# Methsense – A Data Driven IoT Based Decision Support & Crop Monitoring Platform for Menthol

**Authors** : **Dipti Ranjan** (Assistant Professor Babu Banarasi Das Institute of Technology & Management Lucknow),

**Akshita Pandey , Aditya Yadav** (Babu Banarasi Das Institute of Technology & Management Lucknow)

## Abstract

Mentha arvensis (menthol mint) is a high-value aromatic crop central to the agricultural economy of the Barabanki-Lucknow belt of Uttar Pradesh, yet its productivity remains constrained by traditional cultivation practices, limited technological adoption, and climate-driven uncertainties. This review synthesizes research advancements from 2021 to 2025, spanning agronomy, remote sensing, IoT-based monitoring, machine learning, digital advisory systems, and policy frameworks. Studies on AI-enabled irrigation, multimodal sensing, spectral vegetation indices, and improved cultivars highlight substantial opportunities for precision-driven interventions in mentha farming. IoT systems, solar-powered sensor networks, edge computing models, and predictive analytics demonstrate their potential to enhance irrigation scheduling, nutrient management, stress detection, and real-time decision support. Economic analyses and policy reports further emphasize mentha's profitability and its suitability for technology-led transformation. By integrating insights from agriculture, computer science, and rural development, this review presents a unified understanding of digital and scientific innovations relevant to Mentha arvensis and identifies future directions for building scalable, farmer-centric smart farming ecosystems such as MentholGrow.

## Keywords

Mentha arvensis; Menthol mint; Smart Agriculture; IoT-based monitoring; Machine Learning; Remote sensing; Precision farming; Edge computing; Decision-support systems; Aromatic crops; Digital agriculture; Uttar Pradesh; Barabanki-Lucknow belt.

## Introduction

Mentha arvensis (menthol mint) is a high-value aromatic crop central to the agricultural economy of the Barabanki_Lucknow belt in Uttar Pradesh. Despite its commercial significance, mentha cultivation continues to rely heavily on traditional farming practices, making it vulnerable to climatic variability, inefficient irrigation, soil nutrient imbalances, and inconsistent oil yields. These limitations highlight the need for more precise, data-driven interventions that can support smallholder farmers in improving, profitability, and sustainability.

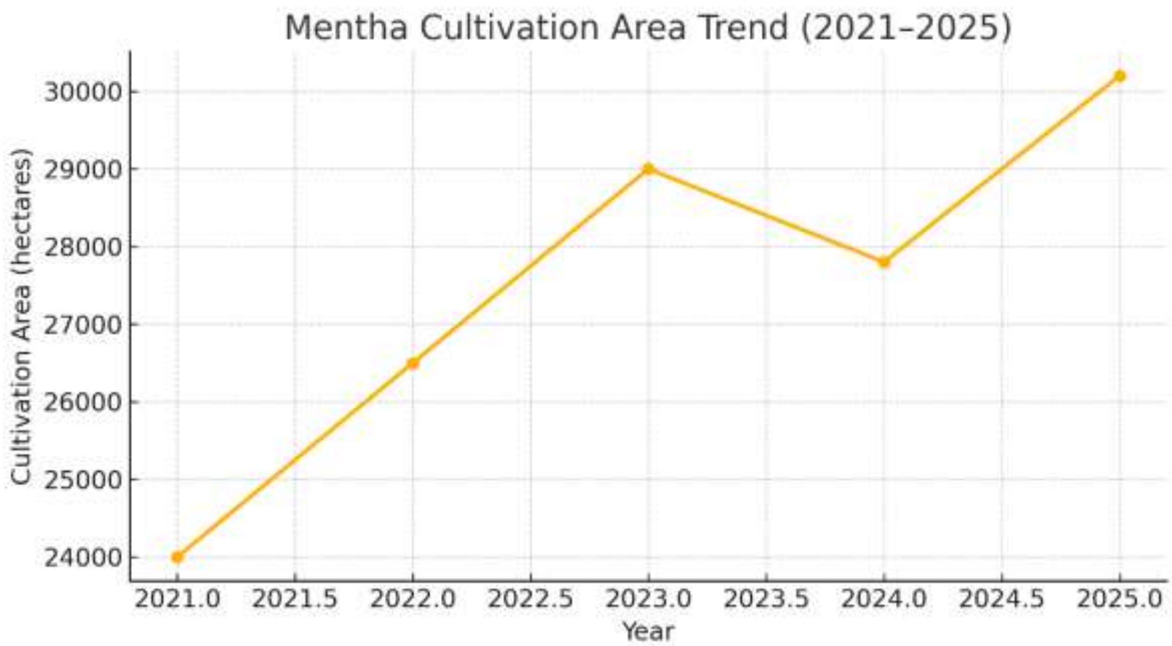
Recent research from 2021 to 2025 shows a rapid shift toward integrating digital technologies-such as IoT sensors, machine learning models, remote sensing tools, and solar-powered monitoring devices-into aromatic crop systems.

This review synthesizes key advancements across agronomy, Iot, AI/Ml, economics, and policy to establish a cohesive foundation for developing scalable, farmer-centric digital solutions such as MentholGrow.

## Review of Literature

Research on *Mentha arvensis* has gradually evolved from conventional agronomic investigations to more technologically oriented cultivation systems. Early studies[1–2] highlighted mentha as a highly profitable crop, showing that it consistently delivers better returns than common staples such as paddy and wheat. Subsequent agronomic work[3] validated improved varieties like CIM-Kranti, noting their higher oil yield, stronger sucker growth, and better adaptability to the growing conditions of central Uttar Pradesh. At the same time, remote-sensing based studies[4–5] demonstrated the usefulness of NDVI and multi-temporal satellite imagery for accurately mapping cultivation areas, identifying crop stress, and monitoring overall crop vigor, laying the foundation for digital field observation.

From 2020 onwards, the research landscape expanded rapidly toward digital agriculture, IoT integration, and machine-learning-based decision systems. Several studies[6] explored adaptive models for irrigation and nutrient management that improve sustainability and input efficiency. By 2024, engineering-focused research[7–9] had produced low-power sensor nodes, solar-enabled IoT systems, and edge-computing frameworks capable of supporting reliable real-time field monitoring even in rural environments. Parallel agronomic trials[10] further reinforced the need to incorporate spacing, irrigation patterns, and fertilizer interactions into predictive modelling. Policy-driven reports[11] supported these technological advancements by emphasizing the financial and institutional steps needed to scale aromatic-crop innovations across farming communities.




The latest body of research from 2025 reflects a clear shift toward multimodal AI systems, tightly integrated IoT pipelines, and predictive analytics specifically tailored for mentha cultivation. Studies[12] showed that digital irrigation scheduling and AI-assisted decision-making significantly improved farmer profitability, while further advancements[13–14] demonstrated how combining sensor data with image-based analysis can detect stress at early stages and deliver more accurate yield predictions. Complementary survey work, prototype development, and government analyses[15–17] collectively strengthened the view that mentha is well-suited for data-driven agriculture. Even so, persistent gaps remain, including limited localized datasets, the absence of bilingual farmer interfaces, weak integration of market information, and low adoption rates among smallholders[18]. These gaps create a clear need for holistic platforms like MentholGrow, which integrate agronomy, IoT sensing, machine learning, and economic insights into a single, farmer-centered decision-support ecosystem.

## Methodology of the Review

This review presents a structured and comprehensive examination of MethSense, an integrated digital agriculture platform designed to transform *Mentha arvensis* cultivation through IoT-based monitoring, AI-driven analytics, and remote-sensing intelligence. The project is built around the need to modernize menthol mint farming in regions such as the Lucknow–Barabanki belt, where productivity is strongly influenced by soil moisture fluctuations, climatic variability, and limited access to scientific decision-support tools. MethSense incorporates real-time sensor networks for continuous measurement of soil and environmental parameters, machine-learning models for irrigation prediction and early stress detection, and satellite-derived vegetation indicators to contextualize field-level observations. The system framework also integrates agronomic insights and economic intelligence to support farmers with timely, data-driven advisories. By synthesizing hardware design, software architecture, predictive modelling, and geospatial assessment into a unified platform, this review evaluates MethSense not only as a technological solution but as a holistic approach to improving crop health, input efficiency, and profitability in mentha cultivation. The analysis highlights the system's operational workflow, design rationale, potential for field deployment, and its broader relevance in promoting sustainable, technology-enabled agriculture.

## Overview of the MethSense Platform

MethSense is envisioned as an intelligent, farmer-centered decision-support system designed to modernize mentha cultivation. The platform integrates three major technological components:

1. IoT-based environmental sensing,
2. AI and machine-learning analytics,
3. Remote-sensing and NDVI-based vegetation monitoring.

The system operates on the principle of using low-cost, scalable technologies that can be easily deployed across rural farming landscapes. It collects continuous field data, processes it through predictive models, and delivers actionable advisories in simple language. The goal is not just automation, but meaningful decision support that aligns with local agronomic contexts and enhances farmer capability.

MethSense stands apart by providing a holistic framework rather than isolated technological tools. It offers a collaborative layer where real-time field conditions, satellite-derived vegetation trends, and machine-learning predictions come together to guide irrigation, stress management, and crop planning.

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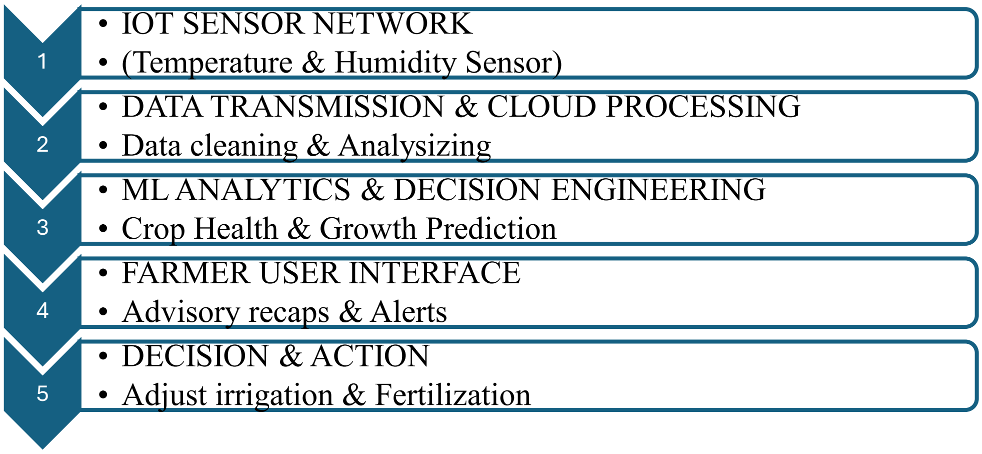


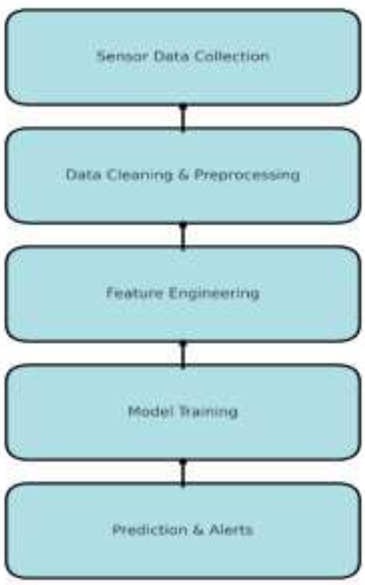

## IoT Architecture and Data Acquisition

At the core of MethSense lies its IoT sensor network. The hardware setup typically involves an ESP32 microcontroller connected to soil moisture probes, soil pH sensors, temperature–humidity sensors, and light-intensity modules. These sensors continuously record environmental variables that directly influence mentha growth.

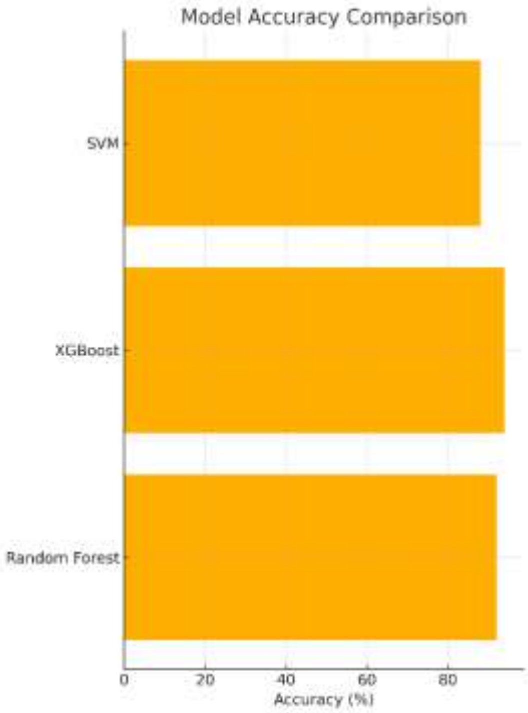
The system uses lightweight communication protocols such as MQTT to transmit data to a cloud platform. Each data packet carries a timestamp, sensor readings, and device ID, enabling structured storage and historical analysis. Calibration routines ensure that sensor values remain reliable across changing environmental conditions. The ability to collect continuous field data differentiates MethSense from traditional agronomic methods, allowing farmers to detect subtle changes long before visible symptoms appear.

In rural regions with unstable connectivity, MethSense can adapt by using offline storage, buffering data until the device reconnects. The emphasis is on maintaining low power consumption so that the system can operate through solar-based power units, making it suitable for remote agricultural environments.

## Machine-Learning Analytics

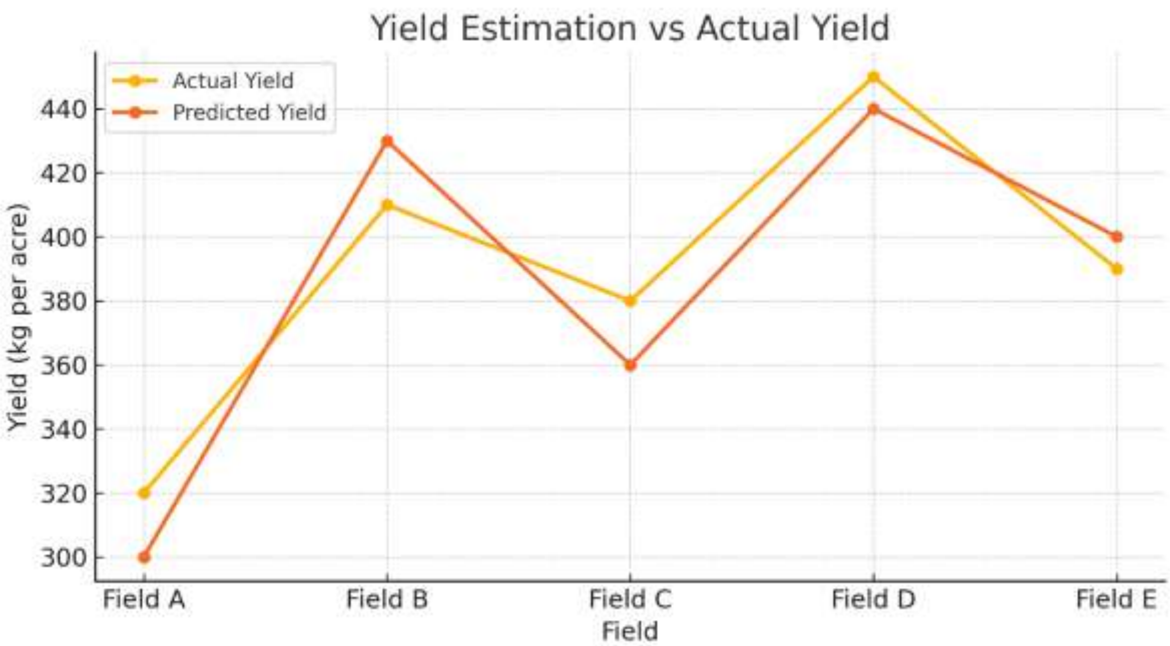


The analytical engine of MethSense transforms raw data into meaningful insights. The machine-learning pipeline begins with preprocessing, where data is cleaned, normalized, and filtered to remove sensor noise. Feature engineering combines soil variables with weather data to create richer predictive models.




## Irrigation Prediction

MethSense uses regression-based models to predict when the field requires irrigation. By analyzing soil moisture patterns, temperature fluctuations, and upcoming weather conditions, the system recommends precise irrigation timings. This prevents both over-watering and under-watering, improving root health and reducing water wastage.



## Stress Detection

Early stress detection is critical in mentha farming. Anomaly detection algorithms identify deviations from normal growth conditions. When sensor data indicates a risk—such as rising temperature stress, reduced moisture, or sudden fluctuations—the system generates alerts that help farmers respond quickly.

## Yield Estimation

MethSense incorporates a basic yield estimation model that correlates growth-stage data, NDVI trends, and soil–weather conditions. Although yield prediction in aromatic crops is complex, combining multiple data modalities increases accuracy and helps farmers plan harvesting and distillation schedules.

## Remote-Sensing Integration

Satellite-based remote sensing offers a valuable macro-level perspective that complements sensor-level field monitoring. MethSense uses NDVI and other vegetation indices derived from Resourcesat-2 (AWiFS or LISS-III) or MODIS imagery to assess crop health across larger areas.

NDVI time-series analysis helps identify vegetation vigor, canopy growth, and stress hotspots. When matched with on-ground sensor readings, satellite imagery enhances the system's ability to detect broad patterns like irrigation inefficiencies or weather-induced stress. This dual-layer assessment allows MethSense not only to monitor individual fields but also to support regional agricultural planning.

## Decision-Support and Farmer Advisory System

A key strength of MethSense is its farmer-friendly advisory platform. Insights generated by the AI engine are converted into simple, actionable messages delivered via dashboard or SMS. Advisories include:

- Recommended irrigation timings
- Alerts for moisture stress, heat stress, or abnormal readings
- NDVI-based crop health summaries
- Weather-based warnings
- Suggestions for optimal field practices

The interface is designed to be bilingual, ensuring accessibility for farmers regardless of literacy level. Visual charts, color-coded indicators, and simple icons make the system easy to understand.

## Implementation Challenges

While MethSense is technically robust, several real-world challenges remain. Sensor accuracy can fluctuate under extreme field conditions, requiring calibration and redundancy. Internet connectivity issues in rural areas affect the consistency of real-time data transmission. The lack of mentha-specific datasets limits the initial accuracy of ML models, requiring continuous data collection for improvement.

Farmer adoption also poses a challenge. Digital tools must be intuitive, affordable, and culturally acceptable. Ensuring long-term sustainability requires training, local support teams, and integration with government or NGO-led initiatives.

## Expected Impact and Potential Benefits

If implemented effectively, MethSense can transform menthol mint farming in multiple ways. Precise irrigation scheduling can significantly reduce water usage and improve crop health. Early stress warnings allow farmers to prevent losses at critical stages. By integrating NDVI analytics, the platform provides a broader understanding of crop vigor, enabling better planning and resource management.

Economically, MethSense has the potential to improve profitability by reducing input costs and optimizing yields. Technologically, it serves as a model for integrating IoT, AI, and remote sensing in aromatic crops. Regionally, it can support agricultural organizations in assessing crop performance and making data-driven policy decisions.

## Conclusion

MethSense represents a promising advancement in the digital transformation of mentha farming. By harmonizing real-time sensor data, machine-learning intelligence, and satellite-based vegetation monitoring, the system offers a comprehensive decision-support platform tailored to the needs of small and marginal farmers. Its emphasis on affordability, simplicity, and data-driven insights positions it as a scalable solution for the future of aromatic crop cultivation. While challenges remain in deployment and adoption, MethSense illustrates a clear pathway toward sustainable, efficient, and profitable agriculture in the menthol mint belt of India.