

Smart Agriculture Database Schema Documentation

Overview

This database schema is designed for an agricultural IoT monitoring system that tracks sensor readings, equipment status, crop management, and environmental conditions across multiple farms and zones.

Enumerations

Equipment Status

Status indicators for equipment:

- **Active:** Equipment is operational
- **Inactive:** Equipment is not currently in use
- **Fault:** Equipment has malfunctioned

Reading Type

Types of sensor readings available:

- **SoilTemperature:** Temperature measurements in soil
- **SoilMoisture:** Soil moisture content
- **SoilPH:** Soil acidity/alkalinity level
- **SoilEC:** Soil electrical conductivity
- **SoilOxygen:** Oxygen levels in soil
- **AmbientTemperature:** Air temperature
- **AmbientHumidity:** Air humidity
- **PAR:** Photosynthetically Active Radiation
- **Rainfall:** Precipitation measurements
- **LeafWetness:** Moisture on plant leaves
- **WindSpeed:** Wind velocity

Threshold Type

Alert threshold categories:

- **BelowMin:** Reading is below minimum threshold
 - **AboveMax:** Reading exceeds maximum threshold
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Database Tables

Farms

Primary entity representing agricultural facilities.

| Column | Type | Constraints | Description |
|---------|---------|--------------------------------------|------------------------|
| Id | int | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique farm identifier |
| Name | varchar | NOT NULL | Farm name |
| Code | varchar | NOT NULL | Farm code reference |
| Lat | float | NOT NULL | Latitude coordinate |
| Lon | float | NOT NULL | Longitude coordinate |
| Address | varchar | NOT NULL | Physical address |

Zones

Subdivisions within farms for granular monitoring.

| Column | Type | Constraints | Description |
|----------|--------------|--------------------------------------|-------------------------------------|
| Id | int | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique zone identifier |
| Name | varchar | NOT NULL | Zone name |
| Area | float | No Constraints | Zone area in square meters |
| SoilType | varchar(100) | No Constraints | Soil type for agricultural analysis |
| FarmId | int | FK → Farms.Id, NOT NULL | Parent farm reference |

Crops

Master list of crop types.

| Column | Type | Constraints | Description |
|--------|---------|--------------------------------------|------------------------|
| Id | int | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique crop identifier |
| Name | varchar | NOT NULL | Crop name |

Reading Types

Defines measurement types and their properties.

| Column | Type | Constraints | Description |
|-------------|--------------|--------------------------------------|---|
| Id | int | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique reading type identifier |
| Code | varchar(50) | NOT NULL, UNIQUE | Reading type code (e.g., "SoilTemperature") |
| Category | varchar(50) | No Constraint | Category: Soil / Weather / Plant |
| DisplayName | varchar(100) | NOT NULL | Human-readable name |
| Unit | varchar(20) | NOT NULL | Measurement unit (°C, %, pH, mS/cm, etc.) |

Equipments

IoT devices and sensors deployed in zones.

| Column | Type | Constraints | Description |
|----------------|------------------|--------------------------------------|---|
| Id | int | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique equipment identifier |
| Zoneld | int | FK → Zones.Id, NOT NULL | Deployment zone |
| SerialNumber | varchar(100) | No Constraint | Device serial number |
| EquipmentModel | varchar(100) | No Constraint | Equipment model number |
| ReadingTypeId | int | FK → ReadingTypes.Id, NOT NULL | Type of reading this equipment provides |
| Status | EquipmentsStatus | NOT NULL | Current operational status |
| InstalledAt | datetime | No Constraint | Installation timestamp |
| LastReadingAt | datetime | No Constraint | Most recent reading timestamp |

Sensor Readings

Time-series data from sensors.

| Column | Type | Constraints | Description |
|---------------|----------|--------------------------------------|---------------------------|
| Id | bigint | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique reading identifier |
| EquipmentId | int | FK → Equipments.Id, NOT NULL | Source equipment |
| ReadingTypeId | int | FK → ReadingTypes.Id, NOT NULL | Type of measurement |
| Value | float | NOT NULL | Measured value |
| TimestampUtc | datetime | NOT NULL | Reading timestamp (UTC) |
| IsAnomaly | bool | DEFAULT: false | Flag for unusual readings |

Alerts

System-generated notifications for threshold violations.

| Column | Type | Constraints | Description |
|----------------|---------------|--------------------------------------|------------------------------------|
| Id | bigint | PK, AUTO_INCREMENT, NOT NULL, UNIQUE | Unique alert identifier |
| EquipmentId | int | FK → Equipments.Id | Related equipment |
| ZoneId | int | FK → Zones.Id | Related zone |
| ReadingTypeId | int | FK → ReadingTypes.Id | Reading type that triggered alert |
| CropId | int | FK → Crops.Id | Related crop |
| Value | float | No Constraint | Reading value that triggered alert |
| ThresholdType | ThresholdType | No Constraint | Type of threshold violation |
| Message | varchar(1000) | NOT NULL | Alert description |
| CreatedAt | datetime | NOT NULL | Alert creation timestamp |
| IsAcknowledged | bool | NOT NULL, DEFAULT: false | Acknowledgment status |
| AcknowledgedAt | datetime | No Constraint | Acknowledgment timestamp |
| StageId | int | FK → CropGrowthStages.Id | Related growth stage |

Crop Seasons

Seasonal planting and harvesting schedules.

| Column | Type | Constraints | Description |
|--------------------|-------------|--------------------|--|
| Id | int | PK, AUTO_INCREMENT | Unique season identifier |
| CropId | int | FK → Crops.Id | Related crop |
| SeasonName | varchar | NOT NULL | Season name (e.g., "Winter", "Summer") |
| PlantingStartMonth | int | NOT NULL | Planting start month (1-12) |
| PlantingEndMonth | int | NOT NULL | Planting end month (1-12) |
| HarvestStartMonth | int | NOT NULL | Harvest start month (1-12) |
| HarvestEndMonth | int | NOT NULL | Harvest end month (1-12) |
| ExpectedRangeDays | varchar(20) | No Constraint | Expected duration (e.g., "10–15 days") |
| Notes | text | No Constraint | Additional notes |

Crop Growth Stages

Growth phases for crop lifecycle management.

| Column | Type | Constraints | Description |
|--------------|---------|-----------------------|---|
| Id | int | PK, AUTO_INCREMENT | Unique stage identifier |
| CropId | int | FK → Crops.Id | Related crop |
| StageName | varchar | NOT NULL | Stage name (Germination, Vegetative, Flowering, etc.) |
| Order | int | NOT NULL | Sequential order of stage |
| DurationDays | int | NOT NULL | Days since planting |
| Description | text | No Constraint | Stage description |

Crop Stage Requirements

Environmental requirements for each growth stage.

| Column | Type | Constraints | Description |
|-------------------|-------|--------------------------|-------------------------------|
| Id | int | PK, AUTO_INCREMENT | Unique requirement identifier |
| CropGrowthStageId | int | FK → CropGrowthStages.Id | Related growth stage |
| ReadingTypeId | int | FK → ReadingTypes.Id | Type of measurement |
| MinValue | float | No Constraint | Minimum acceptable value |
| MaxValue | float | No Constraint | Maximum acceptable value |
| OptimalMin | float | No Constraint | Optimal range minimum |
| OptimalMax | float | No Constraint | Optimal range maximum |

Zone Crops

Tracks active and historical crop plantings in zones.

| Column | Type | Constraints | Description |
|-------------------|-------|--------------------------|----------------------------|
| Id | int | PK, AUTO_INCREMENT | Unique planting identifier |
| ZoneId | int | FK → Zones.Id | Planting zone |
| CropId | int | FK → Crops.Id | Planted crop |
| PlantedAt | date | NOT NULL | Planting date |
| ExpectedHarvestAt | date | No Constraint | Expected harvest date |
| CurrentStageId | int | FK → CropGrowthStages.Id | Current growth stage |
| Notes | text | No Constraint | Additional notes |
| ActualHarvestAt | date | No Constraint | Actual harvest date |
| YieldWeightKg | float | No Constraint | Harvest yield in kilograms |
| IsActive | bool | DEFAULT: true | Active/completed status |

Entity Relationships

Farm Hierarchy

- **Farms** → **Zones** (1:N): A farm contains multiple zones
- **Zones** → **Equipments** (1:N): Each zone has multiple sensors/equipment

Crop Management

- **Crops** → **CropSeasons** (1:N): Crops have multiple planting seasons
- **Crops** → **CropGrowthStages** (1:N): Crops progress through defined growth stages
- **CropGrowthStages** → **CropStageRequirements** (1:N): Each stage has specific environmental requirements
- **Zones** → **ZoneCrops** (1:N): Tracks what crops are planted in each zone
- **Crops** → **ZoneCrops** (1:N): Historical record of crop plantings

Monitoring System

- **ReadingTypes** → **Equipments** (1:N): Defines what each equipment measures
- **Equipments** → **SensorReadings** (1:N): Equipment generates readings over time
- **ReadingTypes** → **SensorReadings** (1:N): Categorizes each reading

Alert System

- **Equipments** → **Alerts** (1:N): Equipment can trigger alerts
 - **Zones** → **Alerts** (1:N): Alerts are associated with zones
 - **ReadingTypes** → **Alerts** (1:N): Specifies what type of reading triggered the alert
 - **Crops** → **Alerts** (1:N): Alerts can be crop-specific
 - **CropGrowthStages** → **Alerts** (1:N): Alerts linked to specific growth stages
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Key Features

Time-Series Data Management

The **SensorReadings** table stores all sensor data with timestamps, supporting historical analysis and trend detection. The **IsAnomaly** flag helps identify outlier readings.

Threshold-Based Alerting

The **Alerts** table integrates with **CropStageRequirements** to automatically generate notifications when sensor readings fall outside acceptable ranges for the current growth stage.

Crop Lifecycle Tracking

The system tracks crops from planting through harvest, monitoring environmental conditions against stage-specific requirements and providing yield data for analysis.

Multi-Level Organization

The hierarchical structure (Farms → Zones → Equipment) enables granular monitoring while maintaining organizational context.

Use Cases

- Real-time Monitoring:** Track current sensor readings across all farm zones
- Predictive Analytics:** Analyze historical data to predict optimal planting times and yields
- Alert Management:** Respond to threshold violations during critical growth stages
- Yield Optimization:** Compare environmental conditions with harvest yields to identify best practices
- Equipment Maintenance:** Track equipment status and last reading times to schedule maintenance
- Seasonal Planning:** Use historical season data to plan crop rotations and planting schedules