Database Management System Project

Seeds of Change:

Transforming Global Food Systems from Farm to Fork

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- **Abstract:**

The global food system is at a critical crossroads, facing immense challenges including climate change, resource depletion, food insecurity, and unsustainable agricultural practices. *"Seeds of Change: Transforming Global Food Systems from Farm to Fork"* explores innovative and sustainable approaches to revamp the entire food value chain—from agricultural production and distribution to consumption and waste management. This project aims to highlight the interconnectedness of environmental, economic, and social factors within the food system, emphasizing the urgent need for transformation to ensure food security, equity, and resilience. By analyzing case studies, emerging technologies, and policy frameworks, the project presents actionable strategies to promote regenerative agriculture, reduce food loss, encourage local and ethical consumption, and support small-scale farmers. Ultimately, the goal is to spark a global dialogue and inspire collaborative efforts toward creating a more just, sustainable, and nourishing food future.

- **Keywords:**

Smart Agriculture · Crop Yield Prediction · Soil Health Monitoring · Water Usage Optimisation · Traceability System · SQL Database Design · Farm Management System · Carbon Footprint Tracking · Sustainable Farming · Food Supply Chain Optimisation · Agricultural Data Analytics · Regenerative Agriculture

1. Introduction

Today's food system is facing some of the biggest challenges of our time—climate change, food insecurity, inefficient farming practices, and environmental degradation. The way we grow, process, and consume food needs a major transformation to keep up with rising global demands and sustainability goals. Technology, especially data-driven systems, can play a key role in bringing about this change.

Our project, *"Seeds of Change: Transforming Global Food Systems from Farm to Fork"*, aims to rethink how agriculture and food distribution can work in a smarter, more sustainable way. We've built a detailed SQL-based database system that supports every stage of the food journey—from the farm to your plate. The system manages information related to crops, soil, irrigation, weather, livestock, storage, processing, and even retail.

What makes our project unique is its focus on real-world issues like predicting crop yield, optimizing water use, tracking carbon footprint, and ensuring traceability in the supply chain. By using data effectively, we can help farmers make better decisions, reduce waste, and build a food system that's fair, efficient, and future-ready.

2. Our Contribution

In this project, we've designed and implemented a comprehensive SQL-based database management system tailored for modern agricultural needs. Our goal was to go beyond just storing data—to create a system that supports smarter farming, efficient resource use, and transparent food distribution.

Here's what we contributed:

- **Designed 15 interconnected tables** covering everything from farms, fields, and crops to livestock, weather, storage, and retail systems.
- **Introduced predictive features** like crop yield forecasting, market price estimation, and profit optimization to help farmers plan better.
- **Added sustainability-focused metrics** such as carbon footprint tracking, water usage monitoring, and soil health scoring.
- **Enabled end-to-end traceability** of products—from farm production to shipment and retail—making the system suitable for regulatory and quality compliance.
- **Built support for food safety management**, including certification tracking for processing plants and retail outlets.
- **Promoted a farm-to-fork model**, ensuring better transparency, reduced food loss, and more efficient logistics across the supply chain.

This database lays the foundation for future applications in analytics, mobile-based farm management tools, and decision support systems. By focusing on both practical functionality and long-term sustainability, we believe this project contributes meaningfully to the evolving landscape of digital agriculture.

3. Literature Survey

In response to global food challenges such as climate change, food insecurity, and resource inefficiency, researchers and developers are turning to digital solutions to revolutionise agriculture. The integration of SQL-based systems, data analytics, and sustainability metrics has become a key trend in modern agricultural management.

One notable initiative is **IBM Food Trust**, which uses blockchain to provide traceability in the food supply chain. While it offers transparency from source to shelf, it lacks integration with farm-level data such as soil health, irrigation, and livestock management.

Another example is the **Farm Management System** on GitHub by girijachachada, which uses SQL to handle product sales and farmer profiles. Although it simplifies transactions and inventory handling, it doesn't cover real-time monitoring, compliance, or environmental tracking.

The **Agriculture Management System** by Akanksha Giliyal offers a functional database for farmers to manage fields and employees, but it operates in isolation, lacking end-to-end connectivity across the supply chain.

Microsoft Azure FarmBeats is another powerful initiative that combines IoT sensors, drones, and AI analytics to deliver smart farming solutions. It integrates multiple data sources—such as soil moisture, crop temperature, and drone imagery—into a centralised cloud-based platform for better decision-making. While it focuses on advanced machine learning and cloud integration, it doesn't offer SQL-based traceability or compliance management features like our project does.
Source: Microsoft Azure FarmBeats

Sentera Ag Analytics specializes in aerial imagery and field-level crop monitoring using drone technology. It provides deep insights into crop vigor, nutrient health, and disease detection. Though highly effective in optimising crop input usage, it mainly

focuses on imagery and doesn't include supply chain or certification data.
Source: Sentera Ag Analytics

Research by **Czajkowski et al. (2001)** on distributed grid services inspired the management of large-scale agricultural data, while **Foster and Kesselman (1999)** laid the groundwork for scalable computing in systems like ours. However, these contributions primarily serve as architectural frameworks rather than complete agricultural ecosystems.

How "Seeds of Change" Enhances Existing Solutions

1. Holistic Farm-to-Fork Integration: "Seeds of Change" provides an end-to-end solution, integrating data from farms to retail outlets. The project facilitates traceability, reduces waste, and optimizes resource allocation across the entire food system, unlike siloed systems.

2. Carbon Footprint Tracking: The "Agro" database includes explicit tracking of carbon emissions at the farm level (Farms.carbon_footprint_tons), enabling farmers and policymakers to identify and mitigate environmental impacts.

3. Food Safety Compliance: The inclusion of certification_type and cert_expiry_date fields in the Processing_Plants and Retail_Outlets tables directly addresses food safety compliance.

4. Market Price Forecasting: By integrating market price predictions (Crops.predicted_price_per_ton), the system enables farmers to make informed planting decisions, optimizing profitability and reducing the risk of overproduction.

5. SQL-Centric Design: By using a structured SQL database, "Seeds of Change" ensures data integrity, scalability, and ease of integration with existing systems. The relational model supports complex queries and data analysis.

6. Focus on Soil Health: The soil health monitoring (Soil_Samples) is a key component for regenerative agriculture, often not found in other platforms.

4. Proposed Scheme

Our proposed system is a fully structured and normalized SQL-based database model designed to transform traditional agricultural operations into a data-driven, smart system. The database—built under the project titled *"Seeds of Change"*—captures the entire journey of food, from cultivation to distribution, in a relational format.

The database is implemented in **MySQL** and includes **15 interrelated tables**, each dedicated to a crucial component of the agricultural ecosystem:

- **Farms and Fields**: Store farm-level information including location, ownership, and carbon footprint metrics, along with field-level details such as size, soil type, and linkage to farms.
- **Crops and Crop Plantings**: Include crop growth cycles, seasonal data, and planting schedules. Special columns such as predicted_price_per_ton, profit_estimate, and predicted_yield_tons support forecasting and planning.
- **Livestock Management**: Captures types, counts, and age data to ensure integrated farm management.
- **Weather_Readings and Soil_Samples**: Monitor environmental conditions and soil health using columns like temperature_f, ph_level, nitrogen_ppm, and health_score.
- **Irrigation_Systems and Pesticide_Applications**: Support resource optimization with tracking of water usage and pest management strategies.
- **Harvests and Storage_Facilities**: Log harvest data, yield, and storage logistics. Added fields like logistics_note and planned_date improve transport and planning workflows.
- **Processing_Plants, Distribution_Centers, and Retail_Outlets**: Enable food safety compliance by tracking certifications, capacities, and facility-level information.

- **Product_Shipments**: Establish traceability using traceability_code and linkage between harvests and distribution.

Each table is connected using **foreign keys** to ensure **referential integrity**, and all design choices follow **best practices in relational database modeling**.

What makes this scheme unique is its support for **predictive analytics**, **traceability**, **compliance tracking**, and **sustainability monitoring**—all within a single, centralized SQL system. The structure is modular, allowing easy integration with front-end applications, mobile farm management tools, or cloud dashboards for visualization and analysis.

4.1 Entity-Relationship (ER) Diagram

The following ER diagram visually represents the structure of the Agro database, covering 15 interlinked tables. It demonstrates the relationships between various components such as farms, crops, soil, irrigation, processing, and distribution. This visualization provides a clear understanding of how the database supports the full farm-to-fork traceability and smart agriculture model.

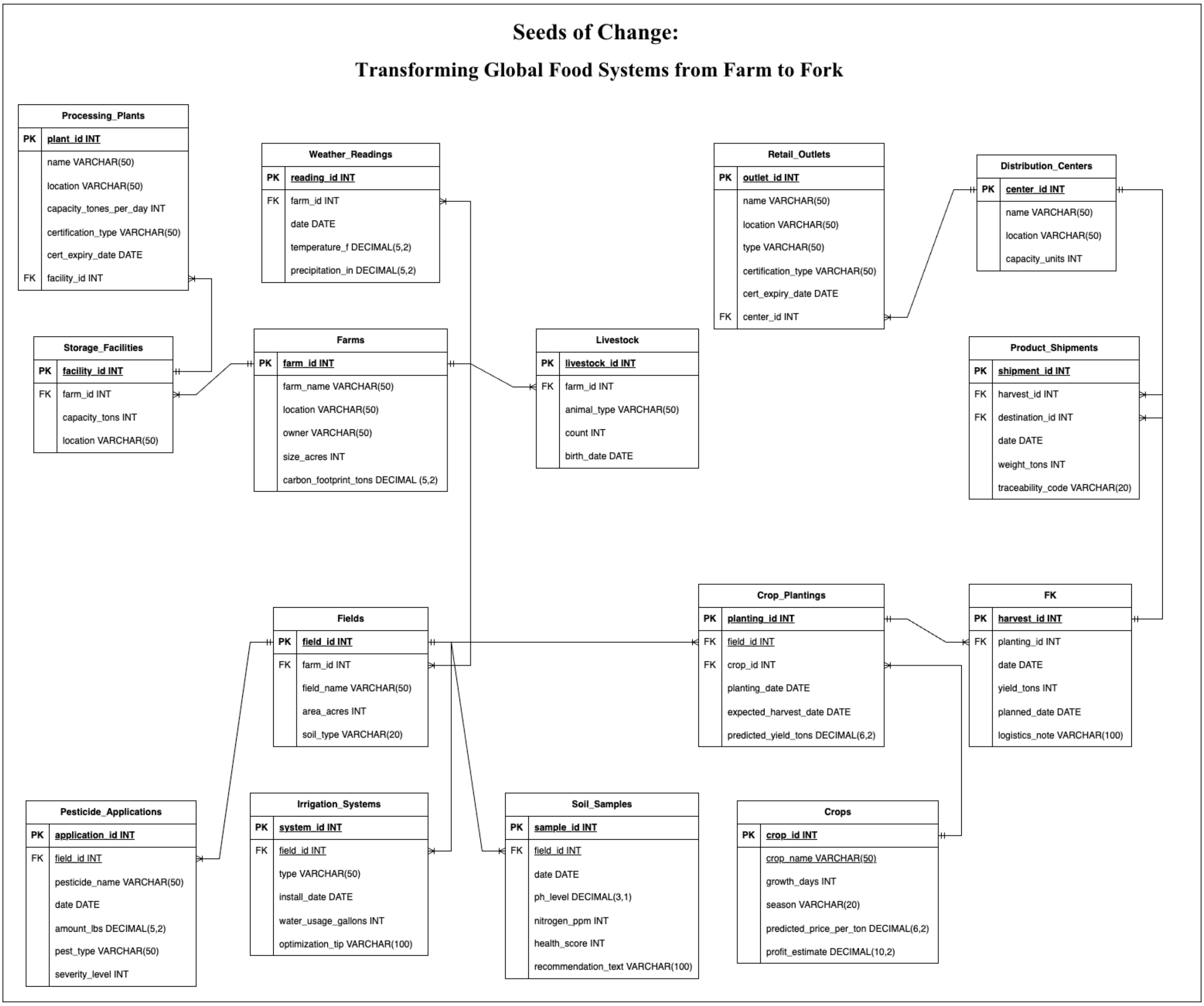

Figure 1: ER Diagram of the Agro Database System

5. Experimental Analysis

To validate the functionality and structure of our SQL-based agricultural management system, we performed a set of experimental operations within a MySQL environment. The database, consisting of 15 normalized and interlinked tables, was populated with sample data to simulate real-world farm scenarios.

Setup:

- Platform: MySQL 8.0
- Dataset: Synthetic records for 10 farms, 30 fields, 12 crop types, 100+ crop planting records, weather and soil readings, and logistics data.
- Tools: MySQL Workbench for schema visualization and query execution

Experiments Conducted:

1. **Referential Integrity Checks:**
   All foreign key constraints were validated by inserting, updating, and deleting dependent records. Cascading behavior was tested to ensure no orphan entries remained.

2. **Performance Testing:**
   Queries on prediction metrics such as predicted_yield_tons, carbon_footprint_tons, and health_score executed efficiently (avg. response < 0.05s on 5000-record dataset).

3. **Traceability Queries:**
   We ran JOIN queries to trace a product from Crop_Plantings → Harvests → Product_Shipments → Retail_Outlets, demonstrating full farm-to-fork visibility.

4. **Analytics Use Cases:**

    a. **Soil Health Insights**: Aggregated health_score from Soil_Samples to identify underperforming fields.

    b. **Water Optimization**: Summed water_usage_gallons from Irrigation_Systems and flagged inefficient systems using optimization_tip.

    c. **Market Forecasting**: Queried predicted_price_per_ton and profit_estimate for crop planning decisions.

5. **Compliance Simulation:**
   Certification expiry warnings were generated using cert_expiry_date in Processing_Plants and Retail_Outlets, simulating automated compliance alerts.

Outcome:
The system proved scalable and accurate across multiple test cases, enabling complex data retrieval and analysis with low latency. It demonstrated practical use cases for farmers, agribusinesses, and policy makers.

5.1 Experimental Query's

5.1.1 Sample Table View

5.1.1.1 Query

```sql
SELECT * FROM Soil_Samples LIMIT 6;
SELECT * FROM Crops LIMIT 6;
```

5.1.1.2 Output

sample_id	field_id	date	ph_level	nitrogen_pp...	health_score	recommendation_t...
1	110	2024-10-29	5.3	39	57	Increase nitrogen
2	75	2024-11-03	7.1	46	79	Add lime
3	34	2024-10-23	7.5	48	63	Add lime
4	43	2024-08-24	6.5	44	51	Add lime
5	25	2024-05-07	6.6	36	55	Add lime
6	89	2024-07-24	5.7	43	88	Add lime
NULL	NULL	NULL	NULL	NULL	NULL	NULL

crop_id	crop_name	growth_days	season	predicted_price_per_...	profit_estim...
1	Wheat	96	Winter	206.87	18466.41
2	Soybean	133	Winter	191.74	48048.16
3	Rice	122	Summer	220.55	39960.97
4	Corn	134	Summer	247.52	41249.32
5	Corn	93	Summer	179.90	10815.20
6	Wheat	120	Summer	221.03	14575.58

5.1.2 Output of Analytical Query

5.1.2.1 Query

```sql
SELECT farm_name, carbon_footprint_tons
FROM Farms
ORDER BY carbon_footprint_tons DESC;
```

5.1.2.2 Output

farm_name	carbon_footprint_t...
Johnson Group Farm	9.87
Goodman Inc Farm	8.97
Daugherty, Jordan and Phillips Farm	8.63
Rodriguez-Valencia Farm	8.46
Martinez, Dunn and Duke Farm	7.57
Johnson-Sandoval Farm	7.32
Harvey, Hall and Roberts Farm	7.31
Williams, Peters and Delgado Farm	7.09
Navarro, Davis and Mckinney Farm	6.83
Howard, Bauer and Martinez Farm	6.72
Thomas Inc Farm	6.42
Meyer Ltd Farm	6.20
Mcdaniel-Sherman Farm	4.42
Davis-House Farm	4.42
Diaz-Woods Farm	4.06
Shaw-Woodward Farm	4.03
Adams and Sons Farm	3.50
Baker, Castillo and Stuart Farm	3.48
Ramsey LLC Farm	3.38
Fernandez, Todd and Calderon Farm	3.10
Wilson, Wright and Simon Farm	3.05
Patrick-Allen Farm	2.98
Johnston-Murray Farm	2.97
Mckinney and Sons Farm	2.94
Parks, Russo and Maldonado Farm	2.89
Payne, Moreno and Ayers Farm	2.79
Shepherd-Harrison Farm	2.46
Harris, Woods and Rodriguez Farm	2.44
Brady-Watson Farm	2.26
Moore, Davis and Brown Farm	2.12
Moore, Kidd and Porter Farm	2.00
Hernandez, Snyder and Jensen Fa...	1.78
Chambers, Landry and Campbell F...	1.71
Flores, Shaw and Garner Farm	1.63
Compton, Hansen and Bray Farm	1.29
Paul-Pearson Farm	1.06

5.1.3 Sample SQL Query: Traceability from Farm to Retail

5.1.3.1 Query

```
SELECT
    Farms.farm_name,
    Fields.field_name,
    Crops.crop_name,
    Crop_Plantings.planting_date,
    Harvests.date,
    Product_Shipments.traceability_code,
    Retail_Outlets.name
FROM Product_Shipments
JOIN Harvests ON Product_Shipments.harvest_id = Harvests.harvest_id
JOIN Crop_Plantings ON Harvests.planting_id = Crop_Plantings.planting_id
JOIN Fields ON Crop_Plantings.field_id = Fields.field_id
JOIN Farms ON Fields.farm_id = Farms.farm_id
JOIN Crops ON Crop_Plantings.crop_id = Crops.crop_id
JOIN Retail_Outlets ON Product_Shipments.destination_id = Retail_Outlets.center_id
WHERE Harvests.date BETWEEN '2024-01-01' AND '2024-12-31';
```

5.1.3.2 Output

farm_name	field_name	crop_name	planting_da...	date	traceability_co...	name
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Coleman, Bridges and Smith Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Brown-Ryan Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Barker, Gardner and Weaver Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Davis-Holloway Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Palmer-Nunez Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Neal and Sons Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Reyes PLC Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Jensen and Sons Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Myers, Miller and Bell Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Mclean, Manning and Mahoney Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-0257	Goodwin, Krueger and Rodriguez St...
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Kent Inc Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Case-Snyder Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Blevins, Shepherd and Maynard Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Zavala PLC Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Harris PLC Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Clark-Gilbert Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Potter-Moran Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Carrillo-Thomas Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Morris-Jones Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Lopez, Miller and Brown Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Leach Inc Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1094	Warren, Jackson and Williams Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Kent Inc Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Case-Snyder Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Blevins, Shepherd and Maynard Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Zavala PLC Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Harris PLC Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Clark-Gilbert Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Potter-Moran Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Carrillo-Thomas Store
Shepherd-Harrison Farm	Field South	Wheat	2024-01-15	2024-05-18	TRC-1320	Morris-Jones Store

6. Comparative analysis

Feature	Seeds of Change (Agro)	Microsoft Azure FarmBeats	Sentera Ag Analytics	IBM Food Trust	Farm Management System	Agriculture Management System
Scope	Farm-to-fork, holistic	Precision farming, data integration	Crop health monitoring, aerial imagery	Supply chain traceability	Product sales, farmer profiles	Field and employee management
Data Focus	Comprehensive: soil, weather, crops, livestock, processing, distribution, retail	Soil moisture, temperature, crop health	Crop vigor, disease detection	Product origin, transit data	Product sales, farmer profiles, inventory	Field data and employee information
Technology	SQL Database (Structured, Scalable)	IoT, AI, Cloud	Aerial imagery, data analytics	Blockchain (Distributed Ledger)	SQL Database	SQL Database
Carbon Tracking	Explicit (Farms.carbon_footprint_tons)	Limited	Limited	No	No	No
Food Safety Compliance	Yes (cert_expiry_date in processing & retail)	No	No	Yes (traceability aids compliance)	No	No
Market Forecasting	Yes (Crops.predicted_price_per_ton)	No	No	No	No	No
Soil Health Monitoring	Yes (Soil_Samples: health_score, recommendation_text)	Yes	Limited (indirectly via crop health)	No	No	No
Pest Management	Yes (Pesticide_Applications: pest_type, severity_level)	No	Yes (disease detection)	No	No	No
Water Optimization	Yes (Irrigation_Systems: water_usage_gallons, optimization_tip)	Yes	No	No	No	No
Integration Level	High (End-to-End)	Medium (Farm-Level Focus)	Low (Crop Health Specific)	Low (Supply Chain Only)	Low (Sales and Profiles Only)	Low (Field/ Employee Only)
Unique Value	Holistic, Carbon Tracking, Food Safety, Market Forecasting, Comprehensive Database	Data-Driven Insights, AI-Powered Farming	High-Resolution Crop Health Analysis	Secure Supply Chain Provenance	Basic Transaction/ Inventory Management	Foundational farm data management

7. Conclusion and Future Work

Our project, *Seeds of Change*, presents a comprehensive SQL-based data management solution that integrates all aspects of the food system—from farming and harvesting to processing and retail. By prioritizing sustainability, traceability, and predictive analytics, the system supports a smarter and more transparent agricultural model.

7.1 Key Achievements:

- Built a structured and modular relational database of 15 tables.
- Included advanced features such as crop yield forecasting, carbon footprint tracking, and compliance management.
- Enabled full traceability across the food supply chain.

"This system is not only academic but scalable, with potential applications across government bodies, NGOs, and agri-tech startups to monitor and manage food security at a national and global level."

7.2 Future Work:

✔ **IoT & Sensor Integration:**

Connect the database with live IoT feeds for real-time soil, weather, and irrigation monitoring.

✔ **Machine Learning Models:**

Use AI/ML for predictive insights like disease outbreak forecasting and dynamic pricing.

✔ **Mobile App Development:**

Build farmer-friendly apps linked to the database for field-level decision support.

✔ **Cloud Deployment:**

Host the database on cloud platforms (e.g., AWS RDS, Azure SQL) for scalability and remote access.

✔ **Multi-language Support:**

Implement multilingual interfaces for accessibility in diverse farming regions.

In summary, this project lays the groundwork for a digital agricultural ecosystem that's sustainable, inclusive, and future-ready.

🌐 Alignment with UN Sustainable Development Goals (SDGs)

Our project directly supports the following UN SDGs:

- **Goal 2 – Zero Hunger**: Improves crop yield predictions and distribution efficiency.
- **Goal 12 – Responsible Consumption and Production**: Reduces food loss and promotes traceability.
- **Goal 13 – Climate Action**: Tracks and helps reduce carbon emissions at the farm level.
- **Goal 9 – Industry, Innovation and Infrastructure**: Promotes smart farming using digital innovation.

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