consumer loyalty and contributes to product sales.

- The VeeMee platform currently contains information on manufacturers and their products, certifications and capacities, their partners and suppliers, as well as market news and trends. The platform provides transparent information through interconnected profiles and database search functionality for any user using any device in any location. We present all VeeMee partners on our social networks, present them where possible and connect with potential clients whenever the opportunity arises.
- VeeMee smart logistics covers the complete logistical coordination of any transfer of goods in physical, informational and organizational aspects, with the primary goal of returning goods to retail or finding other uses. We eliminate or reduce losses and logistics costs for our clients by applying our knowledge and experience, procedures and providing solutions for central warehousing and transportation.

B.2.15. APOLLO[64]

Best practice type: Successful implementation
Location: European Union

APOLLO is an EU-funded innovation project aiming to develop a market-ready platform of agricultural advisory services focused primarily, but not exclusively, at smallholder farmers in Europe.

The APOLLO project aims to bring the benefits of precision agriculture to farmers through affordable information services, making extensive use of free and open Earth Observation data, such as those provided by the European Union's Copernicus programme.

These services will help farmers to make better decisions by monitoring the growth and health of crops, providing advice on when to irrigate and till their fields and estimating the size of their harvest. Ultimately, these interventions should lead to less farm (or agricultural) inputs and higher yields – and therefore increased profitability and competitiveness.

SERVICES

The six APOLLO services support farmers at all stages of the growing cycle. The services are available on the platform over the internet through the desktop, or via the dedicated mobile/tablet application.

- Tillage Scheduling
    - Know when to till for best results, avoiding soil degradation and saving energy.
- Irrigation Scheduling
    - Find out when and how much to water your crops, reduce waste and avoid over-irrigating.
- Crop Growth Monitoring

[64] https://apollo-h2020.eu/

  - Keep an eye on the state and health of crops from emergence to harvest
- Crop Yield Estimation
  - Analyse field productivity and make better-informed decisions on whether to sell or store.
- Weather Forecast and Alerts
  - Weather forecasts and major weather events alerts.
- Farm Management Zoning
  - Analyze the field's past to better understand its future.

Pilots

APOLLO services were piloted during the project in three countries of continental Europe: Greece, Serbia and Spain. The pilots were be user-driven, and implemented with the direct participation of two farmers' associations – the Agricultural Cooperative of Pella (ACP) in Greece and the Association of Farmers of the Municipality of Ruma (UPOR) in Serbia – and an SME providing farm management services (Agrisat in Spain).