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# Smart Viticulture: Integrating IoT, AI, and Remote Sensing For Sustainable Grape Production

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# INTRODUCTION

Precision agriculture is a farming management approach to agriculture that leverages advanced technologies to optimize resource. It is a modern approach to agriculture that uses advanced technologies to maximize resource. It helps us to increase crop yield, enhance sustainability of agriculture practices, and reduce waste. Precision farming is a new approach that uses technology to optimize the efficiency and better utilization of agricultural practices. This includes the use of different types of advanced electric mechanical sensors, GPS technology, drones, and other mechanical tools to collect the data on soil health conditions, crop health, weather patterns, and other factors. This information is then used to make informed decisions about planting, irrigation, and fertilization, and pest control. Farmers can increase maximum yields while traditional farming methods and offers innovative solutions. It aims to enhance efficiency and sustainable farming operations by enhancing efficiency and sustainability.

# The Benefits of Precision Agriculture

- 1. **Increased Yield:** Precision farming (PA) is a technique used to advance farming techniques. With the help of the helps we improved technologies and optimized resources. As well as the results to improve yields.
- ✤ Factor affecting the yield by the use of precision farming.
  - Smart and skilled with machinery.
  - Data analysis and decision support system (DSS) is a software used for data analysis and decision support.
  - Sustainability of precision farming depends on the sustainability of precision farming.
  - ✤ The cropping system.
  - ✤ The water management.
  - Soil texture, Quality of soil and soil health.



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2. Data collection tools and technologies: Data collection is the process of collecting data with the help of different machines, sensors, remote operating devices. The results are used to increase yield and improve agriculture resources.

Commonly used data collection tools are.

**Global positioning system (GPS):** The global positioning system helps us to track equipment, monitor planting and harvesting locations, and map fields etc.

**Remote sensing:** Provide data on crop health, moisture arability of plants, disease or pests attack in plants, and water uses using multispectral or hyper spectral images.

**Soil Sensors:** A soil sample is a mechanical electronic device that helps us to measure soil pH, soil moisture content, nutrient levels in real time in plants or deficiency of nutrient elements in soil. These sensors are used in field to increase field productivity and better management.

Weather Stations: Weather stations assist in improving agricultural practices. Weather stations provide localized, real-time weather data that improves decision making for efficient farming practices as well as the results to proper knowledge about the weather and climate Etc.

Grapes are the most widely grown commercial fruit crop in the world, and they are highly popular in horticulture. Grape farmers continue to look for ways to increase their profits. One effective method is to utilize modern technology to improve production. Precision Viticulture, or PV, is the use of advanced technology to grow grapes more efficiently. It helps improve grape quality, reduce environmental impact, and reduce risk for farmers and processors. PV uses GPS, weather sensors, remote sensing (satellite and drone images) and GIS (Geographic Information Systems) to monitor and manage vineyards.

With PV, farmers are able to better control soil health, fertilizer use, irrigation, pest management, and harvesting. This helps reduce the use of fertilizers, water, and pesticides while improving grape yield and quality. Precision viticulture is a smart farming method that is used in vineyards to improve grape growth. It helps produce more and better-quality grapes, while also reducing harm to the environment and lowering risks for farmers.

#### **Applications of Smart Vineyard Management**

Precision Viticulture utilizes modern technology to improve grape farming for commercial production. It helps farmers grow more grapes with better quality while reducing costs and environmental impact by helping them reduce costs. PV applications include soil and fertilizer management, intelligent irrigation, pest and disease control, and optimized harvesting. Tools like GPS, drones, and sensors provide real-time data, which helps farmers make better decisions and maximize productivity while using fewer resources efficiently (Figure.1).



Fig.1 The process Applications of smart vineyard management.



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The precision process in viticulture (Figure 1) starts with mapping the vineyard's yield and gathering additional important information. This information is then analysed and evaluated in order to make better management decisions. After applying these decisions, the vineyard is observed again in order to check the results. This process of gathering and using data continues in a cycle, leading to gradual improvements in vineyard management. Over time, the data gathered during observation can be used to predict future outcomes.

## **Canopy Management in Viticulture:**

The most widely used practice by farmers and wineries is to monitor the grapevine canopy and growth. This is because it provides detailed and timely information throughout the growing season. This information is useful for managing the canopy, applying fertilizers, and controlling irrigation effectively.

Researchers have investigated how to measure the leaf area index (LAI) in vineyards using mobile laser scanners. They tried three different lengths of rows: 0.5 meters, 1 meter, and 2 meters. The results showed that different calculation methods are needed for different row lengths. The method used for short rows (0.5 meters) is different from the method used for longer rows (1 and 2 meters).

#### **Crop Load Monitoring**

Managing crop load in vineyards is important for good-quality grapes and healthy vine growth. The crop load refers to the balance between the leaf area and the fruit weight. If there are too many leaves, they create too much shade, which reduces fruit quality and can affect future grape production. If there are too few leaves, the grapes take longer to ripen, and the vines may not grow well. Farmers use crop load measurements to assess if their vineyard management is effective. One common way to measure crop load is the Ravaz index, which combines the total grape yield with the weight of the pruned branches. Remote sensing using optical technology helps map important crop features like plant cover, row direction, and leaf area index in precision viticulture. This information is then used to support better vineyard management decisions (Figure.2).



Fig.2 Process of Crop Load Monitoring.

## Practice Management Berry Quality:

Investigate an approach to delineate withinvineyard quality zones that incorporates an estimator of sink size in the data-set. Zone delineation was performed using normalized differences between vegetation index (NDVI), soil apparent electrical conductivity (ECa) and bunch number (BN) data. The source-to-sink size ratio is the balance between leaves and grape bunches, which produce energy through



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photosynthesis, and which use this energy. This balance is important for making wine. However, it is difficult to estimate the sink size remotely. Because of this, precision viniculture divides vineyards into different zones using vegetation indices. While this method helps, it has only been successful in identifying areas with different grape quality levels.

Different types of sensors were used to check berry quality and their management: multiplex sensor, hyperspectral sensor, electrochemical sensor, handheld refractometer, multiplex sensor etc.

#### **Disease Management:**

Diseases caused by insects, germs, and other infections can be a big problem for grapevines. Sometimes, diseases spread rapidly and damage the entire vineyard. For example, grapevines can be easily infected with powdery mildew at the beginning of the growing season, which can harm their growth and fruit quality. This method uses image analysis to automatically detect powdery mildew on grapevine leaves. Powdery mildew is a serious fungal disease that affects grapevines and other important crops. This disease causes yield loss and lowers the quality of wine and produce. Experts believe that using optical sensors up close is a promising way to detect the disease early. However, it is difficult to identify mildew in its early to middle stages because the fungus is small, thin, and spread out, which makes it difficult to identify it. Researchers in the lab tested multi-spectral images of vine leaves and found that detection improved at wider angles, with the best results at a  $60^{\circ}$  view.

## Harvest Management:

Researchers tested a robot in a greenhouse by placing potted grapevines with different disease levels in potted plants with different disease levels. They found that the robot was able to detect and spray 85% to 100% of the infected areas automatically. Furthermore, it also reduced pesticide use by 65% to 85% compared to traditional spraying methods. Ripening grapes is important for making high-quality wine and other grape products. This process takes time and is influenced by both natural climate conditions and the way the vineyard is arranged, along with the type of grape variety planted. Since ripening is complex, it is impossible to measure it by only one factor.

#### CONCLUSION

Recent developments in precision viticulture have gained a lot of attention in vineyards in developed countries. Precision viticulture uses modern technologies like GPS, weather and environmental sensors, satellite images, drones, and mapping systems (GIS) to study and manage differences in the vineyard. Viticulture precision is a very new technology in Turkey. Precision viticulture relies on advanced technologies, including GPS, weather and environmental sensors, satellite and drone-based imaging, and geographic information systems (GIS), for precision viticulture. Precision viticulture tool to manage variations in vineyard conditions, allowing for better decision-making and improved crop quality. Precision viticulture tools are extremely important for growing high-quality grapes. They use advanced technology such as GPS, remote sensing, and environmental sensors to monitor vineyard conditions, use resources wisely, and control diseases. Farmers can make better decisions for each part of the vineyard with the help of these tools. This improves grape quality, improves yield, and reduces harm to the environment. Precision viticulture makes grape farming more efficient, sustainable, and able to meet modern needs.