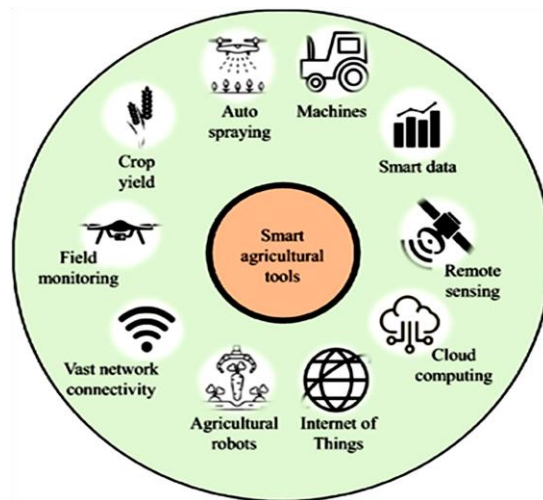


## Digital Tools to Ensure Sustainable Food Systems: Opportunities and Challenges

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### Introduction:

As of **2025**, the global food system faces a dual crisis: a rapidly climbing population nearing **9.7 billion by 2050** and the intensifying disruptions of climate change. Traditional farming is under immense pressure to "produce more with less." In response, the integration of digital tools—often termed **Agriculture 4.0**—has emerged as the primary vehicle for ensuring long-term food security and environmental sustainability.



### The Opportunities: High-Tech Sustainability

Digital transformation across the food value chain is optimizing resources and reducing environmental footprints in ways previously unimaginable.

#### 1. Precision Agriculture and AI-Driven Resilience

Modern agriculture has moved beyond trial and error. Using IoT (Internet of Things) sensors and AI, farmers now engage in "hyperlocal" management.

🔧 **Water Conservation:** Smart irrigation systems managed by moisture sensors

can reduce water usage by up to **30%** while simultaneously improving crop quality.

🔧 **Disaster Mitigation:** According to the **FAO 2025 report** on disasters, early warning systems (like GIEWS) now enable anticipatory actions that yield a return of up to **seven dollars** for every dollar invested.

🔧 **Real-time Insights:** AI-powered image analysis can now detect crop stress, pest damage, and nutrient deficiencies in real-time, allowing for targeted pesticide application rather than blanket spraying.

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## 2. Transparency via Blockchain and Smart Contracts

The "seed to shelf" journey is no longer a black box. Blockchain provides an immutable, decentralized ledger for food products.

- ☞ **Traceability:** Consumers can scan a QR code to verify a product's origin, reducing fraud by an estimated **50%**.
- ☞ **Efficiency:** Blockchain-AI integration has demonstrated a **35% decrease in operating expenses** and a **75% increase in transparency** for supply chain stakeholders.
- ☞ **Carbon Markets:** Digital monitoring allows for the precise measurement of soil carbon, helping farmers access the **carbon credit market** as a new revenue stream.

## 3. Reducing Food Loss and Waste

Currently, nearly **one-third** of all food produced is lost or wasted.

- ☞ **AI Analytics:** Predictive models forecast demand with high accuracy, reducing surplus.
- ☞ **Smart Cold Chains:** IoT-enabled refrigeration tracks temperature throughout transit, significantly reducing spoilage in perishable goods.

## The Challenges: Barriers to Global Adoption

Despite the immense potential, several structural hurdles remain that could prevent these tools from reaching their full impact.

### Key Statistics for 2025

- ☞ **Market Growth:** The Global Digital Agriculture Market is growing at a **CAGR of 10.6% (2025–2032)**.

**Table: - The Challenges: Barriers to Global Adoption**

Challenge	Detail & Impact
<b>The Digital Divide</b>	Over <b>2.6 billion people</b> remain offline globally. Most of these individuals are in rural areas where sustainable transformation is needed most.
<b>High Upfront Costs</b>	While the Digital Agriculture market is expected to reach <b>\$47.92 billion by 2032</b> , the initial investment for drones, sensors, and AI software remains prohibitive for smallholder farmers.
<b>Data Governance</b>	Issues regarding data ownership, privacy, and cybersecurity create trust barriers. There is a risk of "technological exclusion" where only large-scale commercial farms can afford to compete.
<b>Electronic Waste</b>	The manufacturing of millions of sensors and the energy consumption of AI data centers introduce new environmental footprints.

☞ **Yield Gap:** Digital advisory services are critical in closing the yield gap in regions like Asia-Pacific, which accounts for **47% of global agricultural losses** due to disasters.

☞ **Insurtech:** Over **9.1 million farmers** now access parametric insurance through digital platforms, shifting from reactive crisis management to proactive resilience.

### Conclusion

Digital tools are the "central nervous system" of a sustainable food system. They provide the data needed to manage resources ethically and the transparency required to build consumer trust. However, for this revolution to be truly "sustainable," it must be **inclusive**. Policymakers must prioritize digital literacy and infrastructure in developing regions to ensure that the transition to a **high-tech food** system does not leave the world's most vulnerable producers behind.

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