Economic Analysis of Alfalfa Harvest Management Decisions

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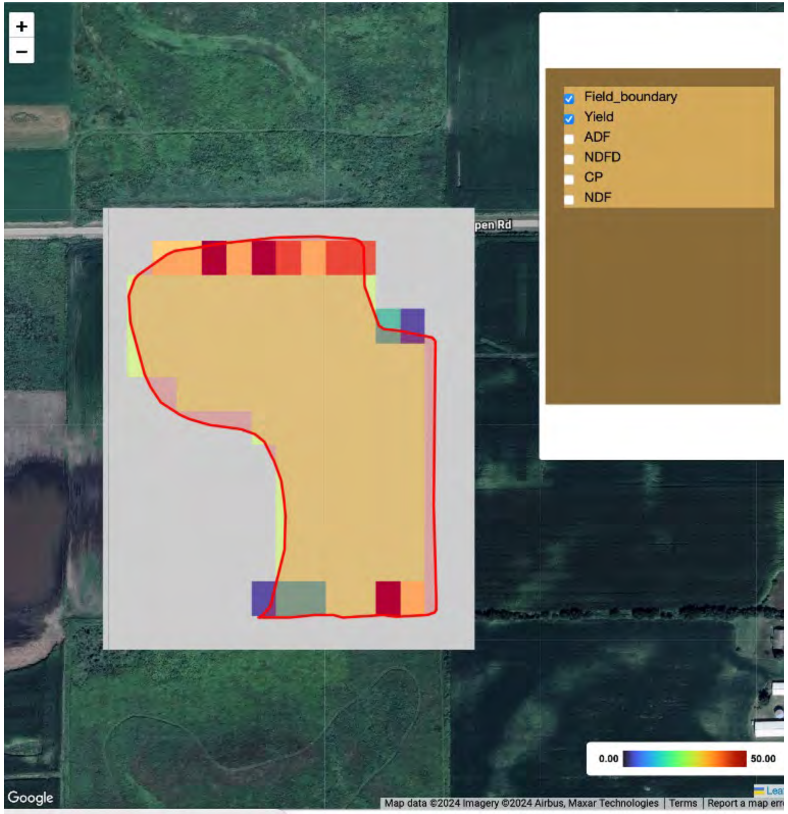
Project Goal

1. Help farmers plan alfalfa harvests
2. Focus on short horizon
3. Maximize value of harvest
4. Minimize losses from operations and precipitation
5. Develop a web-based decision support tool

AlfaAdvisor Overview

1. Farmer input
   - Field boundaries
   - Storage, target moisture, use, and market info
2. Run model prior to harvest week
   - Pull satellite data
   - ML model predicts yield and quality (7d)
   - Pull weather forecast data (11d)
3. Get feedback (Economic Model)
   - Potential Value
   - Probability of rain during drying
   - Breakeven costs of drying operations



The ML Model

- Pulls imagery from Sentinal-1 Satellite
- Uses random forest model
- Features include:

  Gap, NDVI, EVI2, NIRv, NDWI, redE1, redE2, redE3, and solar-viewing angles
- Target variables include:

  TDM, ADF, NDF, CP, and NDFD
- Validated with field sampling data

The Economic Model

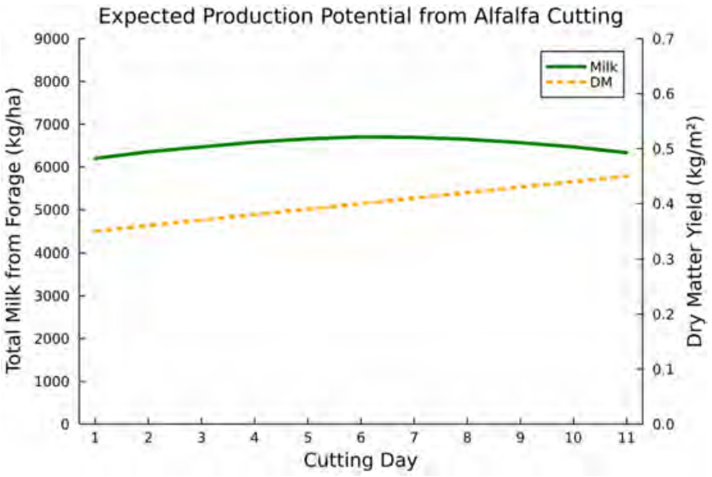
- Farmer chooses timing of cutting and drying operations
- Model objective is to maximize relative profits
- Returns expected value for each day and breakeven cost of operations

Symbol	Definition
t	Timing of cutting
m	Drying operations
p	Price for alfalfa
$q(t)$	Quality of alfalfa
$y(t)$	Yield of alfalfa
l_m	Losses from operations (%)
$l_r(t)$	Losses from rain (%)
c_m	Operation Costs

$$\max_{t,m} \mathbb{E}\left[p(q(t)) * y(t) * (1 - l_m)\left(1 - l_r(t)\right) - c_m\right]$$

The Yield-Quality Tradeoff

$$\frac{\partial y}{\partial t} > 0 \qquad \frac{\partial q}{\partial t} < 0$$



- Farmer chooses 'sell' or 'feed'
  - Sell uses RFV

$$p = \begin{cases} p_1 & RFV \geq 151 \\ p_2 & 151 > RFV \geq 125 \\ p_3 & 125 > RFV \end{cases} \quad , p_1 > p_2 > p_3$$

  - Feed uses Milk2016 (Undersander, 2016)

$$p = p_m * TM(CP(t), NDF(t), ttNDFD(t))$$

Losses After Cutting

Cause of Loss	Loss Function (%)	Reference
Rain	$0.7 \times pcp_{mm}$	Rotz and Abrams (1988)
Tedding	$80 - \mu$	Savoie (1987)
Baling	$(60 - 1.5\mu) * \mathbf{1}_{\mu \leq 40}$	Buckmaster and Heinrichs (1993)
Field Weathering	0.1ρ	Rotz and Abrams (1988)
Storage Moisture	$(2.5\mu - 50) * \mathbf{1}_{\mu > 20}$	Collins et al. (1987)

μ = moisture content (wb)
ρ = dry down days

The Drying Model

1. Calculate drying rate for every hour Rotz and Chen (1985):

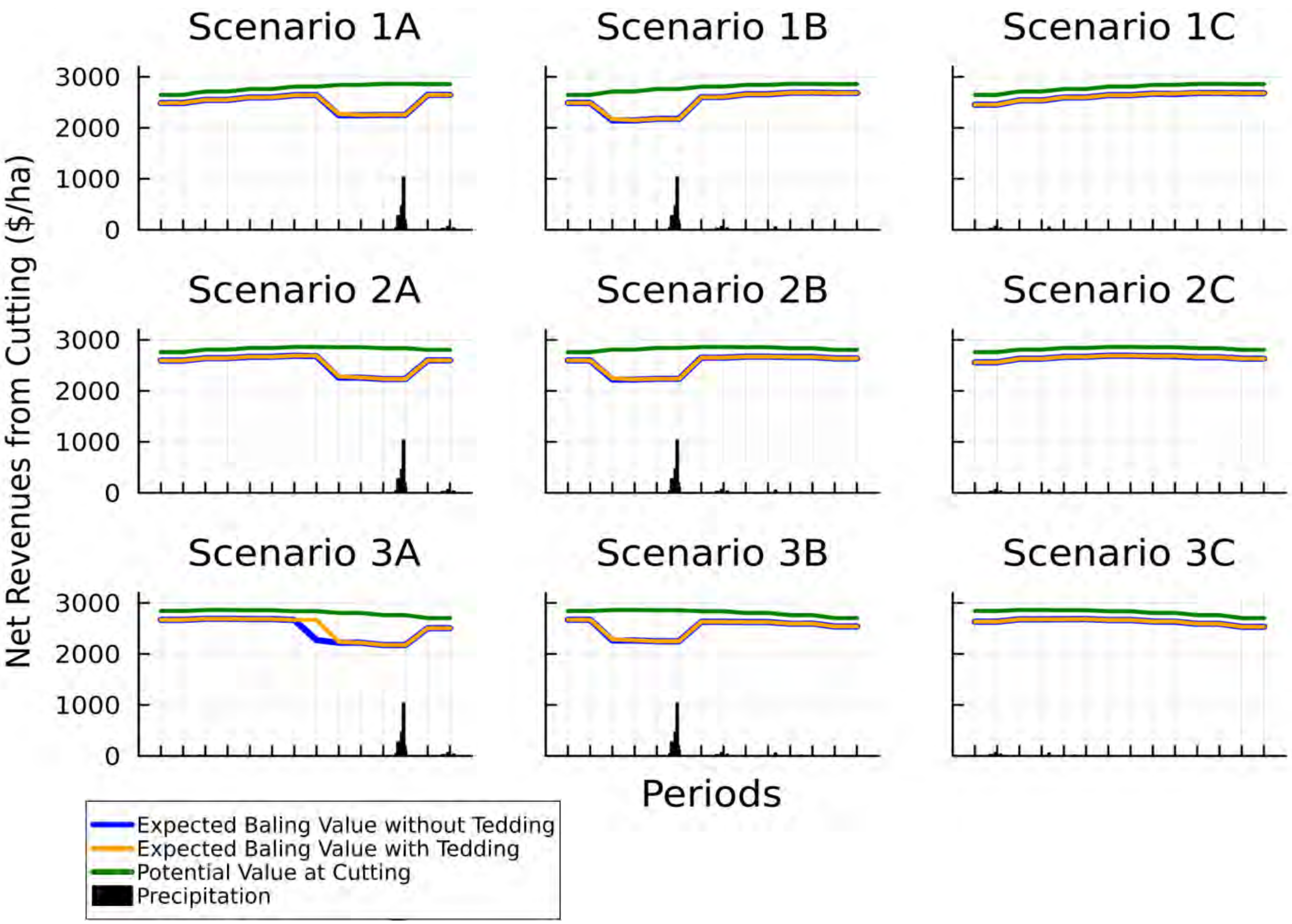
$$DR_h = \frac{SI_h + 5.42 * T_h}{66.4 * SM_h + SD * \left(2.06 - 0.97 * \mathbf{1}_{(DAY=1)}\right) * 1.55 + 3037}$$

2. Loop over rate equation until moisture content drops below target moisture.

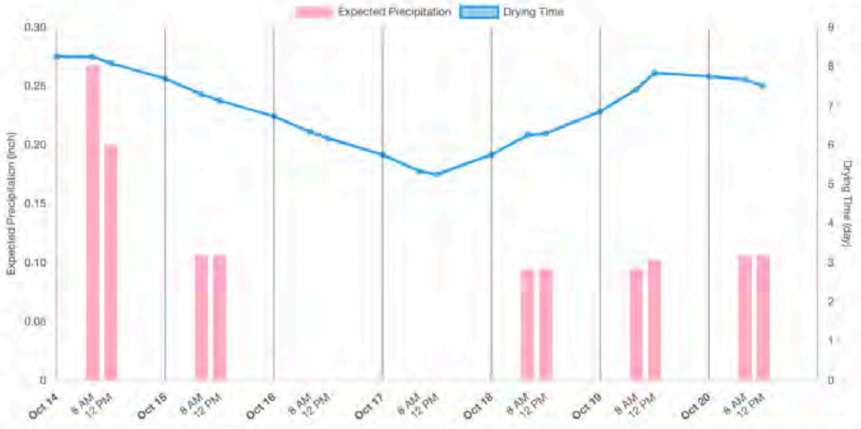
$$\mathbb{E}[M_{h+1}] = M_h * \left((1 - \mathbb{P}_h[R])e^{-DR_h} + \mathbb{P}_h[R]\right)$$

Assumes if it is raining there is no drying and does not account for rewetting.

Example Results



Example Output



If you cut your hay at **2024-10-16**, the values in this plot at that time represent the following:

- Expected Precipitation: **0.00 inches**
- Drying Time: **6 days**

If you cut your hay at **2024-10-16**, the values in this plot at that time represent the following:

- Yield : **86.56 Ton**
- Net Revenue: **$14646.04**

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