B1.10 Autonomous vehicles and robots in agriculture

Autonomous machines in agricultural production

Autonomous machines – robotics, automation, and sensing systems perform tasks without human intervention. The use of autonomous field robots leads to an increase in productivity, an improvement in the quality of products, services, and an increase in work safety during operations on land. New innovative technologies, which are core of precision agriculture, will fundamentally change the implementation of technological operations in agricultural production. It is estimated that their full application will increase productivity 10 times faster than it is today and 300 times faster than it was during the first industrial revolution.

Within the EU countries, fashionable technologies are supported because their importance for competitiveness and sustainability is unquestionable. That is why member states are developing their national strategies and visions (roadmaps), leading to the gradual implementation of these technologies in agricultural practice.

Due to the rapid development and advancement of new technologies, there is a shortage of skilled labour in the agricultural sector. The number of standard-educated workers in agricultural enterprises is decreasing. Thus, one of the important goals will be increasing the qualifications of the workforce. If the qualifications of some workers were changed and they were adapted to new jobs in precision agriculture, the decrease in the labour force within agriculture world would stop.

Autonomous tractors and seed planting robots

Autonomous tractors and sowing robots are currently the first representatives of robotic machines that we can already meet in practice. They represent the way how autonomous technologies will change agriculture production. Driverless tractors aim to release the farmers from 8 –12-hour days of just driving. They allow farmers to take control via an app on their phone or computer. The farmer can use the app to position a tractor, drive the length of a field, turn around, come back and manoeuvre around obstacles.

What *fully autonomous* means is that a farmer can transport the tractor to a field and configure it for autonomous operation using a mobile app to start the machine and monitor its operation as it moves up and down a field while the farmer performs other tasks. The only time the farmer must be present is to re-fuel the tractor or respond to the unexpected situation if the machine can't make its way around an unexpected obstacle.

How autonomous tractors work?

Currently, the majority of the autonomous tractors is navigating by signals from several mobile transmitters, located around the field. They are sending and receiving back the laser signals. Mobile transmitters are accompanied with 150 MHz radios wades to deal with line-of-sight issues. Instead of drivers, the tractor is controlled remotely by people - controllers. Controllers are men/women that supervise the tractors without siting inside them. Controllers can supervise multiple tractors on multiple fields – from one location.

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Another fully autonomous tractor technology send commands using the electrical system build in the tractor or in the farm equipment. Using GPS positioning and radio feedback, automation software manages the vehicle's path and controls farming implements. A retrofit radio receiver and on-board computer are generally used to receive commands from the remote command station and translate it into vehicle commands such as steering, acceleration, braking, transmission, and implement control. Sensor technologies improve safety by detecting and reacting to unforeseen obstacles. Whether it's a forgotten piece of equipment, an animal, or even a bag of waste, when an anomaly is detected, the tractor stops and sends a notification to the farmer.

John Deere autonomous tractors

In 2022, John Deere introduced a "fully autonomous tractor Model 8" that is ready for series production. A GPS guidance system helps in creating a geofence to keep the tractor on course, accurate to within an inch. The tractor is also equipped with six pairs of stereo cameras for 360-degree obstacle detection and to calculate distances. Images from the cameras are routed through a deep neural network via two Nvidia Jetson GPUs that help classify each pixel in 100 milliseconds to determine if the machine should continue or stop for an obstacle.

Autonomous tractor John Deer 8.
From: https://www.deere.com/en/index.html

The autonomous tractor continuously checks its position relative to the plot boundaries and ensures that it is operating where it is supposed to. At the same time, it works with an accuracy of *less than 2.5 cm*.

John Deere cited three reasons for developing the autonomous tractor: a) addressing the labour shortage in rural areas, b) making farming more efficient and c) freeing up a farmer's time to do more important things than being behind the wheel for hours on end.

The autonomous tractors are just the next step in high-tech agriculture. They will automate not only the driving function, but every decision point that the operator would have made, and that includes things like adjusting the tillage tool depth or steering around an obstacle.

There are barriers that will shut out many farmers – namely the price tag. Deere is not releasing information on how much these tractors will cost, but industry insiders routinely throw around figures well over $500,000.

For those who would be looking forward to seeing it soon in European fields, however, an important information needs to be added: sales of the *fully autonomous John Deere tractor from the 8R model series will start already this year, but for now it will be limited to the US region only.*

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The most famous global manufacturers of autonomous technologies for agriculture

John Deere: John Deere has had a strong influence on the development of automated farming technology. In early 2008, Deere and Company launched its „ITEC Pro guidance product“, an automated system based on global positioning technology which automates vehicle functions including end turns. Based on these satellite signals, the tractor follows a previously programmed route via an electronic map. These antennae are also for human operators to control the tractor if satellite signals have trouble penetrating buildings or heavy vegetation.

Autonomous Tractor Corporation: In January 2012, Terry Anderson established a company called Autonomous Tractor Corporation (ATC) located in North Dakota. The ATC produced the „SPIRIT driverless tractor“. Anderson thought tractors were getting bigger and more expensive while not improving in quality. Anderson tested half-scale models of his automated tractor design at his second home in Texas.

Fendt: Fendt, part of the AGCO corporation, has also been working on a driverless tractor. In 2011 in Hanover at the Agritechnica show, Fendt presented their driverless tractor model called the GuideConnect. The GuideConnect is a tractor programmed to mirror the movements of another tractor. An operator-driven tractor maneuvers through a field or through crops and is followed by a driverless tractor. GuideConnect is connected by satellite navigation and radio to the operator-driven tractor.

Case IH: Case IH is a company created by the merging of J.I. Case Company and International Harvester. The company now operates under CNH Global, but the tractors are still branded Case IH. The driverless tractors produced by Case IH are referred to as "supervised autonomy." A tractor driven by a person is followed by autonomous machinery which copies the steering and speed of the former tractor. There is an initial driver, but the autonomous technology is present in the second tractor via „vehicle-to-vehicle“ communication. In 2016, Case unveiled their latest autonomous concept, a cabless row crop tractor of the Magnum model that could operate autonomously.

Sabanto Inc., based in Chicago, their capabilities range from the actual farming until deep-data engineering. It was named winner in the 19th annual Chicago Innovation Awards program. The Sabanto works as a cutting-edge Farming-as-a-Service company performing row-crop field operations using small, cost-effective, autonomous machines. The Sabanto offers autonomous custom farming services to farmers since 2019.

Weeding can, used in Denmark, France, and Germany
https://www.ducksize.com/

Naïo is in Europe the market leader for agriculture weeding robots. Founded in 2011. The commercially vailable weeding robots from Naïo are running on different continents. **FarmDroid** combines seeding and weeding in one agriculture robot that stays on the field during growth. **Farmwise** in the US, operating with a serious fleet of agriculture robots with the recognizable orange tractors. Other key examples for weeding robots. **FarmDroid**, combing seeding and weeding in one agriculture robot that stays on the field during growth. **Agrointelli Robotti** together with the **Kverneland** produce the „Optima sowing machines“.

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Other autonomous machines in agriculture

The autonomous tractor is not the only represent of high-tech innovations that traditional manufacturers of agricultural machinery plan to bring to the market.

There are two key reasons for *agriculture robots* to reduce the soil impaction during sowing. Firstly, the machine tends to be smaller and weigh less. Secondly, a typically agriculture robot is accurately driving on only the areas where no plants will have to grow and with a shortest-path principle. An agriculture robot for sowing is calculating to drive as less meters as possible on the field (with less weight). Often based on RTK GPS and ideally also at the headland.

Tillage robots used in the Netherland, Denmark, France, and Germany
https://www.ducksize.com/

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Other items that are detected as weed, will get a mechanical strike if they are outside the safety zone. It is able to operate with a speed up to 1 km per hour. With thousands and thousands of strikes per day.

Comparing tillage to weeding, the total time spent may indeed be lower on tillage. However, depending on the circumstances, it may be much easier to automate the *tillage task* with agriculture robots or an upgrade kit on the tractor. In normal conditions, the tillage task may be very easy to perform by a robot.

Based on working with the robot on the field, one can see and count that hardly any onions are damaged. Meanwhile, the large majority of weed is being removed.

Another autonomous robot is the "See&Spray Select" *spray system*, in which a series of cameras with computerized image processing can recognize weeds from crops and can spray herbicide directly on the weeds.

It can correctly detect over *ninety percent of weeds* and thus save more than seventy percent of herbicide. Which is cost-effective for farmers and quite important for the environment.

Ecological farmers perform spraying on several crops with biologically composed products. What that in mind, there is enough reason to encourage the development of agriculture robots to do spraying activities with a sustainable vision.

The robots are likely to make spraying on conventional farms also more efficient. And even if there are robots that reduce the application of chemicals with 90%, due to targeted application with the use of camera's it is still 10% more than zero.

Sowing robots, used in Denmark, France, Germany

Weeding robots, used in Switzerland, France, Germany, The Netherlands

Spraying robots, used in Switzerland, France, Poland, The Netherlands, https://www.ducksize.com/

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Shortcomings we encounter

It will be very important for machines from different manufacturers to communicate with each other. In research, it will be necessary to find SW means by which the machines will be able to communicate and integrate with each other as the farmer needs it.

Manufacturers see a limitation in the complete independence of the machine from the person in the legislation of operation on public roads. Here, the autonomous machine cannot move independently of the driver.

It is therefore likely that autonomous driving will only be used in traffic on farmland.

The farmer would then take his tractor to the field, bring tools and possibly other tractors, then connect everything to autonomous and cooperative mode – and while the machines were harvesting, he could, for example, transport the crops on the road.

The autonomous vehicles – tractors and robots – are considered controversial in terms of safety and general public acceptance. A vehicle which operates without a driver can make people nervous. The tractors have sensors to stop them if they detect objects in their path such as people and animals, but "nobody knows what can happen".

The future of autonomous machines and robots in the next 20 years

What developments in the field of application of autonomous machines can we expect in the next 20 years?

The development in the field of autonomous machines is huge and if the world develops in peace and mutual understanding, these technologies will change the world we live in now. The table shows the major changes that we can expect and look forward to.

	0-5 years	5-10 years	10-20 years
SMEs manufacturing and horticulture	2-3 multi-task autonomous systems are able to be changed through minor manual and software interventions. Robots working in parallel with humans, learning through manual guidance of initial procedure. Improved sensing systems for harvested crop quality assessment. Surveillance of crops through smart sensors. Assistive crop pruning, thinning, and harvesting - work alongside.	Task adaptable autonomous machines through only simple software interventions covering all tasks. Humans working with robots to complete a task and helping each other.	RAS autonomous machines smart interpretation of the required task and self-adjusts to required tool set. Human helper robots which can interpret the needs of a human for a specific task. Task learning robots - show and tell - thus requiring no programming. Fully automated crop planting and maintenance pesticide free. We can expect the emergence of SMS cooperations that will jointly share expensive technologies.

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	Assisted harvest crop selection. Automated weed spraying and control.		Agricultural enterprises will increase the area of cultivated land.
Livestock	Real-time personalised livestock performance monitoring. Smart livestock monitoring for disease and sickness.	Herd logistics automation based on personalised livestock performance. Improved milking plant automation inc. real-time sensor data. Automated shed maintenance systems - cleaning. Assistive milking systems. Assisted sheep shearing.	Accessible and Serviceable Automated milking systems. Automated sheep shearing. Farm logistics and monitoring. Changed scope of requirements for farmer. Hands free animal management.
Food and beverage	Semi-autonomous meat processing. Seri-autonomous fish and selfish processing. Assisted bakery goods processing.	Fully autonomous meat processing with only minimal human assistance - humans do not perform cutting. Fully autonomous fish, shellfish, and bakery goods processing.	Completely automated meat processing with only plant supervisors.
Pasture	Handheld pasture monitoring systems. More efficient pasture maintenance - smart fertiliser application.	UAV and UGV farm monitoring systems - remote farm walk. Semi-automated pasture maintenance and management.	Fully automated farm monitoring. Fully automated pasture maintenance.

Adopted from: www.nzras.org.nz and Agriculture 2021, 11, 216. https://doi.org/10.3390/agriculture11030216

Future problems

Network connectivity and cellular coverage on farms are limited, it would be necessary to strengthen them.

Staff needs motivation to obtain new retrain to be able work with new specific technologies.

Finding and keeping individuals with such specialised skills is difficult in area of agriculture due to the small employment base, lower profits, and ultimately lower salary budgets.

Hiring educated immigrants should show help a company to create new products and enter new export markets.

Some employees will necessary be shift into roles which machines cannot do, such as managing people, applying expertise, and communicating.

As a result, if upskilling or retraining into these roles is not undertaken, there will be an excess of lower skilled labour.

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An effective *upskilling* and retraining programme for employees is required to mitigate these potential increases in inequality.

For small farmers, automated technical means will be financially unavailable. It is possible that they will cooperate with each other in sharing technologies, which will be better used, that cooperatives will be formed. This, in turn, could lead to a gradual increase in the size of agricultural holdings, which is contrary to the concept of EU agricultural policy.

Summary

Robotics, automation, and sensing systems perform tasks without human intervention. The use of autonomous field of tractors and robots leads to an increase in productivity, an improvement in the quality of products, services, and an increase in work safety during operations on land. Within the EU countries, fashionable technologies are supported, member states are developing national strategies and visions (roadmaps), leading to the gradual implementation of these technologies in agricultural practice.

Fully autonomous tractor technology involves using the native electrical system of the tractor or farm equipment to send commands, uses GPS positioning and radio feedback, automation software management. Sensor technologies improve safety by detecting and reacting to unforeseen obstacles.

The shortcomings we encounter: machines from different manufacturers do not know to communicate with each other. Manufacturers see a limitation in the complete independence of the machine from the person in the legislation of operation on public roads. Here, the autonomous machine cannot move independently of the driver. For small farmers, automated technical means will be financially unavailable, they could cooperate in sharing technologies, which will be better exploited. Bigger cooperatives should result in the increase in the size of agricultural holdings, which is contrary to the concept of EU agricultural policy.

The autonomous vehicles – tractors and robots – are considered controversial in terms of safety and general public acceptance. A vehicle which operates without a driver can make people nervous.

One of the important goals is increasing the qualifications of the workforce.

List of relevant topics

Friedrich Rübcke von Veltheim * and Heinke Heise 2022 „German Farmers' Attitudes on Adopting Autonomous Field Robots: An Empirical Survey“, https://www.mdpi.com/journal/agriculture

Vrchota, J.; Pech, M.; Švepešová, I. Precision Agriculture Technologies for Crop and Livestock Production in the Czech Republic. *Agriculture* 2022, *12*, 1080. https://doi.org/10.3390/agriculture12081080

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https://www.deere.co.uk/en/agriculture/future-of-farming/

https://www.therobotreport.com/are-farmers-ready-for-autonomous-tractors/

https://asirobots.com/farming/

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weeding can
tillage task
spray system
upskilling

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