



## Data Analytics and Artificial Intelligence in Farm Economics

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Farm economics has traditionally focused on the efficient allocation of scarce resources—land, labor, capital, and management—to maximize farm profitability and ensure sustainability. Classical and neoclassical economic models emphasized production functions, cost curves, marginal analysis, and market price mechanisms to guide decision-making at the farm level. However, modern agriculture operates under increasing complexity driven by climate variability, volatile markets, input price fluctuations, environmental regulations, and global supply chain disruptions. These dynamic conditions have made traditional static decision tools insufficient for managing contemporary agricultural enterprises.

The emergence of data analytics and Artificial Intelligence (AI) represents a transformative shift in farm economics. The rapid expansion of digital agriculture—through sensors, satellite imagery, drones, farm management software, and online commodity markets—has generated vast amounts of structured and unstructured data. Big data technologies allow storage and processing of information related to soil health, crop growth, pest incidence, livestock productivity, weather patterns, and market demand. AI techniques, including machine learning, deep learning, and predictive modeling, enable the extraction of meaningful insights from these datasets.

In recent years, research published in journals such as the *Journal of Big Data and Sustainability* highlights how predictive analytics improves crop yield forecasting, cost optimization, and risk mitigation (Chergui & Kechadi, 2022; Ali et al., 2025). The integration of AI into farm economics enhances productivity, reduces resource waste, improves environmental sustainability, and supports evidence-based policymaking. With climate change intensifying production risks, AI-driven analytics are increasingly critical for adaptive farm management strategies.

### Conceptual Framework

#### Farm Economics

Farm economics examines how agricultural producers allocate resources to maximize returns under uncertainty. It includes cost analysis, revenue forecasting, risk management, and market behavior assessment. Economic efficiency, both technical and allocative, remains central to farm decision-making.

## Data Analytics

Data analytics refers to systematic computational analysis of data to discover patterns and support decision-making. In agriculture, it includes descriptive analytics (what happened), diagnostic analytics (why it happened), predictive analytics (what will happen), and prescriptive analytics (what should be done).

### Artificial Intelligence (AI)

AI encompasses computational techniques that mimic human intelligence. In agriculture, AI includes:

- Machine Learning (ML)
- Deep Learning (DL)
- Neural Networks
- Computer Vision
- Natural Language Processing

AI enhances farm economic decisions by modeling nonlinear relationships between inputs (fertilizers, water, labor) and outputs (yield, profit).

### Precision Agriculture and Data Science Synergy

Precision agriculture integrates spatial data, IoT devices, and analytics to manage field variability. Data science tools convert field-level variability into economic decision metrics, allowing site-specific input application and reducing marginal costs.

### Farm Economic Decision Support Systems (DSS)

Modern DSS combine AI algorithms with economic models to optimize planting dates, irrigation scheduling, livestock feed ratios, and marketing timing. These systems reduce uncertainty and enhance profitability.

## Data Sources in Farm Economics

The foundation of AI-driven farm economics lies in diverse data streams:

- IoT sensor data (soil moisture, temperature, humidity)
- Satellite imagery and drone-based remote sensing
- Weather and climate forecast datasets
- Commodity market price data
- Farm operational data (input use, labor records, yield history)

**Table 1. Key Data Sources Used in Farm Economic Analytics**

Data Source	Origin	Uses	Relevance to Economic Decision
Weather Data	IoT & Forecast APIs	Yield forecasting	Input timing & risk management
Satellite Imagery	Remote Sensing	Crop health & soil quality	Cost optimization
Market Data	Commodity exchanges	Price prediction	Revenue forecasting
Farm Records	Farm management systems	Input-output analysis	Profitability assessment
Livestock Sensors	Wearable devices	Health monitoring	Productivity improvement

The integration of these heterogeneous datasets enhances predictive capacity in farm economics.

## Machine Learning & Predictive Analytics Models

AI models applied in farm economics include:

### Regression Models

- Linear regression for yield prediction.
- Logistic regression for disease probability assessment.
- Useful for cost–benefit and marginal analysis.

## Decision Trees and Random Forests

- Handle nonlinear relationships.
- Identify critical variables affecting productivity.

## Deep Learning

- Convolutional Neural Networks (CNNs) for crop disease detection.
- Image recognition for yield estimation.
- Livestock behavior monitoring.

## Time Series Forecasting

- ARIMA models for price forecasting.
- LSTM neural networks for yield and climate pattern prediction.

Applications include:

- Yield prediction models for profitability analysis.
- Market price forecasting for strategic selling.
- Cost minimization using predictive trimming (input optimization).

Research by Chergui & Kechadi (2022) demonstrates the growing role of big data analytics in crop management and economic optimization.

## Farm Economics Use-Cases

### a) Precision Farming

AI-driven precision agriculture allows variable-rate application of fertilizers and irrigation based on soil and crop variability. This reduces input waste and improves economic returns. Farmers can apply inputs where marginal productivity is highest, aligning with the Law of Equimarginal Returns.

### b) Livestock Economics

AI in livestock systems includes automated health monitoring, feed optimization, and disease detection using computer vision and sensors. According to Menezes (2024), AI-enabled livestock management enhances productivity and reduces veterinary costs.

### c) Dairy & Livestock Yield Forecasting

Machine learning models predict milk yield and feed efficiency, enabling better production planning. Scoping reviews show AI improves herd productivity while reducing feed costs and carbon footprint.

## Economic Impact & Sustainability

AI enhances farm profitability by:

- Increasing yield accuracy
- Reducing input waste
- Optimizing marketing strategies
- Minimizing post-harvest losses

Predictive analytics supports sustainable resource use, reducing excessive fertilizer and water application. AI-driven supply chain optimization reduces food waste and improves price realization.

Evidence suggests that digital agriculture technologies significantly improve both economic output and environmental sustainability.

## Challenges & Constraints

Despite benefits, several challenges exist:

- Data quality and integration problems
- High technology adoption costs
- Limited technical literacy among farmers
- Infrastructure gaps in rural regions
- Ethical concerns and data privacy issues

Smallholder farmers often face financial and digital access barriers, limiting equitable adoption.

## Policy and Adoption

Government policies play a crucial role in AI adoption:

- Subsidies for digital technologies
- Rural broadband infrastructure
- Training and extension programs
- Public-private partnerships

Effective policy frameworks ensure inclusive growth and prevent digital inequality in agriculture.

## Future Directions

Future developments include:

- Integration of IoT, AI, and edge computing
- Use of large language models for advisory systems
- Federated learning for privacy-preserving farm data sharing
- Climate-resilient predictive analytics

Emerging research such as Farm-LightSeek (2025) demonstrates edge AI deployment for real-time agricultural decision-making.

## Conclusion

Data analytics and artificial intelligence are redefining farm economics by transforming data into actionable economic insights. From yield forecasting and price prediction to livestock monitoring and supply chain optimization, AI enhances efficiency, profitability, and sustainability. However, challenges related to data quality, affordability, and policy frameworks must be addressed to ensure inclusive adoption. The integration of AI into farm economic systems represents not merely technological advancement but a paradigm shift toward data-driven, resilient, and sustainable agricultural development.

**Table 2. Major AI Techniques in Farm Economics**

Technique	Description	Farm Economics Use	Example
Regression	Statistical forecasting	Crop yield prediction	ML models
Deep Learning	Pattern recognition	Disease detection	Neural networks
Time Series Forecasting	Predict future trends	Price & yield forecasting	ARIMA, LSTM
Random Forest	Ensemble learning	Risk classification	Profit variability prediction

## Case Studies of Data Analytics/AI in Farm Economics

Case	Region	Tech Used	Economic Outcome
<b>AI-enabled weather forecasting</b>	India	ML weather models	Better timing decisions for planting
<b>Smart connected farms</b>	Global	IoT + analytics	Improved sustainability & profitability
<b>Dairy herd optimization</b>	Europe	AI-based monitoring	Increased milk yield & reduced feed cost

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