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A Spatial Optimization Framework to Customize Timber Supply and Harvest Decisions for the Korean Forest Service: A Case Study

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Objective and Importance

- **Background**
  - **Subjective Forest Planning**

    : Forest planning in South Korea tends to be guided by the personal experiences and subjective judgment of individual managers.
  - **Lack of Scientific and Data-Driven Approaches**

    : The absence of standardized scientific criteria and objective data frameworks leads to arbitrary and inefficient decision-making in forest planning.
  - **Production–Consumption Mismatch**

    : Forest resource production and consumption are not efficiently linked at the regional level, limiting both economic value creation and sustainable forest management.

- **Objective**
  - This study aims to overcome subjectivity and inefficiencies in South Korea's forest planning by applying a spatial optimization model that integrates timber production and consumption and supports legal, sustainable, and data-driven decision-making.

Main Findings

- **Methodology**

Estimation of Total and Harvestable Timber Volume → Classification by Management Objectives → Revenue–Cost Analysis by Objective Type → Application of Optimization Model → Derivation of Harvest Plan

Restriction	Explanation
Legal	Public service forest
Physical	Areas with slope exceeding 40°
Environmental	Adjacent areas within 30 meters of rivers
logistical	Areas beyond 300 meters from forest roads)

Estimation of Total and Harvestable Timber Volume
- Stand volume + Constraints (Legal, Physical, Environmental, Logistical) → Harvestable timber volume

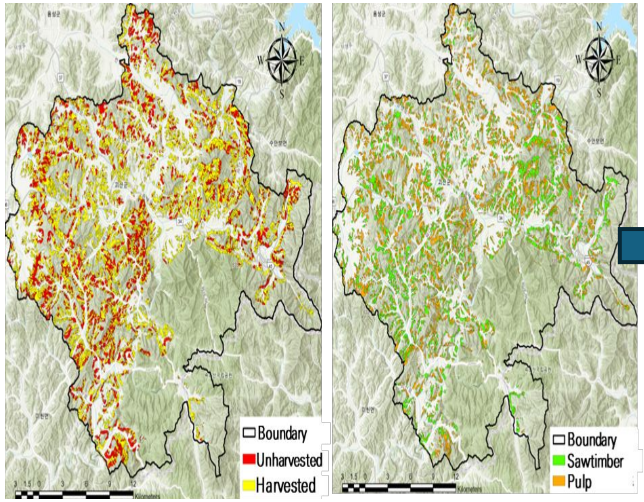
Classification by Management Objectives
- Sawtimber (construction/furniture) vs. Pulp & Chipwood (pulp, boards)

Revenue–Cost Analysis by Objective Type
- Revenues
  - ✓ Timber and carbon credits
- Costs
  - ✓ Afforestation
  - ✓ Thinning
  - ✓ Harvesting & Skidding
  - ✓ Transportation (via Dijkstra-based network analysis)
- Discount rate: 5%

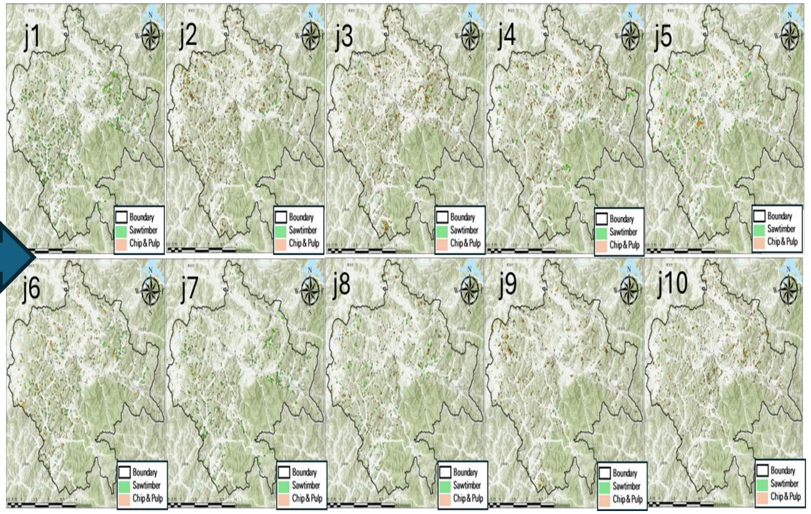
Application of Optimization Model
- Algorithm
  - ✓ Gurobi MILP (Mixed-Integer Linear Programming)
- Objective: Maximize net profit
- Constraints
  - ✓ Legal cutting age
  - ✓ 10-year harvest volume fluctuation limits
  - ✓ Ending condition: minimum residual growing stock (e.g., ≥ 200 m³/ha)

- **Results summary**

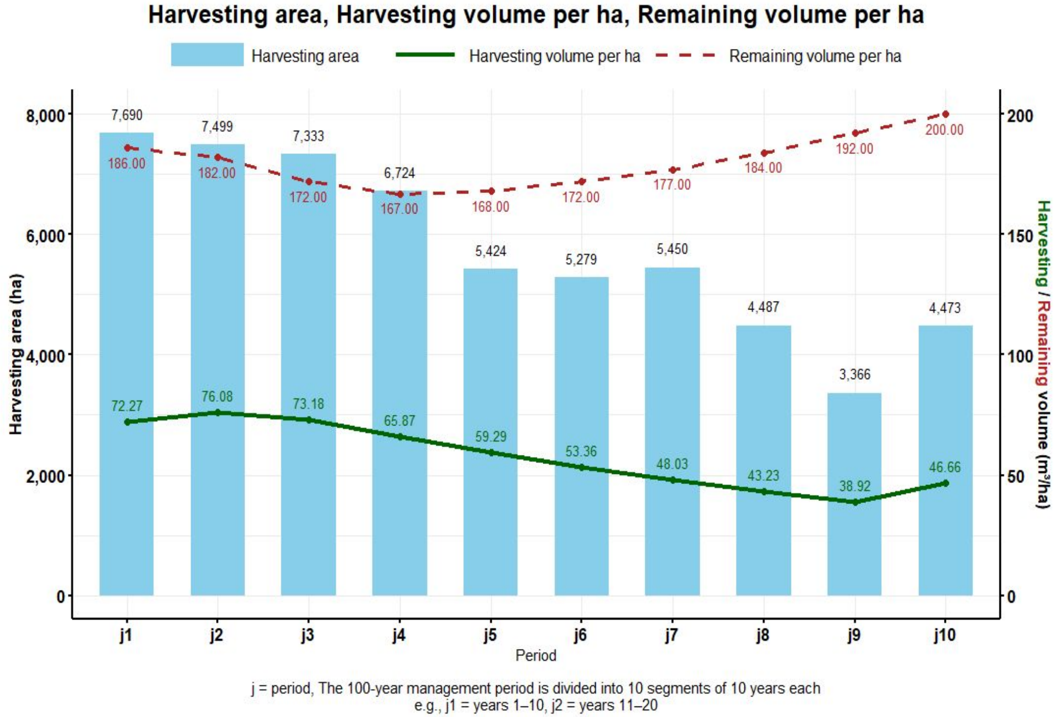
- Harvested area: 16,425 ha (Sawtimber: 7,171 ha; Pulp: 9,254 ha), Unharvested area: 7,495 ha
- Avg. annual harvest volume: 63,000 m³/year (range: 45,000–81,000 m³)
- First 30 years: High volume (≈80,000 m³/year), focused on age class V–VII
- Later periods: Gradual decline due to legal & sustainability constraints



<Harvest status (Left) and Assigned management objectives(Right)>



<Spatial distribution of Harvested stands from period J1 to J10>



Implications

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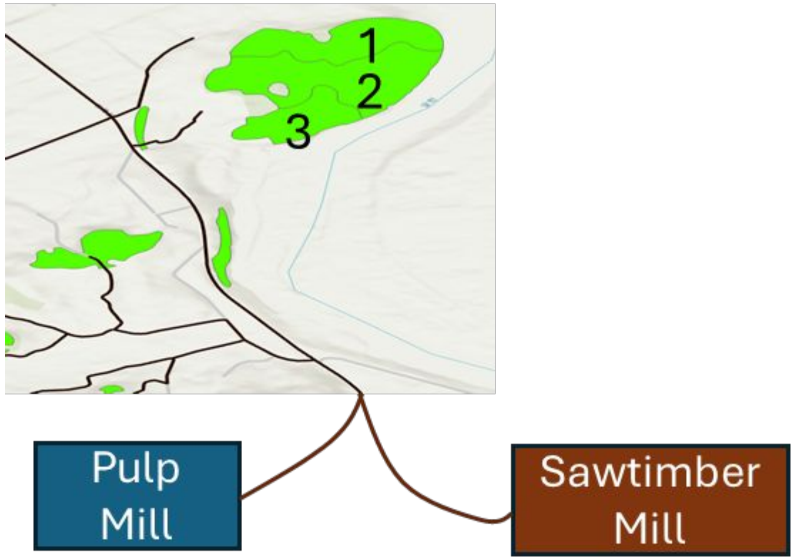
Problemc	Approach	Implication
• Forest planning relies heavily on experience and intuition	• Introduced legal, ecological, and logistical constraints as explicit parameters in the model	• Enables the **transition to model-based decision-making** at the Korea Forest Service
• Lack of spatial harvest allocation strategies	• Applied **spatial optimization** and **Dijkstra-based transport modeling**	• Improves **timber flow efficiency** by linking production sites to nearby processing facilities
• Weak linkage between harvest plans and consumption	• Integrated **actual consumption zones** into harvest scheduling	• Enhances **domestic timber utilization** and addresses supply–demand mismatches
• Limited technical basis for long-term forest strategy development	• Simulated **100-year spatially explicit harvest scenarios** considering sustainability targets	• Provides a **foundation for Korea's national long-term forest strategy**

Conclusion/Next Steps

- **Conclusion**
  - This study demonstrates how spatial optimization can address limitations in Korea's forest planning: subjective decision-making, inefficiencies in timber logistics, and the absence of data-driven tools.
  - By integrating national forest inventory data with legal, ecological, and logistical constraints, we developed a model that generates spatially explicit harvest schedules over a 100-year.
  - The model generates spatially explicit harvest plans that comply with legal cutting age rules, prioritize overstocked stands in the short term, and gradually align with long-term sustainability targets. These outputs provide not only operational clarity but also a scalable foundation for policy implementation.

- **Next Steps**
  - Implement stand clustering to reduce transport costs by grouping harvest stands with shared skid trails and similar timber utilization goals.
  - Introduce variable cutting intensity scenarios (e.g., 30%, 50%, 70%, 100%) based on different silvicultural methods (thinning, selective cutting, clear cutting).



<example of stand clustering>