



## VERTICAL FARMING AUTOMATION WITH AI ROBOTS BOOSTING URBAN VEGETABLE YIELDS

Ravi Kumar Singh<sup>1</sup> and Radheshyam Ramkrishna Dhole<sup>\*2</sup>

### Abstract: -

*Rapid urbanization, shrinking arable land, and climate change are major challenges to global food production. Vertical farming, combined with artificial intelligence (AI) and robotic automation, has emerged as a revolutionary solution for sustainable urban agriculture. By growing crops in stacked layers within controlled environments, vertical farming maximizes space utilization and ensures year-round production. The integration of AI-powered robots enables precise monitoring, planting, harvesting, and resource management, significantly improving productivity and efficiency. These systems reduce labor dependency, optimize inputs such as water and nutrients, and enhance crop quality. This article explores the classification, types, characteristics, applications, and advantages of AI-driven automation in vertical farming, with a focus on boosting vegetable yields in urban settings. It also highlights future strategies for scaling this technology to meet the growing demand for fresh and sustainable food.*

**Keywords:** *Vertical farming, AI robots, urban agriculture, smart farming, automated systems etc.*

### Introduction:

Urban populations are increasing rapidly, leading to higher demand for fresh vegetables and limited availability of agricultural land. Traditional farming methods often depend on climatic conditions and require large areas, making them unsuitable for densely populated cities. Vertical farming addresses these challenges by growing crops indoors in vertically stacked layers using controlled environmental conditions.

**Ravi Kumar Singh<sup>1</sup> and Radheshyam Ramkrishna Dhole<sup>\*2</sup>**

<sup>1</sup>Research Scholar (24MSH003), Department of Horticulture, Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University, Jamuhar, Sasaram, Rohtas – 821305

<sup>2</sup>Assistant Professor, Department of Entomology, Narayan Institute of Agricultural Sciences, Gopal Narayan Singh University, Jamuhar, Sasaram, Rohtas – 821305

The integration of artificial intelligence and robotics has further transformed vertical farming into a highly efficient and automated system. AI-powered robots can perform tasks such as seeding, transplanting, monitoring plant health, and harvesting with high precision. These systems use sensors, cameras, and machine learning algorithms to analyze plant growth and environmental conditions in real time.

Automation in vertical farming not only enhances productivity but also reduces the risks associated with pests, diseases, and weather fluctuations. Studies indicate that robotic vertical farms can produce significantly higher yields compared to conventional farming systems while using less water and land.

## Key Highlights

### 1. Classification of Vertical Farming

#### Automation Systems

Vertical farming automation can be classified based on technological integration:

#### a) Fully Automated Systems

- ☞ Operate with minimal human intervention
- ☞ Use AI algorithms, robotics, and IoT for complete control
- ☞ Suitable for large-scale commercial farms

#### b) Semi-Automated Systems

- ☞ Combine manual labor with automated processes
- ☞ Farmers monitor systems while robots handle repetitive tasks

#### c) Modular Systems

- ☞ Scalable units that can be expanded based on demand
- ☞ Ideal for urban setups and container farms

#### d) Smart Controlled Environment Systems

- ☞ Maintain optimal temperature, humidity, CO<sub>2</sub> levels, and lighting
- ☞ Ensure consistent crop growth regardless of external conditions

These classifications reflect the adaptability of vertical farming systems in different urban environments.

### 2. Types of AI Robots Used in Vertical Farming

#### a) Planting Robots

- ☞ Automatically sow seeds at precise depths and spacing
- ☞ Can plant thousands of seedlings per hour with high accuracy

#### b) Monitoring Robots

- ☞ Equipped with cameras and sensors
- ☞ Detect plant stress, diseases, and nutrient deficiencies

#### c) Harvesting Robots

- ☞ Use AI vision systems to identify ripe vegetables

- ☞ Perform delicate harvesting without damaging crops

#### d) Pruning and Maintenance Robots

- ☞ Trim plants and optimize growth patterns
- ☞ AI-guided pruning improves plant health and yield (EVS Robot)

#### e) Transport Robots

- ☞ Move trays of plants between growth stations
- ☞ Reduce manual labor and improve workflow efficiency

These robots work together to create a fully automated farming ecosystem.

### 3. Characteristics of AI-Based Vertical Farming

- ⇒ **High precision:** AI ensures accurate input application and crop management
- ⇒ **Continuous monitoring:** Real-time data collection and analysis
- ⇒ **Space efficiency:** Multi-layer farming increases productivity per unit area
- ⇒ **Resource optimization:** Efficient use of water, nutrients, and energy
- ⇒ **Year-round production:** Controlled environments eliminate seasonal limitations

Vertical farming systems integrate robotics, AI, and data analytics to optimize crop growth and reduce environmental impact.

### 4. Application Methodology

The implementation of AI-based vertical farming involves several steps:

#### Step 1: Infrastructure Setup

- ☞ Construction of vertical racks or towers
- ☞ Installation of LED lighting and climate control systems

#### Step 2: Sensor and AI Integration

- ☞ Deployment of sensors to monitor environmental parameters
- ☞ Integration of AI software for data analysis

#### Step 3: Robotic Deployment

- ☞ Installation of robots for planting, monitoring, and harvesting

#### Step 4: Crop Selection

- ☞ Selection of suitable vegetables such as lettuce, spinach, herbs, and tomatoes
- ☞ Leafy greens dominate due to their short growth cycles

#### Step 5: Automated Operations

- ☞ AI systems control irrigation, lighting, and nutrient delivery
- ☞ Robots perform farming operations with minimal human intervention

#### Step 6: Data Analysis and Optimization

- ☞ Continuous monitoring and improvement of crop performance
- ☞ Use of machine learning to refine farming strategies

This methodology ensures efficient and scalable urban vegetable production.

## 5. Advantages of AI-Driven Vertical Farming

- a) **Increased Yield-** Vertical farms can produce significantly higher yields compared to traditional farming. Some systems achieve multiple times higher productivity per unit area.
- b) **Efficient Land Use-** Vertical stacking allows maximum production in minimal space, making it ideal for urban areas.
- c) **Water Conservation-** Advanced systems use up to 90–95% less water than conventional farming due to recirculation and precision irrigation.
- d) **Reduced Labor Costs-** Automation minimizes the need for manual labor, lowering operational costs.
- e) **Improved Crop Quality-** Controlled environments ensure uniform growth and higher-quality produce.
- f) **Reduced Chemical Use-** Indoor systems minimize pest and disease risks, reducing the need for pesticides.
- g) **Sustainability-** Lower transportation needs and efficient resource use reduce the carbon footprint.

## 6. Applications in Urban Vegetable Production

AI-based vertical farming is particularly suitable for urban vegetable crops:

- ⇒ **Leafy Greens (Lettuce, Spinach):** Fast-growing and highly adaptable to indoor systems
  - ⇒ **Herbs (Basil, Mint):** High demand and easy automation
  - ⇒ **Tomatoes:** Robotic pollination and harvesting improve productivity
  - ⇒ **Strawberries:** AI robots ensure delicate handling and high-quality yield
  - ⇒ **Microgreens:** Short growth cycles and high market value
- Companies like iFarm and Stacked Farm are already using AI-driven automation to produce large quantities of vegetables in urban environments.

### Future Strategies

The future of vertical farming automation with AI robots is promising, with several advancements expected:

1. **Integration with Advanced AI and Machine Learning-** AI systems will become more predictive, enabling early detection of crop issues and automated decision-making.
2. **Development of Autonomous Farming Systems-** Fully autonomous farms will operate with minimal human intervention, from planting to harvesting.
3. **Expansion in Urban Areas-** Vertical farms will be integrated into residential

buildings, supermarkets, and urban infrastructure.

#### 4. Energy Efficiency Improvements-

Use of renewable energy sources and energy-efficient LED lighting will reduce operational costs.

#### 5. Diversification of Crops-

Advancements in technology will allow cultivation of a wider range of vegetables, including root crops.

#### 6. Affordable Technology for Small Farmers-

Development of low-cost automation systems will enable wider adoption in developing countries.

### Conclusion

Vertical farming automation with AI robots represents a transformative approach to urban vegetable production. By combining advanced technologies such as robotics, artificial intelligence, and controlled environment agriculture, this system offers a sustainable solution to the challenges of food production in urban areas. It enhances productivity, optimizes resource use, and reduces environmental impact, making it a key component of future agriculture. As technological advancements continue and costs decrease, AI-driven vertical farming is expected to play a crucial role in ensuring food security and sustainability in rapidly growing urban populations.

### References

1. Găgeanu, I., et al. (2025). *Automation and robots in vertical farming*. Acta Horticulturae.
2. Materials Today Proceedings (2023). *Automatic robotic system design for vertical hydroponic farming*.
3. Strategic Market Research (2024). *Indoor Farming Robots Market Report*.
4. Khaberni (2025). *Automation of Vertical Farms: Robots in Indoor Farming*.
5. EVS Robotics (2025). *AI Pruning in Vertical Farms*.

