Optimization model to support decision making for silvopastoral systems in Uruguay

CLAIO 2024

Costa[1], M.; González[1], J.D.; Martínez[1], V; Cancela[1], H.; Piñeyro[1], P.; Viana[2,3], V.

1 Facultad de Ingeniería (Udelar), 2 CENUR Noreste (Udelar), 3 ITRCS (UTEC)

October 30, 2024

CLAIO 2024
XXII CONGRESO LATINO IBEROAMERICANO DE INVESTIGACIÓN OPERATIVA

CSMIO 2024
XII CONGRESO DE LA SOCIEDAD MEXICANA DE INVESTIGACIÓN DE OPERACIONES

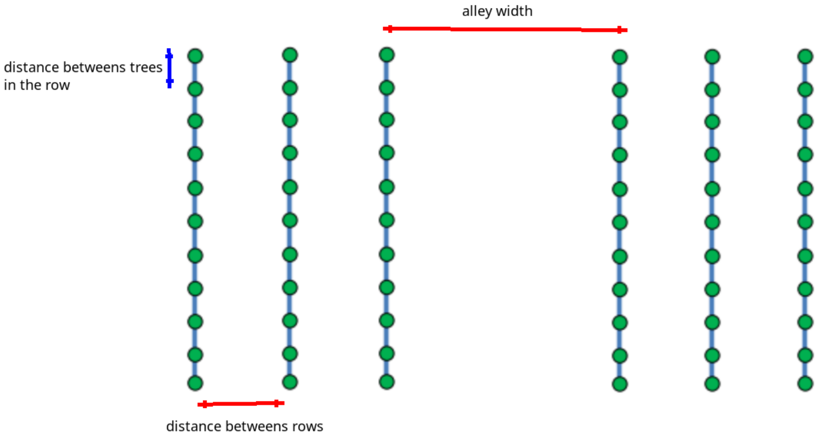
Outline

What are Silvopastoral Systems (SPP)?

- Agroforestry practice combining:
  - Forestry
  - Livestock
  - Pastures
- Seeks to maximize economic & environmental benefits
- Typical cycle: 8-15 years

Figure: Silvopastoral system in Tacuarembo, Uruguay. Photo by J. L. Dutra

Rows and alleys



Rows and alleys(cont.)

Research Objectives

1. Determine optimal spatial arrangement of trees
2. Calculate maximum livestock load per year
3. Optimize profits for both forestry and livestock
4. Consider terrain features and component interactions

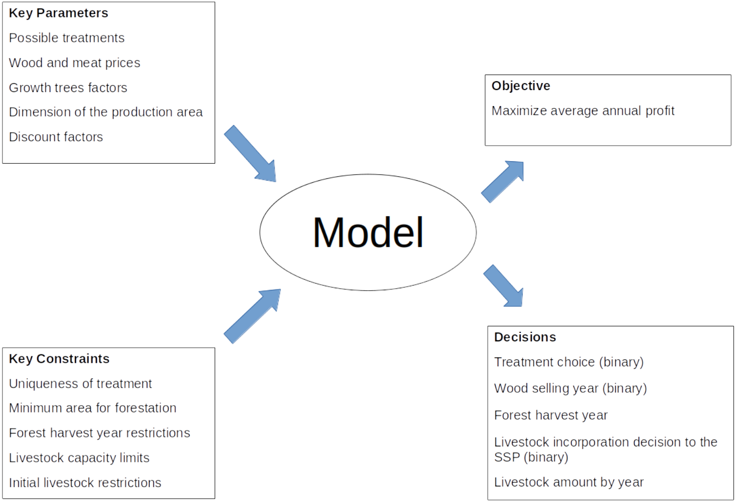
Key Decisions to Optimize

1. Forestation treatment
   - Number of rows
   - Distance between rows
   - Distance between trees
   - Corridor width
2. Forest harvest year
3. Maximum livestock load per year

Methodology

- Mathematical programming approach
- Mixed-integer nonlinear programming (MINLP) model
- Linearization technique used
- Validation through base case and sensitivity analysis
- Actual data from an Uruguayan livestock farm

Model


Key Parameters
Possible treatments
Wood and meat prices
Growth trees factors
Dimension of the production area
Discount factors
Objective
Maximize average annual profit
Model
Key Constraints
Uniqueness of treatment
Minimum area for forestation
Forest harvest year restrictions
Livestock capacity limits
Initial livestock restrictions
Decisions
Treatment choice (binary)
Wood selling year (binary)
Forest harvest year
Livestock incorporation decision to the SSP (binary)
Livestock amount by year

Base Case Results

- Production area: 150 m $\times$ 200 m
- Treatment chosen:
  - 4 rows
  - 6 meters between rows
  - 3.5 meters between trees
  - 30 meters corridor width
- Optimal forest harvest year: 13
- Total profit: $14,402 USD
- Average annual profit: $1,108 USD

Base Case Results (cont.)

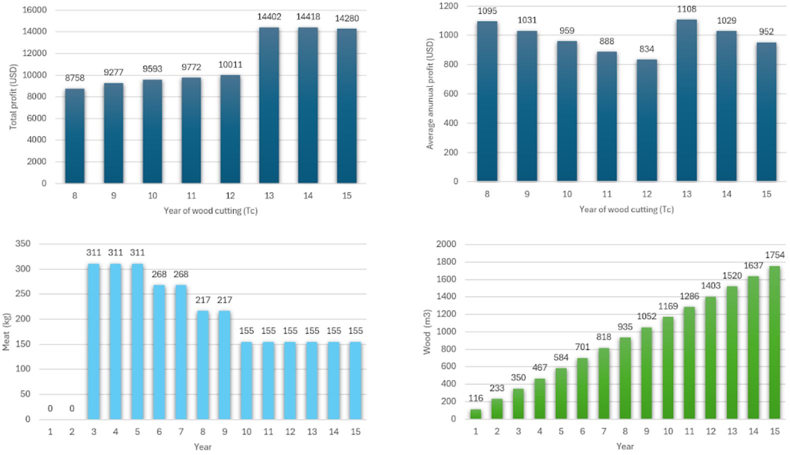


Figure: Inverse relationship observed (wood volume increases, livestock capacity decreases)

Economic Analysis

Forest harvest year Impact:

1. Year 13 maximizes both:
   - Total profit
   - Average annual profit
2. Factors:
   - Wood quality increase
   - Price changes
   - Discount factor

Model Sensitivity

- Responsive to:
  - Wood growth factors
  - Tree density
  - Dry matter availability
- Lower density $\rightarrow$ higher individual tree growth
- Trade-off between quantity and quality

Conclusions, key findings

1. Forestry more profitable than livestock
2. Optimal balance needed for system sustainability
3. Model accurately represents real-world trade-offs
4. Year 13 optimal for wood cutting
5. Consistent treatment choice across scenarios

Research Impact

1. Decision support tool for producers
2. Scientific approach to system optimization
3. Contribution to Uruguay's productive matrix
4. Framework for future research
5. Promotes sustainable agriculture

Limitations and Future Work

1. Improve component interaction modeling
2. Include environmental factors
3. Consider soil quality preservation
4. Develop more detailed shade functions
5. Enhance tree growth relationships

Questions?

Thank you for your attention!