📋 AI-Enabled Precision Fertilizer Advisory System

Product Requirements Document (PRD)

Version 1.0 | January 2024

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1. Executive Summary

This document outlines the requirements for developing an AI-Enabled Precision Fertilizer Advisory System designed to address the critical challenges in Indian agriculture. The system leverages data-driven insights to provide localized, transparent, and sustainable fertilizer recommendations, aiming to reduce input costs, improve crop productivity, and promote soil health.

Key Highlights:

- Rule-based decision support (no black-box models)
- Integration of multiple real-world data sources
- Bilingual interface (English & Telugu)
- Alignment with government standards (ZREAC)
- Scalable web-based platform

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2. Product Vision & Objectives

Vision

To empower Indian farmers with accessible, data-driven fertilizer recommendations that enhance productivity, reduce costs, and promote sustainable agricultural practices.

Objectives

1. Increase Farmer Profitability: Reduce fertilizer costs by 15-20%
2. Improve Crop Yield: Enhance productivity by 10-15%
3. Promote Sustainability: Minimize environmental impact
4. Ensure Transparency: Provide explainable recommendations
5. Enable Scalability: Support 10,000+ farmers in Year 1

3. Problem Statement

Current Challenges

Challenge	Impact
Blanket Recommendations	Nutrient imbalance, soil degradation
High Input Costs	Reduced farmer profitability

Low Productivity	Suboptimal crop yields
Environmental Harm	Pollution from over-fertilization
Lack of Personalization	One-size-fits-all approach

Root Causes

- Insufficient consideration of local soil variability
- Ignorance of crop growth stages
- Lack of real-time weather integration
- Absence of field-level crop health monitoring

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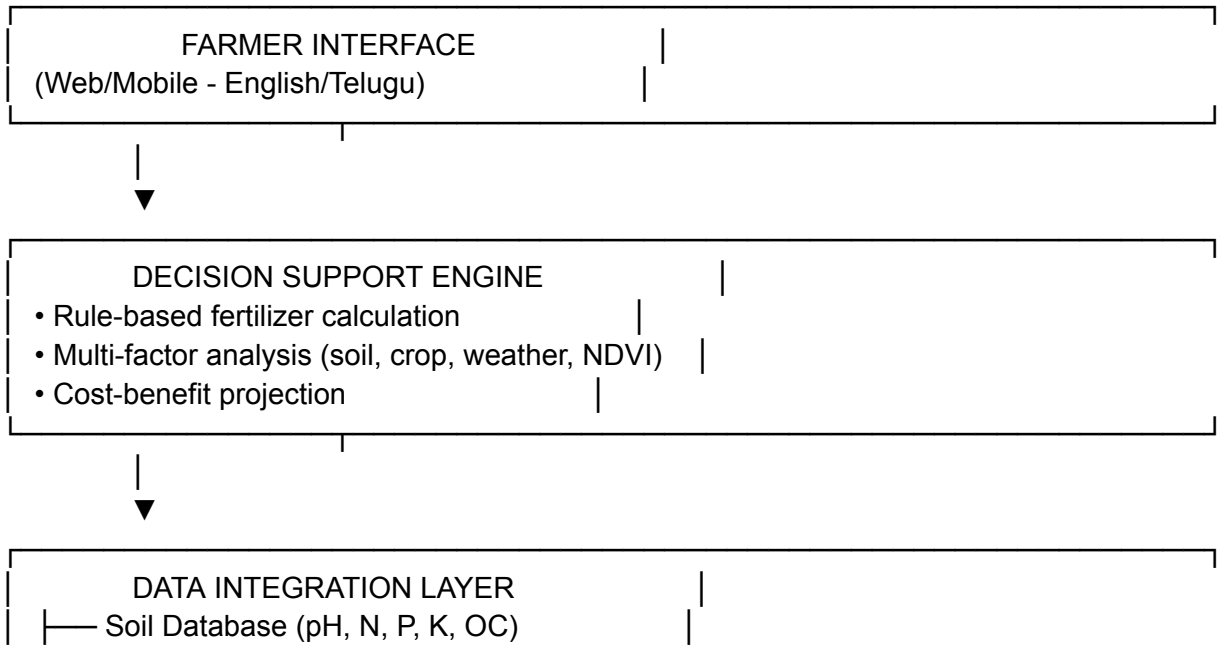
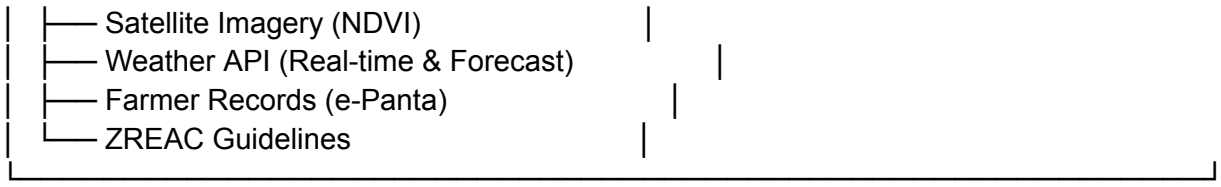
4. Solution Overview

System Architecture





Key Innovation Points

- Transparent Algorithm: Rule-based approach for trust
- Multi-source Integration: Holistic data consideration
- Localized Recommendations: District/village-level precision
- Actionable Insights: Clear, implementable guidance

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5. Target Users & Personas

5.1 Primary Users: Farmers

Persona	Characteristics	Needs
Small Farmer (Ramesh, 45)	2 acres, basic smartphone, cost-conscious	Simple interface, cost savings, local language
Progressive Farmer (Ananya, 35)	10 acres, tech-savvy, educated	Detailed analytics, export features, advanced insights
Cooperative Member (Vikram, 50)	Part of farmer group, relies on community	Bulk features, group reports, cooperative discounts

5.2 Secondary Users

Role	Use Case
Agricultural Officer	Monitor adoption, generate reports, validate recommendations
Researcher	Analyze trends, study impact, refine algorithms
Policy Maker	Assess program effectiveness, plan interventions

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6. Core Features & Requirements

6.1 User Management Module

Feature	Requirements	Priority
Registration	Mobile OTP verification, basic profile creation	P0
Login	Secure OTP-based authentication	P0
Profile Management	Update personal details, farm size, location	P1
Field Registration	Add multiple fields with boundaries	P1
Language Selection	Toggle between English/Telugu	P0

6.2 Advisory Generation Module

Input	Source	Processing Logic
Sowing Date	Farmer input	Calculate crop stage
Soil Data	District soil DB	Nutrient status assessment
NDVI	Satellite API	Crop health/stress detection
Weather	IMD/Weather API	Application timing decision
ZREAC Guidelines	Government DB	Base recommendation framework

6.3 Output & Reporting

Each Recommendation Includes:

1. Fertilizer Details:
    - Type (N, P, K, micronutrients)
    - Quantity (kg/acre)
    - Brand suggestions (optional)
2. Application Guidance:
    - Timing (based on crop stage & weather)
    - Method (broadcast, foliar, etc.)
3. Economic Analysis:
    - Estimated cost
    - Expected yield increase
    - Potential income impact
4. Visualizations:
    - Soil nutrient charts
    - NDVI crop health maps
    - Cost-benefit comparison graphs

6.4 System Administration

Feature	Description	Access Level
Dashboard	System metrics, user statistics	Admin
Content Management	Update crop lists, fertilizer prices	Admin/Editor
Audit Logs	Track all recommendations	Admin
Bulk Operations	Register farmer groups	Admin/Cooperative

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7. Technical Architecture

7.1 Technology Stack

Component	Technology	Rationale
Frontend	React.js + Tailwind CSS	Mobile-responsive, modern UI
Backend	FastAPI (Python)	High performance, easy deployment
Database	PostgreSQL + PostGIS	Spatial data support
Cache	Redis	Session management, OTP storage
Containerization	Docker	Consistent deployment

Cloud Platform	AWS/Azure	Scalability, reliability

7.2 Data Pipeline Architecture

Data Sources → API Gateway → ETL Processor → Rule Engine → Recommendation API
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Soil DB Authentication Cleaning Calculations Frontend
Weather API Rate Limiting Validation ZREAC Rules Mobile App
Satellite API Logging Enrichment Cost Analysis SMS Gateway
e-Panta API Security Storage Reporting Admin Panel

7.3 API Integration Specifications

API	Provider	Frequency	Data Format
Satellite NDVI	Sentinel Hub	Daily	GeoTIFF/JSON
Weather	IMD/OpenWeatherMap	Hourly	JSON
Soil Data	State Agriculture Dept	Static (updated annually)	CSV/JSON
ZREAC Guidelines	ICAR/Government	Static (seasonal updates)	PDF/JSON

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8. Non-Functional Requirements

8.1 Performance Requirements

Metric	Target	Measurement Method
Page Load Time	< 3 seconds	Google Lighthouse
API Response Time	< 2 seconds (p95)	Application monitoring
Concurrent Users	10,000 simultaneous	Load testing
Data Freshness	NDVI: < 5 days	Timestamp validation
System Uptime	99.5% (agricultural season)	Monitoring dashboard

8.2 Security Requirements

1. Data Protection:
    - Encryption at rest (AES-256)
    - TLS 1.3 for data in transit
    - Secure API key management
2. Access Control:
    - Role-based access (RBAC)
    - OTP-based authentication
    - Session timeout (30 minutes)
3. Compliance:
    - GDPR principles for data handling
    - Indian IT Act compliance
    - Agricultural data privacy standards

8.3 Usability Requirements

Aspect	Requirement	Validation Method

Accessibility	WCAG 2.1 AA compliance	Automated testing
Mobile Optimization	Responsive design on all devices	Device testing
Load Time	< 3 seconds on 3G networks	Network throttling test
Language Support	Full Telugu localization	Native speaker review
Error Handling	Clear, actionable error messages	User testing

8.4 Scalability Requirements

1. Horizontal Scaling:
    - Stateless microservices
    - Load-balanced API servers
    - Database read replicas
2. Data Growth:
    - Support for 1M+ farmer records
    - Efficient spatial queries
    - Automated data archiving
3. Geographic Expansion:
    - Modular regional adaptations
    - Multi-state data integration
    - Local language additions

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9. Success Metrics

9.1 Business Metrics

Metric	Target (Year 1)	Measurement Method
Active Farmers	10,000	System analytics
Retention Rate	60% (seasonal)	Login frequency analysis
Recommendations Generated	50,000	Database logs
Adoption Rate	30% of target districts	Government partnership data

9.2 Impact Metrics

Metric	Target Improvement	Measurement Period
Fertilizer Cost Reduction	15-20% per farmer	Seasonal comparison
Crop Yield Increase	10-15%	Harvest data collection
Soil Health Improvement	Reduced imbalance cases	Soil test comparison
Farmer Satisfaction	4.2/5 rating	Quarterly surveys

9.3 Technical Metrics

Metric	Target	Monitoring Tool
System Availability	99.5% uptime	Prometheus/Grafana

API Success Rate	99.9%	Application monitoring
Data Processing Time	< 5 seconds	Performance logs
Security Incidents	Zero critical	Security monitoring

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10. Project Timeline

Phase 1: Foundation (Months 1-3)

Week 1-4: Requirement Finalization & Architecture Design
Week 5-8: Core Backend Development (FastAPI, Database)
Week 9-12: Basic Frontend (React) & API Integration
Week 13: Internal Testing & Bug Fixes
Deliverable: MVP with soil + weather integration

Phase 2: Enhancement (Months 4-6)

Month 4: Satellite NDVI Integration
Month 5: Bilingual Interface (Telugu)
Month 6: Advanced Dashboard & Reporting
Deliverable: Pilot launch in 1 district (100 farmers)

Phase 3: Scaling (Months 7-12)

Month 7-8: Performance Optimization & Security Audit
Month 9-10: Mobile App Development (React Native)
Month 11-12: Multi-district Expansion & Partner Integration
Deliverable: Full deployment across 3 districts

Phase 4: Maturity (Year 2)

Quarter 1: AI/ML Enhancement (Predictive Models)

Quarter 2: Additional Language Support
Quarter 3: IoT Device Integration
Quarter 4: Pan-State Deployment

11. Risk Assessment

Risk Matrix

Risk	Probability	Impact	Mitigation Strategy	Owner
Poor Data Quality	High	High	Data validation layer, manual override	Data Team
Low Farmer Adoption	Medium	High	Training programs, incentive schemes	Outreach Team
API Service Outages	Medium	Medium	Caching, fallback data sources	DevOps
Network Connectivity Issues	High	Medium	Offline mode, SMS-based service	Product Team
Regulatory Changes	Low	High	Modular rule engine, policy monitoring	Legal Team
Security Breach	Low	Critical	Regular audits, penetration testing	Security Team

Budget Overruns	Medium	Medium	Agile development, milestone-based funding	Project Manager

Contingency Plans

1. Data Unavailability: Use historical averages or neighboring district data
2. API Failure: Implement graceful degradation with cached data
3. Low Adoption: Partner with local agricultural cooperatives
4. Technical Issues: 24/7 support hotline for farmers

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12. Stakeholders

Core Team

Role	Responsibilities	Key Deliverables
Product Owner	Vision, roadmap, stakeholder management	PRD, product strategy
Project Manager	Timeline, budget, resource allocation	Project plans, status reports
Lead Developer	Technical architecture, code quality	System design, technical docs
Agriculture Expert	Rule validation, scientific accuracy	Advisory algorithms

UX Designer	User research, interface design	Wireframes, prototypes
Data Engineer	Data pipelines, API integration	ETL processes, data models
QA Engineer	Testing, quality assurance	Test plans, bug reports

External Stakeholders

Stakeholder	Interest	Engagement Level
Farmers	Usability, cost savings	High (end users)
Agricultural Department	Policy alignment, data sharing	High (partnership)
ICAR/ZREAC	Scientific validation, guidelines	Medium (advisory)
Fertilizer Companies	Product recommendations, data	Low (potential partners)
NGOs/Cooperatives	Farmer training, dissemination	Medium (implementation)

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13. Appendices

Appendix A: Glossary of Terms

Term	Definition
NDVI	Normalized Difference Vegetation Index - satellite-based vegetation health indicator
ZREAC	Zone-wise Research and Extension Advisory Council - government fertilizer guidelines
e-Panta	Electronic crop recording system used in Indian agriculture
OTP	One-Time Password - authentication method
FAST API	Modern Python web framework for building APIs
PostGIS	Spatial database extender for PostgreSQL
Rule-based System	Decision system using predefined rules rather than machine learning models

Appendix B: Data Sources Details

Source	Format	Update Frequency	Access Method
Soil Health Cards	CSV/JSON	Annual	Government API/Data sharing
Satellite Imagery	GeoTIFF	Daily (Sentinel-2)	Sentinel Hub API

Weather Data	JSON	Hourly	IMD/OpenWeatherMap API
Crop Calendar	JSON	Seasonal	Agricultural department
Fertilizer Prices	JSON	Weekly	Market data API

Appendix C: Wireframe References

(Note: Wireframes would be included as separate attachments in actual PDF)

Key Screens:

1. Login/Registration: Mobile OTP entry
2. Dashboard: Overview of fields and recommendations
3. Field Input: Crop selection, sowing date, location
4. Recommendation Detail: Fertilizer advice with cost analysis
5. History: Past recommendations and outcomes
6. Profile: Farmer information and settings

Appendix D: Testing Strategy

Test Type	Scope	Tools	Success Criteria
Unit Testing	Individual components	pytest, Jest	90% code coverage
Integration Testing	API endpoints, data flow	Postman, Newman	All critical paths working
Performance Testing	Load, stress, scalability	JMeter, Locust	Meets NFR targets

Security Testing	Vulnerabilities, penetration	OWASP ZAP, Burp Suite	Zero critical vulnerabilities
User Acceptance Testing	End-to-end with farmers	Real user testing	90% satisfaction score

Appendix E: Deployment Checklist

Pre-Deployment:

- Security audit completed
- Performance testing passed
- Data backup strategy in place
- Monitoring tools configured
- Rollback plan documented

Post-Deployment:

- System monitoring active
- User support channels established
- Feedback collection mechanism ready
- Analytics tracking implemented
- Documentation updated

Document Control

Version	Date	Author	Changes	Approval
1.0	2024-01-15	Product Team	Initial Release	Pending

1.1	TBD	TBD	Future revisions	TBD

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Distribution List: Project Team, Stakeholders, Partners

This document serves as the authoritative source for the Precision Fertilizer Advisory System requirements. All development activities should align with the specifications outlined herein.

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Approval Signatures

Role	Name	Signature	Date
Product Owner	_____	_____	_____
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Lead Developer	_____	_____	_____

Agriculture	_____	_____	_____
Expert	__		

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