

## Multisensory Systems for Smart Farming

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### INTRODUCTION

Smart farming represents the integration of information and communication technologies (ICT) into machinery, equipment, and sensors for use in agricultural production. One of the most transformative innovations in this domain is the application of multisensory systems, which collect and integrate data from diverse sources to provide a comprehensive picture of the farm environment. Unlike single-sensor systems, which can offer only a limited perspective, multisensory approaches leverage complementary sensor modalities to detect, analyze, and interpret a wider range of agricultural phenomena—leading to more precise and timely interventions. These systems are key enablers of precision agriculture, autonomous operations, and sustainable food production.

### 2. Components and Types of Sensors

A multisensory system for smart farming typically includes various types of sensors, each collecting specific data related to environmental conditions, crop health, soil quality, and more.

#### 2.1 Optical and Visual Sensors

These include RGB cameras, multispectral cameras, and hyperspectral sensors. They are used for:

- Crop monitoring (growth stages, color changes, leaf area)
- Disease detection
- Weed identification



Source: <https://www.mdpi.com>

#### 2.2 Thermal Sensors

Thermal imaging cameras detect temperature differences in plants and soil. Applications include:

- Water stress detection
- Irrigation planning
- Early disease diagnosis

### 2.3 Soil Sensors

Used to monitor:

- Soil moisture
- Nutrient levels (e.g., nitrogen, phosphorus, potassium)
- pH and salinity

### 2.4 Weather and Climate Sensors

Deployed in open fields and greenhouses to track:

- Temperature
- Humidity
- Rainfall
- Wind speed and direction

### 2.5 Acoustic and Vibration Sensors

These sensors detect sounds and vibrations for:

- Pest detection (e.g., insect activity in crops)
- Equipment monitoring

### 2.6 Gas and Chemical Sensors

Used for:

- Monitoring greenhouse gases (e.g., CO<sub>2</sub>, methane)
- Detecting volatile organic compounds (VOCs) from plant stress or soil emissions

### 2.7 Positioning and Motion Sensors

GPS and inertial measurement units (IMUs) help in:

- Mapping and navigation of autonomous equipment
- Field boundary tracking

## 3. Applications in Smart Farming

Multisensory systems are instrumental in revolutionizing conventional agriculture into an intelligent, data-based process. The systems are applied to numerous operations to offer real-time information, facilitate automation, and aid precise intervention tactics.

### 3.1 Precision Crop Management

By combining inputs from visual, soil, and weather sensors, farmers can apply fertilizers, pesticides, and water with precision. This eliminates wastage, saves costs, and increases crop yield and quality.

### 3.2 Livestock Monitoring

Multisensory wearables monitor animal health parameters like body temperature, heart rate, and movement. This information

enables the early detection of disease, enhancing animal well-being and minimizing losses.

### 3.3 Autonomous Vehicles and Robotics

Intelligent farming hardware such as drones and automated tractors use multisensory data to conduct operations autonomously, such as:

- Crop spraying
- Harvesting
- Weed detection and elimination

### 3.4 Greenhouse Automation

Sensors within greenhouses measure and control important variables such as illumination, humidity, and CO<sub>2</sub> levels. This automation provides ideal plant development conditions and reduces hands-on intervention.

### 3.5 Disease and Pest Forecasting

Sensor information, through analysis using AI software, can detect patterns that signal potential pest infestation or disease outbreaks. Early warnings allow for early intervention by farmers in taking preventive control measures that reduce crop losses and damage.

## 4. Advantages of Multisensory Systems

Multisensory systems bring revolutionary advantages to contemporary agriculture by combining various data streams for integrated farm management. With real-time, multisource data acquisition, farmers make well-informed, timely choices, ensuring accuracy and responsiveness. Such systems ensure resource efficiency through precise utilization of water, fertilizers, and pesticides, leading to cost savings and environmental protection. Timely problem detection enhances crop yield and quality, leading to productivity. Automation and remote sensing reduce dependency on human labor and increase efficiency. Furthermore, by reducing waste of inputs and improving ecological harmony, multisensory systems promote long-term sustainability in farming.

## 5. Challenges and Limitations

Multisensory systems have a lot to offer, yet they also have real-world challenges that can

discourage widespread implementation. The initial expense of buying and implementing sophisticated sensor networks can be out of reach for small and medium enterprises. Also, the sheer volume of generated data necessitates robust IT infrastructure and capable personnel for quality analysis and decision-making. Power supply and internet connectivity in most rural areas remain poor, restricting sensor operation and real-time monitoring. The absence of standardization by various brands of sensors makes integration complicated, routine maintenance and calibration are vital to maintain accuracy, raising operational complexity and long-term expenses.

## 6. Future Trends and Outlook

The future of multisensory systems in smart farming is being defined by fast-paced technology advancements that are focused on making things more efficient, precise, and sustainable. The fusion of Artificial Intelligence (AI) and Machine Learning (ML) will make deeper data analysis, predictive analysis, and self-governing decision-making possible.

Edge and cloud computing will enhance the speed of data processing and real-time response capabilities by routing workloads intelligently. WSNs are becoming more scalable and energy-efficient, making high-scale deployment more feasible. Seamless communication between devices will be made possible through IoT integration, which will facilitate centralized control of farms.

Further, advances in bio- and nano-sensors will enable highly sensitive real-time sensing of plant and soil states, opening the way to ultra-accurate agriculture.

## 7. CONCLUSION

Multisensory systems lie at the center of the smart farming revolution. Through facilitating the convergence of various environmental information, these systems give farmers real-time information, maximum resource efficiency, and anticipation-based management. Though issues of cost, complexity, and infrastructure persist, continued technological breakthroughs hold the promise of rendering multisensory systems more affordable and efficient. Their increasing uptake will be instrumental in securing global food supply alongside ensuring environmental sustainability.

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