FARMING 4.0

Curriculum for ICT knowledge and skills for VET in agriculture

This curriculum has the purpose to transfer the specific knowledge skills and competences in the area of ICTs, needed for students in the VET for agricultural, advisors and all other participating subjects going through the process of VET for agriculture.

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

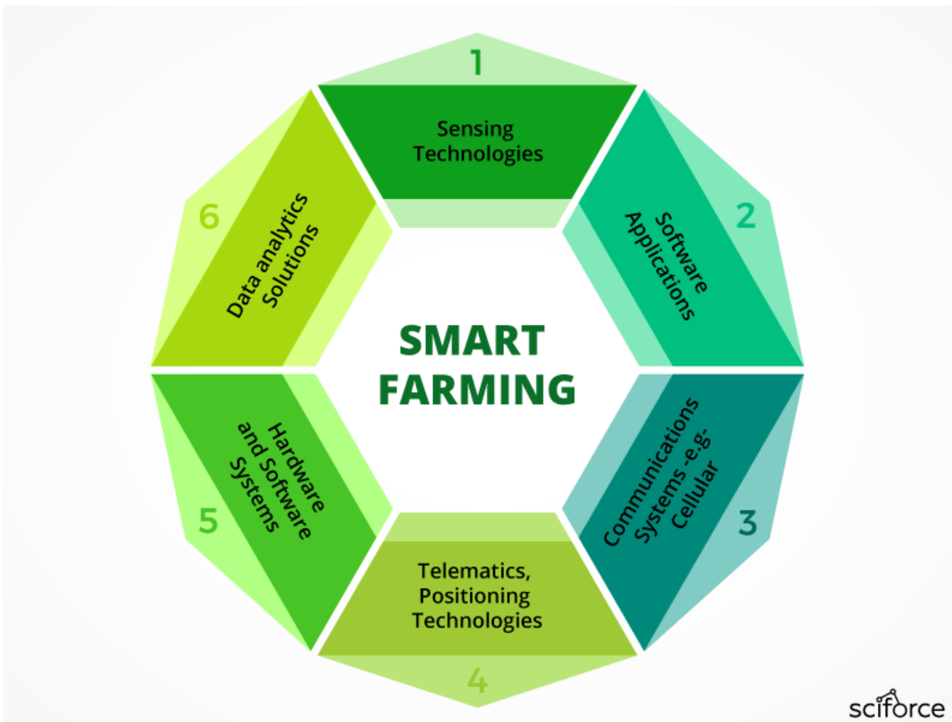
Table of content

1. WHAT IS AGRICULTURE 4.0?

Agriculture 4.0/Farming 4.0/Future Farming

Agriculture 4.0 also called Farming 4.0 or digital agriculture, in the narrower sense, precision agriculture means the intertwining of

- information and communication technologies (ICT),
- decision support based on the processing of bigdata,
- automation and robotization



Technologies involved in smart farming, Beecham Research

Source: Medium.com

We can also say that this is a reform of technology and management that will lead to a change in the business models of production, plant management and product lines. But how did we get there?

A quick overview of the phases of agricultural production

1. The first pre-industrial era of agriculture lasted from prehistoric times to the 1920s. In these self-sufficient, small, labour-intensive farms approximately **one hectare** was needed to meet **one person's food needs.**

2. The second phase, industrial agricultural production was between 1920 and 2010. Tractors, combine harvesters, fertilizers and hybrid seeds made it possible to emerge large commercial farms. The productivity of the development resulted in **half a hectare** sufficient to supply **five people.**

3. **How can we sustainably feed 9 billion people by the year 2050?**
   The third phase is now emerging, with large amounts of data required for production being made available by satellite systems or by plant and plant sensors. As part of these efforts, CLAAS, in collaboration with T-System, has developed a web-based intelligent harvesting system for the combine-tractor fleet. Like Industry 4.0, it was called Agriculture 4.0. The combine and the tractor communicate via a network, which means that when the seed hopper is full, the combine automatically calls the tractor with the trailer to empty the hopper. With this option, the harvest operation is uninterrupted, which saves time and expense. These intelligent solutions can be extended to other areas.

There are other approaches, for example Ulrich Adam (CEMA) talks about agricultural revolutions, the main chapters of which are:

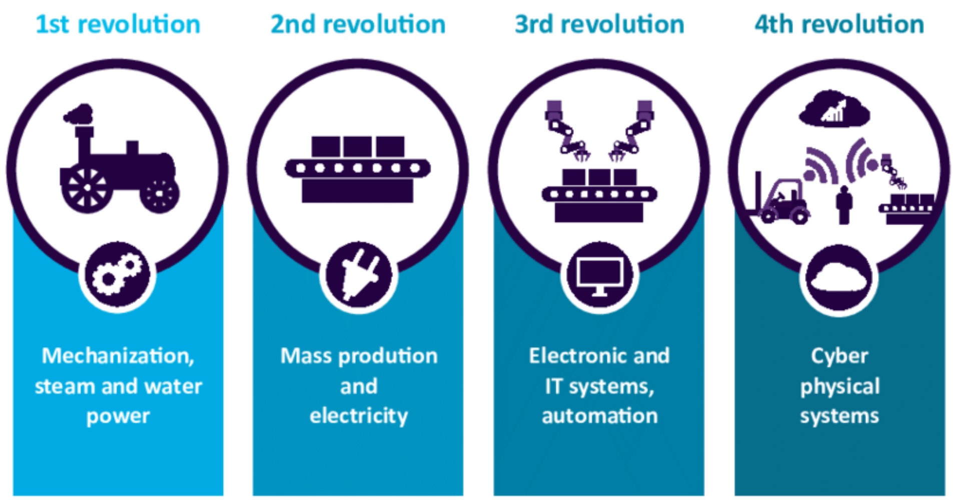
- mechanization,
- fertilization,
- industrial agricultural operations,
- Farming 4.0 - Smart Digital Farming, Smart Digital Ecosystems

Overview of the effects of agricultural development on mechanization

Stages of development:

- Conventional Farming (Everybody knows this, does it, it does not want to be detailed)
- Precision Farming
- Smart Farming/Connected Farming
- Farming 4.0/Future Farming

Precision agriculture

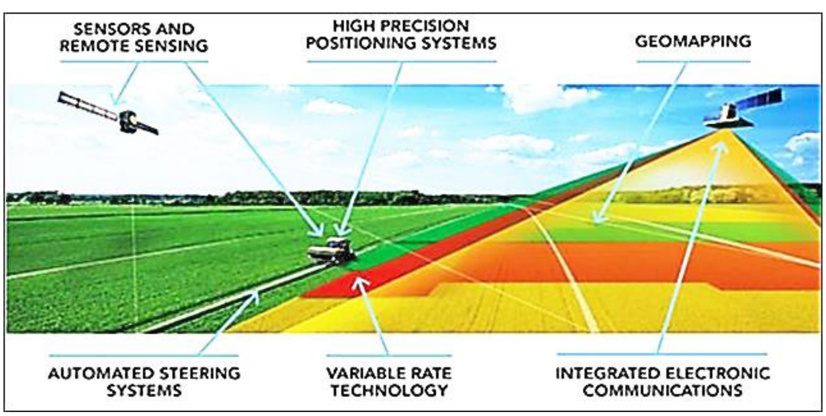


Evolution towards Industry 4.0

Source: [ResearchGate]

Precision farming is a combination of technical, IT, information technology and crop technology applications that make crop production and agricultural machine management more efficient. At the same time, it supports environmental and sustainability expectations (Gebbers and Adamchuk, 2010).

Precision Agriculture is a system that can apply the right agricultural operation at the right place and time. Agri-informatics tools, systems, services are generally related to the concept of precision farming, which by its present definition is a complex farm management system that adapts production processes through the means of observation, measurement and intervention, according to time and geographical variations.



Precision Agriculture: Key technologies and concepts

Source: ResearchGate

Smart Farming/Connected Farming

As digitalization becomes common, precision farming is gradually transformed and the result of this process is Smart Farming. There is no clear dividing line between precision farming and Smart Farming.

One of the features of Smart Farming is the concentrated collection, management and processing of large amounts of data called Big Data. Along with GPS and broadband internet, data processing will be key technology and focus on software. It is crucial for Smart Farming that the information generated during the various stages of production and processing can be linked to each other. Smart Farming covers and integrates the entire production process, so it is important to be based on standard solutions.

Source: eGov hírlevél

Video:

The Future of Farming https://www.youtube.com/watch?v=Qmla9NLFBvU&t=3s

2. Data sources

2.1 Sampling

Sampling technologies

In agriculture, it is essential for the farmer or consultant to think and plan ahead, which requires sufficient quality and quantity of data. Recently, farmers and consultancy companies have come to realize that not all farm fields are the same, but due to the large size of the fields, there may be significant differences within it.

The practical implementation of precision farming requires that we measure and understand the spatial and temporal variability of soils and plants within the field.

It is inexpensive and generally unnecessary to measure everything! A well-designed sampling is capable of mapping differences within the table, from which we can draw reliable conclusions. While in general the purpose of sampling was to survey the average condition, in precision agriculture farmers are interested in changing parameters within a given area.

Accredited laboratory soil (and crop) testing is a mandatory requirement for the CAP and agri-environment applications, as well as for farmers in nitrate areas. It is also important to continue the nutrient supply based on these test results. An important factor in the effectiveness of interventions designed on the basis of accredited laboratory soil (and plant) tests is professional sampling.

Inappropriate or inadequately representative samples, and their laboratory results, may lead to false conclusions in the area.

2.1.1 Soil sampling

In soil science, soil is defined as 'an independent body in nature with a unique morphology from the surface down to the parent material as expressed by the soil profile'

Soil is the product of biochemical weathering of the parent material, and its formation is influenced by the soil formation factors: climate, organisms, parent material, relief, and time (Jenny, 1941; Brady, 1990).

The purpose of conventional soil sampling is to examine the average nutrient level in a given area and to provide some level of nutrient supply.

The main objective of soil sampling in the context of precision agriculture is to understand the nutritional levels in the soil over separate and distinct areas (zones) within a field subject to cultivation, and hence observation.

Soil sampling
Source: WinField United

The basis for mapping differences within a field is well-defined, well-planned soil sampling, which is suitable for mapping homogeneous patches (zones) within the field.

During precision soil sampling, the fields are divided into smaller areas or zones, soil samples are taken within each zone, then the required nutrient doses for each zone are designed and the nutrient supply is delivered in a targeted and differential manner.

By performing analyses on soil samples, agricultural experts and farmers can begin to understand the relationship between soil fertility levels and other properties of the field that can be predicted and measured. Factors that influence soil nutrient levels, and hence the determination of the soil sampling approach to be employed, include:

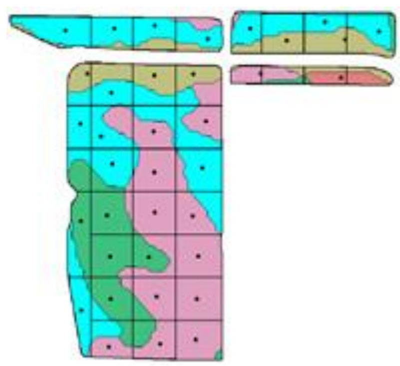
- soil type
- topography
- cropping history
- manure applications
- land levelling for irrigation
- fertilizer management practices.

The process of statistical sampling, in the context of soil analysis, provides information about the population (in this case, a group of soil samples which significantly represents the field area that is that subject of analysis) characteristics on the basis of representative sample observations. Obtaining a truly representative soil sample can be a very challenging job.

Sampling errors are more frequent than analytical errors (Reed and Rigney, 1947), so the importance of accurate sample cannot be overstated. The extent to which the result of an analysis actually identifies a real characteristic of the soil population depends critically upon on the accuracy of sampling.

Grid based (systematic) soil sampling

Sampling takes place at specific points on an imaginary net / grid in the field and then uses this data to create the application map. On the basis of the map, the machines identify the various nutrient demand areas using the positioning GPS and implement the variable rate application (VRA).



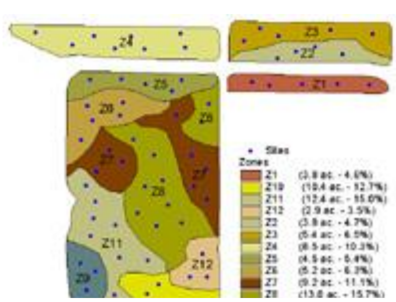
Grid by Soiltype

Source: Agronomic Solutions

Management zone based soil sampling

A cultivation zone, also known as a management zone, means that smaller, more homogeneous units of a filed are delimited by some variable or variables. This makes it possible to match needs and inputs. If part of the field requires more fertilizer, it will get more, if a part of the field is ripened sooner is harvested sooner.

Field boundaries of the management zone is based on the collection of data and the examination and analysis of this data. Soil sampling, conductivity, yield, topography and satellite imagery, as well as the experience of the farmer are the basis for distinguishing the zones within the field.



Management zone based soil sampling

Source: Agronomic solutions

Crops sampling

Samples from plants are used primarily to assess the nutritional status of plants, and data obtained from these will serve as a guide to nutrient management.

For example, the analyzed samples may provide information on the possible additional nutrient supply to plants and pastures. Sampling is important in many ways and can be used for many purposes, such as:

- to assess the nutrient supply of fields, parcels and different soil types
- as an indicator of environmental toxicity

Laboratory testing of some or all of a plant is called plant analysis. In contrast to soils, plant growth and crop dependence. Depending on the analysis, leaves, roots or other parts of the plant are to be sampled. Crop harvesting, which is a vital task within their businesses. Farmers require accurate yield estimates for a number of reasons:

- crop insurance needs
- delivery estimates
- planning harvest and storage requirements
- cash flow budgeting

2.1.2 Live-stock sampling

The main purpose of livestock sampling is to

- monitoring animal health, early detection of diseases and infections at the level of individual animals
- monitoring the activity and behaviour of each animal
- Collection of data to support decision making at farm or organization level

There is a wealth of information we can collect about animals, whether it is one-off, regular or ad hoc.

The collected information is processed by computer software, the data analyzed serve as a basis for decision support and provide the opportunity for feedback to plan and execute the necessary quick interventions.

Tissue tag sampling
Source: Datamars

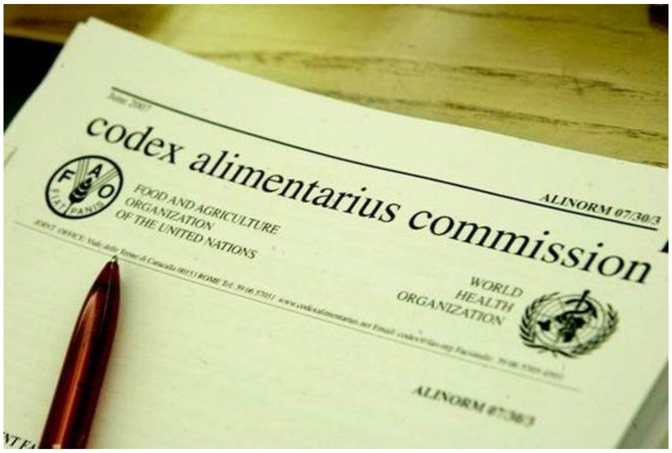
2.1.3 Production sampling (plant production, live-stock)

It is necessary to provide a representative sample to a laboratory for analysis in order to determine whether an agricultural product complies with regulations such as:

- Maximum Residue Limits (MRLs) for chemical residues
- Maximum Levels (MLs) for metal residues
- Determining whether soils contain organochlorine insecticide residues such as dieldrin or DDT, which are a concern to many agricultural interests.

There are a set of general rules for sampling fruit, vegetables and grains. The following procedures are based on sampling methods as recommended by the Codex Alimentarius Commission and the Food and Agriculture Organization. Sampling should be performed separately in the following situations:

- with different fruits, vegetables or grains
- with different cultivars or varieties
- in areas of crop which have had different chemical treatments, or which have been sprayed on different days
- with produce sourced from different growers for repacking or processing.



Codex alimentarius
Source: Agronaplo

2.2 Remote Sensing

Sensors

For the proper operation of intelligent machine groups, it is important to have real-time knowledge of soil, plant, environmental and especially operational characteristics. This is provided by various sensor systems. In systems based on sensory measurement, the following types of sensor can be found:

- soil sensors: electrical conductivity, soil salinity, soil moisture, soil temperature, etc.,
- plant sensors: stock characteristics, crop moisture, nutrient supply, etc.,
- environmental sensors: relative humidity, air temperature, precipitation, wind speed and direction, leaf humidity, solar radiation, etc.,
- Function monitoring sensors (machine).

Source: Dr. Jóri J. István: A jövő mezőgazdasága

Smart farming sensors

Source: RFwireless

Based on the measurement technology, several sensors are distinguished:

- Electromagnetic: Used to measure soil, salinity, organic matter and moisture.
- Optical: Optical sensors have reflectivity to characterize the soil. Used to predict the moisture content of clay, organic matter and soil
- Air: measures the air permeability of the soil
- Acoustic :: Used to determine soil texture
- Electrochemical: Measures soil nutrient and pH

2.2.1 Soil sensing technologies

Soil is an essential element of agriculture and an important factor in crop production and crop yields. It influences the quality of most agricultural products through its internal properties and external factors.

Spectroradiometer

Spectroradiometer is a hyperspectral (high spectral resolution, up to hundreds of bands) sensor. This type of sensor collects and processes information in the electromagnetic spectrum, which makes it possible to identify and measure soil characteristics. By further narrowing the spectral range, hyperspectral sensors can measure mineral composition, nitrogen, carbon, carbonate and organic matter composition in the upper soil layers, as well as soil moisture and vegetation status. Spectral analysis is a fast and inexpensive method. Hyperspectral images can be taken with:

- satellite sensors e.g. MODIS on Terra and Aqua satellites
- aircraft mounted sensor
- hyperspectral cameras mounted on drones
- field spectroradiometer

ASD FiledSpec spectroradiometer

Source: Malvern Panalytical

Frequency-domain reflectometry FDR / Capacitance (Frequency)

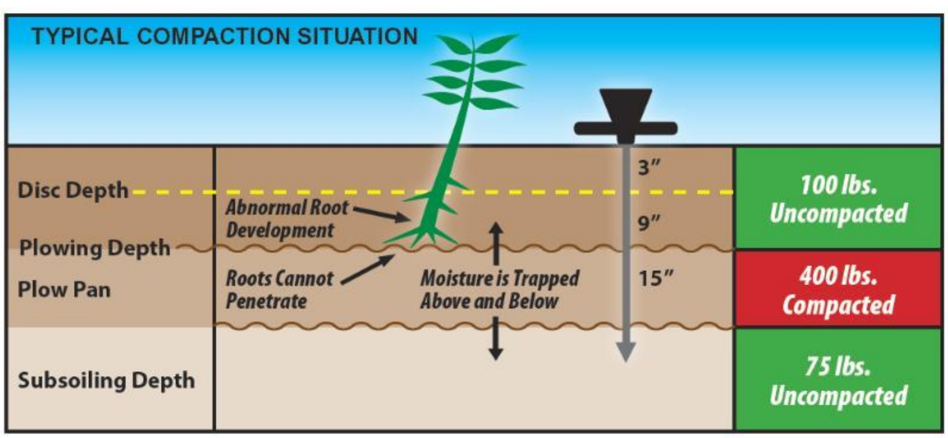
FDR and capacitance sensors developed for measuring soil moisture content. FDR and capacitance probes measure the soil dielectric constant using two or more plates or rods which are embedded into the soil. They can be used to detect areas with high salinity and to measure the moisture content of sandy soils. It provides accurate and very intuitive information of soil water status. The data can be used to make a more accurate irrigation plan, which can lead to savings.

Frequency domain reflectometry

Source: Soil sensors

Penetrometer

A penetrometer is a tool used to test the compaction level and tilt of your soil. Penetrometers measure the resistance of the soil, giving an indication of how compacted your soils are as an indication of the soil quality. The lower the resistance, the more oxygen is available for soil microbial life and the more easily the roots of plants, nutrients and water can penetrate through the soil.



Penetrometer

Source: Truf-Tec

Shear strength sensor

Soil shear strength is soil resistance to deformation by applied external shear forces, for example, during soil cutting process with different tillage tools. Sensors can measure the shear resistance of the soil in different depths as they pass through the field. These data provide valuable information on soil properties and can help support decision-making and make farming more economical.

2.2.2 Crop sensing technologies

Nutrition management, plant health, plant protection

Sensors for nutrient management

A wide range of sensors are available to produce vegetational indexes of plants that measure plant development and photosynthetic activity. Based on their principle of operation, there are two types, passive and active sensors.

• Passive sensors measure the amount of sun energy reflected from the objects Passive sensors are mostly multispectral or hyperspectral. The collection and processing of information from the electromagnetic spectrum makes it possible to calculate several vegetation indices. Because these sensors rely on sunlight, data can only be recorded when the sun is illuminating the target area and cloud cover is minimal.

• Active sensors use their own modulated light at defined or fixed wavelengths. The sensor illuminates the object and uses photodiodes to measure the portion of light that is reflected. Active sensors are limited to mid-wavelength ranges, so they can only be used to calculate a few specific vegetation indices. One primary advantage of active sensors over passive sensors is their ability to obtain measurements at any time, regardless of the time of day or season, while removing the effects of sun angle and cloud cover.

Sensors to detect plant stress

The reduction of qualitative and quantitative losses of crop production and the achievement of higher yields largely depend on the early detection of various plant diseases and pests. Optical techniques such as RGB colour, multi - and hyperspectral imaging, heat maps, or chlorophyll fluorescence sensors can detect plant diseases at an early stage. The advantage of the images is that they are objective, can be repeated several times and can identify and quantify various plant diseases. 3D laser scanner technology can be used to monitor physiological changes in plants. With this technology, you can display even more useful data about plant condition, such as:

- water requirements of plants
- soil moisture content
- quality and quantity of yield

- nutrient content
- weed tracking
- monitoring plant protection interventions

Various platforms, ranging from local to remote sensing, are available for multi-stage monitoring, which can analyze a given plant or part of a plant or entire fields. In general, sensor-based measurements and analyzes are very well applicable in precision agriculture, displaying well the factors that influence the development of plants and the quantity and quality of the crop.

Sensors for plant protection

Factors that cause plant stress can be biotic or abiotic. Abiotic factors refer to non-living, physical and chemical elements of the ecosystem, e.g. elements from the atmosphere or the hydrosphere, such as water, air, soil, sunlight and minerals. Biotic factors are living organisms in the ecosystem. Factors, animals, birds, plants or fungi from the biosphere that can reproduce.

Various parameters such as plant height, moisture content, soil compaction, and dry biomass yield data can be extracted from a single field run and mapping using multiple sensors at the same time.

Laser rangefinder sensors

Laser rangefinders and laser scanners are widely used for industrial purposes and for remote sensing. In agriculture information about crop parameters like volume, height, and density can support the optimization of production processes.

LIDAR uses for forestry

Source: Agrotechno Market

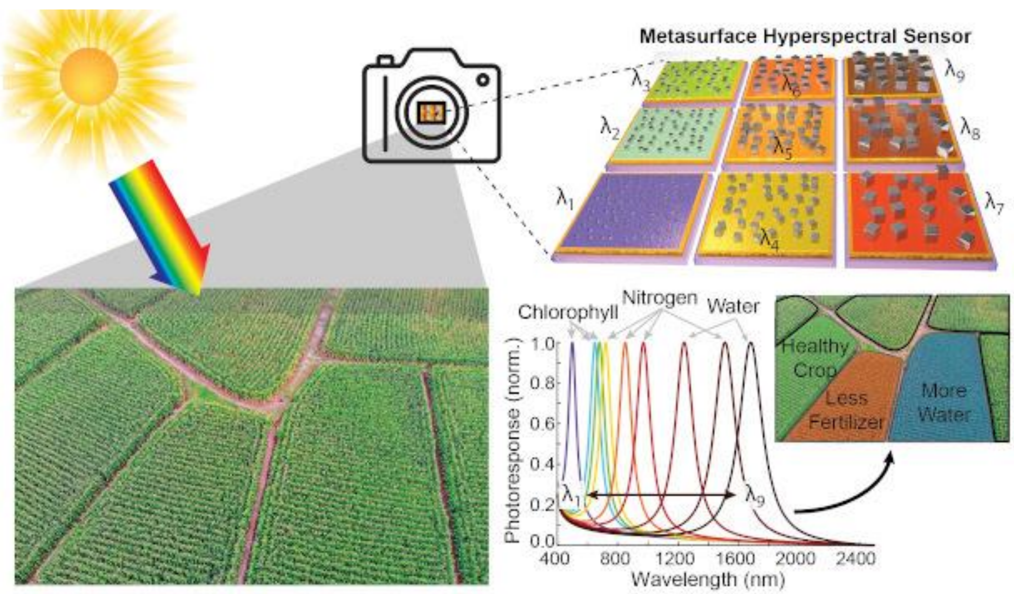
Time-of-Flight 3D camera

These cameras also use a built-in light source, capable of simultaneously processing depth and intensity information on each pixel. Provides 3D images with an accuracy of 1 cm and a high frame rate. These sensors are suitable for studying the phenotype of plants, i.e. to determine the

Hyperspectral imaging

Spectral imaging is the detection of light reflected by the crop with the use of specialized sensors. Almost every farming issue (weeds, diseases, nutrient deficiency, etc.) changes a physiology of the plant, and therefore affects its reflective properties. Using hyperspectral imaging it's possible to detect very small changes in the physiology of the plant and correlate it with spectrum of reflected light.

Various plant diseases can cause significant losses in the agricultural sector, therefore continuous monitoring of plant health for damage detection is essential in order to rapidly reduce the spread of the disease. Information collected from monitoring can be used for effective interventions.



Hyperspectral cameras designed to improve agricultural practices

Source: Control Engineering

Weed control

Weed control can be done with real-time technology where weeds are detected and treated at the same time. Cameras mounted on the tractor take pictures across the field, then the computer evaluates the data and the controlled sprayer handles the marked spots.

With offline method, weed mapping and intervention are separated in time. Based on the weed coverage survey, the resulting data is mapped to geographic positions (DGPS) and a weed map is prepared. Then, later, only sprayers are applied.

Precision (sensor driven) cultivation
Precision cultivation enables inter-row cultivation. An autopilot ensures accurate 2 cm return accuracy for seeding (seeding) and row parallelism. The autopilot saves time, since the operator does not have to count the rows, and on the other hand, the optical sensor mounted on the cultivator ensures that the cultivator's blades do not cut the rows. These two security devices allow approx. 7 cm row approach and doubles tractor speed. Cultivating root crops can begin immediately after germination and emergence, when the sensor has already "seen" the rows. Source: https://www.biokontroll.hu/precizios-megoldasok-a-gyomnoevenyek-ellen/

Pest management
Scout crops for pest pressures, surveillance and management of pest insect populations is a key issue for successful plant protection. Farmers conduct periodic surveys of insect traps in their area, although this activity is labour and time consuming. Nowadays, low-cost detection systems are available that can remotely, accurately, and efficiently control pests. For example, battery-operated wireless image sensors, which accurately measure pest populations, transmit data, eliminating the need for human intervention during the monitoring process.

.

2.2.3 Sensors in Live-stock

Precision Livestock Farming (PLF) using advanced technology and with unique identification of livestock, enables continuous, automated, real-time monitoring of livestock health and welfare and its impact on the environment. With the use of livestock sensors, farmers can easily track changes, identify problems early and have the ability to act quickly, effectively. Livestock sensors are used mainly in ruminants, in more precise dairy farms, and in the pig and poultry sectors. Information collected by sensors provides valuable data to farmers, supporting decision-making with the following benefits:

- improved animal well-being
- improving product quality
- minimizing adverse environmental effects
- reduced use of antibiotics through preventive health measures
- better profitability
- improving the quality of life of the farmer

There are a number of sensors available on the market, which together form a complete toolkit for tracking the various activities and conditions of animal monitoring.

Electronic identification

Individual identification of animals is a prerequisite for implementing PFL. This is the "backbone" of all PFL systems.

Foot mounted accelerometers

Electronic identification in sheep
Source: 4D4F

These sensors are used in a number of areas, such as farm estrus detection, health monitoring, activity, steps, lying and standing behaviour.

2.2.4 Sensors for Agricultural Machines

There are many different sensing technologies in precision agriculture that provide data that help farmers monitor soil or plants to optimize processes and adapt to changing environmental factors.

These sensors can be:

- positioning sensors that use signals from GPS satellites to determine latitude, longitude and altitude
- optical sensors that use the properties of light to measure soil properties
- electrochemical sensors that carry key information such as pH or soil nutrient supply
- mechanical sensors for measuring the physical properties of soil

- soil moisture sensors
- air flow sensors that measure the air permeability of the soil
- weather station sensors.

Some applications in precision agriculture:

- In yield mapping systems as part of harvesting machines.
- For variable rate application with manual or automatic computer control.
- For weed mapping with the help of visual recognition systems mounted on the working tool.
- For variable rate spraying, optimizing the application rate by switching the nozzles on and off.
- For high accuracy recording of topographic data and field borders with GPS technology.
- For various control devices, lane keeping, automatic steering

2.2.5 Environmental (meteorology)

Agriculture tries to replace the water content of the soil and the water demand of the plants with irrigation. There are many forms of water loss and evaporation. Water can be released into the atmosphere from the surface of soil, seas, lakes and rivers, as well as through the evaporation of plants and the breathing of living organisms.

Agricultural evaporation (evapotranspiration - ET) has two components:

- *evaporation from the soil surface*
- *transpiration: release of moisture from plants*

One of the most difficult tasks in crop production is how to regulate evaporation and how to replace lost water. Evaporation can cause significant loss of water. Its degree depends on the type of crops grown and the soil and also many more factors. The water evaporating from the leaves comes from the roots, which means that the deep-rooted plants evaporate more. Factors that affect evaporation include the plant's growth phase, maturity level, percentage of land cover, sunlight, humidity, temperature and wind. If the potential evaporation of an area is higher than the actual rainfall, the soil will dry out if not irrigated.

Evapotranspiration (ET; mm / day) is a commonly used method for determining how much water should be applied to a given area by estimating the amount of water lost from the soil. Evapotranspiration is basically the sum of the water loss resulting from evaporation from the soil surface and the water loss of the plant.

Irrigation sensors fall into two main categories:

Meteorology / climate based controls

Within this, there are three groups:

- Signal-based sensors use publicly available meteorological data (temperature, sunlight, humidity) and calculate the ET value of the grass surface at a given location. The ET data is then transmitted wirelessly to the irrigation controller.
- Traditional ET sensors use a pre-programmed water use curve based on water use in different regions. The curve can be adjusted as a function of temperature and sunlight.
- Local meteorological sensors use weather data collected at a given location for continuous ET measurement and water volume calculation

Agro-Meteorological Weather Station
Source: Pulsonic

Soil moisture based sensors

Instead of using weather data, soil moisture sensors are located below the soil in the root zones of the plant to determine water demand. Soil moisture sensors provide estimates of soil water content.

Water content or moisture content is the quantity of water contained in a material, such as soil (called soil moisture). Water content is used in a wide range of scientific and technical areas, and is expressed as a ratio, which can range from 0 (completely dry) to the value of the materials' porosity at saturation. It can be given on a volumetric or mass (gravimetric) basis.

The irrigation controls can be set so that when the water content reaches a predetermined value, the irrigation valves are opened. The appropriate moisture values also depend on the type of soil and vegetation. Soil moisture sensors should be located in representative areas for efficiency.

Choosing the right technology for the area is crucial to achieving potential water savings and delivering the right amount of water for plants.

Automatic irrigation systems should ideally use multiple sensors, such as soil moisture, rain, wind, relative humidity and temperature.

Soil moisture sensor
Source: *Edaphic Scientific*

Other sensors

Wind sensors

Equipartition of the irrigation is important for successful irrigation. Strong winds can affect the even distribution of irrigation water and the application of water to specific soil profiles and plant needs. Wind sensors, if the wind speed is above a specified value, can stop irrigation to prevent uneven irrigation.

Wind speed, wind direction, evapotranspiration, frost, temperature

Source: Davis

Rain and frost sensors

In heavy rain or during frost, there is no need for irrigation. These sensors automatically stop the irrigation cycle when they detect these conditions thus avoid unnecessary irrigation. There are three main types of rain sensors that operate on different principles.

The first type of rain sensor consists of a small cup or a pool that simply collects rainfall. The sensor measures the weight of water collected during rainy weather and stops the irrigation cycle from the set values. Other materials (sand, debris, leaves, etc.) that enter the measuring vessel may affect the accuracy of the measurement, therefore it is advisable to periodically check its purity.

The second type of rain sensor uses a vessel having two electrodes positioned at a defined distance from the bottom. When the water reaches the electrodes, the irrigation cycle is interrupted.

A third type of rain sensor is based on water-swellable discs.

If the plates become wet, watering will be interrupted. As the plates dry, the system will resume the scheduled irrigation cycle.

All sensors should be located outdoors in an undisturbed location.

2.3 UAVs (UNMANNED AERIAL VEHICLES)

The FAO's "Drones for Agriculture" publication presents the various uses of unmanned aerial vehicles (drones). Drone-mounted sensors collect real-time data and analyze these data to provide farmers with useful information, enabling them to detect problems early and take action. The use of drones is growing most dynamically in crop production, early warning systems, disaster risk reduction, forestry, fishing and wildlife conservation.

More information: FAO Drones for agriculture

In the past, the use of high resolution remote sensing data in agriculture has been limited by its cost and lack of data availability. However, with the spread of drones in agriculture, farmers now have an easily available, inexpensive tool that enables them to assess crop life, intervene more effectively and make decisions. In its field of application, drones are commonly used in agriculture as an aerial platform, equipped with various sensors to obtain detailed image data. Thanks to the high spatial resolution, drone shots can increase efficiency in areas such as:

• soil condition assessment, examination of the effects of each operation,
• plant counting, determination of population number,
• monitoring the ripening and state of health of the plant,
• control of nitrogen supply,
• crop estimates,
• estimation of wildlife damage, determination of other agricultural damage (drought, ice, wind, inland water)

Another important application is the monitoring, counting and recording of livestock using drones equipped with thermal imaging cameras. With the help of the appropriate sensors, each individual is displayed as a separate heat signal, allowing for a more accurate counting mode. Focusing on one animal will allow for more detailed data collection, such as temperature comparison of health conditions, allowing rapid identification and treatment of diseased animals.

Other applications include aerial spray drones, which are subject to varying legal regulations in different countries. Spraying drones on pre-surveyed fields are capable of quickly and specifically addressing (pathc-like) various problems.

There are many benefits to using drones in agriculture, such as:

• cheaper imaging than other aerial photography
• high field resolution (depending on flight altitude)

- early detection of problems
- simultaneous data collection across the whole filed
- easy deployment, frequent use (up-to-date information)
- easy to configure for special needs, quick installation
- enables quick, immediate response, saving time and resources
- more detailed decision-making by farmers

Aerial shooting with drones

Compared to satellite images, drones have higher field resolutions, allow for more frequent shots, and eliminate cloud-influencing factors, compared to traditional aerial photography, they are lower cost and easier to deploy.

The two most common types of drones are

- Multicopters (including quadcopters). Their biggest advantage is being able to stay in the air at a particular point, thus gathering more accurate data on certain areas of the filed.

Quad-rotor drone
Source: FAO: Drones for agriculture

- Fixed-wing drones biggest advantage is that they have a much longer flight time and can be loaded well, but they have the disadvantage of not being able float and they cannot take off and land from one place.

Fixed-wing drone
Source: FAO: Drones for agriculture

2.4 Open sources

Remote sensing is used in agricultural practice to assess land use, segregation of cultivated plants, biomass determination, yield estimation, soil analysis (Burai–Pechmann, 2004). Let's see what this really means?

Remote sensing

The human eye is able to resolve and interpret only a very small part of the electromagnetic spectrum, the so-called visible light range (380-780 nm). Nevertheless, vision is one of our most important means of remote sensing.

Technological development and widespread of the imaging techniques make it possible to provide image documentation at different distances or for remote photographic detection.

The resolution and measurement of the wavelength of the visible and invisible light is made possible by the use of spectroscopy or spectrometry, the device by which we measure it is called a spectrometer.

The spectrometer is capable of detecting various electromagnetic waves from a given surface and recording the measurement the results. The composition and distribution of the wavelengths from the measured surface characterize the physic-chemical state of the given surface.

The spectrum of wavelengths encodes many material properties in a "fingerprint" -like manner. This method, which has long been known in analytical laboratory technology, has received a new interpretation when used in satellites, airplanes, or hand-held tools. Controlled laboratory measurement has been replaced by distance measurement, which allows distances of 1m, 1000m or even greater between the instrument and the sample, creating the science of spectral remote sensing. Spectral remote sensing is now significantly expanded, both in its technical solutions and applications. Source: ÖMKI: Spectral remote sensing

Modern remote sensing technologies have become an essential tool in agriculture.

Remote sensing methods

- Remote sensing, data collection
- Satellite multispectral / multiband remote sensing
- Aerial hyperspectral technology (airplane, helicopter, balloon, drone, spectral video camera).

Advantages of Remote Sensing Data Collection

- provide accurate, reliable, real-time data over large areas,
- allows for repetitive reporting,
- cheap data acquisition,
- various measurements can be made (e.g. soil heterogeneity, stock purity, yield estimation, irrigation planning),
- farmers receive sampling results within a short period of time, providing decision support opportunities to increase efficiency and reduce damage

Use of drones in precision agriculture

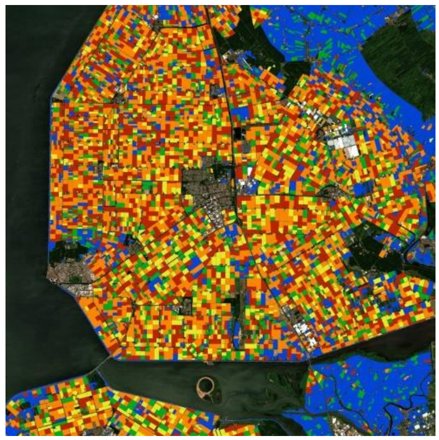
Source: Cropaia

The most common operations supported by remote sensing technologies in agriculture

- preparation of management plan, decision-making activities
- retrospective studies (comparison of current and past data)
- for different farming processes (e.g.: nutrient supply, differentiation of manure)
- area control, monitoring

2.4.1 Satellite data

The European Union has an own Earth observation program called Copernicus program, which currently has six satellite families known as Sentinel satellites. Sentinel-2 satellites provide useful information and satellite imagery for agriculture. The satellites produce accurate, reliable, high-quality, diverse information and data types on a daily basis, which can be useful for identifying plant types and for monitoring the condition and growth of vegetation. Remote sensing through the Copernicus program satellites can help to simplify and modernize aspects of the Common Agricultural Policy (CAP), particularly in the areas of sustainability, environment, biodiversity and climate. It can also simplify bureaucracy and increase the efficiency of farmers, such as data provided by Copernicus Sentinels (and other monitoring systems) can replace on-farm monitoring visits, for example, where EU payments would require on-the-spot checks of farms.



Crops in the Netherlands
Source: ESA

The Sentinel-2 image above shows different crop types around Emmeloord in the Netherlands. Here, green shows summer crops, red is potatoes, orange is market crops, yellow is cereals and blue depicts grassland. The area is important for the agrofood sector and, in particular, has strong ties to the international potato industry. By integrating Copernicus Sentinel-2 based crop-type monitoring directly into existing industry workflows, the agrofood industry can gain information about the growth and potential yield of crops, potatoes in particular, including the impact of ongoing droughts.

The Copernicus program was established by the European Commission and its technical implementation is provided by a number of organizations:

ESA European Space Agency

- EUMETSAT Monitoring weather and climate from space
- EEA European Environment Agency
- ECMWF European Centre for Medium-Range Weather Forecasts

The missions of the Sentinel satellites

The EU and ESA are currently developing seven missions under the Sentinel program. These include radar and super-spectral imaging to monitor land, ocean and atmosphere. Each Sentinel mission includes two satellites that perform and re-examine the coverage requirements for each mission, providing reliable data sets.

Sentinels 1 and 2 has a specific agricultural purpose and provides a range of additional, up-to-date information on the whole of Europe every 3-4 days.

Sentinel-1

- Provides all weather, day and night radar for terrestrial and ocean services.
- Its radars provide data on plant biomass, and field crop maps provide detailed information on when the crops were harvested.

Sentinel-2

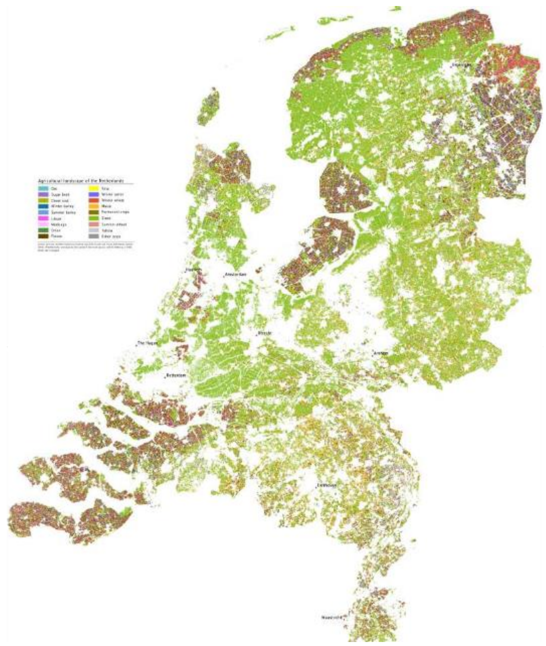
- Provides high-resolution optical imaging for terrestrial services, including images of vegetation, soil and water cover, inland waterways and coastal areas.
- Carries high-resolution cameras, and its data can be used to track plant development, health, and changes in land use, besides defining different crop types.

Crop production, the monitoring of the diversity of cultivated plant species, is very important, for example for farmers, in determining their eligibility for CAP payments.

According to the rules of greening, depending on the size of the farm, the cultivation of different crops is compulsory (crop diversification). Sentinels 1 and 2 can monitor current agricultural activity and crop conditions, determine the types of the plant, and monitor their growth and harvest time during the growing season.

Use of satellite imagery in agriculture

Landsat and Sentinel-2 satellite imagery can be further divided into two groups for agricultural use, crop production and animal husbandry, although these two areas are closely linked. Satellite images can be used for vegetation index calculations but can also be visualized by spectral analysis in the visible range or expanded to include other wavelength ranges.



Crop map
Source: ESA

Each material has a characteristic reflectance curve which shows how much a given material (e.g. plant species, mineral, rock, soil type) absorbs and reflects at different wavelengths of electromagnetic radiation. This feature makes it easier to distinguish and possibly recognize on a multi- and hyperspectral satellite image.

When measuring the reflected energy at different wavelengths of a subject and displaying the reflectance values on a graph, the curve that connects the values is called the spectral reflectance curve of the given object, in short the **reflection curve**. (Horizontal axis is the wavelength (µm), vertical axis is the reflectance value in%)

The spectral curve not only provides information about the spectral properties of the object, but also determines the wavelength range or ranges within the object can be examined in detail by remote sensing.

The spectral curves have a characteristic shape for any given surface type (vegetation, soil, water), but may differ from the expected shape due to various living and inanimate environmental influences.

The shape of the spectral curve may be influenced by:

- physical state of the surface (water content, temperature)
- chemical composition

The spectral curves make it possible to study the current state of the plants and to monitor their physiological changes. It is also important to study the shape of the spectral curve in areas not visible to the human eye as they provide a wealth of useful information on the current state of vegetation.

Visible light

The chlorophyll in the leaves of the plant absorbs blue and red light strongly, while it reflects very strongly the energy emitted in the green range, that is why we see healthy vegetation in green. When a plant suffers from a disease or a deleterious effect, its normal growth slows down or stops, and this is reflected in a decrease in chlorophyll content. Lower chlorophyll content leads to weaker blue and red absorption. Due to the increase in red reflection, the plant (as a combination of green and red) will turn yellow.

Near infrared

In the near infrared range (0.7-1.3 µm), the reflectivity of vegetation is primarily due to the internal structural features of the foliage of the plant. The internal structure is very different from species to species, so measuring reflectance allows species to be distinguished, even if species are very similar in visible light. For similar reasons, we can use sensors in this range to detect disease, since plant stress and disease also change the reflection properties.

Livestock breeding

Livestock production is closely linked to crop production. In animal husbandry, satellite imagery is used to track a more complex process, including monitoring of grassland conditions, risk of drought or soil erosion. The same principles apply to the spectral characteristics as described above.

2.4.2 Orthophoto

The orthophoto looks like a traditional photo, but is free from any geometric distortion, has a uniform aspect ratio, allowing accurate measurements.

Like most maps, orthophotos are the orthogonal projections of the Earth's surface. It combines the beneficial features of photos and maps therefore often called as a "photo map".

Of course, orthophotos can be taken not only from the fields but also from any other object (e.g. a building).

UAV orthophoto mosaic of an agricultural area in Tanzania
Source: *Agriculture and Rural Development*

There are many uses for orthophotos, basically in two main groups:

- Orthophotos taken from aerial photographs depicting the earth's surface at a given scale. On the one hand, existing thematic maps can be updated on the other hand serve as visual background information for various spatial information systems.
- Also can be used for architectural data collection and design.

Previously, orthophotos were made using helicopters, airplanes, special cameras and required skilled personnel, which made their production very expensive. Nowadays, it is possible to make orthophotos with drones, which have many advantages over conventional (RGB) images.

• cheaper production costs

• provide real-time data on the economy

• fast, efficient reconnaissance capabilities to save time

• easy to use

• you can create not only simple pictures but also terrain maps and 3D models

• providing large amounts of diverse information

2.4.3 Weather data and forecast

Almost every National Hydro Meteorological Institute provides, not only an overview of current weather conditions and short-term forecasts. As well as data from national organizations, there are a number of applications and tools for the future. These applications make it very easy to obtain basic weather information. Some of the most widely used applications and tools are *YR, Windy, OpenWeatherMap,* etc. These are the most widely used tools for Android and iOS mobile / smartphone platforms. Direct import into systems (APIs) for direct import into systems.

2.4.4 Market data and business data

Data and information handling will be one of the key factors for the European farming sector in its drive to become more productive and sustainable, and to remain competitive on the global market.

Within the agricultural value chain as a whole, data is a key component in the production of more, better, and safer food for a growing population, while at the same time reducing the environmental impact. Automated process-data provided by a wide range of ICT devices is at the very heart of the drive towards information-led agricultural production. For example:

- IoT devices include a range of sensors (e.g., for soil, crop, irrigation, etc.) able to collect large amounts of valuable data needed for effective and efficient decision-making and **decision support systems.**
- Digital technologies, such as provided by *satellites* and *drones,* can provide remotely sensed data in real-time relating to in-season crop growth and development, soil moisture, and other dynamic variables (Capolupo et al., 2015).

Advances in the *performance* of computers have paved the way for the processing of very large amounts of data in short time frames. Today's computing power supports that handling of extremely large data sets that can be analysed to reveal patterns, trends, and associations - basically providing an 'explanation' of large quantities of data. These datasets and systems are generally known as 'big data' (NESSI, 2012)[1].

Data can be used to scale and validate plant management models in ways not previously possible, and to make available to large numbers of end users. Today's farming community expects, and relies on, more and higher quality of information to be available in support of daily decision-making in the farming business.[2]

There are many benefits for information-based farming, including:

- **Data as a technology enabler**. Precision agriculture tools rely on relevant and accurate farming data. For instance, many **variable rate technologies (VRT)** are reliant on soil sampling. Initially soil samples were quite limited, but the volume and quality of data was significantly improved with yield monitoring applications based on ITC. It is possible now to improve variable rate maps even more, using algorithms based on data from multiple fields and taking into account parameters not directly related to the field itself, e.g. seed characteristics and environmental conditions.

- **Improved production processes and transparency**. For the end customer, *traceability* within the entire value chain has been greatly enhanced through IoT devices and software systems, working in conjunction with automated collection and the targeted analysis of data. This traceability provides much higher levels of transparency for the end customer. Traceability enables more effective evaluations of current operations within the agricultural value chain, as well as indicating directions for further improvements.
- **Decision support.** Today's ICT solutions in digital farming enable data processing and data analysis to be undertaken at a much higher scale than that possible even a small number of years ago. The quality of, and value from, data analysis as enabled by new technologies in digital farming, and supported by tried and tested algorithms, represents a now invaluable tool in farming decisions support systems.
- **Data exchange / benchmarking**. Networking always opens up new opportunities, and farming is not an exception. Working with external partners, and in particular accepting the benefits of automated integration of information and data, can lead to a considerably broader knowledge base being developed, and hence to decision-making based on well-founded data and cases. Value (and the development of trusted algorithms) is created based on data captured in all areas of the production chain.
- **Optimization of farm operations and resources**. Digital solutions can improve and enhance the optimization of available resources in farm processes. Having access to accurate data that defines the given conditions in a particular field (e.g. soil composition, plants and climate) supports improved decision making and use of resources. Resources can also begin to be optimized to match the needs of the business and to suit specific environmental conditions pertaining to a particular farming site.

3. Digital Farm management systems and equipment

Numerous new and advanced information and communication technologies can be applied to farming 4.0 systems and software solutions, which are central to research and development, and in many cases are driving forces for innovation. Geographic information systems provide the basic tools for managing data on agricultural parcels, management zones, variable dose interventions, and many other techniques of precision agriculture. Various databases, data analytics and cloud computing help farmers make better decisions and can help machines with different self-learning capabilities. Precision farm machines and smart farm equipment

Sectors of precision agriculture

Precision Farming (PF) is a term used primarily in arable crop production, but nowadays more and more is heard about Precision Livestock Farming (PLF) Precision Horticulture or Precision Viticulture (PV).

Precision Farming

Precision (site-specific) crop production technology primarily serves the development of agricultural production, utilizing the results of technical and IT (and other) sciences, applying modern methods of basic sciences (Németh et al. 2007). On the other hand, it contributes significantly to the solution of our environmental and ecological tasks, to the production of healthy food raw materials (medical and nutritional science).

Precision farming conditions:

- location: GPS, RTK, proper machine,
- GIS, remote sensing: data collection, data integration, data analysis;
- machine operation: power-machine-machine connection, variable rate application thanks to intelligent machines.

The basic machine for precision crop production is the intelligent tractor, which performs operations in the right place (navigation and automatic steering), optimized power utilization (engine control and intelligent power transmission system), properly controlled implements (linkage control, ISOBUS), environmentally friendly (engine control system, tire pressure regulation).

Controlling systems that continuously monitor and optimize the operating parameters of the power machine/machine groups, significantly relieve the operator, who can pay more attention to the quality of the work done and, if necessary, intervene in the system.

Precision Livestock Farming

The use of agro-informatics solutions is mainly characteristic of livestock farms through automated systems and digital data collection and data analysis. Precision animal husbandry is based on a low-cost, wireless, unique electronic animal identification system that allows individual tracking of animals in pigs, poultry and cattle. It is also suitable for observing the behaviour, welfare, productivity, physical environment (microclimate, emission) of animals and for signs of disease. The GNSS-based virtual fence is capable of keeping animals in the pen by sound or electronic signalling.

Precision horticulture

Precision farming is also present in the open field, in greenhouses and in viticulture due to the rapid development of technology. The new technology can produce crop maps by remote sensing and instrumental measurement, which prevents the harvesting of healthy and damaged / diseased crop mix. The spread of precision horticulture is accelerated by the use of new machine vision techniques. Horticulture has accelerated the use of precision irrigation, which is water-saving, quality-enhancing and yield-enhancing.

There are three phases in the development of precision horticulture:

- sensor technology, which increases the performance of the machines,
- sensor technology capable of changing the machine's operating characteristics,
- sensor technology, which is capable of collecting highly distributed crop characteristics (colour characteristics, sugar content, crop yield).

3.1.1 Machines (tractors, harvesters, seed-spray-irrigation-fertilizer machines)

Intelligent machine refers to a tractor-implement group or a stand-alone power machine that can identify its geodetic work point, determine the need for cultivation, measure, evaluate, and change the machine setup and work quality.

System conditions:

- tractor / power machine with on-board computer, DGPS and ISOBUS;
- digital maps (crop, nutrient, weed, cultivation);
- Implement with ISOBUS system (sensors and tools);
- site-specific application solutions.

Positioning System (DGPS)

Main features of DGPS / RTK positioning system:

- Differential correction can greatly improve the accuracy of GPS data.
- Essentially, at least two locations are being collected at the same time. On the one hand, it has a known position on a stable ground station (the so-called reference station) and on the other hand it has an unknown position on other GPS receivers.
- Reference station data can be used to compensate for mobile GPS receiver errors.
- Accuracy: ± 2 cm.

Field operations do not require uniform accuracy, for example, for fertilization or pesticide application, a 15 to 20 cm pass-to-pass accuracy is sufficient. However, in the case of seeding or row cultivation, an accuracy of 2-3 cm is acceptable. This requires the use of RTK (Real Time Kinematic) to achieve positioning accuracy.

Digital maps

In addition to positioning, various digital maps are essential for the proper operation of intelligent machine groups, which provide setup / cultivation requirements for the on-board computer.

The most important map types:

- a map of the field boundaries and objects to avoid,
- soil type map,
- weed map,
- nutrient map,
- yield map.

Sensors

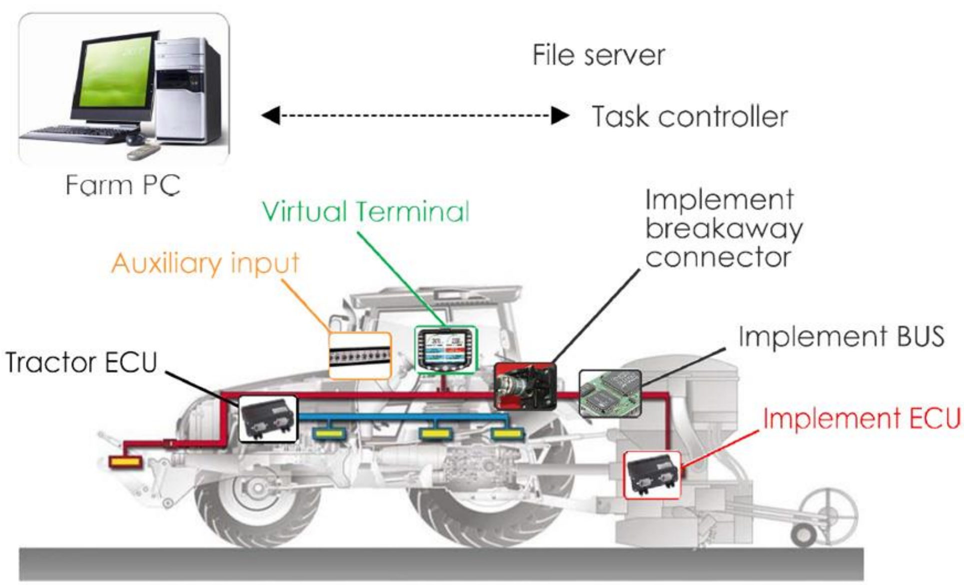
A further precondition for the proper operation of intelligent machine groups is the real-time knowledge of soil, plant, environment and, above all, operational features provided by various sensor systems. For sensor based systems, there are the following sensor types:

- soil sensors: electrical conductivity, soil salinity, soil moisture, soil temperature, etc.,
- plant sensors: plant characteristics, crop moisture, nutrient supply, etc.,
- environmental sensors: relative humidity, air temperature, precipitation, wind speed and direction, leaf humidity, solar radiation, etc.,
- function monitoring sensors (machine).

Tractor-implement management (ISOBUS ISO 11783)

The basis of precision crop production is the intelligent machine groups. Methods and tools for locating the system and specifying operational requirements are described above. However, these are necessary but not sufficient conditions for precise operation. The tractor-implement assembly can only operate accurately if they can communicate with each other. This is achieved by the ISOBUS (ISO 11783) system.

Structure of the ISOBUS system:



ISOBUS
Source: IDEAgri

Virtual terminal

The virtual terminal is a device built into the cab, through which the operator can communicate with the control units (ECUs) connected to the ISOBUS network. Its main function is to display the information sent by the control units and to receive and transmit the operator's instructions to the control units. Unfortunately, different manufacturers have developed their own terminals, which, unfortunately, are not always compatible, meaning that farmers buy a smart tractor and implement in vain because different brands cannot communicate with each other. For this reason, an organization (Competence Center ISOBUS e.V. / CCI / joint European organization) has been set up to test the compatibility of different products and issue a certificate.

Connectors

The connection between the tractor and the implement can be achieved by standardized quick couplings, i.e. the shape and size of the plugs and sockets are defined on both the tractor and the implement.

Electronic Control Unit (ECU)

The components that determine the intelligence and capabilities of an ISOBUS network. There are many such control units on the tractor, but in many cases inside the machine as well, which are all responsible for controlling a particular subsystem

Task Controller (TC)

Task Controller is a control system that can provide instructions to machines, change their various operating parameters according to their position (site-specific application), or follow a time schedule. Programming is done on a computer basis using the Farm Management System which is uploaded to the virtual terminal installed on the tractor.

ISOBUS compatibility

The introduction of the ISOBUS standard was first initiated by large tractor manufacturers, but its widespread adoption was hampered by the fact that everyone favoured its own system, which prevented machine manufacturers from following the system. Therefore, the German DLG institute has conducted a compatibility test and, if successful, issued a certificate of suitability for the machine. As a next step in the development, large field machine companies have established the "Agricultural Industry Electronics Foundation (AEF). The mission of the AEF is to develop ISOBUS-related basic areas:

farm management information system (fmis),
electric drives,
camera systems,
high speed isobus and wireless communication at work.

Machines that have been tested and approved by AEF are labelled and this is only valid to prove ISOBUS compatibility from 2017. (www.aef-isobus-database.org).

Video: https://youtu.be/8tpR2K6diX4

Source: Dr. Jóri J. István: A jövő mezőgazdasága

The spread of the ISOBUS protocol has greatly facilitated precision agriculture by enabling standard data exchange between different sensors, data processing and control units. With a single universal terminal, it is possible to control any manufacturer's ISOBUS-enabled device. At the touch of a button, the user can choose whether to see the machine or any device (seeder, sprayer, fertilizer spreader) on the terminal.

Using the ISOBUS network, not only data but also control signals from the implement can be received by the tractor.

3.1.1.1 Tractors - Soil tillage

Farmers most often use GPS, remote sensing and geographic information system (GIS) to obtain the maximum possible information on soil condition and quality and to apply the required amount of fertilizer, water and nutrients based on the data.

In order for farmers to be able to manage land properly while respecting all the principles, some engineers and manufacturers are also trying to help, by producing machines for inter-row mechanical cultivation of wide-row crops and machines for pre-sowing preparation. These are designed for soil-protective technologies that are closely linked to precision farming.

The strip preparation, or strip-tillage, is the treatment of the soil in strips of a certain width, prepared in the direction of the sowing rows. At the same time, the proportion of such processed land is only 25% of the total area of land under preparation. This technology addresses the issue of soil erosion that complies with the GAEC 2 standard and allows the establishment of wide-line crops on erosion-endangered soils, but this is just one of the advantages of this precision farming technology. The principle and advantage of strip processing is the combination of the advantages of full-area tillage, minimization, sowing into mulch, protective interim crops or direct sowing without plowing into untreated soil.

The use of strip soil preparation is in maize, sunflower, cotton, soybean, and bean growing systems and can be used in Europe for growing sugar beet and rape. As far as European countries are concerned, Germany, the Russians, the French, the Belgians, the Hungarians, and now the Czech Republic are the furthest in utilizing this system.

In addition to erosion control, this system has great advantages in terms of plant root system formation, the use of nutrients from the lower soil layers, water management and increased soil temperature in the seedbed area. This brings economic advantages in the form of fuel savings, fertilizer savings and the consequent increase in yield of such sown crops.

Autonomous tractors

Autonomous tractors, that is to say, driverless tractors (Fig. 1), are of great interest to agricultural machinery manufacturers and farmers themselves. These machines are now being developed based on existing tractors, but they are equipped with electronic components for automatic tool recognition and its width. The machine then calculates the optimal route of its processing based on the shape and size of the plot and on the terrain irregularities. The operator can then control the machine from a laptop or tablet.

These tractors can then work on one or more plots. The advantage of this is that one person can remotely control multiple machines without having to be present on the cultivated land. This can

Case IH Magnum Autonomous Tractor
Source: FarmingUK

also be used if there is a shortage of qualified tractor operators.

With the help of radars, LiDARs and cameras mounted on the tractor, the machine can detect stationary or even moving obstacles and stop until the operator, who is notified of the problem, decides on a new trajectory or action.

The machine also stops immediately as soon as the GPS reception connection is interrupted or is manually switched off. Tractors can also be controlled by remote tools or automatically react to weather changes. Of course, all of these options should lead to even greater efficiency in crop production.

3.1.1.2 Seeders, Sowing Control System

Objectives of precision sowing

The main aim is to check the volume and density of sowing. The first one is defined in kg per ha, the second in the number of seeds per area unit. The spatial location of the seeds in the field is also Important. This helps achieve two goals - distributing the seeds all over the area and the depth of sowing. All These objectives are heavily dependent not only on the relevant crops, but also on sowing methods. Different crops, soils and climates require a very wide range of sowing density. Sowing methods depend to a large extent on the appropriate seed density. The exact sowing of individual seeds can only be realised for crops with relatively low density of sowing due to costs. For high-density crops – such as small grains, grasses, clover and alfalfa – it is still necessary to practice mass sowing. However, the manual adjustment of the calibration to ha can be replaced by an instrument control directly targeting the required number of seeds per ha and the density of sowing. Given that this is a number; the goal of precision farming should be to use on-the-go control based on counting the seeds that pass through the seed pipes.

Precision seeders

They let seeds through one after another. They allow seed savings of the order of 25 to 30%. They are used primarily for sows of sugar beets, sunflower and maize. They are somewhat harder to use for rape due to a small working speed of about 6 km/h and a limited spread. It is possible to use them when a smaller plant density is required in a row ranging from 10 to 18 seeds to a normal metre, and it is necessary to avoid the risk of lengthing the stem and lie-down.

Mechanical precision seeder
Source: VMP

The Intelligent Distribution System IDS is an optional equipment of the seed machine and allows the distribution head of the AEROSEM 1002 series pneumatic seed to provide a wide range of setting options for seeders and rail lines without the need for any mechanical or manual intervention on the distribution head or the sowing mechanism. Each distribution head outlet is equipped with its own flap and servo motor, which allows simple operation of individual outlets via the power control panel or CCI, or directly through the tractor monitor using an Isobus connection. The IDS System allows you to change the following parameters directly from the driver's cabin: line spacing, track line width, rail line widths, special rail line shifting, supplementary rail line systems, half-cut lines on the left or right side. In addition, up to 6% of the seeds is saved when the rail line is sown or half-spread sowing – IDS automatically adjusts the sowing by feeding the excess seeds back into the distributor head tube.

Sowing Control System

This system ensures a balanced distance between the falling seeds. The density of sowing varies according to the different crop types. The spread in small grains ranges from 150 to 400 seeds per m2. It depends on the type of crop, variety, time of sowing, plant water supply and soil structure. An argument against the need to accurately control the density of sowing is usually the plasticity of crops, the ability to adapt to the environment. Plants adapt to the imbalance of density of sowing and grow in the space available to them. This means that the impact of precise density control on the overall yield is relatively small. At the same time, this means that accurate sowing can lead to substantial savings in seed costs. It should be mentioned that for low-plasticity crops, e.g. sugar beet or potatoes, the impact of the sowing density is very significant.

3.1.1.3 Seed-spray-irrigation-fertilizer machines - Nutrition and Conservation

Precision farming is an approach to farm management that collects and evaluates farmland data with modern technology. Then take action at the right time, in the right place, with the right dosage, thus saving farmers costs and reducing negative environmental impacts.

First, the farmer has to determine the condition of the managed areas. This is usually done by analyzing soil samples, analyzing site topography, remote scans from airplanes or satellites, yield monitoring, etc. Sensor technology connected to GPS is indispensable in this step. Sensors, for example, can use spectral analysis to determine how nutrient-rich vegetation is, or how much organic matter the soil contains. Geographic coordinates are assigned to all data obtained. It is possible to determine the position within centimetres, for example due to a correction signal (ground reference station [DGPS] or mobile virtual reference system).

However, more information is usually needed to achieve more accurate results, preferably over a longer period of time, so experts prefer to create application maps that can be used over long term. The farmer then enters appropriate cultivation measures, for example, fertilization or plant protection. With a machine that can read such maps, the measure is applied in practice: the GPS-guided machine tracks the map and continuously adjusts the fertilizer or herbicide dose based on it. At the same time, the driver's current position is displayed on the monitor and alerts when he is out of the way or an obstacle is approaching. The most advanced systems currently control the machine altogether without the need for a driver. The machines are also equipped with automatic section control, which gradually turns off individual nozzles at the crossing points. Thus, the application is more accurate, without overlapping or skipping.

Other methods include, for example, weed mapping by field survey or pest and disease damage assessment. All of these methods are carried out to provide a basis for variable application of fertilizers and pesticides. Again, however, the density of the measurement points, their location over the plot, and the frequency of observations are substantial. Hand-held sensors measuring the spectral properties of plants are often also used. Spectral measurement uses sensing the amount of radiation passing through the sheet or the reflectivity measured by the sensors. Aging plants or plants suffering from stress subsequently show changes in reflectivity. It is possible to detect growth differences relatively reliably, such as inadequate nutrition, plant infestation, etc. However, the exact cause of the identified stress can usually not be determined by these devices. The devices used are, for example: N-tester (www.greppa.nu), N-Pen and PlantPen (www.psi.cz).

The method of measuring the reflectance of vegetation and its quantification in the form of vegetation indices is also used in remote sensing. For agricultural purposes, aerial or satellite imagery can be used. Remote sensing makes it possible to take into account a number of accompanying factors in determining fertilizer dose, which online systems cannot.

NDVI (Normalized Difference Vegetation Index) is one of the most commonly used vegetation indexes in mapping vegetation in agriculture. Vegetation indices use the reflectance difference in red and near infrared (NIR) radiation. NDVI can be used to quantify selected plant parameters. These include the amount of biomass, leaf area coverage, photosynthetic activity, and percent coverage. NDVI is mainly used for mapping vegetation using satellite imagery.

On-the-go online systems or online systems operate on the principle of measuring the spectral parameters of the growth, data processing; their interpretation and application are carried out as part of a single operation during land crossing. Current sensor data is a source of information. The best-known device used in practice is the Yara N-Sensor (www.agricon.de), which is used for variable application of nitrogen fertilizers. The Yara N-Sensor is mounted on the tractor cabin carrying the spreader or on the spray booth. The instrument detects the state of the plants while driving based on their spectral reflectivity, the control computer evaluates the data and determines the fertilizer dose, which is then applied by the spreader. The device can be used for fertilization of nitrogen fertilizers in cereals, maize, winter rape and potatoes. There are other on-the-go devices working on a similar principle. Topcon CropSpec uses laser-induced reflectivity, and NTech GreenSeeker uses LED radiation. A different measurement method is used by Claas CropMeter, which derives the application rate of fertilizers, growth regulators or fungicides based on mechanical density measurement.

The potential benefits of using a precise application of nitrogen fertilizers can be higher yields per ha, nitrogen fertilizer savings, better crop harvesting conditions, higher quality of harvested commodities, less nitrogen leaching to groundwater, etc. Expenditures in this area include N-Sensor, functional terminal, software, chlorophyll meter needed for instrument calibration, etc.

According to research conducted in Europe, the expected average increase in yield is 4% using precision fertilization. Even if the average yield does not increase, the amount of nitrogen fertilizer consumed can be reduced by up to 44 kg per ha. It is reported that the benefits of precision application in the form of higher yields and reduced fertilizer costs start to show up when applied to fields with approximately 175 ha area.

3.1.1.4 Harvesters

The basic characteristic of precision farming is to make interventions at the right time, with the right dose and at the right place. This modern management principle is based on the use of new technologies, especially GPS (Global Positioning System) and GIS (Geographic Information System).

One of the basic tasks of precision farming is to investigate the land and its heterogeneity. Soil blocks are not viewed as of the same quality, with same level of nourishment, fertility, with the same irrigation or with the same risk of disease and pest infestation.

Yield meters

Yield mapping solutions
Source: Precision Decisions

Harvesting in a precision farming system uses combine harvesters equipped with a GPS yield meter, which produces data that can be used to generate yield maps. These yield maps show how much grain was harvested in specific parts of the site and are then used to produce variable fertilization application maps.

Precision farming harvesters include yield gain sensors and image analysis software. These two essential components of harvesting machines enable further data processing, including statistical processing, to measure and record land yields in any time period (usually 3 to 10 seconds) along with the vehicle position. Other relevant sensors include, for example, grain moisture, machine speed and slope. The on-board computer then processes all the measured data. The information is stored on data cards and subsequently transferred to a computer equipped with mapping software to generate yield maps. Yield maps show high or low yield locations. So next season, the amount of fertilizer delivered to the soil can be adjusted to maximize the productivity of the land.

Information in yield maps can be an important tool for agronomists to make decisions. Therefore, great emphasis is placed on proper data collection and correction. To eliminate the error values, it is important to know all the properties of the device from which the data was taken. One of the main characteristics is the type of the combine harvester itself. These machines have a different system for evaluating instantaneous yield and therefore different accuracy. Several types of errors occur during machine data collection, which cannot be eliminated by more accurate data collection. We distinguish systematic errors that can be eliminated by appropriate sensor calibration and random errors. While systematic errors (errors affecting the accuracy of yield measurement) can be eliminated by appropriate sensor calibration, correcting random errors (positional errors due to the absence of data) is more problematic and therefore random errors are considered minimal and ignored.

Autopilots

Autopilots or automatic controls are technical devices that enable tractors, harvesters and other machines used in precision farming to refine the routing of individual rides. Driving with autopilots is always more accurate than driving manually without any assistance. Accurate movements of machines across the field are more efficient with autopilots, reducing overlaps and omissions in field operations and significantly saving fuel. Thus, for agronomists, they represent an advantage not only in economic term, but also provide ecological and timesaving benefits.

It is technically possible to devise an autopilot for any agricultural machine. There are two basic types of implementing an autopilot:

- Electronic steering wheel and hydraulic valve

This includes installing an electronic steering wheel and electrohydraulic valve for machines that were not factory-ready for autopilot.

- Connecting to existing autopilot preparation

Some types of machines are built with the possibility for future autopilot implementation.

Attachable agricultural machinery can also be controlled automatically.

Even with agricultural machines equipped with autopilots, the biggest issue is correction of errors. In the case of autopilots, the system is a correction called RTK (Real Time Kinematics). This allows agricultural machines equipped with autopilots to be controlled automatically with an accuracy of +/- 2-5 cm, both immediate and year-to-year. The transmission of the correction signal to the agricultural machine is ensured either via GPRS telephone modem or via shortwave radio.

Of the precision machine solutions, automatic steering is the most widespread. The main advantages of GPS-guided machines on a predefined track using map software:

- following the same path for each operation;
- reduced levels of human error, trampling and overlap;
- High load reduction for the operator.

Tracking assistance systems show the tractor driver the track to follow and the magnitude of any deviation. Navigation aids can be divided into two groups according to the display mode: LED display devices, LCD display devices.

There are several ways of tracking their operation:
- follow a straight line,
- following a curved line,
- following a spiral line,
- end-of-field rotation with or without selection.

Possible solutions for automatic steering are:

Power machinery:

- friction wheel autopilot,
- assisted steering - ez-pilot
- hydraulic autopilot.

Working machinery:

- passive steering,
- active machine steering.

3.1.2 Variable Rate Technology

Site-specific nutrient management

Site-specific Nutrient Management (SSNM) aims to optimize the supply of soil nutrients over time and space to match the requirements of crops, soil or that location. The amount of seed, nutrient or chemical to be applied within the field is changed based on a prescription map. These prescription maps are based on preliminary survey data and the experience of agronomists, advisors or farmers. Data of the prescription maps will be uploaded to the target machine or group of machines. During the application, the following process is performed:

- Determine the machine's geographical position (GPS, DGPS, RTK).
- Read out the dispersion quantity for the given coordinate values from the map.
- The controller sends the information to the executing unit.

Variable Rate Technology (VRT)

The intelligent machine groups of precision agriculture systems, with the abilities described above, can perform variable rate operations in.:

- soil cultivation
- nutrient supply
- spraying
- sowing
- irrigation

3.1.3 IoT

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

IoT system has three basic components:

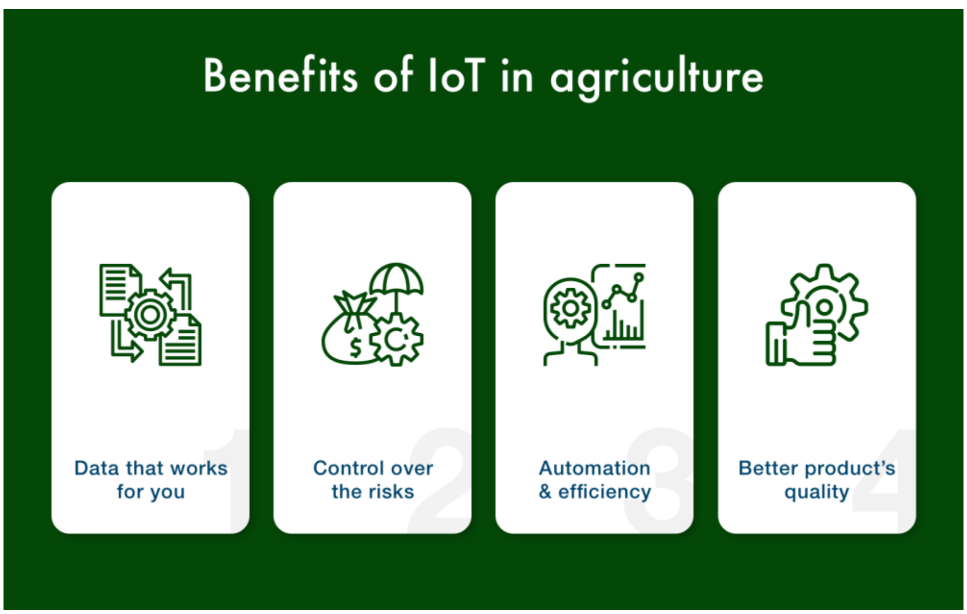
- Objects: Devices share data they collect and are connected to each other when connected to a network. The network can be wired or wireless.
- Network: A network or “IoT gateway” (a device or software program that serves as an interface between controllers, sensors, smart devices and the cloud) or other where data is sent for later analysis
- Cloud: A remote server, a data center that is used to store and analyze data securely.

In some cases, these devices communicate with other related devices and act based on the information they receive. Devices do most of the work without human interaction, although people can interact with devices, for example. setting up different configurations, giving instructions or accessing data. Connection, network and communication protocols used with such web tools are highly dependent on the specific IoT applications used in the area.

In agriculture, the introduction of intelligent technology involves the use of sensors, robots, control systems and cordless machines.

IoT-based automated systems offer many opportunities for farmers, for example:

- Systems for monitoring arable land (light, humidity, temperature, soil moisture, etc.)
- Operation of driverless machines
- Remote sensing, remote monitoring in animal husbandry
- Automation of greenhouses
- Automation of irrigation systems
- Application of environmentally friendly pesticides
- Monitoring of natural factors (soil, weather, climate change)



IoT in agriculture
Source: The IOT Magazine

Data collection is continuous through IoT applications. Farmers can monitor the situation and changes in crop production or animal husbandry, thus giving them the opportunity to make early decisions, interventions and corrections.

Handhelds, tablets and smartphones

Smartphones are one of the most used devices in agriculture. Whether connected through wireless or using Internet data through your mobile provider (GSM networks), these devices can connect with websites, applications and other information services needed in today's precision farming.

Applications are generally third-party software services for smartphones and tablets that perform specific functionality, either online or offline.

Agricultural applications (apps) fall into a small number of basic functional categories:

1. Farm Management/Data Collection Apps. These are applications used for farm planning, generally allowing for the easy tracking of data such as sensors inputs, soil tests, stocking rates, pest/disease issues and treatment, machinery procedures, staff management. etc.
2. Calculator Apps: These are apps that support field calculations in the paddock. Examples of these apps can include calculators to optimize how much spray is needed to treat a particular area, to calculate fertilizer quantities and costs, to advise on seeding rates, and to estimate yields and lambing statistics.
3. Information/Resource Apps: These are apps that connect to valuable information sources, allowing farmers to make informed decisions in the paddock. There are a huge variety of apps available covering a large array of information for pest, disease and weed identification, for marketing, and information on the very many products used in agriculture.
4. News Apps: These are simple news 'aggregators' that collate and deliver specific industry information and news.
5. Weather Apps: Perhaps one of the most widely used app, weather apps provide access to frequently updated weather forecasts.
6. Enabling Apps: Simple apps that help with everyday tasks. Examples of this type of application are apps providing digital mapping, simple notetaking and calendaring (setting dates and reminders), livestock counters, cameras, and document storage.

AgriApp
Source: [SCG pacewisdom]

Smartphones have become an essential tool for farmers in their everyday work, and their use is being seen in almost all operations, such as:

- navigating fields
- the identification of weeds, diseases, and pests
- calculating fertilizer and chemical blends
- checking rainfall measurements
- meeting with agricultural advisors
- tracking grain harvests, etc.

3.1.4 Yield mapping and monitoring

In precision agriculture, yield mapping technology is an important area.

What is the yield map for?

- shows the variability within the field;
- shows how vegetation responds to applied management techniques;
- helps identify causes and effects of yield changes;
- assist in planning site-specific nutrient supply;
- provides accurate information about differences within the field, site specific yield returns;
- provides yield and grain moisture data, and supports storage decision-making;
- shows the performance of a given year and provides information for planning the following year

- easy to convert to a profit map

Sensors are installed on combines and harvesters for continuous measurement of grain volume. With the help of these data they are able to calculate the yield. Several types of sensors have been developed for yield measurement that operate on different principles, e.g. impact plate system, metering cell system, balance cell system, infrared sensor system, gamma ray system

The basic components of a grain yield mapping system include:

- grain flow sensors - to determine the grain volume harvested
- grain moisture sensors – to compensate for grain moisture variability
- clean grain elevator speed sensors - used by some mapping systems to improve the accuracy of grain flow measurements
- GPS antenna – to receive satellite signals
- yield monitor displays (with GPS receiver) –to show geo-reference and recorded data
- header position sensors - distinguish various measurements logged during turns
- travel speed sensors - determines the distance a combine travels during a specific logging interval.
- travel speed is sometimes measured with a GPS receiver or a radar or ultrasonic sensor.

Each sensor must be properly calibrated according to the operator's manual. Calibration converts the sensor's signal to physical parameters for display and/or recording. A proprietary binary log file may be created during harvest to record the output of all sensors as a function of time. This file can eventually be converted to a text format, or displayed as a map, using appropriate yield monitor software – as generally supplied by the vendor.

An essential part of precision farming is yield mapping, where data can be recorded automatically during harvesting. Yield monitoring and mapping offers many other on-farm and off-farm benefits:

- On-farm: benefits include real-time information gathering during harvest, easier on-farm testing, improved variable rate management, evaluation of whole-field improvements, and the creation of historical spatial databases.

- Off-farm: benefits include more equitable property owner negotiations, crop documentation for identity preserved marketing, 'trace back' records for food safety, and the documentation of environmental compliance.

Yield map
Source: Frontier

3.2 SW AND SYSTEMS

Information systems and concepts used in agriculture 4.0

Several new and advanced information and communication technologies are applied in agriculture 4.0 systems and software solutions, being the focus area of research and development and main driver of innovations in many cases.

Geographical information systems provide essential tools to deal with data related to the use of land parcels, management zones, variable rate applications and many other techniques in precision agriculture. Distributed ledger technology is most often used in traceability-oriented applications. Big data analysis and cloud computing can assist better decision making by the farmer or even by machines with self-learning capability.

3.2.1 Geographical Information Systems

Geographic Information System (GIS) is a specialized information system for analyzing geographical data. GIS is considered as a system of hardware, software and various methods that help to collect, manage, process, analyze, model, and render spatial data for complex design and management tasks.

Though the underlying systems may perform complicated analytical functions, GIS can present results that can be visually evaluated in form of simple maps, tables or graphs - allowing the farmer to virtually see and predict issues based on the underlying information. Ready visualization supports accurate decision-making and other courses of action.

The agricultural use of GIS systems is now widespread, although it was first used in the mid-90s. It is an integral part of precision agriculture and an integral part of soil sampling and other management processes. It plays a major role in the creation, implementation and further development of new technologies.

GIS is thus a computer system designed to collect, storage, manage, analyze, display, geographic location data and observe and model geographic phenomena. GIS is a fusion of cartography, statistical analysis, and database technologies that is present in the fields and operations of engineering, planning, management, transportation, logistics, insurance, telecommunications, business, and agriculture.

Various farmer decisions are greatly influenced by geographical location and other spatial phenomena. Understanding the geographical location and environment can also identify other environmental, administrative and social needs.

GIS plays an important role in today's agricultural production by helping farmers increase production while reducing other farm costs. It fundamentally influences the success and profitability of the economy by balancing the inputs of the economy and the output.

GIS outputs are generally portrayed through three principle views:

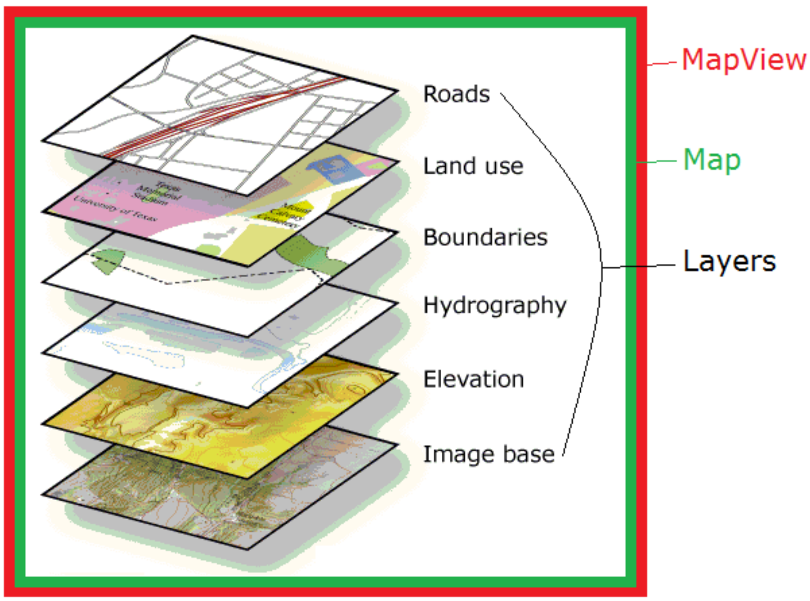
1. ***Database View***: *GIS is a unique kind of database of the world - a geographic or geo referenced database. All data are expressed with longitude and latitude coordinates, with the objective of creating digitalized maps*.
2. ***Map View****: GIS output can be represented as a set of intelligent and interactive maps, with views showing features and feature relationships on the earth's surface. These maps are used like 'windows into the database' to support queries, analysis, and editing of the information.*
3. ***Model View****: GIS also provide a set of information transformation tools that derive new geographic datasets from existing data sets. These geo-processing functions take information from existing data sets, apply analytic functions, and record results into new, derived datasets for various potential uses.*

There are many GIS tools available for working with remote sensing imagery. The main tools include:

Map window with layer displays

- **Layer selection window** – satellite image (timeline window option), underlying maps (WMS – ČUZK, LPIS - topographic maps, orthophoto, erosion, ...). For the satellite image, selection of following displays is available: RGB, color synthesis (CIR, ...), basic vegetation indexes (NDVI, EVI, SAVI, NRERI, ...). For vegetation indices, it is possible to lower the minimum and maximum values with a slider.

- **Timeline window** to display available scenes in the selected time span. Clicking on a location in the map renders NDVI values for a given pixel in the timeline according to a defined range. When you move the mouse to NDVI values, it displays a label. At the same time, it allows you to select a scene that is displayed in the map window. The timeline provides an overview of available scenes for the territory, including usability indication (low NDVI values in the vegetation period signalize cloudiness). At the same time, it offers a view on the dynamics of vegetation growth and the changes of land management in time.
- **Modification** – Time window display as the average data for the plot - but it is necessary to solve loading plots from LPIS.



Map Layers Diagram
Source: UC ANR

One of the tools in the interactive map is also the option to display the field statement. Under the interactive map, there are spaces for displaying information from remote sensing about the harvest history. In the right part of the application, there are spaces for field parameters, data export, and weather.

3.2.2 Enterprise IS (ERP, DSS, planning, business, etc.)

Enterprise information systems

Enterprise information systems provide a technology platform that enables organizations to integrate and coordinate their business processes on a robust foundation. Their most widely used and well-known manifestations are the Enterprise resource planning (ERP) systems.

An EIS is often used in conjunction with customer relationship management (CRM) and supply chain management (especially linked to traceability in agriculture) to automate business processes.

An enterprise information system provides a single system that is central to the organization that ensures information can be shared across all functional levels and management hierarchies.

Enterprise Information Systems (EIS) support service improvements and operations, deal with large volumes of data, and support processes and decision-making in large and possibly complex organizations or enterprises. When adopted, they tend to be used by all parts, and all levels, of an enterprise.

These information systems serve the general management purposes of an organization or a company, including business management, but also the specific sectoral activities, such as agriculture and food processing.

Enterprise resource planning (ERP)

Enterprise resource planning (ERP) is business process management software that allows an organization to use a system of integrated applications to manage the business and automate many back-office functions related to technology, services and human resources.

The main task of an enterprise resource planning system is to create a single central repository for data created and shared by all the various ERP facets, to enhance and improve the flow of data across the enterprise. ERP software integrates all facets of an operation, including product planning, development, manufacturing, sales and marketing.

A business can use ERP software to manage back-office activities and tasks including:

- distribution process and supply chain management
- services knowledge base, to configure, prices, improve accuracy of financial data
- facilitating better project planning
- automating employee life cycle, managing human resources and payroll.
- standardizing critical business procedures, reducing redundant tasks
- assessing business needs
- accounting and financial applications, lower purchasing costs

Some of the most common ERP modules include those for product planning, material purchasing, inventory control, distribution, accounting, marketing, finance and HR.

Agricultural ERP modules

In many cases agriculture-oriented functionalities are integrated into the complex ERP solution, which has the advantage that many of the data of the enterprise can be shared and reused within the agricultural processes therefore providing full interoperability with the other segments of the organization.

Possible most frequent use of agricultural facets in ERP systems:

1. Compliance with traceability (see next chapter)
2. Human resource management (HRM) for seasonal work administration
3. Livestock tracking, also in relation with traceability
4. Breeding calendar
5. Field mapping and land cultivation management

Source: https://www.erpfocus.com/essential-agriculture-erp-features.html

ERP Solution to Precision Agriculture

SAP is the world's leading integrated enterprise resource planning (ERP) system. SAP's industry-specific solutions are used by over 32,000 companies in over 120 countries, both small and medium-sized and large. SAP's agricultural industry offers several agro-business software to meet different needs. SAP solutions can help to run business processes more effectively across the agri-economic value chain.

More information: https://www.sap.com/westbalkans/industries/agribusiness.html

Decision Support Systems, DSS

DSS are used for planning and analyzing activities, and for aiding decision-making.

A Decision Support System (DSS) is defined as an information system application that assists the mangers in decision making. They generally include: a database, a model base, and a user interface.

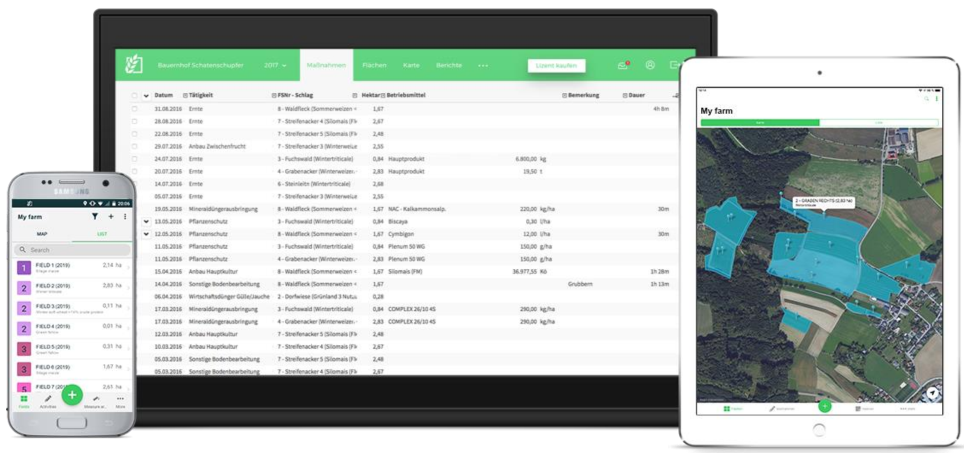
By providing an interactive user interface to interact with the underlying data, various types of information of managerial end users can be assisted in decision-making processes. DSS help managers to manage, and even solve, the various semi-structured and unstructured problems they typically face in their professional life.

An agricultural information system (IS and DSS) can be defined as a system in which agricultural information is generated, transformed, transferred, consolidated, received and fed back in such a manner that these processes function synergistically to underpin knowledge utilization by agricultural producers (Roling, 1988).

3.2.3 Specialized IS (plant production, live-stock)

Farm Management Information Systems (FMIS)

The Farm Management Information System (FMIS) has evolved from a simple farm record to a sophisticated and complex system. They are designed to support production management, reduce production costs, meet agricultural standards, and ensure high product quality and safety.



FARMADOC *Farm Management Information System*
Source: Farmadoc

Dependent of the farm size and the input data that is collected, farm software systems can support the unique circumstances of, and individual and custom decision-making operations, on a farm.

These systems are only as good as their underlying data, which might include the costs of tractor and implements, fuel and oil prices, labor charges, farm size, yield of crop and value of crop, etc. - in addition to the various 'constants' that might be used in the programs.

Farm management information systems (FMIS) for precision agriculture have certain additional requirements over traditional FMIS, which makes the implementation of these systems technically more complicated in several ways. The basic components of a precision farm management information system include a computer, software, a controller and a differential global positioning system (DGPS).

Record keeping and reporting

Farm record keeping usually means the administration of main production units - inputs, land parcels, livestock heads, etc. -of the farm and the main activities - tillage operations, cultivation practices, application of materials etc.- performed during the actual farming period.

In Hungary for example, in order to qualify for most of the agricultural subsidies, farmers must keep a logbook. This also applies to farmers in nitrate-sensitive areas, so that about two thirds of producers are now affected by the logbook obligation. State-run software allows the farmer to track information about his farm, such as statements of crop size, inputs, or yields. The software notifies farmers of important deadlines and alerts you when to report events.

In addition to the state-run economic log, many other agricultural software is available on the market. In Hungary, the most widely used software in agriculture is the so-called Farming LogBook (FLB), being the related data record keeping and reporting task an obligatory requirement for farmers engaged in most of the CAP direct payment schemes and Cross Compliance rules. Below we provide a short description of the FLB, and a separate example of a more context-neutral land parcel management solution.

https://gn.eurofarmer.hu/

The main characteristics are the following:

- Works on a web interface
- Complies with the regulations at national and EU level
- In addition to record keeping of farm operations, it is also possible to create a soil nutrition plan, land use plan, nitrate report and breeding calendar
- Compatible with e-government systems, with a few clicks the user can easily save and load the following files:
    - Data export for annual electronic report to the government
    - Importing parcel data from the e-claim submission system
    - Creating LPIS Data
    - Importing livestock data from state identification system, calculation of herd data
    - Accessing and using state accredited plant protection and fertilizer product catalogue web service in real time
- There are several ways to manage data of farm operations both on web interface and in Excel,
- Flexible printing in PDF and HTML format according to official requirements, the entire report can be printed at once or by type per page
- Many data queries can be exported to Excel so the user can transfer to MS Office system for other uses
- Filtering options, e.g. parcels and operations may also be listed for a given financial year or for a full five-year period
- Manage parcel drawings on Google Maps

Main data managed by the software:

Basic data: provide personal and basic enterprise / farm data of the farmer. Add crop types, applied farm operation, LPIS parcels, used materials - pesticides and fertilizers - specific to the farm.

Parcels: are the individual, non-separated pieces of land used by the farmer by type of plant (utilization), inside the LPIS block. If farmer uses several pieces of separated land of same or different plants, it should be entered into the system as separate parcel records. Map drawing and calendar entries can be accessed from the Parcels page too (see below short hint for Map).

Livestock group (flocks, herds): Provide data according to type of animal, age group, breed and other details, including the number of heads. The monthly changes in the flock can also be inserted and updated, and annual report generated, enhanced by built-in calculations of livestock units and annual average number of heads.

Livestock head (individual animal): functionality is based on interoperability good practice with IACS national bovine animal identification system, taken its HTML/XLS report, uploaded as File and imported to the system for further processing, giving the possibility to generate annual monthly change report similar to mentioned above.

Field operations management: here can be entered further details about the specifics of farmer's activities – tillage, use of input materials, plant protection etc.

Additional functionalities managed in relation with the FLB:

- **Soil nutrition planner** - using soil or/and leaf samples data taken from the field parcel, as well as reference database and other modifying parameters, the software can help to calculate the nitrogen phosphorus and calcium status of the soil, and provide suggestion for possible fertilization quantities, based on the planned crop and yield, and possible limiting factors - such as specific rules and regulations of subsidy schemes and cross compliance.
- **Nitrate directive reporting** - obligatory data provision is required annually by the government, from farmers with parcels on nitrate sensitive areas and / or keeping livestock.
- **Land use administration** - for example to keep track of land lease contracts, partners, payments, etc.

Agricultural production management

Within the category of agricultural information systems, various farm management software has emerged as a more complex solution. Farm Management Software are used to optimize and manage farm operations and production activities. The software helps in automating farm activities such as record management, data storage, monitoring and analysing farming activities, as well as streamlining production and work schedules.

Software vendors have come up with several farm management software that helps farmer monitor and analyse all activities on the farm. Some commonly used examples are Agrivi, Granular, Conservis, etc.

These management software helps farmers in data-driven decision making for improving productivity and profitability. They can also improve teamwork efficiency, measure profit down to the field-level, and simplifies farmland research and transactions. Tillage, planting, spraying, fertilization, irrigation, harvesting and all other activities can be managed.

Many service provider and farmer use the AgLeader SMS software. SMS Software is an easy-to-use decision-making tool, it is very user friendly thanks to the built-in wizards guide, the user step-by-step and the easy-to-use interface.

Useful link: https://www.youtube.com/user/AgLeaderSMSTutorials

3.3 Services

The needs of farmers are changing as a result of new pressures and emerging opportunities. As the farm sector evolves, service providers must also evolve. There are many services on the market to support the farm sector to be productive, competitive and sustainable. This major group includes soil preparation services, crop services, veterinary services, other animal services, farm labor and management services, and landscape and horticultural services. In today's agriculture, information about the field is becoming more and more important, therefore, many service providers appeared on the market offering different data collecting methods. Soil sampling methods, aerial imagery, sensor-based technologies are very popular to collect as much valuable information as possible.

4. DATA INTEGRATION

The agriculture sector has its own data complexities and challenges, some of which may be specific to the sector.

For example, an individual farm may collect data on a wide range of fronts - plant production results, livestock production, farm food production, etc. There is therefore an essential need for **data integration**.

There are two key considerations for data integration:

- combining results from <u>all</u> fields of interest
- timing – obtaining results in acceptable timeframes.

Both of these should be targets for data integration, or 'data warehousing' - technologies that are used to aggregate structured data from one or more sources so that it can be compared and analysed for greater business intelligence. This is at the heart of digital farm management systems.

Similarly, data that is needed for studying agricultural systems can spread across several areas (domains), including ecology, crop science, agronomy, meteorology, economy, policy and demographics. Any modelling framework that aims to integrate crop biophysical models and agro-economic models, at different scales of time and space, needs to offer processes and tools for the seamless and sound management of data. Data integration permeates every aspect of farm management and studies.

Data integration presents its own problems, including ensuring that data can be accessed by people and systems that need to use it, data from different sources need to be homogenized (combined from disparate sources into meaningful and valuable information), documented and properly annotated before it can be used to effect. Once these issues had been resolved, then higher level considerations – such as interpreting the rich meta-data required for simulation results – must be taken into account so that the data can be unambiguously interpreted to build knowledge bases that can be tapped to provide some degree of quality control.

To improve the use of agricultural data for farming in the 21th century there are projects to create integrated databases for the storage of farm data across different areas of agriculture. To achieve **standardization** in agriculture, there is a need to create such systems based on common data structures, though this process is much slower and more complicated than in other areas of business or industry due to the specific circumstances seen in the agro-sector.

There are many agricultural databases available, but the scale and technological differences make them difficult to use coherently. For example, the Food and Agriculture Organization (FAO) of the United Nations has approximately 200 systems supplying information for access on the World Wide Web. These data sources need to share and exchange data between each other, and around the community, coherently but the technological history of these various systems means that there are incompatibilities between the databases. Some differences are technological; others are structural or to do with language.

Technology must be adapted to support interoperability of data sources, and potentially the management of multilingual variants, but without changing the underlying database structures. Currently, there is no standard way of managing language variants of data structures, which generates inconsistencies between applications.

The 'solution' to some of these issues is found in the many web developments - technologies that support problems in e-business, easing the ability to both represent and describe data structures in ways that are relatively easy to implement and to maintain.

Importantly these approaches can be implemented on multiple public and vendor platforms, with minimal effort and disruption to any existing systems. The FAO approach is detailed here - http://www.fao.org/docrep/008/af229e/af229e05.htm.

5. Traceability systems

The International Organization for Standardization (ISO) and Codex Alimentarius Commission (CAC) defines traceability as the "ability to follow the movement of a feed or food through specified stage(s) of production, processing and distribution"

Globalization has massively increased the cross-national trade of food products, but with this increase comes a corresponding potential for an increase in the number of food-borne illnesses.

Outbreaks of botulism, salmonellosis, etc. cause various food poisoning outbreaks, and several deaths, every year. Food safety and public health concerns have therefore forced food producers and processors to adopt preventive measures for product identification and traceability.

Traceability is the ability to track and follow the movement of products throughout the food chain, i.e. all stages and operations involved in the production, processing, distribution, storage and handling of a food and its ingredients - from production to consumption.

Food safety and quality management systems have been developed to establish and maintain a traceability system, enabling the identification of products to batches of raw materials, processing and delivery records. Traceability is of such importance that it has become a regulatory requirement.

The ISO standard sets out the principles and specifies the basic requirements for the design and implementation of a traceability system in the agro-food and feeds industry. The standard demands that organizations operating at any step of the food chain be able to:

- trace the flow of materials - feeds, foods, ingredients and packaging
- identify necessary documentation and tracking for each stage of production
- ensure adequate coordination between the different actors involved
- improve communication among the involved parties, and most importantly
- improve the appropriate use and reliability of information, effectiveness and productivity of the organization.

The main processes of traceability systems are:

- identification of units / batches of all ingredients and products
- registration of information on when and where units / batches are moved or transformed
- a system linking these data and transferring all relevant traceability information with the product to the next stage or processing step.
- In order to implement a traceability system within a supply chain there is a need for all parties involved to adopt uniform industry requirements regarding the identification of

products, and to link the physical flow of the products with transparency and continuity across the supply chain.

Two dimensions:

1) External traceability

If all traceable items are uniquely identified, and information is shared between all affected distribution channel participants, then external traceability is achievable. External traceability allows:

- tracing back (supplier traceability);
- tracking forward (client traceability).

2) Internal traceability

Internal traceability implies that processes must be maintained within an enterprise in such a way as to link identities of raw materials to those of the finished goods.

The implementation of effective traceability systems improves the potential of implementing verifiable safety and quality compliance programs. The resulting visibility of relevant information enables agro-food businesses to better manage risks, and to allow for rapid reaction to any emergencies, recalls, and withdrawals.

Effective traceability systems significantly reduce response times when an animal or a plant disease outbreak occurs, by providing rapid access to relevant and reliable information that helps to determine the source and location of implicated products. Thus, information (about animal and plant health, country of origin etc.) collated at any, or every, point in the chain - from producer to consumer - has become a crucial requirement.

Useful link: https://prezi.com/0vau8dui3rpb/traces-en-trade-control-and-expert-system/