APPLICATION OF THE SENSOR IN AGRICULTURE: A REVIEW OF RECENT DEVELOPMENTS

Biljana BOŠKOVIĆ[1]*, Irina MARINA[2], Miloš PAJIĆ[1], Jonel SUBIĆ[2]

[1]University of Belgrade, Faculty of Agriculture, Belgrade-Zemun, Serbia
[2]Institute of Agricultural Economics, Belgrade, Serbia
[*]Corresponding author: biljana.boskovic@agrif.bg.ac.rs

Abstract

The constant increase in the world population is a trend that also requires the increase in food production, i.e. the increase in crop yields, which represent the main challenge of agricultural production in recent years. This paper aims to provide insight into new trends and technologies necessary for the development of precision agriculture, emphasizing the advantages of integrating smart sensors and innovative technologies. The transition to modern agricultural production enables the increase in yields, a reduction in production costs, and the production of healthier and better quality products. The goal of precision agriculture is to increase yield, efficiency, reduce costs and resources, as well as to minimize the negative impact on the environment. In frames of precision agriculture, there is a trend of introducing sensor detection as a more rational data collection technique. Sensors are devices for detecting, registering and measuring the radiation of electromagnetic energy, its own or reflected. They enable the collection of a larger group of data by applying a simpler technique with minimal costs which can determine the quality of soil and crops. They are also used on a variety of agricultural machinery and robots in order to speed up the data collection process and at the same time prevent the occurrence of malfunctions. The development of precise agricultural production technologies represents a perspective for the improvement of traditional agricultural practices and the transition to modern agricultural production with greater efficiency and sustainability of food provision.

Keywords: *Precision Agriculture, Food production, Data, Innovative technologies.*

Introduction

Agriculture has always been the cornerstone of human civilization, providing a stable source of food and raw materials. However, with a growing world population and limited natural resources, traditional agricultural approaches increasingly show their limitations. In this context, precision agriculture has emerged as an innovative response to the challenges of modern farming, offering sustainable and efficient methods to increase yields and reduce environmental pollution (Yadav & Kumar, 2023).

Precision agriculture relies on advanced technologies to enable accurate and timely management of agricultural processes. One of the key aspects of this practice is the integration of sensors, which collect data on various parameters of the environment and crop conditions. This data allows farmers to make timely decisions, optimize the use of resources such as water, fertilizers, and pesticides, and improve the overall efficiency of agricultural production.

Sensors used in precision agriculture can measure various parameters, including soil moisture, nutrient levels, temperature changes, the presence of pests, and many other factors (Pajić, 2022). These sensors are often linked to systems for remote control and data analysis, allowing real-time monitoring and swift interventions. The use of drones equipped with cameras and multispectral sensors allows for precise mapping and analysis of large arable land (Dibyajyoti Nath, 2023).

This paper aims to investigate the importance and application of sensors in precision agriculture. It analyzes how these technologies contribute to improving yields, reducing costs, and preserving the environment. The paper will focus on practical examples and case studies of the application of optical sensors, showcasing successful implementations of these technologies in various aspects of agricultural production. Finally, the paper will explore the challenges and future directions of development in this area, which has the potential to transform agricultural production methods.

Sensors

Sensors are devices that can measure various physical quantities such as temperature, humidity, speed, acceleration, position, and light intensity. They provide measurable representations of the measured physical quantity in the form of an electrical signal or changes in the electrical characteristics of an electrical component (Pajić et al., 2022). The purpose of sensors is to detect changes in a given environment and send information to a computer processor. The most commonly used sensors in agriculture are used for measuring meteorological conditions, soil moisture, and plant conditions, as well as for monitoring yield. The sensors are characterized by their ability to register a wider or narrower spectral range, individual spectral lines (rays of one wavelength), or multiple separated spectral lines within one spectral region at once. The fact that sensors are not only used for measurement but also in other areas such as shipbuilding, sports, various sciences, household, medicine, etc. indicates how important sensors are in everyday life.

The sensors can be divided into two types based on the kind of energy they detect: passive or active (Kostić, 2021). Active sensors emit and receive energy, capturing the reflected part from the measured object. They have their light source and can be utilized year-round and throughout the day, regardless of weather conditions and the position of the Sun. Active sensors, unlike passive ones, can send and receive energy. This category includes radars and laser scanners. Active and passive sensor technologies are used in remote sensing to take measurements from a distance or to measure phenomena that are not visible to the naked eye. Passive sensors only detect the energy emitted by the object being observed. Passive multispectral sensors depend on natural light, which can be significantly influenced by factors like sun exposure, cloud cover, architectural structures, and the reflective properties of scanned objects (These variables can impact the consistency of imaging over time, especially when observing a wide area that necessitates prolonged scanning (Fahey et al., 2020; Kostić, 2021). Examples of passive sensor technologies include photographic, thermal, chemical, and infrared sensors. Also, sensors can be classified according to different criteria (Pajić, 2022):

- by the sizes they measure,
- types of signals and interfaces,
- features and characteristics,
- quality class,
- principle of work,
- production technology,
- fields of application,
- values.

The sensor's main features include:

Sensitivity - refers to how the output value changes when the measured value changes, such as in an electrical measuring instrument. If a displacement of 0.1 mm results in a voltage change of 0.1 V at the output, then the sensor's sensitivity is 1 V/mm. Sensors used to detect small changes must have high sensitivity.

Linearity - ideal sensors are designed to be linear, i.e., the sensor's output signal is linearly proportional to the measured value. Linearity is challenging to achieve, and any deviations from the ideal are called linear tolerances. Linearity is expressed as a percentage of deviation from the linear value. It is the maximum deviation of the output curve from the line that best fits one calibration cycle, and it is related to the accuracy of the sensor.

Accuracy is typically assessed through absolute and relative error. Absolute error is the disparity between the actual value of the measured quantity and the measurement result (sensor output value). Relative error is calculated as the ratio of the absolute error to the actual value. The relative error is often presented as a percentage.

Signal resolution - represents the smallest value change that a sensor can recognize in the measured quantity. Resolution is related to the accuracy of the measurement and represents the sensor's ability to reproduce a certain set of readings within a given accuracy.

Sensors in precision agriculture

The use of sensors in agricultural production has evolved alongside technological advancements. Initially, sensors were complex systems designed to measure temperature or humidity, but today's sensors are modern, precise, and offer a wide range of capabilities. It is expected that sensor applications in agriculture will continue to expand in the future, playing a crucial role in achieving sustainable, efficient, and productive agricultural practices. Modern agricultural systems now integrate various types of sensors, enabling the monitoring and control of numerous parameters, leading to improved efficiency, productivity, and overall sustainability in agricultural production (Saiz-Rubio & Rovira-Más, 2020; Paul et al., 2022).

In precision agriculture, sensors are used on devices to test soil properties, on machines for feeding and protecting crops, and for harvesting crops. These sensors are installed on the machines and connected to the control unit and GPS receiver. The data obtained through these measurements is precise because the measurements are taken during agrotechnical operations. The most well-known system of this kind is OptRx from Ag Leader (https://www.agleader.com/blog/ag-leader-releases-optrx-crop-sensor/). The sensors are calibrated to the machinery (sprayer). What sets it apart is its direct connection to the display, which allows access to sensor readings. The sensor uses a wave that responds even in high-density plant environments. Another widely used approach for assessing soil properties involves the Veris MSP3 sensor system (Jurišić & Plaščak, 2009). These sensors function based on the same principle as the previously mentioned system, offering essential information for soil management. However, unlike the other system, the Veris MSP3 necessitates using processed data alongside a computer program to generate different types of maps that can be applied for agricultural purposes.

Sensory measurement of crop characteristics

Sensory measurement of crop properties is one of the main approaches in modern agricultural production systems. Accurate measurement of plant characteristics is made possible by sensors that have achieved high tracking accuracy through technological progress (Marković et al., 2020). Sensory measurement of crop properties enables optimization of the use of resources such as fertilizers, pesticides and water, thereby reducing production costs. Multispectral sensors used in remote sensing and sensor measurement of crop properties can determine the state of the plant by observing it outside the visible part of the spectrum. Multispectral images have a high resolution and offer the analysis of different wavelengths, which allows identification of plant problems, timely detection of diseases, deficiencies of nutrients, water and other essential elements. The obtained multispectral images enable the calculation of data from different channels based on the absorption and reflection of solar energy. The visible and invisible part of the spectrum of solar electromagnetic radiation is represented by means of bands. So the bands represent parts of the spectrum of different wavelengths and frequencies. Visible spectrum (VIS) refers only to part of solar radiation and represents a wavelength of 400 - 700 nm (Skendžić, 2022). Part of the spectrum with a wavelength of 700 – 2500 nm is called Near infrared (NIR) and it is invisible to the naked eye (Figure 1). The NIR spectrum has two sublevels (I – wavelength range - 1,300 nm, II – wavelength range 1,300 - 2,500), (Wójtowicz et al., 2016; Kostić, 2021).

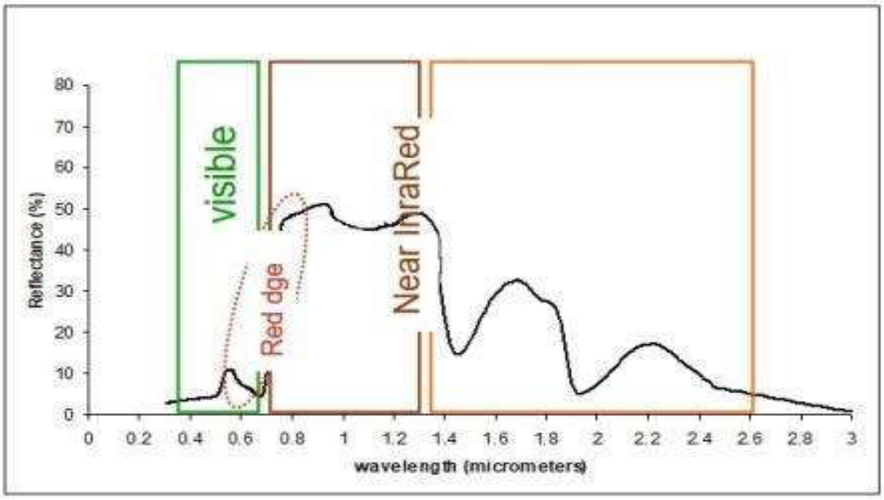

Figure 1. Visible and invisible part of the spectrum

An example of a device for measuring crop characteristics

The Plant-O-Meter device (Figure 2) is a handheld multispectral proximal sensor. This type of sensor belongs to active sensors because it uses its own light source. It has six optical channels: blue (455 nm), green (740 nm), red (657 nm), RedEdge (740 nm), NIR1 (810 nm), NIR2 (940 nm). All information collected in the field can be saved through the application installed on smartphones. Obtaining information from different channels allows the recalculation of over 30 vegetation indices (these indicators make it easier to understand the obtained data).

Figure 2. Plant-O-meter (https://www.plant-o-meter.com/)

Vegetation index values describe crop health in a good way, monitoring growth stages and identifying problems (Xue & Su, 2017). The values obtained by recalculating the amount of solar radiation of different wavelengths make it possible to identify the area and precisely apply the necessary measures in order to respond in a timely manner.

Conclusion

The application of sensors in agriculture has brought many reliefs to agricultural producers. Sustainable and more efficient production using different types of sensors enabled the control of conditions and timely intervention. With further technological progress of the precision agriculture system and the sensors themselves, it is possible to expect improvements in terms of various sensor characteristics and contribute to the creation of a sufficient amount of health-safe food.

References

Dibyajyoti Nath (2023). Smart Farming: Automation and Robotics in Agriculture. In book: Recent Trends in Agriculture, Chapter 16, Rohini, Delhi, India, 283-310.

Fahey, T., Pham, H., Gardi, A., Sabatini, R., Stefanelli, D., Goodwin, I., Lamb, D. W. (2020). Active and passive electro-optical sensors for health assessment in food crops. Sensors, 21(1), 171.

https://www.agleader.com/blog/ag-leader-releases-optrx-crop-sensor/, (10.07.2024.)

https://www.plant-o-meter.com/, (10.07.2024.)

Jurišić, M., Plaščak, I. (2009). Geographic Information Systems (GIS) in Agriculture and Environmental Protection, Faculty of Agriculture in Osijek.

Kostić, M. Marko (2021). Precision Agriculture, Faculty of Agriculture Novi Sad, University of Novi Sad.

Marković, D., Koprivica, R., Veljković, B., Vujičić, D., Pešović, U., Ranđić, S. (2020). Application of Image Analysis for Determining the Dimensions of Rapeseed Using the IoT Concept.

Pajić, M., Dražić, M., Gligorević, K. (2022). Precision Agriculture, University of Belgrade, Faculty of Agriculture.

Paul, K., Chatterjee, S. S., Pai, P., Varshney, A., Juikar, S., Prasad, V., Dasgupta, S. (2022). Viable smart sensors and their application in data driven agriculture. Computers and Electronics in Agriculture, 198, 107096.

Yadav, R. & Kumar, R. (2023). Sensors in Agriculture, Rohini, Delhi, India, 61-80.

Saiz-Rubio, V., Rovira-Más, F. (2020). From smart farming towards agriculture 5.0: A review on crop data management. Agronomy, 10(2), 207.

Skendžić, S. (2022). Vegetation Indices—Tools for Assessing the Condition of Wheat Crops. Plant Protection Bulletin, 22(3), 329-344.

Wójtowicz, M., Wójtowicz, A., Piekarczyk, J. (2016). Application of remote sensing methods in agriculture. Communications in biometry and crop science, 11(1), 31-50.

Xue, J., Su, B. (2017). Significant remote sensing vegetation indices: A review of developments and applications. Journal of sensors, 1353691.