

Precision Agriculture in Vegetable Production: Current Status and Future Prospects

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Abstract: -

Precision agriculture is an innovative farming approach that helps farmers manage crops more efficiently by using modern technologies such as sensors, drones, satellite images, and digital tools. In vegetable production, where crops require precise management of water, nutrients, and plant protection measures, precision agriculture can play an important role in improving productivity and resource use efficiency. This approach allows farmers to monitor field conditions in real time and apply inputs such as irrigation, fertilizers, and pesticides only where and when they are needed. As a result, it helps reduce input costs, increase crop yield, and improve vegetable quality while minimizing environmental impacts. At present, technologies such as drip irrigation, remote sensing, soil sensors, and variable rate technology are increasingly being used in vegetable farming in many parts of the world. However, the adoption of precision agriculture is still limited in many developing countries due to high initial investment, lack of technical knowledge, and limited infrastructure. With the rapid development of digital agriculture, artificial intelligence, and Internet of Things (IoT) technologies, the future of precision agriculture in vegetable production looks very promising. Wider adoption of these technologies can contribute to sustainable vegetable production, better farm profitability, and improved food security.

Keywords: *Precision agriculture, vegetable production, remote sensing, smart irrigation, sustainable farming etc.*

Introduction:

Vegetable production plays an important role in providing nutrition, food security, and income for farmers. However, vegetable farming often requires high amounts of water, fertilizers, pesticides, and labour. In recent years, farmers and researchers have

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started adopting precision agriculture to manage these resources more efficiently. Precision agriculture is a modern farming approach that uses technologies such as sensors, satellite images, drones, and digital tools to monitor crops and manage fields more accurately (Padhiary et al., 2025).

The main goal of precision agriculture is to apply the right input, at the right place, and at the right time. This approach helps improve crop productivity, reduce input costs, and protect the environment.

Concept of Precision Agriculture in Vegetable Crops

The concept of precision agriculture is based on collecting real-time data using tools such as sensors, GPS, drones, and remote sensing systems. These technologies allow farmers to assess soil moisture, nutrient status, and crop health at a micro level. By analyzing this data, farmers can make informed decisions about irrigation, fertilization, and pest management. This reduces input wastage and ensures that crops receive exactly what they need for optimal growth (Saha et al., 2025). Recent studies highlight that precision agriculture integrates Artificial Intelligence (AI), Internet of Things (IoT), drones, and machine learning for better decision-making in vegetable cultivation. These technologies assist in yield prediction, disease detection, and efficient farm management, ultimately

enhancing productivity and quality of vegetables (Rajput et al., 2026)

Moreover, site-specific nutrient management and variable rate technology (VRT) ensure balanced fertilization, which improves soil health and reduces environmental pollution (Chaudhari et al., 2024). Vegetable crops such as tomato, potato, cucumber, capsicum, and leafy vegetables are highly sensitive to nutrient, water, and environmental conditions. Therefore, precision agriculture can play a significant role in improving their growth, yield, and quality.

Current Status of Precision Agriculture in Vegetable Production

1. Use of Sensors and IoT Technology

Soil moisture sensors, temperature sensors, and nutrient sensors are widely used in precision farming. These devices collect real-time data from the field and help farmers make better decisions about irrigation and fertilization. IoT-based systems can automatically control irrigation and monitor crop conditions through mobile applications or digital platforms (Hasib & Akib, 2026).

2. Precision Irrigation and Fertigation

Water management is very important in vegetable crops. Precision irrigation systems such as drip irrigation combined with sensors can deliver water directly to the root zone based on crop requirements. Studies have shown that smart irrigation systems can reduce

water use by up to 40% while maintaining good crop growth (Sembrar, 2024).

Similarly, fertigation systems allow nutrients to be applied through irrigation water in controlled amounts, which improves nutrient efficiency and reduces fertilizer losses.

3. Remote Sensing and Drones

Remote sensing technologies, including satellite images and drones, help monitor crop health, soil moisture, and pest infestation. These technologies allow farmers to detect problems early and take corrective measures before major damage occurs (Yasrab et al., 2021).

Drones are also used for targeted spraying of pesticides and fertilizers, which reduces chemical use and labor costs.

4. Variable Rate Technology (VRT)

Variable rate technology allows farmers to apply fertilizers, pesticides, and water at different rates across the field depending on crop needs. Research shows that such systems can increase vegetable yields by 20–30% while reducing water use and input wastage (Zinkernagel, 2024).

Benefits of Precision Agriculture in Vegetable Production

Precision agriculture offers several advantages in vegetable farming:

- ⇒ **Efficient use of resources:** Reduces water, fertilizer, and pesticide wastage.

- ⇒ **Higher crop yield:** Better monitoring and management improve crop productivity.

- ⇒ **Improved crop quality:** Balanced nutrient and water supply enhances vegetable quality.

- ⇒ **Lower production costs:** Reduced inputs and labor increase farm profitability.

- ⇒ **Environmental protection:** Minimizes pollution and conserves natural resources.

Studies indicate that precision farming can increase vegetable yield by 10–20% while reducing input use by 15–30% (FAO, 2022).

Challenges in Adoption

Although precision agriculture has many benefits, its adoption in vegetable farming is still limited in many developing countries. Some common challenges include:

- ⇒ High initial cost of equipment
- ⇒ Lack of technical knowledge among farmers
- ⇒ Small landholdings
- ⇒ Limited access to digital infrastructure

Training programs, government support, and farmer producer organizations (FPOs) can help overcome these challenges.

Future Prospects

The future of precision agriculture in vegetable production is very promising. With the advancement of digital technologies,

farmers will have better access to real-time information and decision-support systems.

Emerging technologies such as artificial intelligence, machine learning, robotics, and advanced sensors will further improve crop monitoring and management. Integration of satellite data, drones, and mobile applications will allow farmers to manage crops more precisely and sustainably (Padhiary et al., 2025).

In the coming years, precision agriculture is expected to become an essential part of vegetable farming, helping farmers increase productivity while conserving resources and protecting the environment.

Conclusion

Precision agriculture is transforming vegetable production by introducing advanced technologies for better crop management. Tools such as sensors, drones, remote sensing, and automated irrigation systems help farmers use resources efficiently and improve crop productivity. Although challenges exist, increasing awareness, technological advancements, and government support will encourage wider adoption. Precision agriculture will play a crucial role in making vegetable farming more profitable, sustainable, and climate-resilient in the future.

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