Integrating Multifunctional Forests into the Rubber Tree Industry in São Paulo, Brazil: A Model for Balancing Resource Availability and Market Constraints

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1) Context

1

- According to Brazilian Forest Law we must have 20% (in SP) of all private properties covered with tree species (at least 50% native species). >>> Legal Reserve (RL)
- If it is not there, landowner has to restore $$$

2

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- West and Norwest:
  - +200.000 ha RL deficit
  - Degraded Pasture
  - Rubber hub

3

Hevea brasiliensis

5

Agreement

Financial Institution

BANCO DO BRASIL

Industry

Future Contract
to reduce risks

Funding

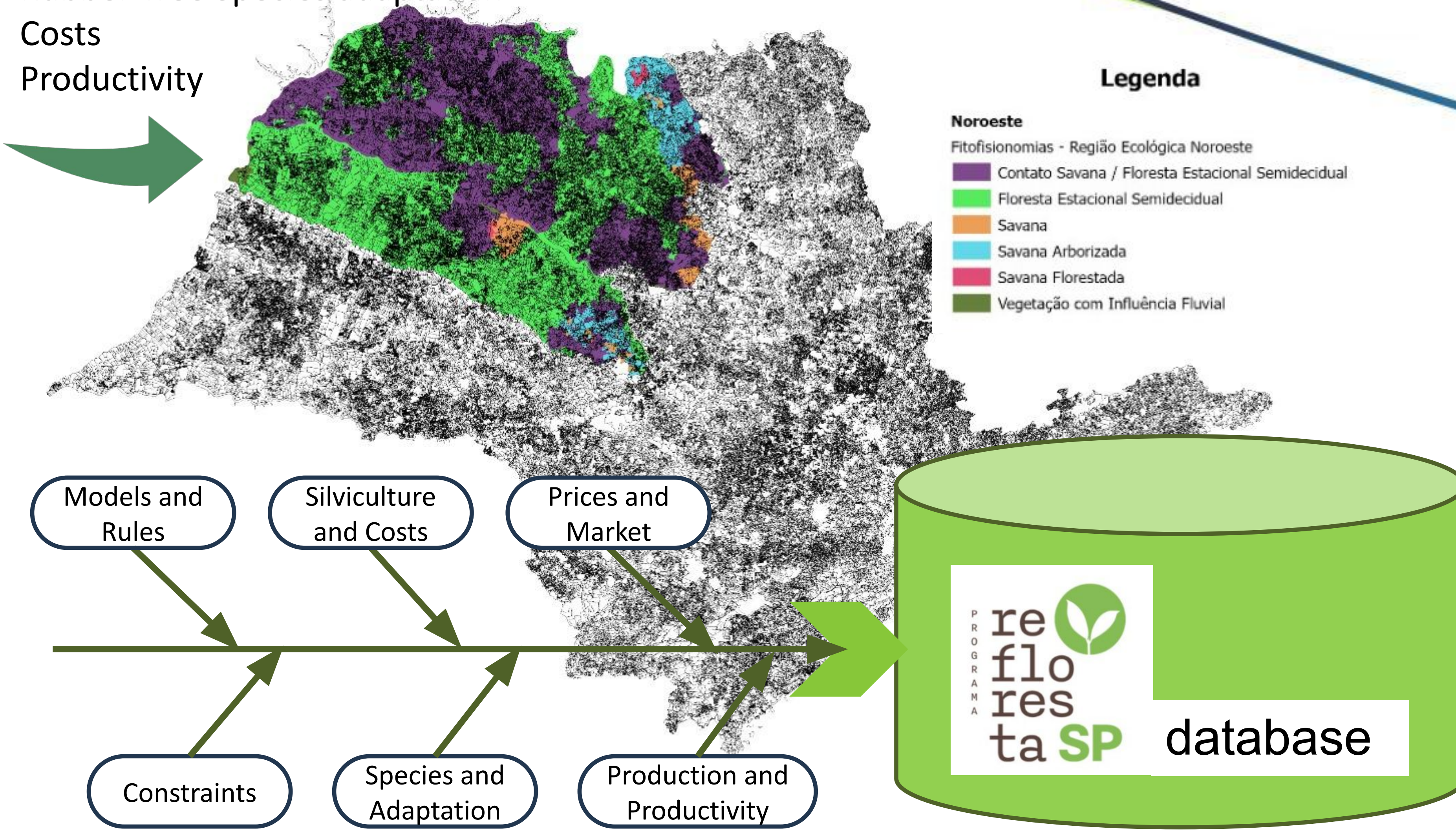
RL Restoration

Raw Material to
expand
Rubber production

Landowner

2) Tools to support the negotiation

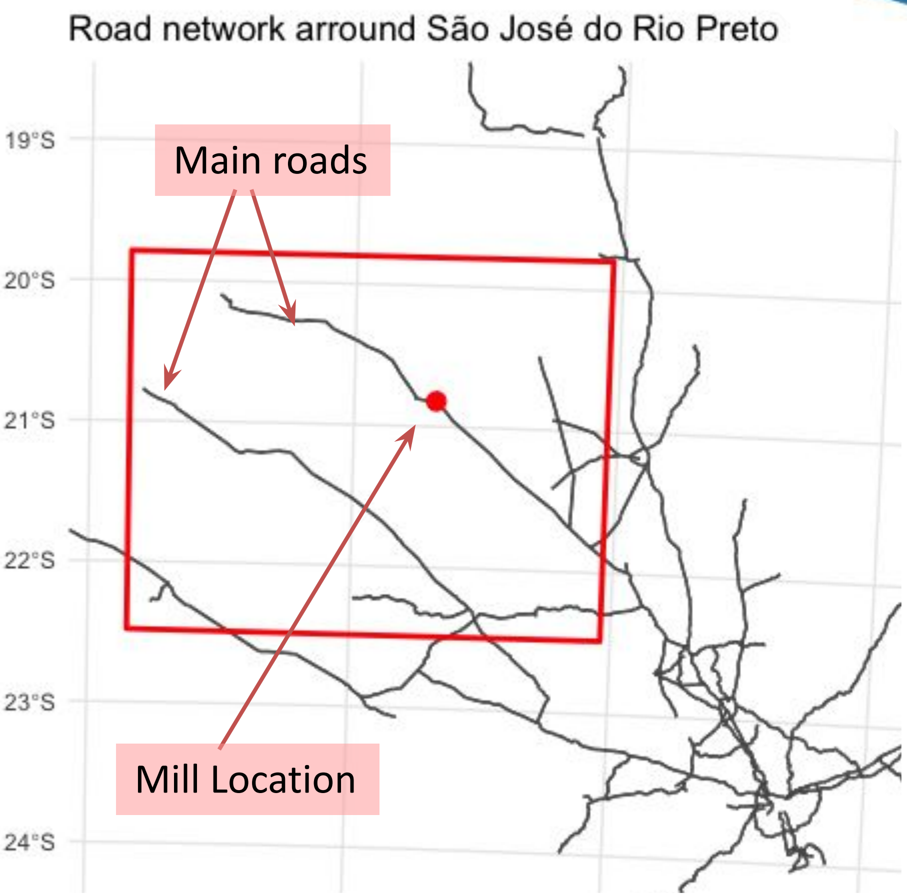
Good Infrastructure
Structured Production Chain
67% of Brazilian Rubber production
Rubber Tree Species adaptation
Costs
Productivity



Where would the best locations be for the beginning of negotiations?

Key considerations:

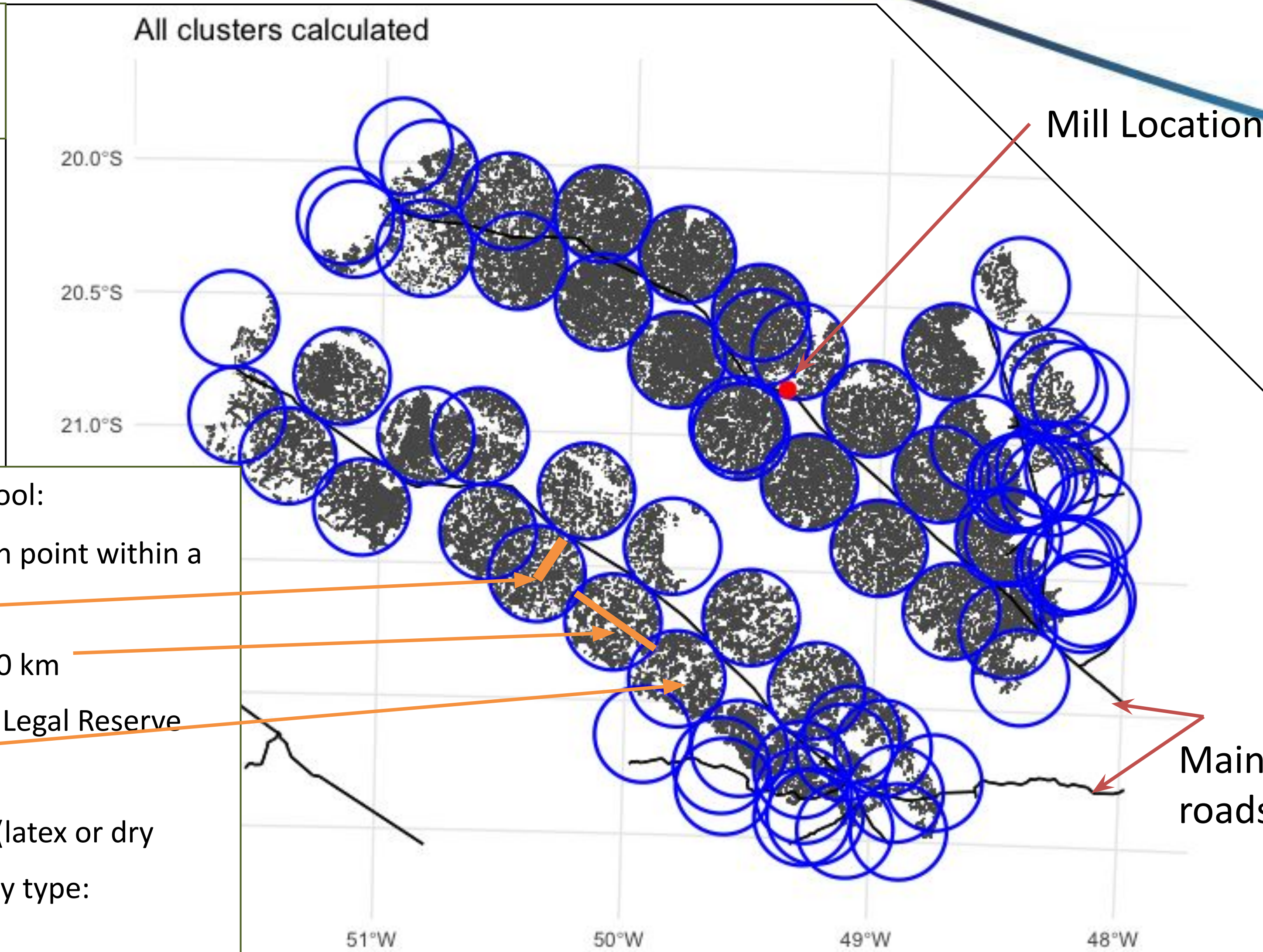
- Inclusion of small landowners
- Prioritize clusters with collection points
- Minimize logistical costs
- Assume only ~10% acceptance rate
- Restrict planting to the Legal Reserve (RL)
- Use 50% rubber trees and 50% native species



Build Clusters along the main roads

Using CAR(*) database with declared RL

(*) Private Properties National Database



Clusters defined with a GIS tool:

- Each includes a collection point within a 20 km radius
- Total cluster diameter: 40 km
- Minimum of 4,000 ha of Legal Reserve (RL) within the cluster
- Transportation distance (latex or dry rubber) varies by industry type:
- → Latex: up to 20 km

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Optimization Model

What does the model do?

Selects a set of clusters that:

- satisfy area and inclusion constraints,
- are suitable for negotiation (considering acceptance rate),
- do not overlap,
- minimize the total distance to the rubber mill.

Key Assumptions:

- Need to secure at least 150,000 ha of total RL area.
- From this area, expect only 10% acceptance rate → ~15,000 ha planted.
- Each cluster contains ~4,000 ha of Legal Reserve (RL).
- Production: 1 ton of dry rubber per hectare/year.
- Goal: 15,000 t/year of rubber → enough to expand 15%
- Each cluster must include at least 1/3 of small landowners’ RL area.
- Clusters that spatially intersect are mutually exclusive.

Model Formulation

Let:

$x_i \in \{0,1\}$: *binary variable to indicate cluster i selection*

d_i : *distance from cluster i to the mill*

A_i : *cluster i's RL area*

S_i : *cluster i's smal properties RL area*

τ : *set of conflicting (intersecting) cluster pairs*

I : *set of clusters*

Objective function:

Minimize total distance

$$\min Z = \sum_{i=1}^{I} d_i \, . \, x_i$$

Constraints:

1) Minimum total Area Selected $\sum_{i=1}^{I} A_i \, . \, x_i \geq 150{,}000$

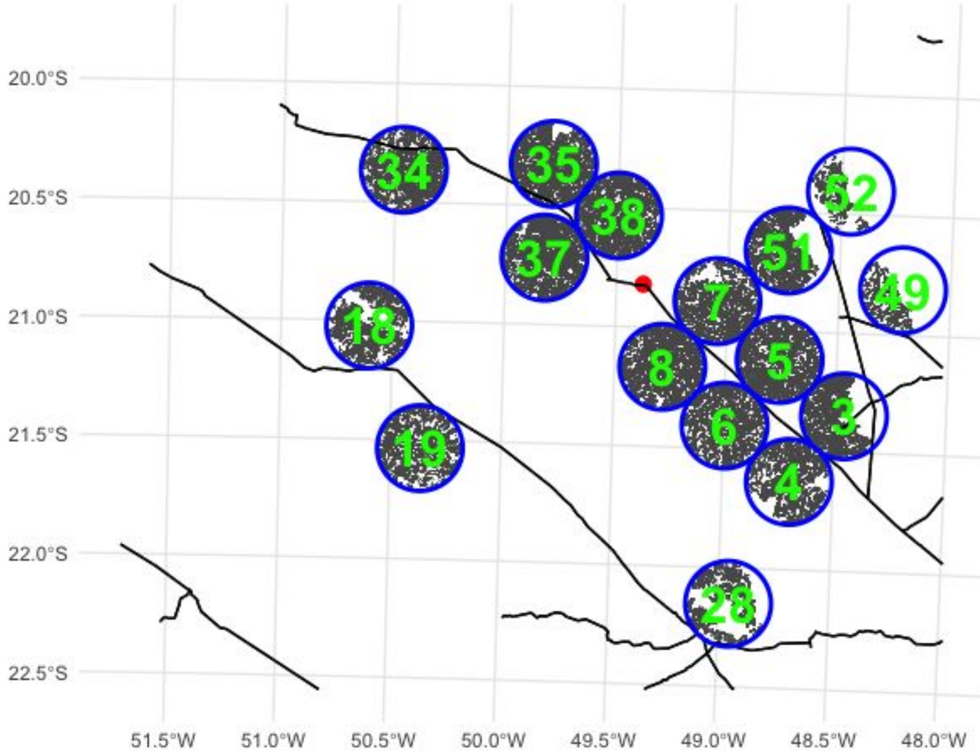
2) Small properties Inclusion: $\sum_{I=1}^{I} S_i \, . x_i - 0.33 \, . \sum_{i=1}^{I} A_i \, . \, x_i \geq 0$

3) No overlapping clusters: $x_i + x_j \leq 1 \;\; \forall \, (i,j) \in \tau$

4) Binary Decision Variables: $x_i \in \{0,1\} \;\; \forall i$

3) Preliminary Results

Selected Clusters



Selected Clusters	Distance to the Mill (Km)	RL area (ha)	RL in Small Properties (ha)
7	36	11,636	3,352
8	36	11,405	4,582
37	47	10,397	5,867
38	47	11,853	4,013
5	76	11,582	3,292
6	76	12,516	2,898
35	87	10,673	4,180
51	90	11,053	2,445
52	90	3,681	489
3	115	7,521	2,854
4	115	7,550	3,141
19	123	6,822	2,771
34	126	11,179	3,026
49	130	3,536	1,130
18	164	11,943	2,917
28	214	7,100	2,924
		150,448	49,880
			33.15%

Acceptance rate%	10%	
Area to be planted	15,045	ha
Production of Dry Rubber	15,000	t/ha.year

4) Conclusions

1. It is a preliminary model to show that we can choose the: "negotiation space" with criteria

2. Model will be improved:
   a) More constraints
      - related to characteristics of the landowners
      - region characteristics (like soil, water proximality)
      - Labor availability
   b) Different parameters
      - Total Area
      - Acceptance rate
      - Productivity
      - Cluster size
      - Cluster location

3. Apply to other industries: Tropical fruits, Juçara, Macaúba

Thanks!!

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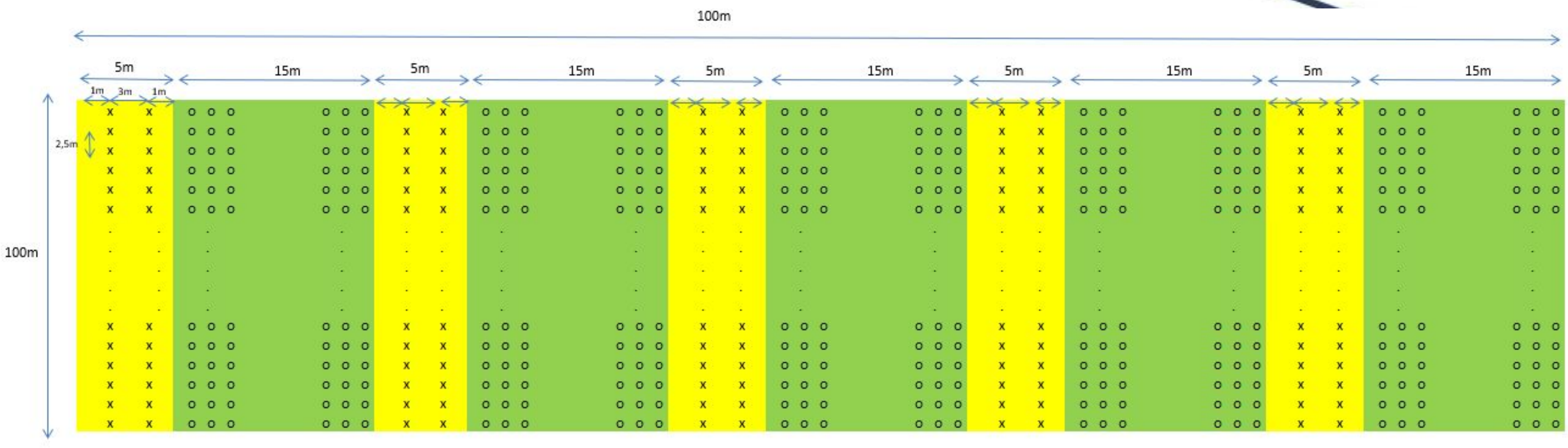
If somebody asks how we plant rubber tree with other species



If somebody asks about technology

- Solver: Gurobi
- Optimization software: Python + Pyomo + Pandas
- Cluster building: R and packages
    - data: dplyr
    - GIS functions: sf, geosdist, dodgr
    - Vizualization: ggplot2