## **Extension Roadmap for Research-Driven Variants**

The HydroFarmIoT system was designed with flexibility and extensibility in mind. Future research-driven variants of the project can build on this foundation to expand functionality, introduce intelligent decision-making, and scale up to more complex agricultural setups.  
  
• Automated Nutrient Dosing: Introduce real-time control of nutrient levels using peristaltic pumps, guided by TDS readings and crop-specific nutrient needs.  
  
• Environmental Sensing Expansion: Integrate additional sensors such as air humidity, ambient temperature, and CO₂ concentration to enable full environmental monitoring and closed-loop control.  
  
• AI and Predictive Control: Incorporate machine learning algorithms to learn from historical sensor data and optimize dosing strategies for maximum plant health and resource efficiency.  
  
• Solar-Powered and Off-Grid Operation: Add photovoltaic panels with battery management to support sustainable, off-grid deployment in rural or underserved areas.  
  
• Mobile App and Cloud Integration: Develop a companion mobile app for remote access, alert notifications, and cloud-based logging of sensor data.  
  
• Data Logging and Visualization: Store sensor readings in a database (e.g., InfluxDB or Firebase) and visualize long-term trends using tools like Grafana or advanced Node-RED dashboards.  
  
• Multi-Tank or Multi-Zone Support: Scale the system to support multiple reservoirs or grow zones, allowing for diversified plant types and environmental conditions.  
  
• Integration with Agricultural Platforms: Connect HydroFarmIoT to larger agricultural or smart city platforms for broader ecosystem management.  
These extensions offer significant opportunities for academic research, industrial application, and development of commercial-grade hydroponic automation systems.