Smart Farm Planner: Prescriptive Analytics for Optimal Crop

Mix Decisions

Final Report – ISOM 835
Student: Patrick Tinashe Ndowa

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.

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?

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.

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.

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.

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.

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.

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.

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

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

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.