Smart Farm Planner: Prescriptive Analytics for Optimal Crop Mix Decisions

Final Report – ISOM 835

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1. Executive Summary

This project presents *Smart Farm Planner*, a prescriptive analytics tool designed to optimize crop allocation decisions for smallholder farmers. Using Gurobi-based linear and quadratic optimization integrated with a Streamlit user interface, the system determines the best distribution of crops across limited land, water, labor, and financial resources.

The goal is to demonstrate mastery of optimization modeling, scenario-based risk quantification, and the deployment of a functional analytical product.

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2. Problem Definition

Small-scale farmers face complex decisions under uncertainty. Traditional crop planning often lacks analytical rigor and does not account for trade-offs between profitability, resource constraints, and risk exposure.

This project addresses the following questions:

- How should a farmer allocate acres to different crops to maximize expected profit?

- How can risk of price volatility be incorporated into planning?

- How can a practical digital tool support real-world decision-making?

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3. Data Description

The project uses structured crop-level data, including:

- Yield per acre
- Water use per acre
- Labor hours per acre
- Input cost per acre
- Expected market price
- Price volatility (simulated)

Synthetic datasets were generated to reflect real agricultural environments.

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4. Methodology

4.1 Optimization Model

Decision variable:

- Acres planted for each crop.

Objective:

- Maximize expected profit.
- Optionally minimize variance through a quadratic penalty term.

Constraints:

- Land availability
- Water budget
- Labor capacity
- Input budget
- Min/max acreage per crop

4.2 Risk Modeling

Scenario-based price sampling produces multiple price outcomes used to compute expected profit and variance. Risk aversion is modeled using a penalty term in the quadratic objective.

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5. System Architecture

The system contains three main modules:

1. **Data Handler** – Loads or generates crop and scenario data.

2. **Optimization Engine** – Gurobi solver executed through Python.

3. **Streamlit App** – Web interface for user interaction.

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6. Implementation

The final deliverable includes:

- `optimizer.py` – Core model

- `app.py` – Streamlit interface

- `requirements.txt` – Dependencies

- `README.md` – Documentation

Key libraries: Gurobi, Pandas, NumPy, Plotly, Streamlit.

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7. Results

The model successfully generates optimal crop mixes with clear outputs:

- Land allocation by crop

- Expected profit

- Profit variance

- Scenario profit distribution

Visualizations (pie charts, bar charts) enhance interpretability.

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8. Streamlit App

The deployed app supports:

- Adjustable inputs (acres, budgets, labor, risk)

- Editable crop tables

- Interactive visualizations

- CSV export of recommendations

This demonstrates a functional prescriptive analytics product ready for portfolio use.

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9. Discussion and Insights

Key insights include:

- Profitability is sensitive to price fluctuations

- Water usage constraints significantly affect crop allocations

- Risk aversion shifts allocation from high-reward to stable crops

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10. Limitations and Future Work

Future enhancements may include:

- Real historical price data

- Multi-period planning

- Crop rotation constraints

- Mobile deployment

- Integration with GIS data

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11. Conclusion

Smart Farm Planner effectively demonstrates prescriptive analytics capability, combining optimization, uncertainty modeling, and interactive deployment. It provides practical decision support and serves as a strong portfolio project.

Appendix

- Screenshots

- Code snippets

- Additional tables