Partitioning and Solving Large-scale Tactical Harvest Scheduling Problems for Industrial Plantation Forests

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Background

- ✓ **Industrial forest plantations** and **decision support models**
- ✓ **Tactical planning** and **operational efficiency**
- ✓ Decide the **operations** carried out in **space** and **time**
- ✓ **Combinatorial complexity**

Tactical Harvest Scheduling Problems for Industrial Plantation Forests

- **Objective:**

  Minimize operational costs and achieve volume production targets

- **Optimized Operations (most expensive activities):**

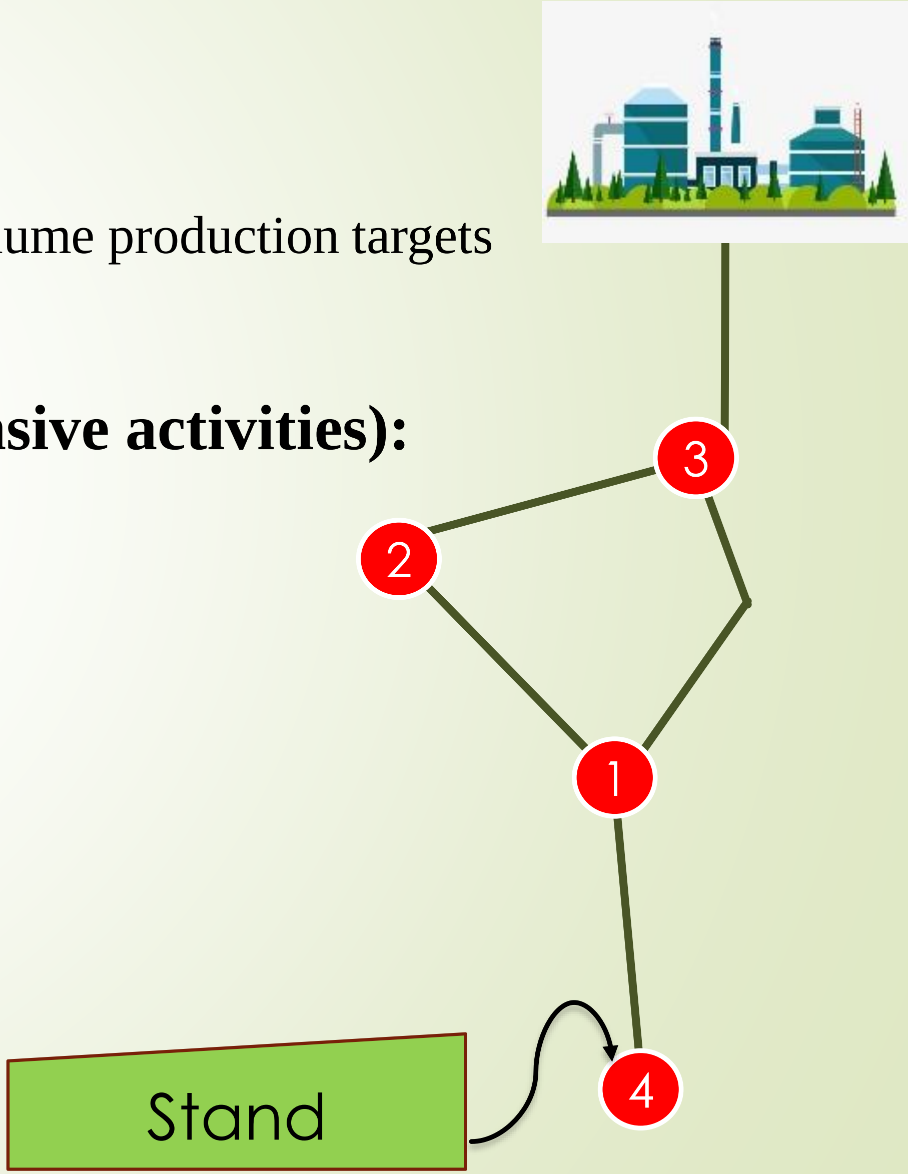
  Harvesting

  Road maintenance

  Transportation

- **Time horizon and periods:**

  6 Years with six-month periods



Objective

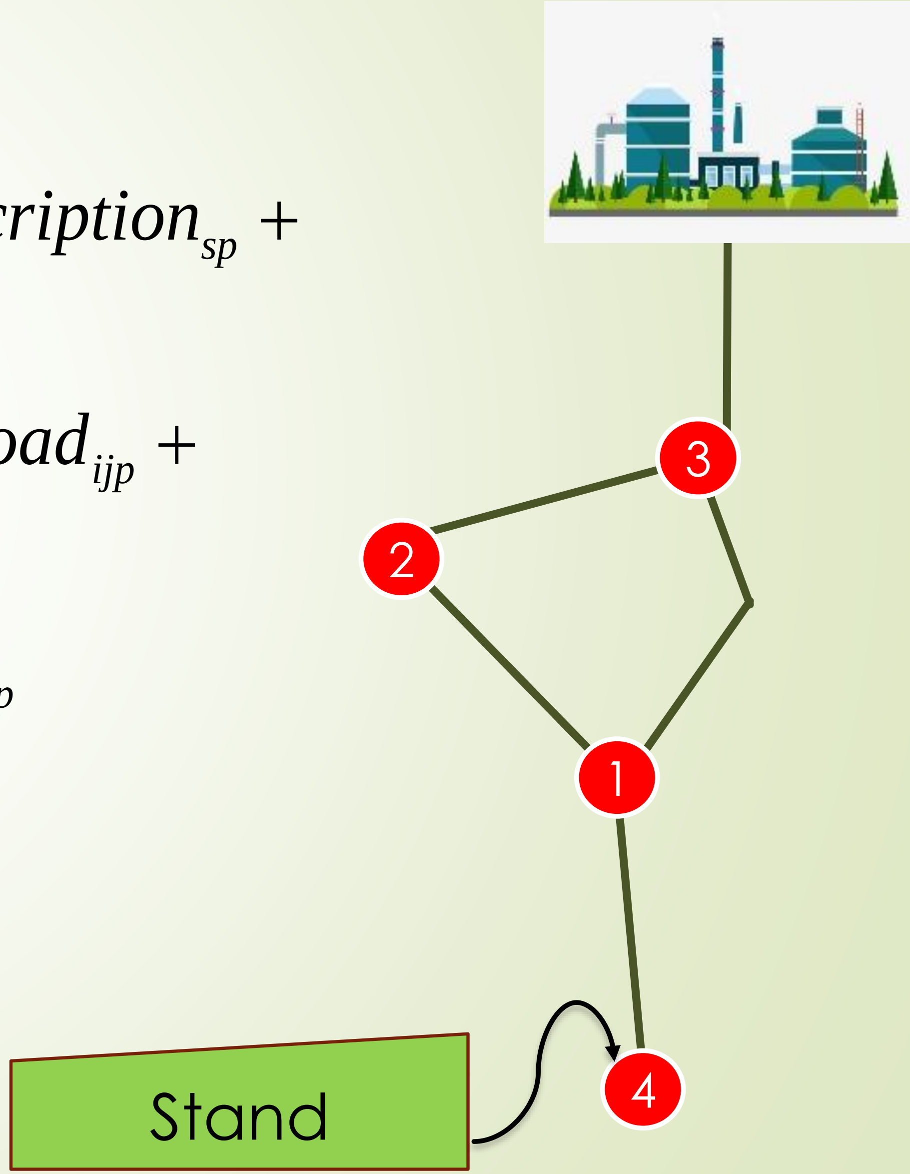
- ✓ The **main objective** of this study is to develop an optimization procedure to overcome the limitation of the mixed integer linear programming approach in solving large combinatorial tactical problems.

Decision variables

$$\sum_{s=1}^{S}\sum_{p=1}^{PH} Harvesting\_Cost_{sp} * Prescription_{sp} +$$

$$\sum_{i,j=1}^{N}\sum_{p=1}^{PH} Maintainance\_Cost_{ijp} * Road_{ijp} +$$

$$\sum_{i,j=1}^{N}\sum_{P=1}^{PH} Transport\_Cost_{ijp} * Flow_{ijp}$$



Fixed Charge Transportation Model Formulation

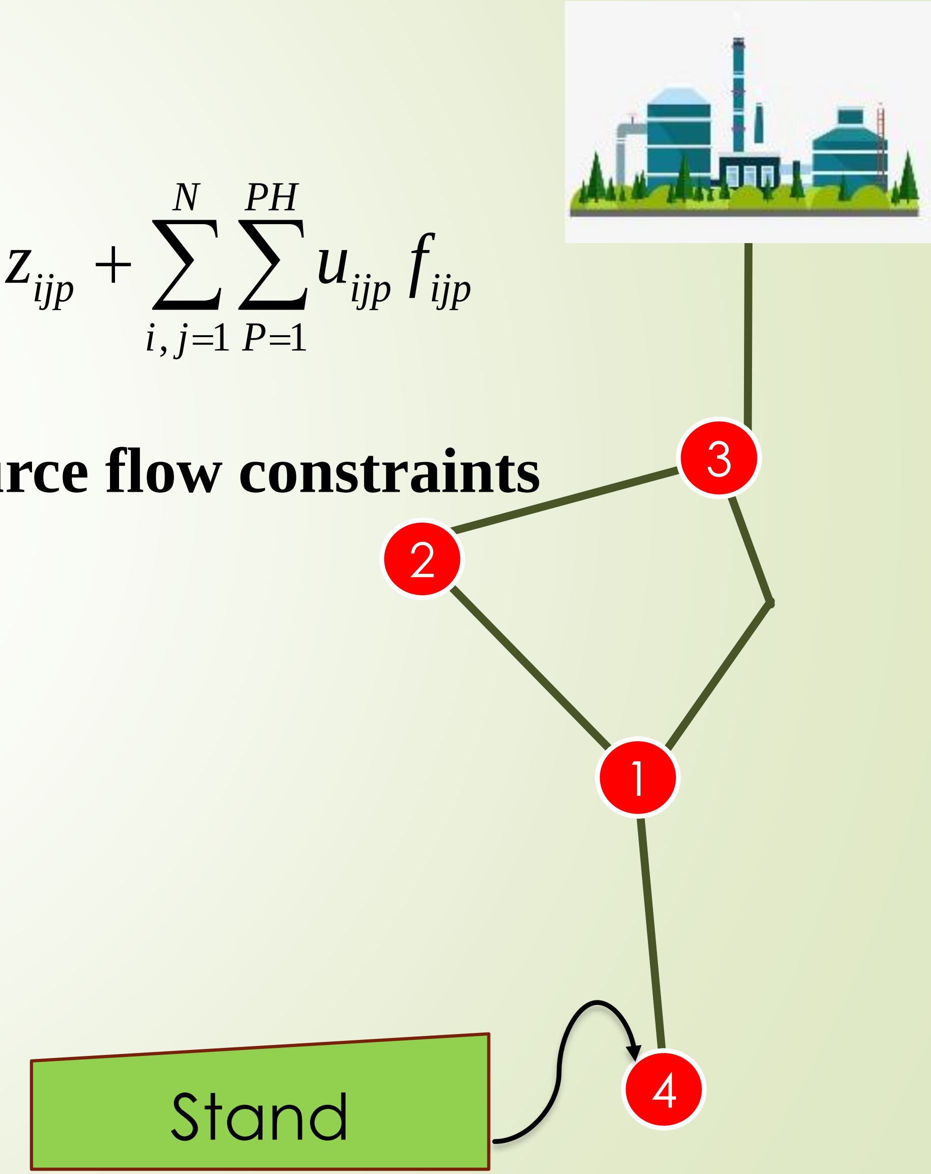
- **Objective function**

$$MinZ = \sum_{s=1}^{S}\sum_{p=1}^{PH} c_{sp} r_{sp} + \sum_{i,j=1}^{N}\sum_{p=1}^{PH} c_{ijp} z_{ijp} + \sum_{i,j=1}^{N}\sum_{P=1}^{PH} u_{ijp} f_{ijp}$$

- **Management prescriptions and source flow constraints**

$$\sum_{p=1}^{PH} r_{sp} \le 1 \qquad \forall s \qquad (1)$$

$$\sum_{j \in n\bar{s}} f_{\bar{s}jp} = Vol_{sp} r_{sp} \qquad \forall s, p \qquad (2)$$



✓ Conservation flow constraints

$$\sum_{j\in n\bar{s}} f_{\bar{s}jp} + \sum_{i\in N_j} f_{ijp} - \sum_{k\in N_j} f_{jkp} = 0 \qquad \forall j, p \qquad (3)$$

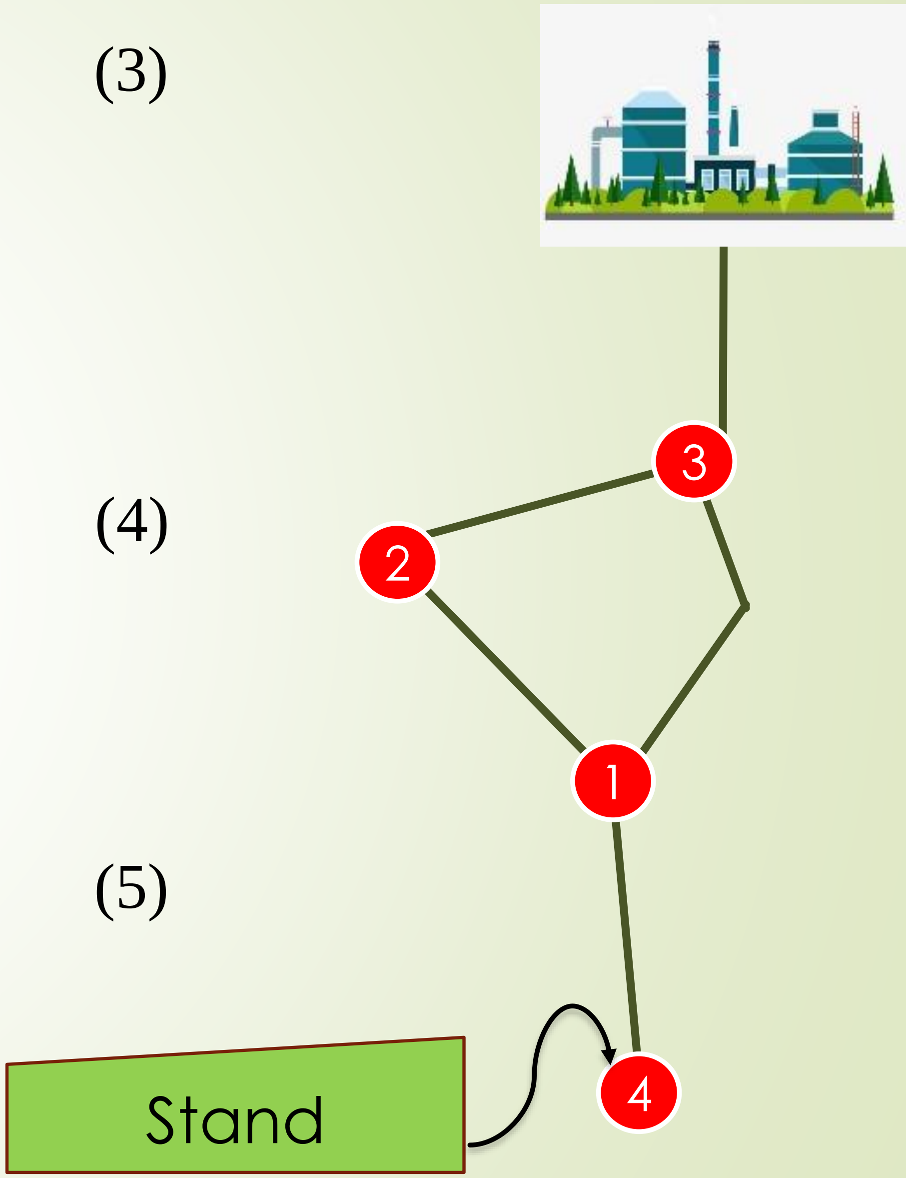
✓ Demand constraint

$$f_{i\bar{c}p} \geq t_{volp} \qquad i \in n\bar{c}, \forall p \qquad (4)$$

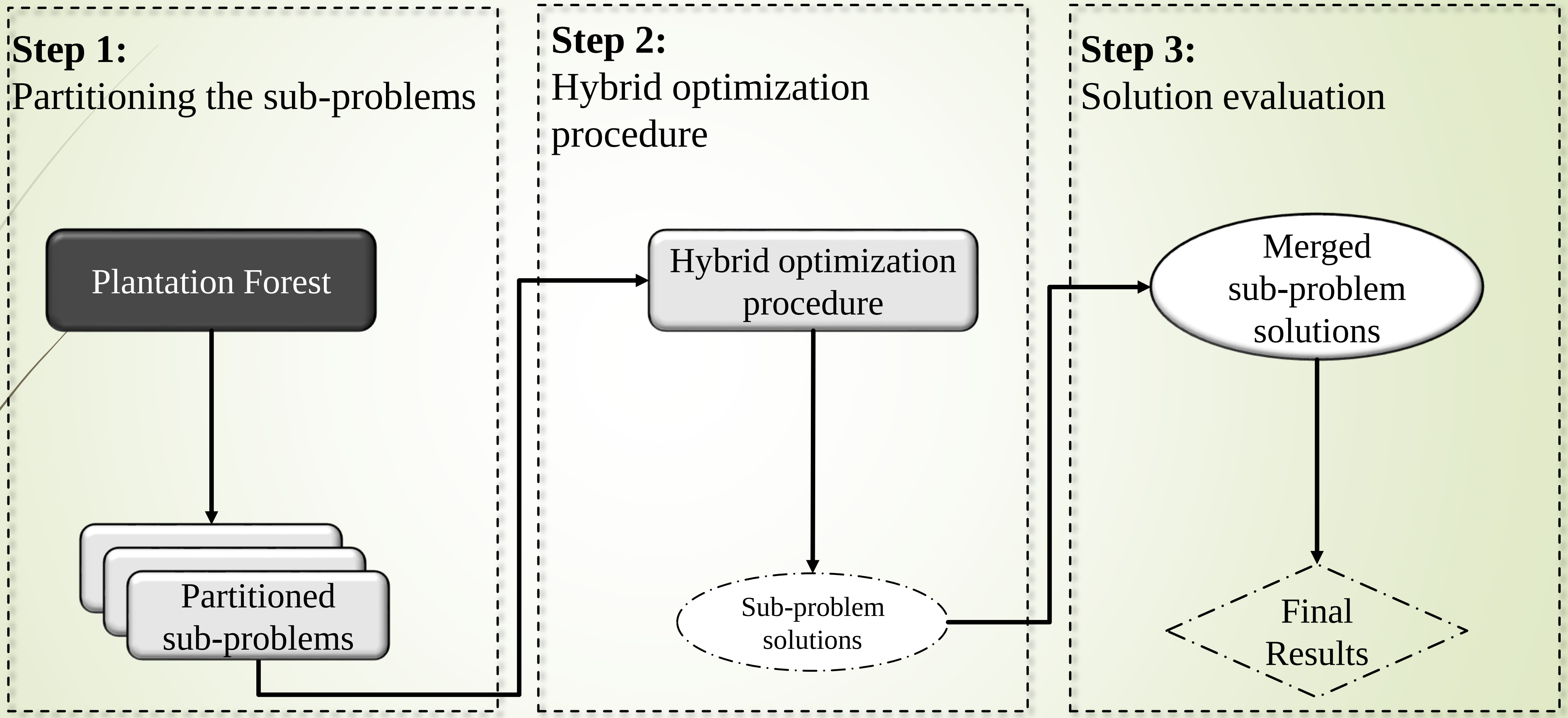
✓ Fixed charge constraints

$$f_{ijp} + f_{jip} - Mz_{ijp} \leq 0 \qquad \forall j, p \qquad (5)$$

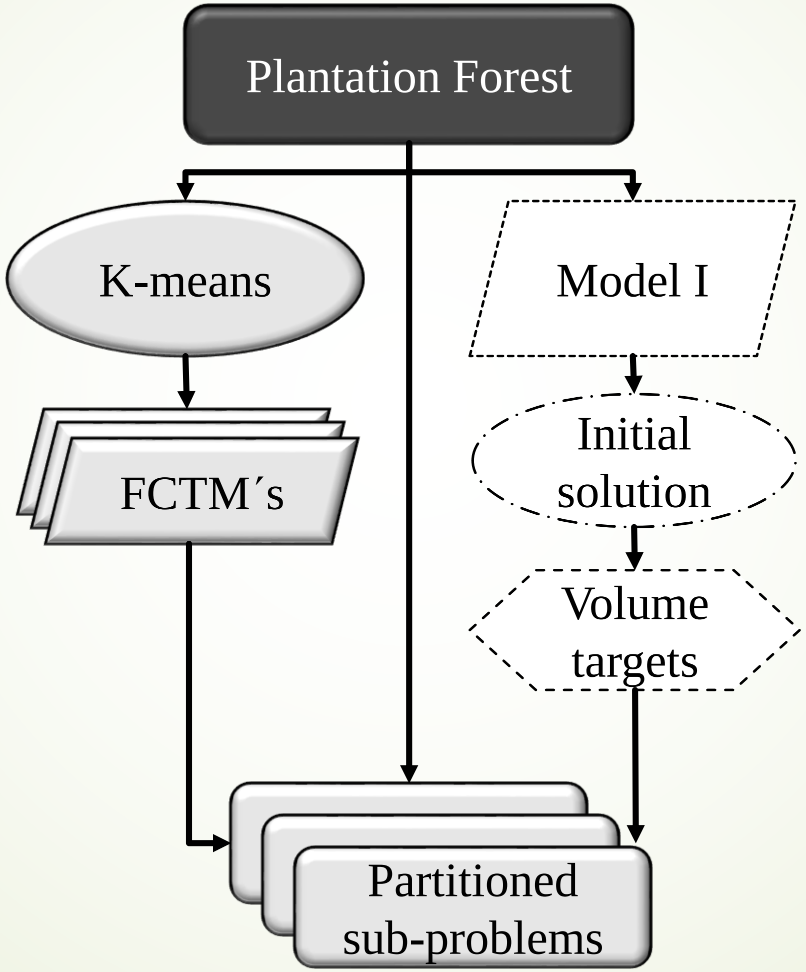
$$r_{sp}, z_{ijp} \in \{0,1\}$$



✓ Optimization procedure

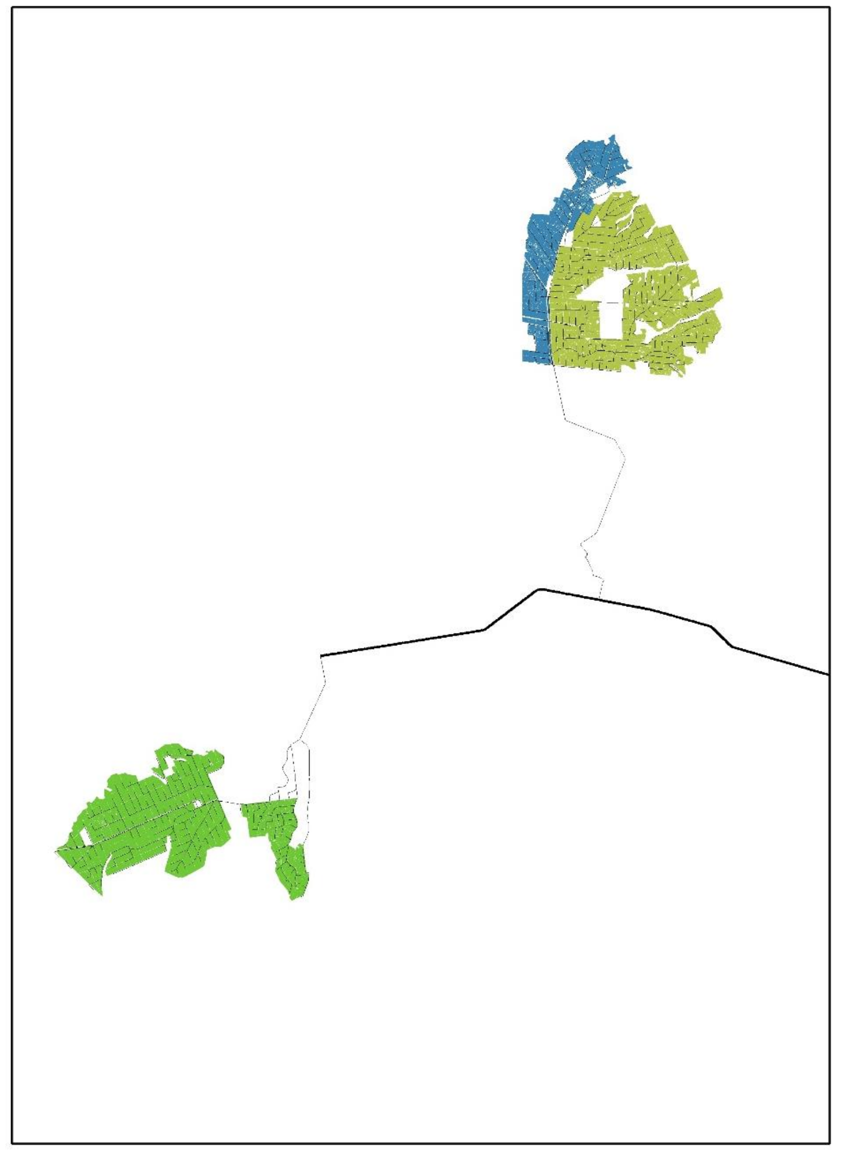


Step 1: Partitioning the sub-problems

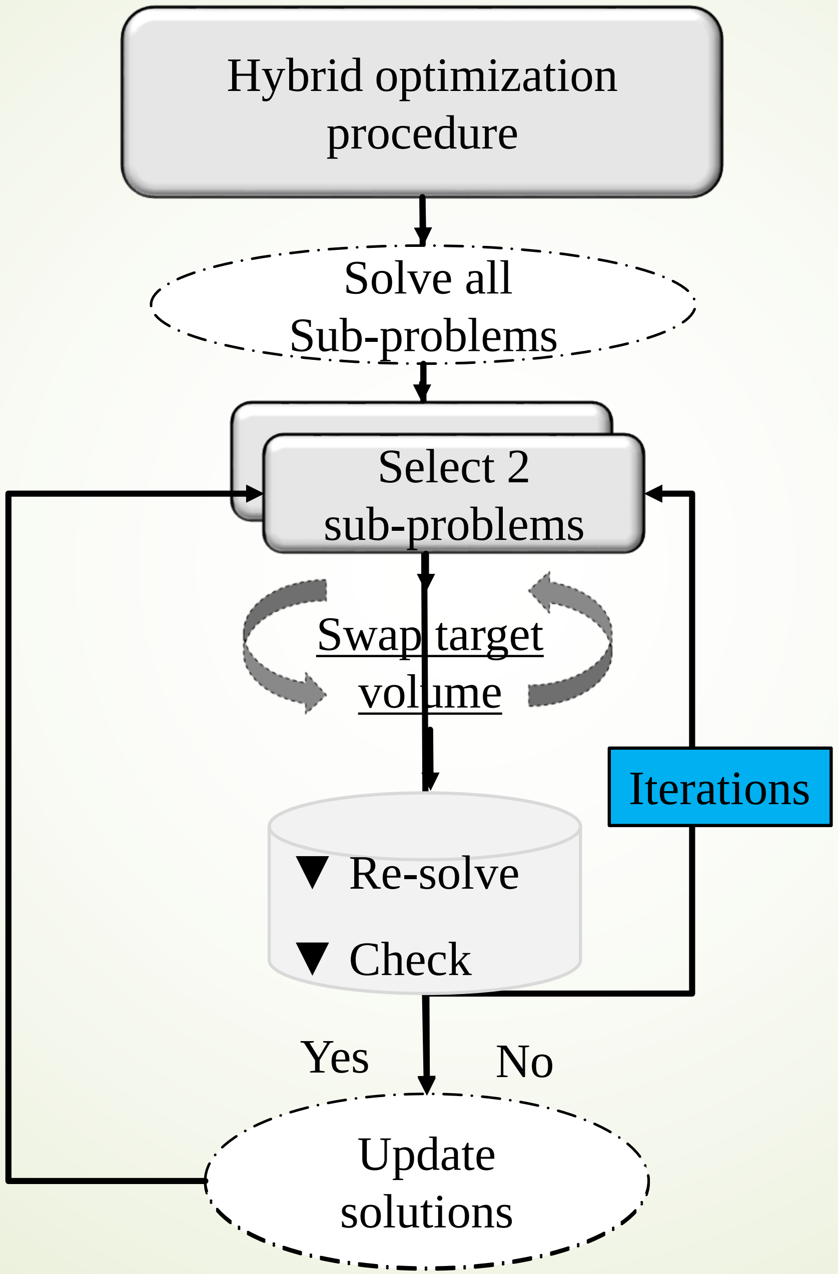


K-means clustering algorithm (Hartigan, and Wong, 1979)

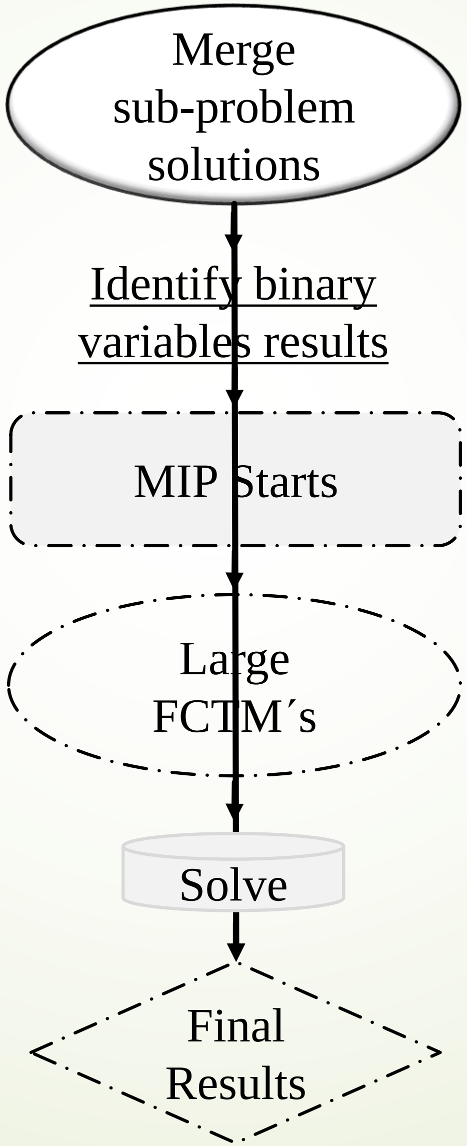
- ✓ K-means clustering algorithm
- ✓ Minimize the stand distance by road in each cluster
- ✓ Dijkstra's Shortest Path algorithm for each pair of existing stands



Step 2: Hybrid optimization procedure



Step 3: Generating the MIP start to the large problem



Gurobi Optimizer 8.1 with R Interface Intel® Core ™ i7-7700U 3.60GHz with 32 Gb of RAM.

Case study

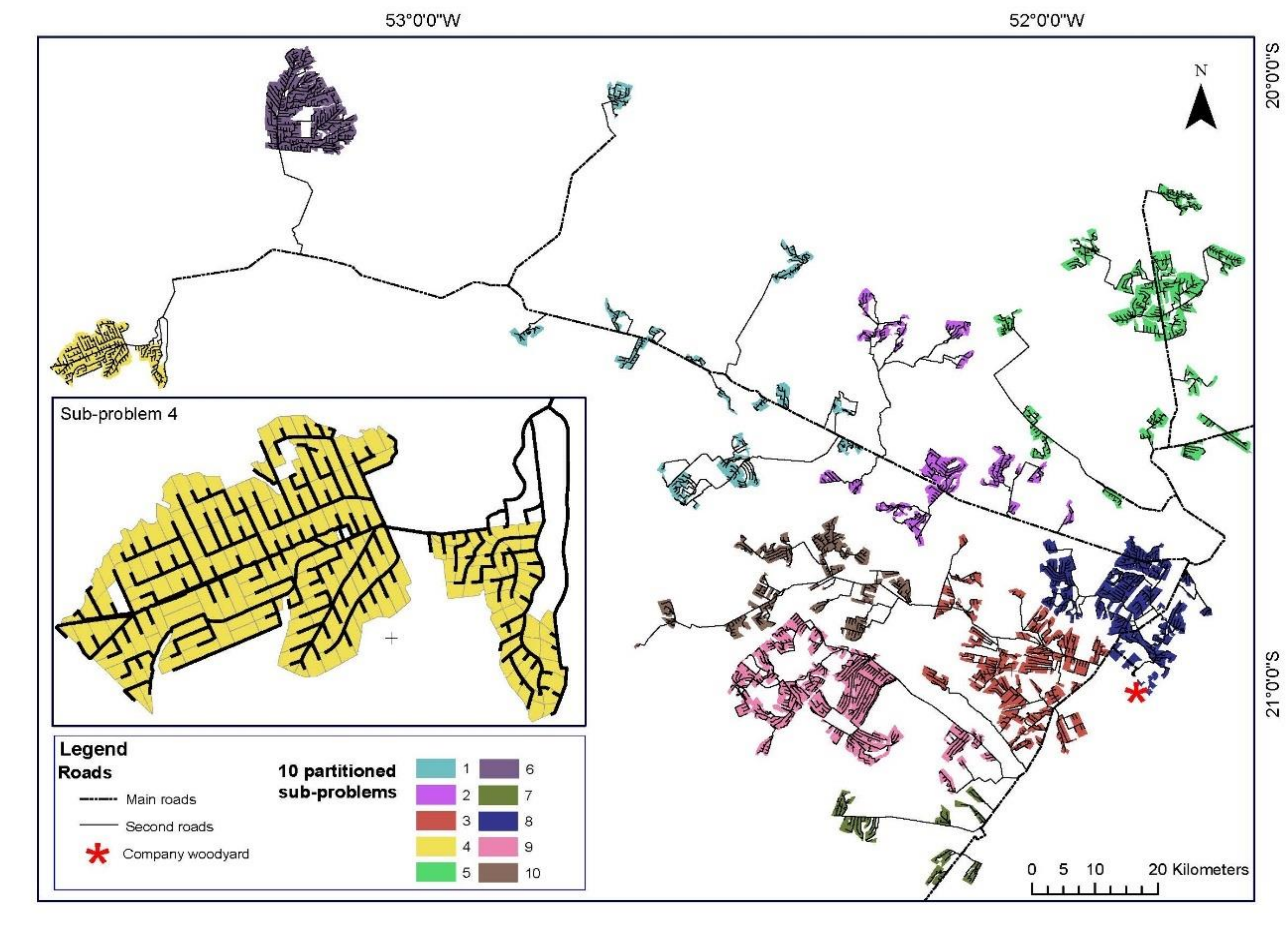
- ***Planning horizon of 6 years with 12 six-month periods***

- ***Shapefiles:***
  - 2,935 *eucalyptus* spp. stands
  - 3,900 road sections

- ***Production target to the entire forest:***
  - 4.1 millions of m^3 per six-month

- ***Operational costs** (average values are used):*
  - Harvesting: 8.9-13.4 R$/m3
  - Road maintenance: 25,000 R$/km
  - Log transportation: 0.4 R$/m3/km

Study case



53°0'0"W
52°0'0"W
20°0'0"S
21°0'0"S
N
Sub-problem 4
Legend
Roads
Main roads
Second roads
Company woodyard
10 partitioned sub-problems
1
2
3
4
5
6
7
8
9
10
0 5 10 20 Kilometers

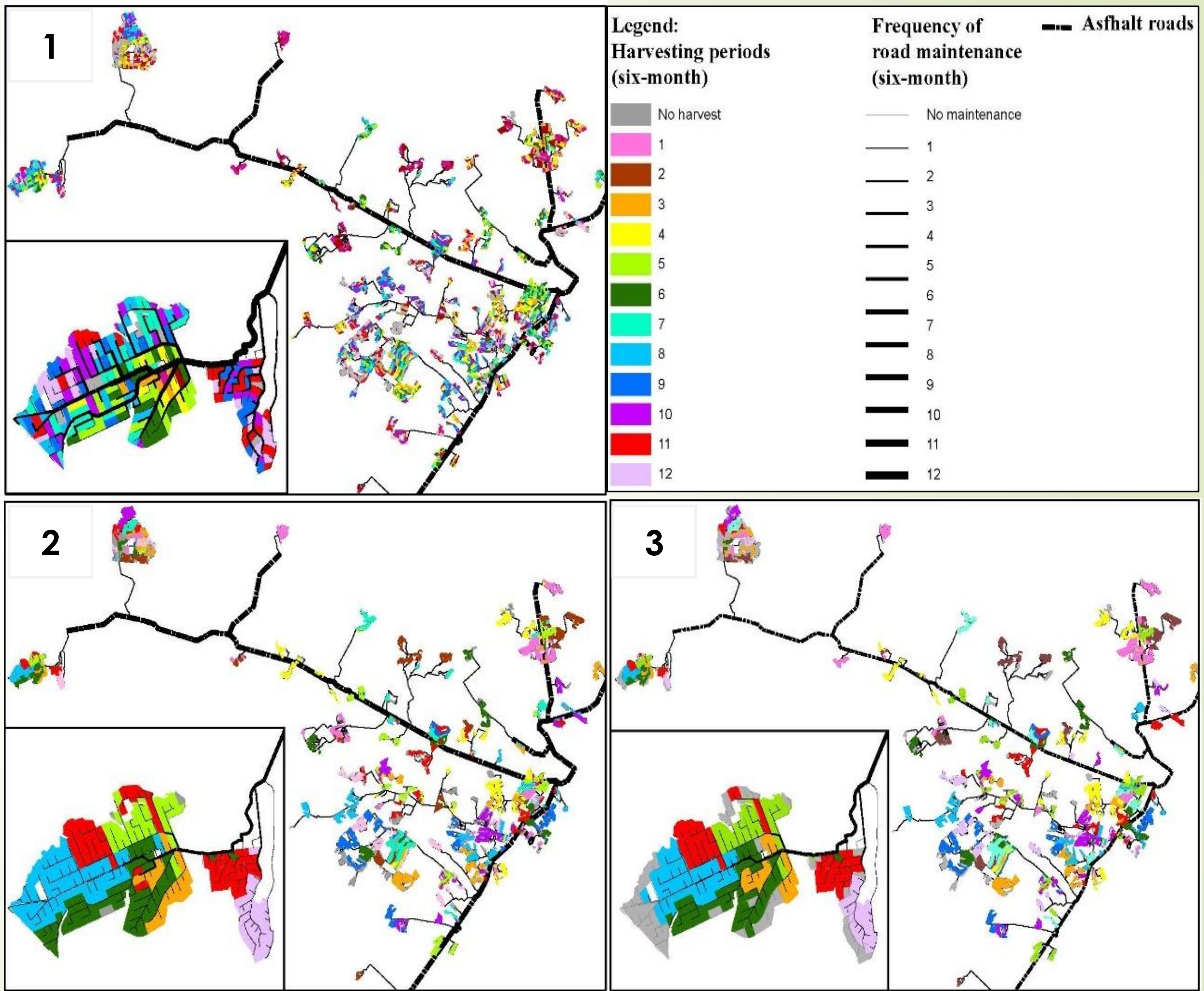
Results

Comparisons of Step 1, Step 2 and Step 3 solutions in terms of operational costs.

Case	Step 1	Step 2	Step 3
Harvesting (MM.R$)	423	431	425
Road cost - maintenance (MM.R$)	405	180	163
Road cost - transporting (MM.R$)	164	164	155
Total cost (MM.R$)	992	774	742
Volume production (MM.m^3)	49	49	49
Unit production cost (R$/$m^3$)	19.97	15.56	15.04
GAP (%)	-	-	8

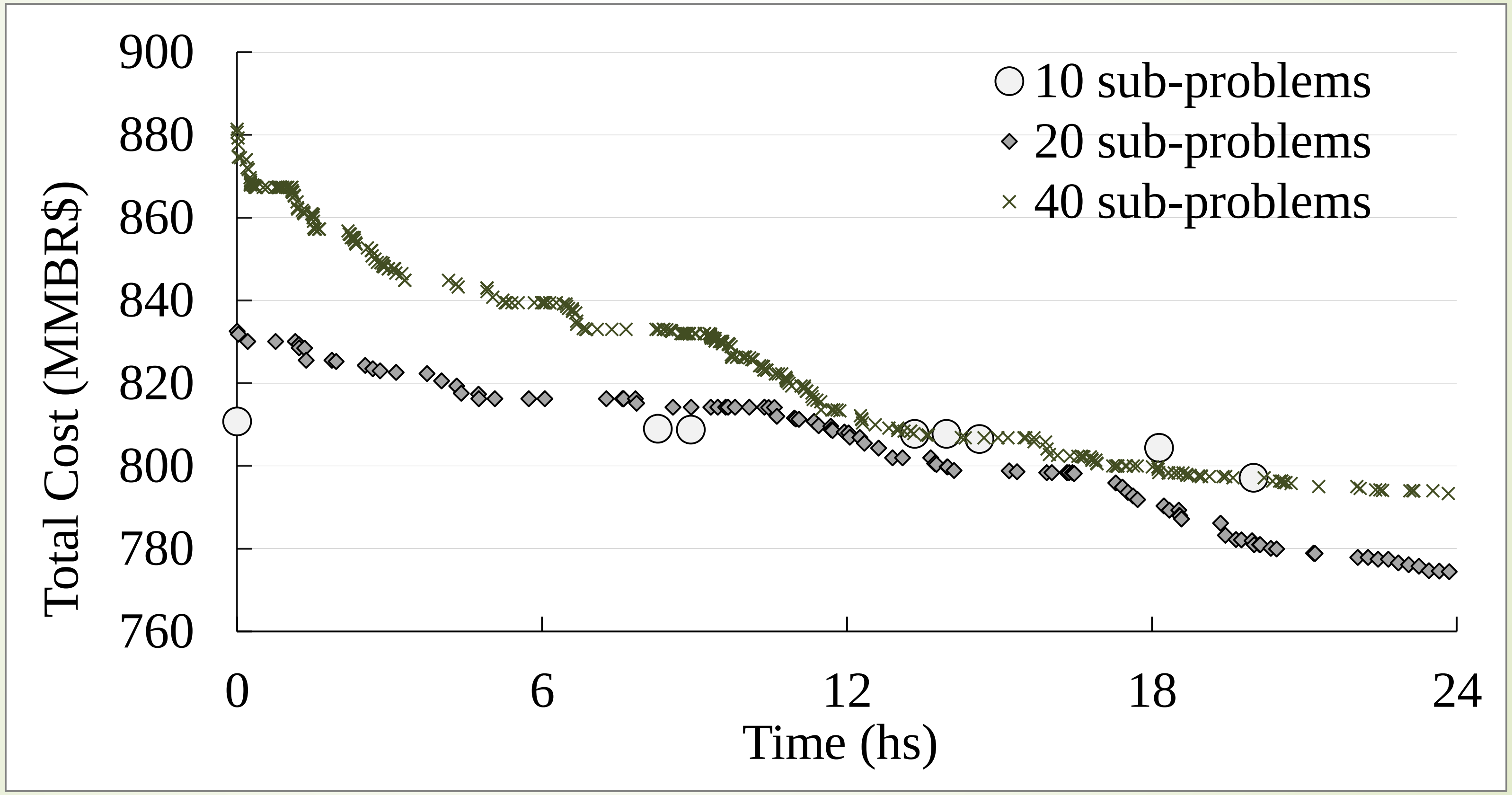
Results

Spatial and temporal distribution of the harvesting schedule developed in Step 1-3.



Results

Sensitivity analysis for the number of 10, 20 and 40 partitioned sub-problems (Step 2).



Results

General results of Step 1-3.

Step	1	2(10)	2(20)	2(40)	3(10)	3(20)	3(40)
Harvesting (MM.R$)	423	427	431	430	425	425	425
Road cost maintenance (MM.R$)	405	207	180	201	186	163	168
Road cost transporting (MM.R$)	164	163	164	163	154	155	150
Total cost (MM.R$)	992	797	774	793	765	742	743
Gap (%)	-	-	-	-	12	8	8
Volume production (MM.m^3)	49,7	49,4	49,8	49,7	49.4	49.3	49.3
Unit production cost (R$/$m^3$)	19,97	16,13	15,56	15,95	15.50	15.04	15.05

Conclusions:

- Tactical planning integrating harvest and road network
- The partitioning and solving optimization approach generated a good quality solution
- The information allows to evaluate different investments
- Alternative optimization tool for decision support systems

Acknowledgements:

SUZANO
PAPEL E CELULOSE

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