III. MODULE

Agricultural technologies

Module 3. Agricultural technologies

Meaning and benefits of agricultural technology application

Modern agricultural business is developing in different directions at the same time. However, its primary focus is using agricultural technologies to increase yields through better planning and smarter management. By promoting more efficient and sustainable farming methods, advanced technology in agriculture is helping farmers thrive in today's agribusiness.
Time-oriented practices such as crop rotation and the application of new agricultural technologies, such as monitoring the productivity of the field with machines and satellite images or special agricultural software, contribute to the sustainability of agriculture.

The modernization of agriculture during the last three decades is progressing progressively, while the development of the IT sector in it is one of the main drivers of this process.

Factors that determine the pace of technological innovation in agriculture are:

- climate change and global warming
- the degradation of the environment
- change in consumer demands
- limited natural resources
- food scraps
- issues related to consumer health and chronic diseases
- growing global population expected to reach 9 billion by 2050

Today, innovations in the food industry are mainly focused on solving the following challenges:

- food scraps
- CO_2 emissions
- chemical residues and freezing
- drought
- labor shortage
- better health and sugar consumption
- murky supply chains and distribution inefficiencies
- food safety and provenance
- farm efficiency and profitability
- unsustainable meat production

What is agricultural technology?

Agricultural technology, also known as "agritech", encompasses a wide range of disciplines and devices that improve agricultural production. This includes vehicles, robotics, computers, satellites, drones, mobile devices and software. The use of big data analytics and artificial intelligence (AI) technology in agriculture is also an example of how the agricultural sector is embracing technological advances.
Modern farms and agricultural crops operate very differently than they did a few decades ago, primarily due to advances in technology, including sensors, devices, machinery and information technology. Today's agriculture routinely uses sophisticated technologies such as robots, temperature and moisture sensors, aerial imagery and GPS technology.

These advanced devices and precision agriculture and robotic systems enable businesses to be more profitable, efficient, safer and more environmentally friendly.

The benefits of technology in agriculture

Agricultural technology aims to make work in the field more efficient, easier and more comfortable. Every year there are various new agricultural innovations and occasionally revolutionary and innovative technologies emerge. As agribusiness continues to modernize and grow, it is increasingly crucial for agricultural consultants, food producers and technology managers to be familiar and up-to-date with the latest technology standards.

Water, fertilizers, pesticides and other products are no longer applied "by eye" or evenly across the field by large agricultural producers. The use of advanced agricultural technologies allows precise application of only what is needed in each location, as well as careful adaptation of the treatment to each plant.

The implementation of smart agricultural technology is beneficial for all participants in the agri-food chain. By using it to optimize and automate agricultural operations and field activities, growers and landowners can now save significant amounts of time and effort.

These are just a few examples of how agriculture has benefited from advances in agricultural technology:

- using less water, fertilizers, pesticides and other inputs allows agricultural producers to reduce costs and keep more of their profits;
- by preventing or drastically reducing the amount of chemical runoff into waterways, businesses reduce the impact of agriculture on the environment and take steps towards greater sustainability;
- increasing crop yields while reducing labor inputs;
- facilitating farmers, agronomists or other agricultural workers to communicate and coordinate activities using mobile devices, applications or web-based resources;
- reducing barriers to access to agricultural insurance and financial services, as well as market and technological data;
- mitigating damages that can be caused by pests, natural disasters and bad weather in agriculture with the help of affordable, always-on agricultural monitoring systems;
- increasing farm income through improved product quality and increased quality controls;
- timely recognition of lack of nutrients in plants and notification to the agricultural authorities
- producers for the type and amount of fertilizer and other necessary changes;
- ability to predict potential farm problems through visualization of production patterns and trends derived from analysis of current and historical agricultural data.

By estimating their total yield, agricultural producers can accurately budget for the next growing season and better prepare for emergencies.

Evolution (development) of Agricultural Technology

Technological progress in agriculture is intrinsically linked to the rise of urban centers and commercial exchange. New technological advances have always prevailed in this field.
However, the technological model of agricultural production remained largely subsistence-based and characterized by low productivity until the beginning of the 20th century. This era, known as "Agriculture 1.0", is marked by the invention of the plow and the widespread use of animal drafts.

Agriculture 2.0 began in the late 19th century with the introduction of mechanical machines such as tractors. And later, agricultural technology went through a number of active development cycles as the pace of technological progress increased tremendously.

Agriculture 1.0

In the beginning, people were hunters and gatherers. As early as 6000 years ago, farmers began to grow wheat and domesticate animals. With iron plows, they found they could bring more land to work. For the first time, agricultural technology enabled large-scale, organized food production and storage. It enabled the growth of villages and cities.

Agriculture 2.0

The technology of agriculture was practically unchanged. Oxen pulled ploughs; people worked manually. But in the 18th and 19th centuries, new tools and techniques suddenly transformed the speed and efficiency of farms. Crop rotation, steam power, steel work, drilling technology, seed production and crossbreeding made ploughing, planting and harvesting more efficient and productive.

Agriculture 3.0 or precision agriculture

Between the 1950s and 1970s, industrial chemistry and new opportunities for mechanization contributed to a new wave of agricultural efficiency and productivity. Fertilizers, herbicides and pesticides, crop spraying, tractors, the use of combine harvesters and the development and advent of various veterinary drugs all helped to turn farms into factory farms. With all these benefits, farms produced more food more cheaply and made more profits for landowners.

Precision or smart agriculture evolved here due to the need to monitor and more efficiently manage all inputs into crop production. The pursuit of precision agriculture and its associated agricultural technology has led to the development of new agricultural methods and tools.

The Global Positioning Satellite System (GPS) was the breakthrough technology that made this era of agriculture possible. GPS helps to find deviations in a given area for agricultural production, which allows for more effective use of available resources. This was the main reason why the idea of sustainable agriculture and a number of automation options emerged.

Agriculture 4.0, or connected agriculture

The leap from smart agriculture to connected agriculture is a good example of how quickly the production technology used in agriculture has moved forward at the turn of the century. Technology such as autonomous machines, sensor-equipped robots, augmented reality, Internet of Things (IoT), drones and satellites are part of the new agricultural environment, called Agriculture 4.0

Decision making in the agricultural sector is now based on data that is digitally stored and accessible through digital tools. With the help of this analyzed data, farmers and other major participants in the agricultural industry can make better decisions.

Agriculture 4.0 is born in an era of ubiquitous automation and digital connectivity. All developments in agricultural technology are becoming more and more integrated and networked, in order to optimize all stages of the production process and to strengthen the monitoring, management and control of the business.

It can be described as: "Integrated internal and external connection of agricultural operations", ie communication with external partners, such as suppliers and end users, as well as transmission, processing and analysis of all data.

At the same time, it also includes a number of concepts from which common terms have been created in the IT industry, but which are now also used in the field of agriculture.

Internet of Things (IoT) - a network of physical devices, vehicles, home appliances and other objects with embedded electronics, software, sensors, actuators and connectivity that allow these devices to connect and collect and exchange data

-In the same way that the Internet connects smart cities, the digitization of Agriculture 4.0 collects data through wireless IoT sensors that provide real-time information about the soil and the environment, including moisture, water absorption through the roots, the presence of nitrates, salinity, CO_2 in the air, temperature and brightness, among other parameters. This technology also facilitates the exchange of information with IoT sensors on, for example, drones and satellites. In other words, they are all interconnected and interact with each other to optimize crops.

Through this wireless network, this data is immediately stored in the cloud computer and can be accessed from anywhere using a smartphone or computer. Furthermore, more experienced farmers who can learn advanced information techniques can share them with third parties, e.g. partners across the value chain.

- **Big Data** - a term that refers to data sets that are too large or too complex for traditional data processing application software to adequately process.

This digital tool facilitates automated analysis of data collected from various types of IoT sensors on crops and from any other sources, including drones and robots. And provides predictive information; data is interpreted and turned into actionable knowledge, enabling digital farmers to make informed crop and marketing decisions and thus gain a competitive advantage. To do that, a large volume of data must be generated quickly.

- **Artificial Intelligence** - intelligence demonstrated by machines, as opposed to the natural intelligence displayed by humans and other animals, as well as practices in IT - collaboration, mobility, open innovation

Digital agriculture applies artificial intelligence to automate and optimize tasks with the help of machines and

management software that processes and evaluates data and makes decisions in real time. One of the main areas of application of AI in this industry is machine vision. With information gathered from images captured by cameras and sensors (on fixed and mobile media), he makes decisions as if he were the digital farmer.

Key technologies and concepts

High-precision positioning systems (such as GPS and Galileo) are the key technology for achieving precision in off-road driving. With Galileo, Europe's global navigation satellite system, baseline accuracy will be obtained much faster and maintained more reliably.

Automated steering systems: enable specific driving tasks to be undertaken such as automatic steering, overhead turning, field edge tracking and row overlap. These technologies reduce human error and are the key to effective site management:

Driving assistance systems show drivers the road to follow in the field using satellite navigation systems such as GPS. This allows for more precise driving, but the farmer still has to steer.

Automated steering systems take full control of the steering wheel, allowing the driver to take their hands off the wheel during row trips and the ability to keep an eye on planters, sprayers or other equipment.

Geomapping: used to produce maps including soil type, nutrient levels etc in layers and assigning that information to a specific location in the field. (see picture on the left)

Sensors and remote sensing: collect data from a distance to assess soil and crop health (moisture, nutrients, compaction, crop diseases). Data sensors can be mounted on moving machines.

Integrated electronic communication between the components in the system, for example between the tractor and the farm office, the tractor and the seller or the sprayer and the sprayer. These systems are still mostly proprietary.

Variable Rate Technology (VRT): the ability to adjust machine parameters to apply, for example, seeds or fertilizers according to exact variations in plant growth or nutrients and soil type.

Blockchain technology

Just as the digitization of the agri-food sector is redesigning the value chain, blockchain technology improves traceability throughout the supply chain by storing all information in an immutable data registry. Among other benefits, the introduction of this technology in agricultural practice will provide consumers with transparency regarding the origin, date of production and quality of the product. It can also be used to ensure food safety, as it quickly locates the source of the contaminant and sends health alerts for affected products. In short, Agriculture 4.0 delivers the best performance; it produces more with fewer resources, reducing costs in a way that is more sustainable for the planet.

Agriculture 5.0, or digital agriculture

Agriculture Technology 5.0, or simply put, "digital agriculture," refers to the next generation of agricultural methods and tools to maximize crop yields and other agricultural outcomes. One such technology is 5G, which is currently in the process of rapid development and will improve the reach and accessibility of the latest agrotechnical developments worldwide. Just as the industry brought a new an era of social responsibility in production, Agriculture 5.0 seeks to bring higher yields, but with more sustainable agricultural techniques that will be within the reach of every farmer.

Robotics, cloud computing, specialized software, and the Internet of Things are integrated into agricultural machinery using less labor, energy, chemicals, and destructive machinery. And, thanks to indoor and vertical farming techniques, to produce food without any access to conventional farmland.

Compared to previous farming methods, digital farming technology excels in the following aspects:

- efficiency of data collection: how much data can be collected in a certain time or space;
- data accuracy: how close the measurement is to the truth;
- timeliness: how quickly data can be processed into actionable information and reported to end users.

When it comes to weather, pests and diseases, farmers have little or no control. However, with the advent of digital technologies in agriculture, they can reduce the negative impact of these elements. Meanwhile, digital agricultural technologies give farmers the opportunity to greatly increase decision-making efficiency and returns to factors they directly control. Some examples are:

- what types of crops to grow;
- how to rotate crops for best results;
- when and how much water to use for precise irrigation;
- when, how much and what nutrients and plant protection products to apply;
- what type of tillage works best with a given type of soil

Agricultural experts agree that digital agriculture's most valuable tools and technologies in terms of competitive advantage are state-of-the-art farm management software, space-based solutions (especially those that provide high-resolution satellite imagery), proximal sensors, connectivity instruments and data such as and threat prediction algorithms.

Challenges for the development of Agricultural technologies

Demographics

One of the main problems is that we need to produce more from less. According to the UN, the global population is expected to grow from 8 billion in 2022 to 9.7 billion in 2050. This growth means that there is an increased demand for food, while the accompanying urbanization reduces the amount of land available for agriculture.

Plus, per capita food consumption generally increases as a country develops, further increasing demand.

Climate change

Changes in weather patterns are already affecting agriculture around the world. This is widely predicted to worsen, leading to further challenges around maintaining – never mind increasing – production.
Also, climate change will lead to competition for natural resources, such as water, which will make agriculture more difficult.

How to overcome these challenges?

Just as modern technology has massively changed every other aspect of our lives, today's development of intelligent agricultural robots is revolutionizing the industry like never before.
To perform agricultural tasks, agricultural robots must have a blend of intelligent decision-making, precise navigation and excellent dexterity.

Sensors

Sensors play a vital role in many of these processes. For example, sensors are needed to detect hazards that might impede the robot's movement, identify crops that are ready for harvest, and detect when the robot has grabbed a piece of fruit with enough force to pick it.
Sensors likely to be incorporated include touch, azimuth, ultrasound (for spraying), GPS, RGB, LiDAR, moisture and near-infrared spectroscopy (NIRS, for milk quality testing).

Sowing robots

By planting seeds in exactly the right positions and with minimal waste, there can be big production gains for farmers. Robots are being developed that can dig soil, plant seeds, add fertilizer and then water.
FarmDroid is one such seeding robot, which can also weed (see below). It is powered by solar panels and uses GPS to precisely record where the seeds are placed. This data makes it easier to weed between and within the rows later. The manufacturer claims that its solar panels can provide up to 24 hours of CO2-free operation.

Fieldwork robotics

Robots can harvest a range of crops, such as maize, rice and soft fruit. While the delicate nature of some fruits and vegetables has been a limiting factor for the use of robots in the past, improved sensor technology and precise movement mean this is no longer the case.
Field Robotics is developing horizontal and vertical harvesting robots for selective harvesting. Manufacturer Says: Manufacturer Says: "Precise redesign of sensor and holder technology minimizes slippage, significantly reducing harvest time. Using 3D cameras, sensors and machine learning, our robots pick fruit at the perfect level of ripeness, ensuring efficiency and precision."

Drones

The use of drones in almost every sector of the economy is growing rapidly, but the use of drones in the agricultural industry is booming. According to some reports, the agricultural drone market is expected to grow from a $1.2 billion (USD) industry in 2019 to a $4.8 billion industry in 2024. years. Information collected by drones on farms is often used to better inform agronomic decisions and is part of a system commonly known as "precision farming".
In many areas, the use of drones has already become an essential part of large-scale precision agriculture operations. The data collected from the drone recording fields helps farmers plan their planting and treatments to achieve the best possible yields. Some reports indicate that using precision farming systems can increase yields by as much as 5%, a significant increase in an industry with typically thin profit margins.

Drone for monitoring plant health

One use of drone imagery that has already been demonstrated with great success is monitoring plant health. Drones equipped with special imaging equipment called Normalized Difference Vegetation Index (NDVI) use detailed color information to indicate plant health. This allows farmers to monitor

crops as they grow, so any problems can be fixed quickly enough to save the plants. This image simply illustrates how NDVI works.
Drones that use "regular" cameras are also being used to monitor crop health. Many farmers already use satellite imagery to monitor crop growth, density and color, but access to satellite data is expensive and in many cases not as effective as closer drone imagery. Because drones fly close to fields, cloudiness and poor light conditions are less important than when using satellite imagery.
Satellite imagery can offer meter accuracy, but drone imaging is capable of producing accurate image location down to a millimeter. This means that after planting, areas of stand gaps can be noted and replanted as needed, and disease or pest problems can be detected and treated immediately.

Drone for monitoring field conditions

Drone field monitoring is also used to monitor soil health and field conditions. Drones can provide accurate terrain mapping, including elevation information that allows growers to find any irregularities in the terrain.
Having field elevation information is useful for determining drainage patterns and wet/dry areas that allow for more efficient irrigation techniques. Some agricultural drone vendors and service providers also offer soil nitrogen monitoring using advanced sensors. This allows for precise fertilizer application, eliminating weak growing spots and improving soil health for years to come.

Drone for planting and sowing

One of the newer and less widespread uses of drones in agriculture is for planting seeds. Automated drone seeders are mostly used in the forestry industry at the moment, but the potential for wider use is on the horizon. Drone planting means that very hard-to-reach areas can be replanted without endangering workers. They are also able to plant much more efficiently with a team of two operators and ten drones capable of planting 400,000 trees per day.

Spraying of agricultural areas

The use of drones to apply spray treatments is already widespread around the world. Drone sprayers are capable of navigating very hard-to-reach areas, such as steep high-altitude tea fields. Drone sprayers save workers from having to navigate fields with backpack sprayers, which can be hazardous to their health. Drone sprayers deliver very fine spray applications that can be targeted to specific areas to increase efficiency and save on chemical costs.
Currently regulations on drone sprinklers vary widely between countries. In Canada, they are not currently legal because more testing needs to be done to understand the impact of spray drift. Some regulatory proposals recommend that only trained professionals be tasked with flying spray drones, as is the case with Yamaha, which does not sell the spray drones it manufactures but rents out drone spray services complete with licensed operators.

Drone pollination

Some of the newer uses for drones in agriculture are still in testing and development. One of the most publicized (and often invented) uses is pollination drone technology that is capable of pollinating plants without damaging them. The next step is to create autonomous pollination drones that will operate and monitor crop health without constant instructions from operators.

AI drone

Another emerging drone technology also involves machine learning. Improving artificial intelligence (AI) in drones is important to make them more useful to small farmers in developing countries. Current drone technologies are more efficient at tracking familiar crops like corn planted in large monoculture fields.
Drone monitoring programs, as they stand, have difficulty recognizing areas of increased crop diversity, lesser-known products, and grains that look similar throughout their growth stages and are therefore less effective at monitoring crop growth and health. More work is needed to train AI systems to recognize rarer crops and more diverse planting patterns.

Irrigation by drone

New research also creates exciting opportunities for the use of drones in agriculture. As climate change increasingly affects drought conditions, creating more efficient irrigation solutions is vital. Using sensors that use microwaves, drones can capture very accurate information about soil health, including moisture levels, without plants getting in the way. This means that water can be distributed to the field in the most efficient way in an effort to conserve resources.

Safety

Drone security is a key link that is beneficial to farm management. Using drones to monitor remote parts of the farm without having to go there saves valuable time and allows for more frequent monitoring of hard-to-reach areas. Drone cameras can provide an overview of farm operations throughout the day to ensure operations are running smoothly and locate equipment in use.

Security drones can be used to monitor the fence and perimeter of more valuable crops like cannabis, instead of employing more security personnel. Drone cameras are also being used in exciting ways to protect farm animals by locating missing or injured herd animals in distant grazing areas. Observation of remote areas, which used to take hours of walking, can now be completed in minutes.

Conclusion

Drones have already greatly changed the agricultural industry and will continue to grow in the coming years. While the use of drones is becoming increasingly useful for small farmers, there is still a way to go before they become part of every farmer's equipment list, especially in developing countries. Regulations around the use of drones need to be drawn up and revised in many countries, and more research needs to be done on their effectiveness for certain tasks, such as pesticide application and spraying. There are many ways that drones can be useful to farmers, but it is important to understand their limitations and functions before investing in expensive equipment. Drone Deploy, an agricultural drone supplier and programming company, suggests starting small and slowly incorporating drone data into your organization for best results.

Negative impacts of agricultural technology: are there any?

While it is true that modern agriculture has reaped many benefits from technological development in terms of greater efficiency, lower costs and higher yields, there is another side to the coin, which is specifically related to large-scale extensive agriculture. The most significant are its harmful effects on nature.

The primary problems with agricultural technology that have a negative impact on the ecosystem are:

- soil and water pollution from the widespread use of pesticides;
- loss of biodiversity due to the elimination of indigenous species in favor of agricultural crops;
- the release of greenhouse gases, resulting from the clearing of forests to make way for agricultural land and the further overuse of machinery.

All the disadvantages of technology in agriculture are not related to the impact on the environment. Some are related to various aspects of adoption of agricultural technology by growers and their staff, namely:

- farmers who lack the necessary education and practical experience cannot work efficiently with machines and software, making them unable to take advantage of today's advanced agricultural technology;
- the maintenance costs of the machines are really high;
- the use of chemical fertilizers and pesticides can harm the health of farmers and other agricultural workers who work on the land.

As agricultural technologies enable us to meet the food needs of an expanding world population, it is clear that we cannot turn our backs on them. But we can make their negative effects less severe by using and improving precision farming techniques that go hand in hand with ecological practices.
Because these technologies have the potential to reduce or even eliminate the negative impacts of conventional farming methods, they help solve a wide range of environmental problems. In this way, industrial agricultural producers can gain two privileges: increase their competitive advantage and at the same time benefit from global long-term welfare.