SMART INDIA HACKATHON 2025

- **Problem Statement ID –** 25099
- **Problem Statement Title-** AI-powered monitoring of crop health, soil condition, and pest risks using multispectral/hyperspectral imaging and sensor data.
- **Theme-** Agriculture, FoodTech and Rural Development
- **PS Category-** Software
- **Team ID-**
- **Team Name (Registered on portal) -** FarmAssist

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IDEA TITLE

Challenges Faced

- Data Integration: Aligning hyperspectral images (large-scale) with localised soil sensor data (point-based).
- Environmental Factors: Cloud cover, temporal mismatch between satellite pass and sensor timestamps.
- Model Complexity: Limited ground-truth data for training robust models; variability across crops, soil types, and depths.
- Farmer Adoption: Need for simple, mobile-friendly interfaces and actionable insights rather than raw data.

Value Proposition

- Early Detection → Farmers can act before yield loss occurs (unlike traditional reactive methods).
- Cost Savings → Optimised use of irrigation, fertilisers, and pesticides.
- Sustainability → Reduces chemical overuse, conserves water, supports climate-smart farming.
- Scalability → Works with freely available datasets (e.g., Sentinel-2) and can integrate local low-cost sensors.
- Decision Support → Converts complex data into simple, visual insights (maps, alerts).

Proposed Solution

- An AI-powered precision agriculture platform integrating hyperspectral/multispectral satellite imagery with in-situ soil & environmental sensors.
- Uses deep learning (CNN, LSTM) on fused data to detect early stress, disease, and pest risks before visual symptoms.
- Provides zone-specific recommendations via an intuitive farmer dashboard with maps, alerts, and soil condition summaries.

Key Features

- Hyperspectral Analysis: Derives vegetation indices (NDVI, PRI, etc.), soil indices, and stress indicators.
- Sensor Fusion: Integrates data on soil moisture, temperature, salinity, humidity, and leaf wetness to provide context.
- AI Models: CNN for spectral classification, LSTM for temporal trend prediction, hybrid fusion models for combined insights.
- Interactive Dashboard: Health maps, soil summaries, anomaly alerts, pest risk zones, time-series charts.
- Continuous Learning: Improves predictions over time with localised ground-truth feedback.

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TECHNICAL APPROACH

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Programming Languages:

Python → For ML model development & preprocessing

TypeScript → For frontend development

Frameworks & Libraries:

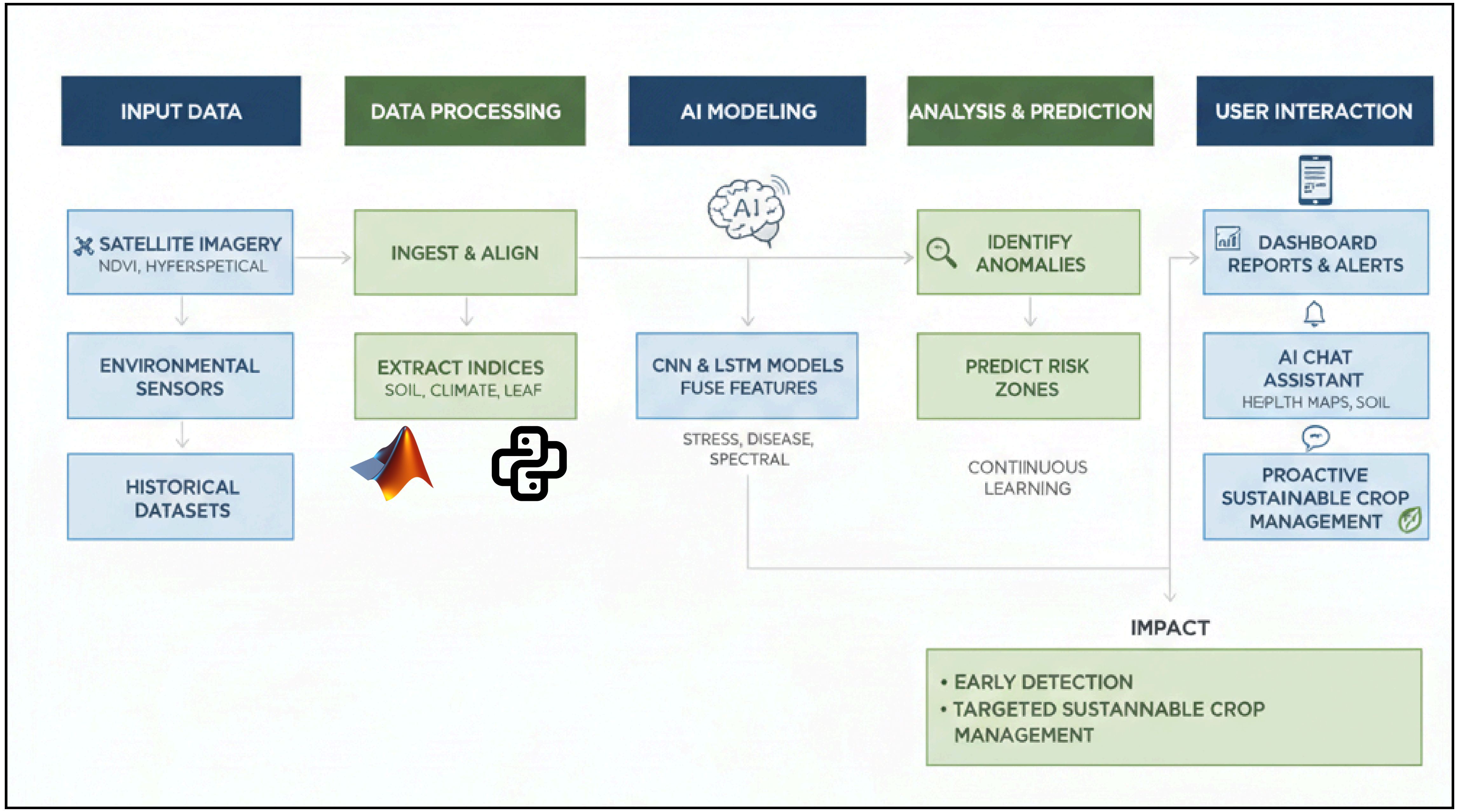
Next.js & React → Scalable frontend framework & UI components

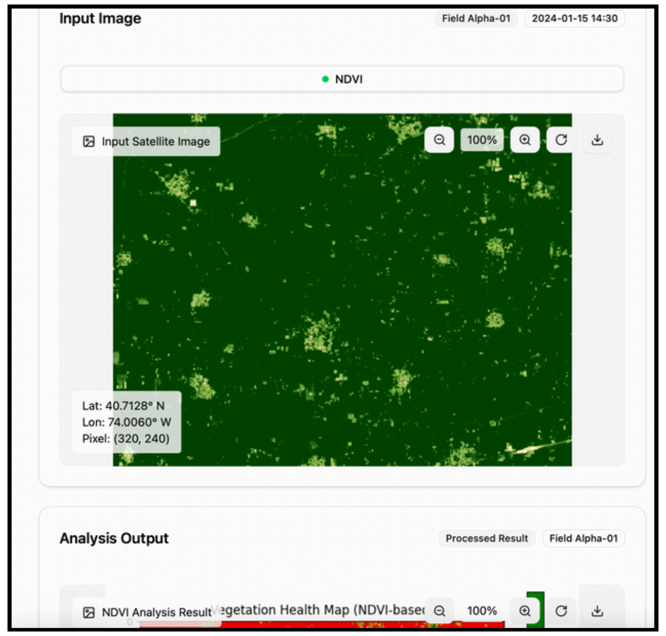
Tailwind CSS & Radix UI → Styling and accessible UI primitives

Recharts → Data visualization & analytics

MATLAB (Hyperspectral Imaging, Image Processing, Deep Learning Toolbox) → Spectral data analysis & model training

TensorFlow / PyTorch → ML/DL model training & deployment





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FEASIBILITY AND VIABILITY

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Analysis of the feasibility of the idea

- Data sources exist: Sentinel-2 / Indian Pines for hyperspectral imagery, plus soil/environmental sensors (moisture, pH, temperature, etc.).
- Tools and libraries (Python, MATLAB toolboxes, TensorFlow, PyTorch) are available with open-source options.
- Initial deployment limited to small pilot fields for validation before scaling.

Challenge 1
Alignment & Synchronization Issues:
Errors due to GPS inaccuracy or time mismatch between satellite passes and ground sensor readings.

Solution
Data Harmonization:
Use small patch aggregation and apply tolerances (±2 days for time, ≤30 m for space) to align satellite and sensor data accurately.

Challenge 2
Environmental Factors:
Cloud cover, haze, and inconsistent image quality affecting spectral data reliability.

Solution
Quality Control:
Apply cloud masks and use quality flags during preprocessing; schedule multi-temporal acquisitions to reduce data gaps.

Challenge 3
Crop & Soil Variability:
Performance varies across crop types, soil conditions, and sensor depth, reducing model generalizability.

Solution
Model Customization:
Train separate models per crop/soil type or build generalized models using larger, diverse datasets.

Challenge 4
Computational & Expertise Limitations:
Deep learning models require significant compute power and specialized domain knowledge.

Solution
Progressive Scaling:
Start with baseline models (Random Forest, SVM) for early results, and scale up to CNN/LSTM once sufficient data and compute resources are available.

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IMPACT AND BENEFITS

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Data-Driven Farming

- Integration of satellite + field sensors
- Ensures precision agriculture

Soil Health

- Monitors soil condition
- Boosts efficiency and sustainability

Crop Growth

- Early detection of stress, pests, and diseases
- Support healthier yields

Farmer Empowerment

- Equips farmers with actionable knowledge
- Shifts from reactive to proactive action

Economic Value

- Increased yield and reduced input costs
- Strengthens rural economy and reduces financial stress

Sustainability

- Encourages eco-friendly farming
- Reduces long-term environmental impact

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RESEARCH AND REFERENCES

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Research Basis:

- Hyperspectral Imaging for Crop Stress Detection → Used to identify early signs of disease & nutrient deficiency.
  (Mahlein et al., 2018 – Hyperspectral Imaging for Precision Agriculture)
- Soil Moisture & Vegetation Health Link → NDVI & spectral indices influenced by soil moisture levels.
  (Gao et al., 2020 – Monitoring Soil Moisture using Remote Sensing)
- AI for Early Detection & Prediction → CNN, LSTM, SVM effective in classifying stress & spectral patterns.
  (Kamilaris & Prenafeta-Boldú, 2018 – Deep Learning in Agriculture)

Citations:

- Mahlein, A.K. et al. (2018). Hyperspectral Imaging for Precision Agriculture.
- Gao et al. (2020). Monitoring Soil Moisture with Remote Sensing.
- Kamilaris & Prenafeta-Boldú (2018). Deep Learning in Agriculture: A Survey.
- Indian Pines Dataset – Purdue University.
- Victoria Soil Sensor Open Data Portal.