





# Northern Hardwoods Research Institute

A group of researchers in a forest wearing orange safety vests and red hard hats. The researchers are seen from behind, walking through a dense forest of green trees. The text "Northern Hardwoods Research Institute" is overlaid in large white font on the left side of the image.



# PRECISION FORESTRY REDIFINED

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## **NHRI's AI-Enabled Inventory Services**

Presented by Dr. Rakesh Mishra, NHRI Head of Research  
– Remote Sensing & AI  
April 9, 2025



# Agenda



Partial Harvest Determination Tool

Tree Species Identification

Basal Area (BA) and PAI Prediction

Tree Vigor Prediction

NHRI's Ongoing AI-based Initiatives

## ➤ The Challenge

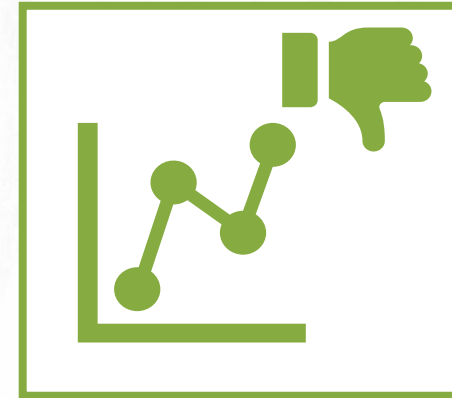
- Timely and accurate forest inventory is critical
- Current reliance on **Photo Interpretation** and **LiDAR** has drawbacks:



**High cost**



**Infrequent updates**

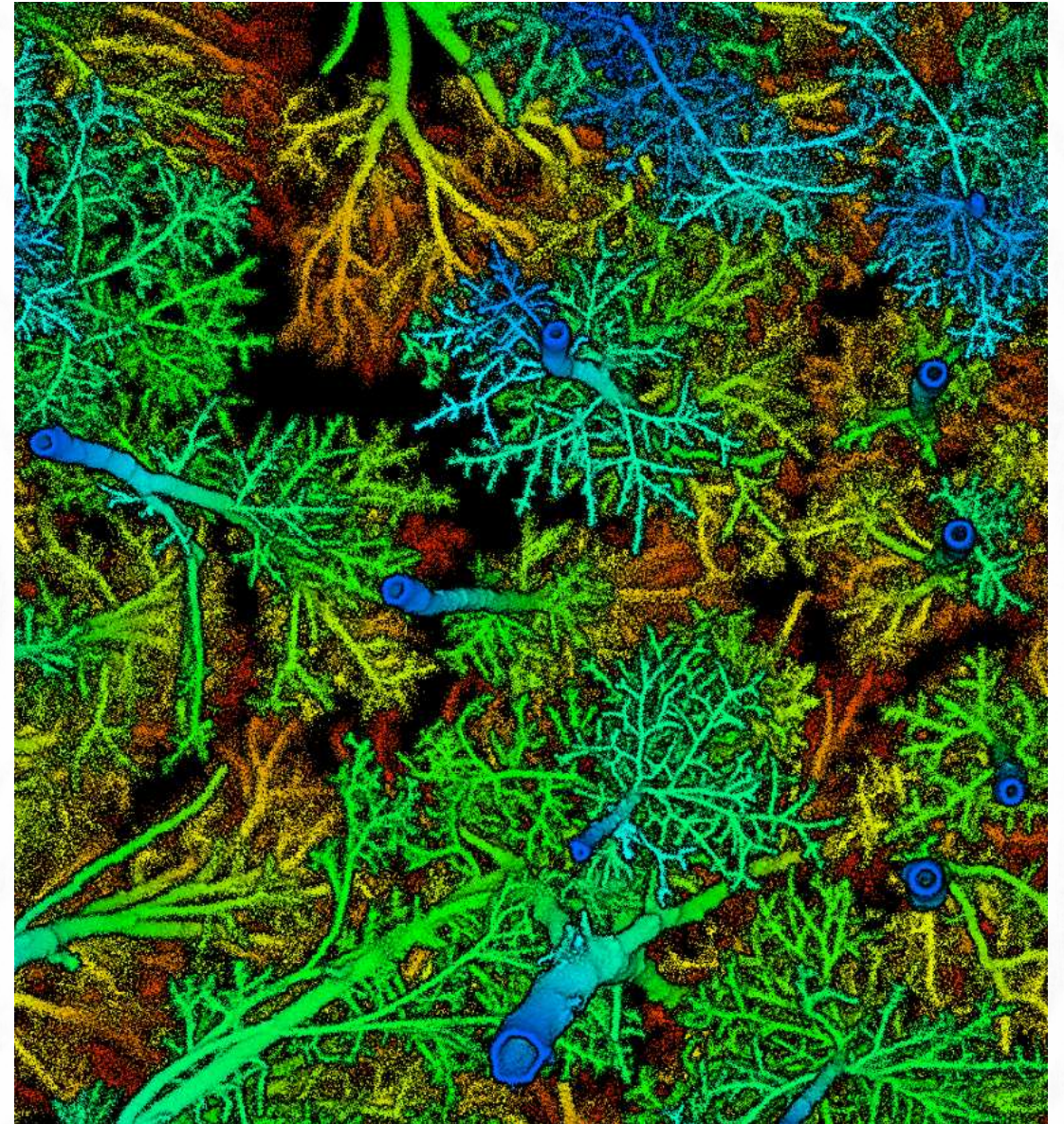


**Rapid forest changes  
make data outdated**



## ➤ Problems

- Static snapshots in a dynamic ecosystem
- Early metrics become obsolete
- Budget constraints prevent frequent updates

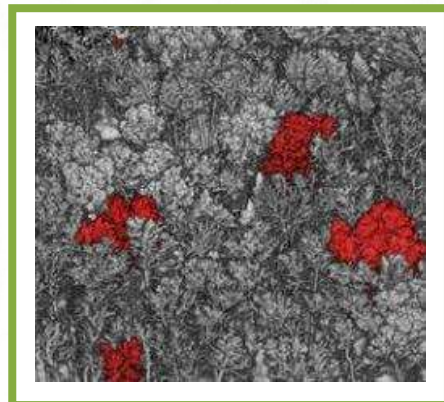


## ➤ An Integrated Approach

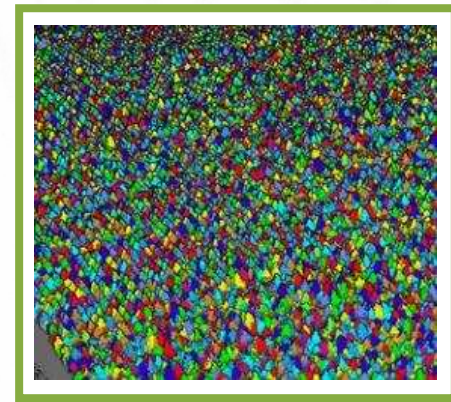
- **Combine:**



**Satellite imagery  
(MS, SAR, HS)**



**LiDAR  
(legacy/targeted)**



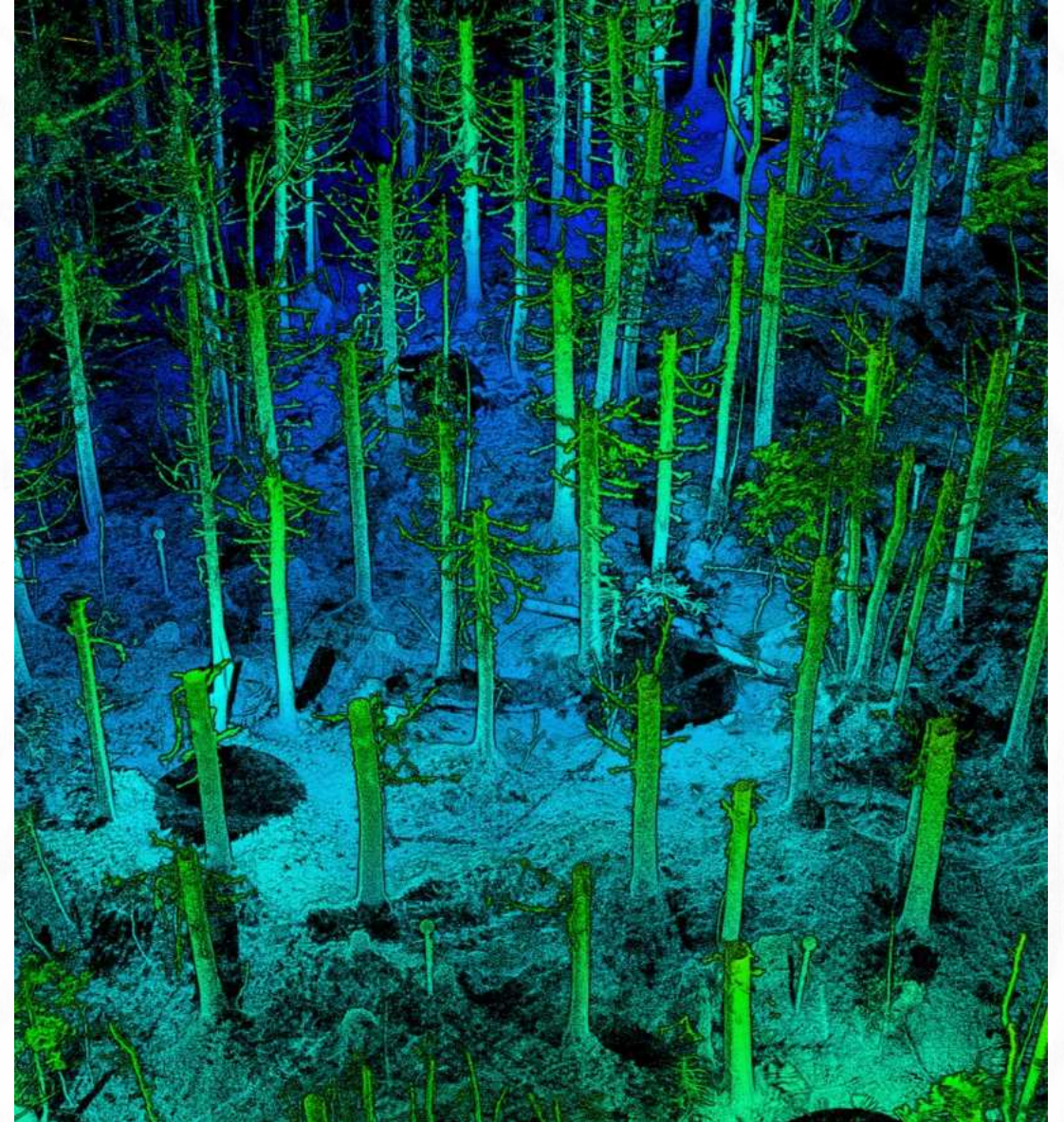
**Field data &  
environmental variables**

- **Use AI for near real-time insights**

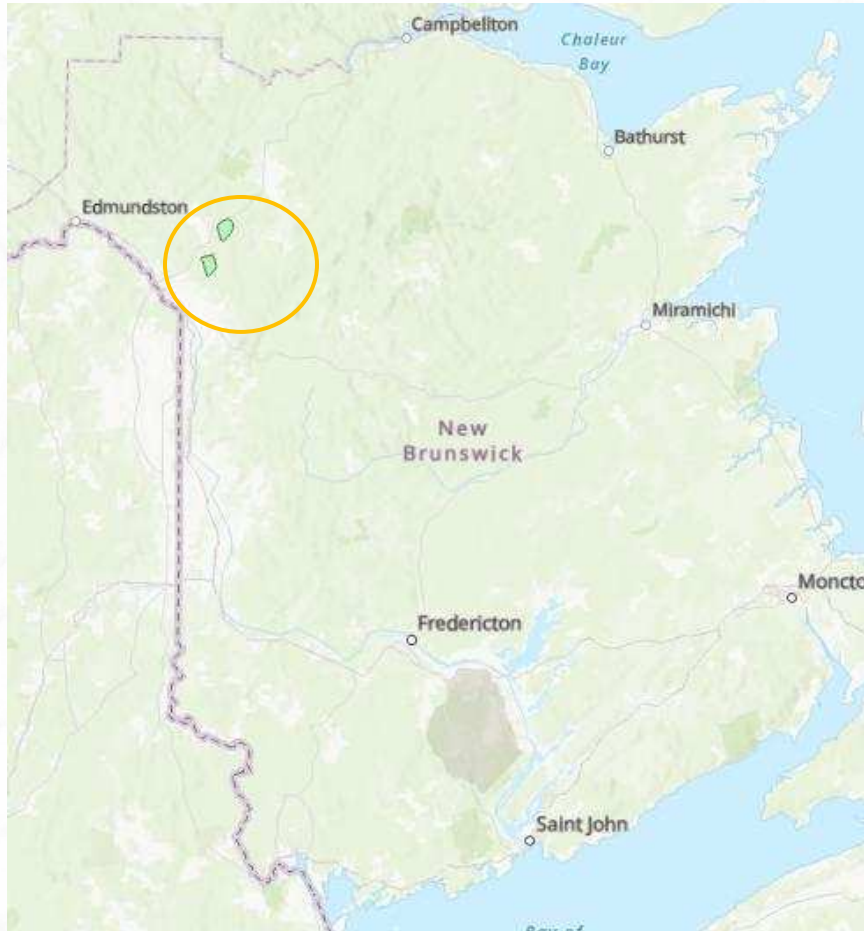


## ➤ Benefits

- Fully digital forest management
- Supports smart planning and monitoring
- Saves forests, money, and time



# The NHRI Partial Harvest Determination Tool



A pilot was conducted to validate the results of the advanced prototype in an area of Northwestern NB that had received partial harvests between fall 2023 and fall 2024.

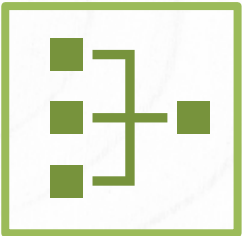
- ✓ Nearby stands have undergone recent clearcuts and thinning treatments.
- ✓ Two areas of interest (AOIs) were created, with no harvest information provided to the remote sensing team to ensure an unbiased assessment.



# The NHRI Partial Harvest Determination Tool



- ✓ In collaboration with CERFO, NHRI produced a tool to predict partial harvests using multispectral high-resolution and frequently acquired satellite imagery.
- ✓ The tool can be used several times during the year when foliage is on.



- ✓ It applies to stands with an average canopy height >6m.
- ✓ Cloud-free images from before and after treatment within the same growing season are required.
- ✓ The tool utilizes Planet Imagery at 3.7 m resolution.



- ✓ As of March 2025, the solution reached a Technology Readiness Level (TRL) of **8–9**. It is fully **developed, field-proven**, and **ready for operational launch**.



August 2024



Area of Interest #1

Prediction



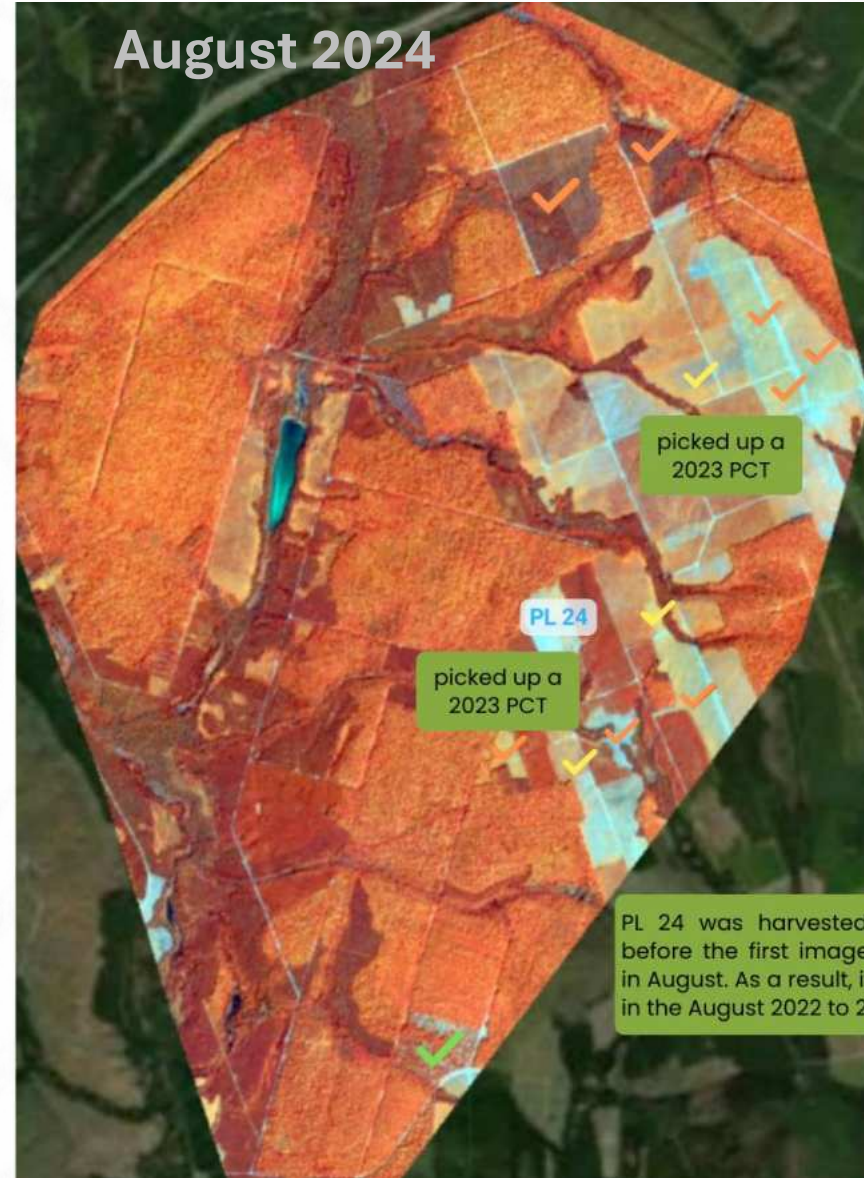
➤ 13 out of 13 polygons were correctly predicted (**Black**)



August 2022



August 2024



picked up a  
2023 PCT

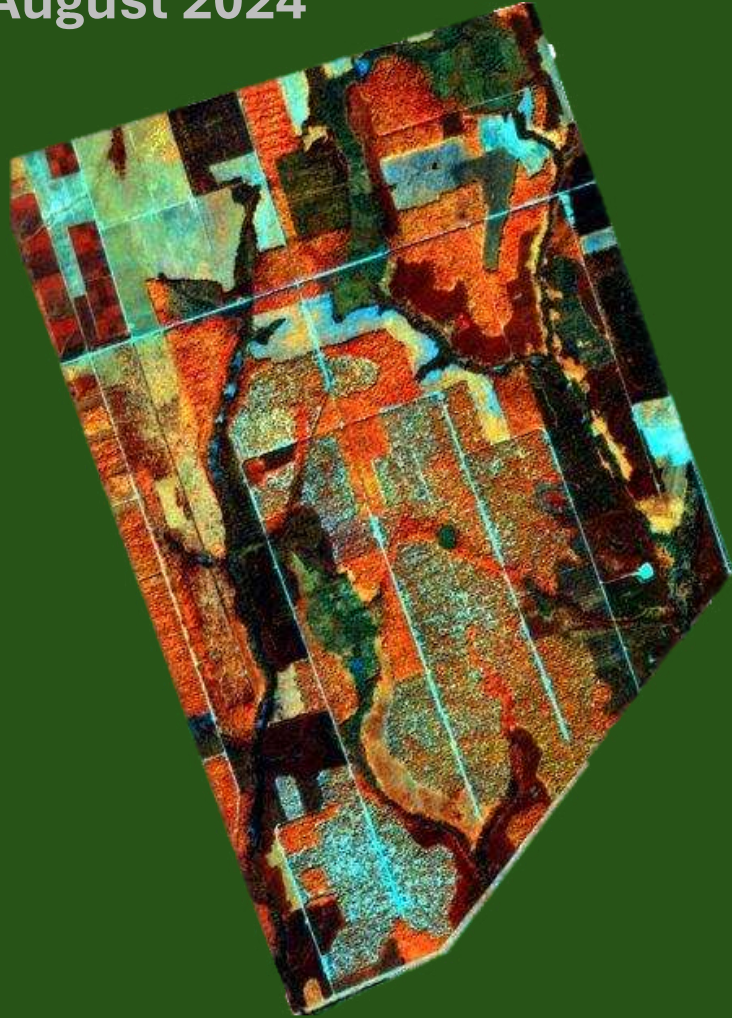
PL 24

picked up a  
2023 PCT

PL 24 was harvested earlier in 2022,  
before the first imagery was captured  
in August. As a result, it doesn't show up  
in the August 2022 to 2024 comparison.

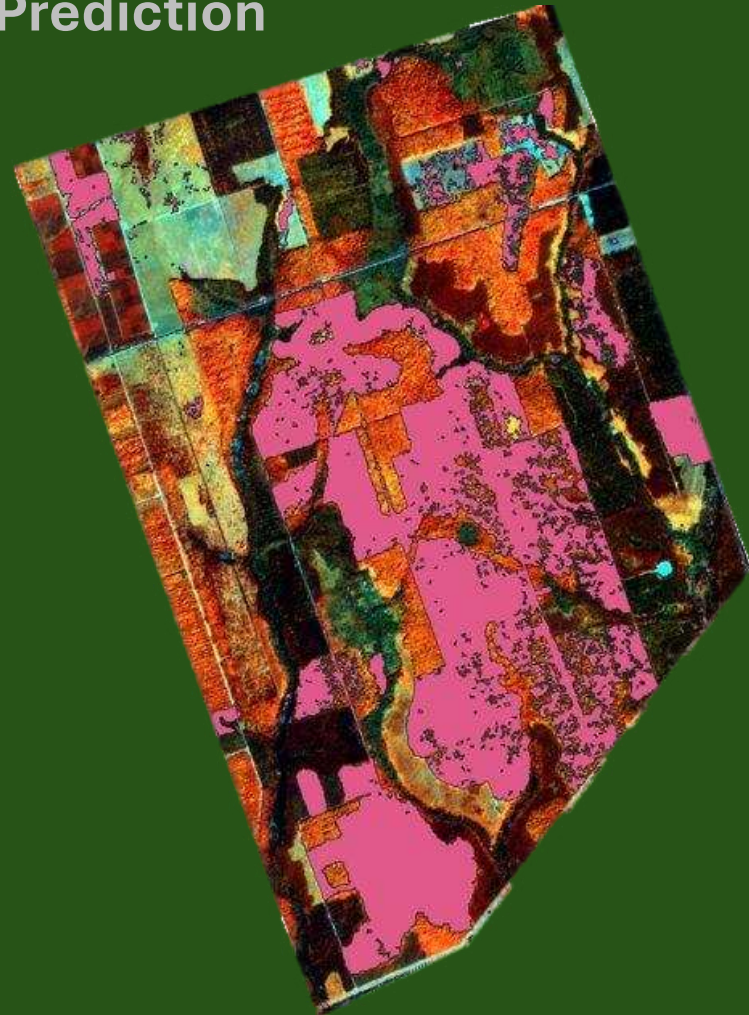


August 2024



Area of Interest #2

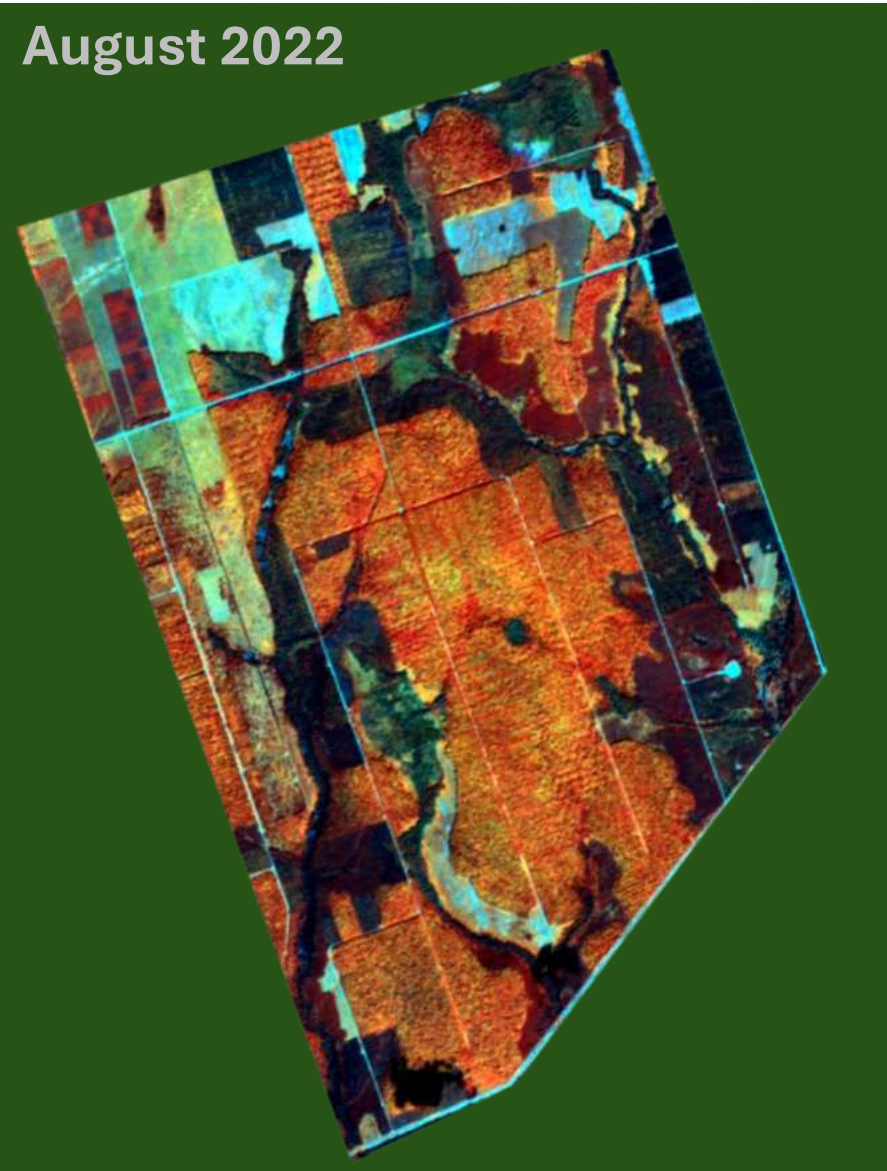
Prediction



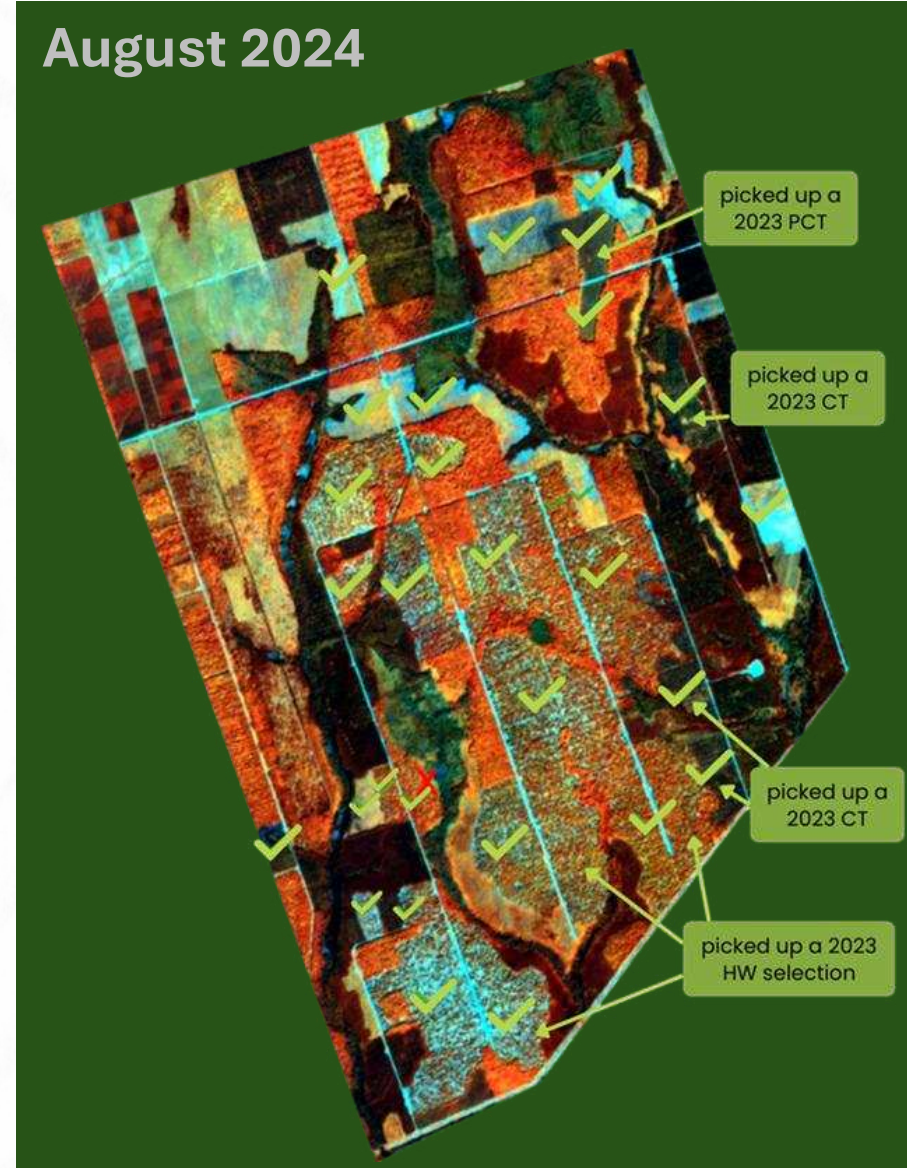
- 30 out of 31 polygons were correctly predicted (**Pink**)



August 2022



August 2024



# Discussion

## Observed Issues (minor)

- In the area of interest (AOI) #2 (north of Beaver Brook Road), some false positives were observed where the tool predicted harvesting activity in young plantations.
- These misclassifications were caused by open, field-like conditions that confused the algorithm.

### Solution:

- We now filter out areas with **canopy heights below 6m** to reduce these errors.
- We're also refining the spectral algorithm to improve accuracy.



# Discussion

## Bonus Capabilities



### **Detects Silviculture Operations:**

- Captures recent PCT (pre-commercial thinning) and CT (commercial thinning) with high accuracy.

### **Superior Spatial Resolution:**

- Outperforms harvester data by providing detailed residual stand canopy structure.

## Next Steps



### **Broad treatment type/configuration:**

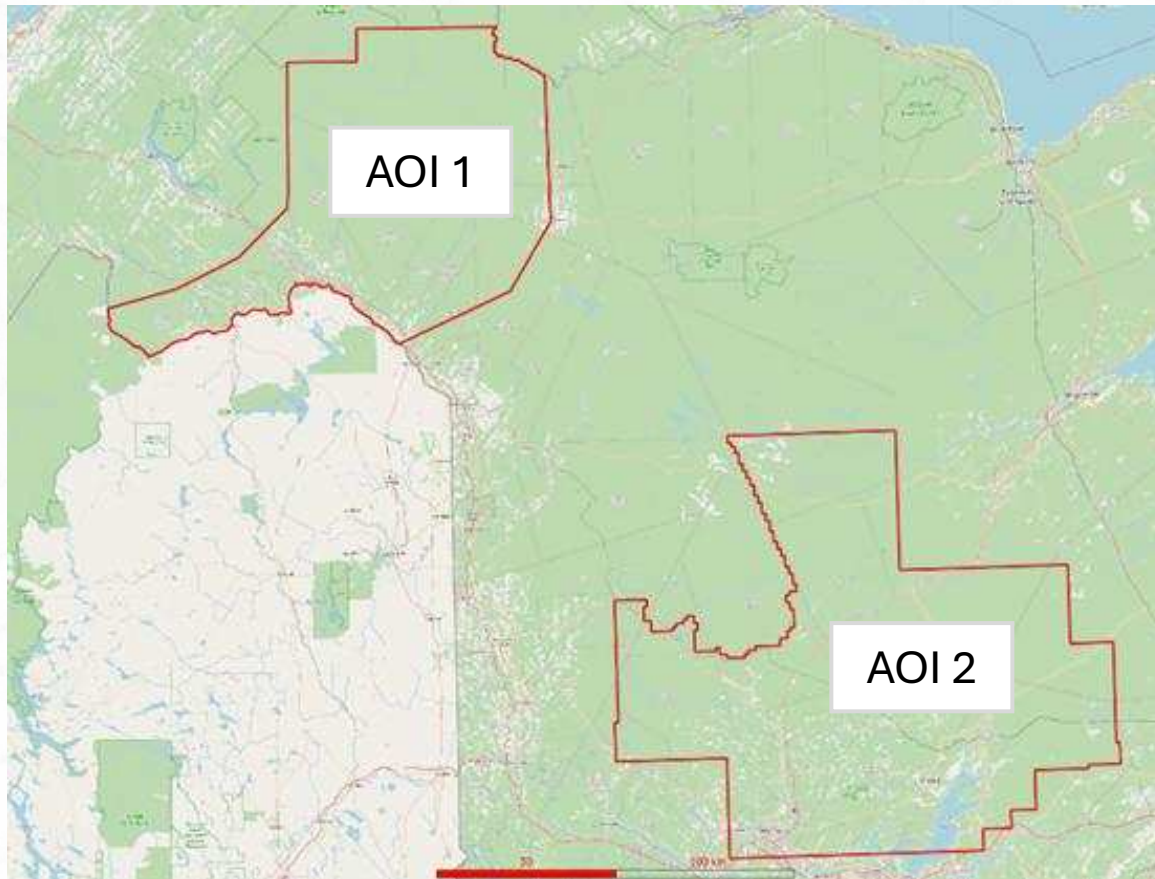
- Determine whether the partial harvest polygon is a **strip cut**, **commercial thin**, or **patch**

### **Post-harvest condition:**

- Describe the post-harvest condition in terms of species composition - % basal area of tolerant HW/sugar maple, % spruce.
- Testing is required to assess the system's ability to detect natural disturbances, such as **windthrow**, **blowdown**, and **dead trees**.



# Tree Species Identification



A pilot was conducted to validate the results of the advanced prototype in two areas of interest (AOI's).

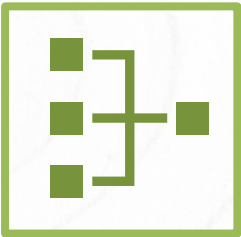
- ✓ The first AOI (600,000 ha) is situated in the northwestern region of the province.
- ✓ The second AOI (900,000 ha) is in the southeastern portion of New Brunswick, extending towards the Bay of Fundy region.



# Tree Species Identification



- ✓ In collaboration with CERFO, NHRI produced a tool to predict tree species using Sentinel-2 imagery.
- 



- ✓ Predicted basal area by dominant tree species group.
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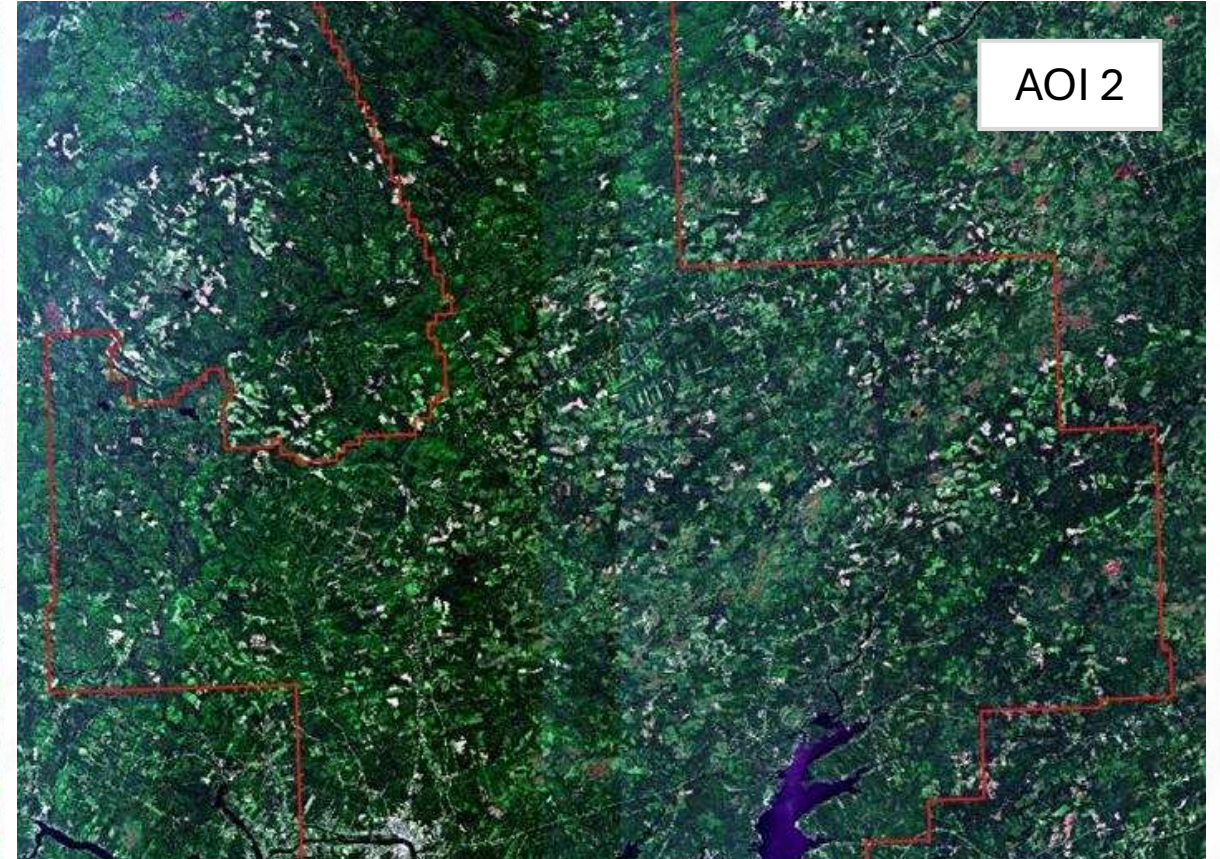
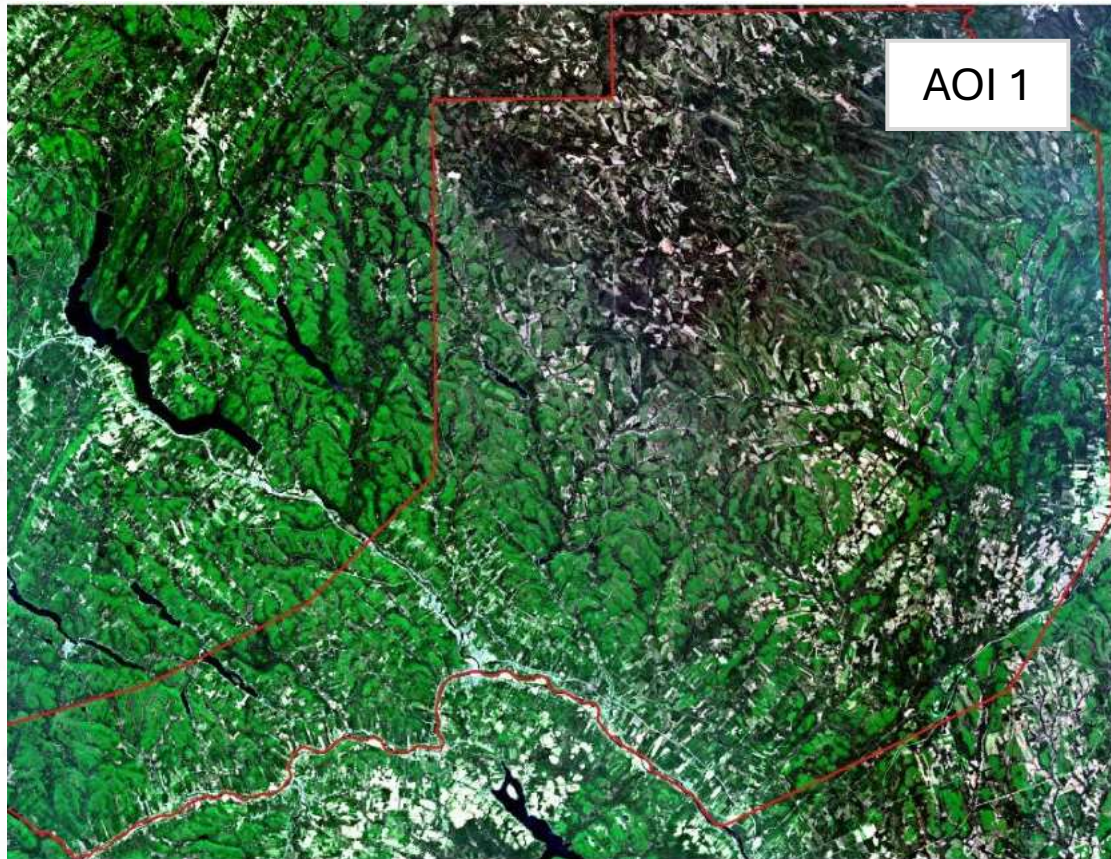


- ✓ As of March 2025, the technology readiness level (TRL) is surpassing **TRL 7** — it has been **tested** in real forestry operations as a **working prototype** and is ready to be launched operationally.



# Tree Species Identification

Sentinel-2 imagery for the AOIs



# Tree Species Identification

## Results

**87%**

Results with three tree species class  
(SP, BF, other)

**84%**

Results with three tree species class  
(BF, MA, PI, SP, WP)



# Periodic Annual Increment (PAI)

## Change in Basal Area (BA)

### Key Points



**Basal area** and **growth rate** are essential for **harvesting schedules** and **early interventions**. For example, young trees grow as much as 7 meters in 10 years and metrics calculated early on become obsolete quickly.

**Airborne LiDAR**, though accurate, is **expensive, infrequent, and limited in detail**.

Existing LiDAR data is **obsolete** for fast-growing forests.

Forestry stakeholders are seeking **affordable, remote-sensing** alternatives.



# Periodic Annual Increment (PAI)

## The time is now to scale up digital forest measurement



**The Need:** Large-scale, cost-effective solutions for monitoring tree growth are critical for modern forest management.



**The Timing:** As of March 2025, the system has been tested in the field and is ready for real-world use.



**The Opportunity:** This tool offers forestry practitioners a fast, cost-effective way to detect partial harvests, inform silviculture decisions, and optimize forest value.

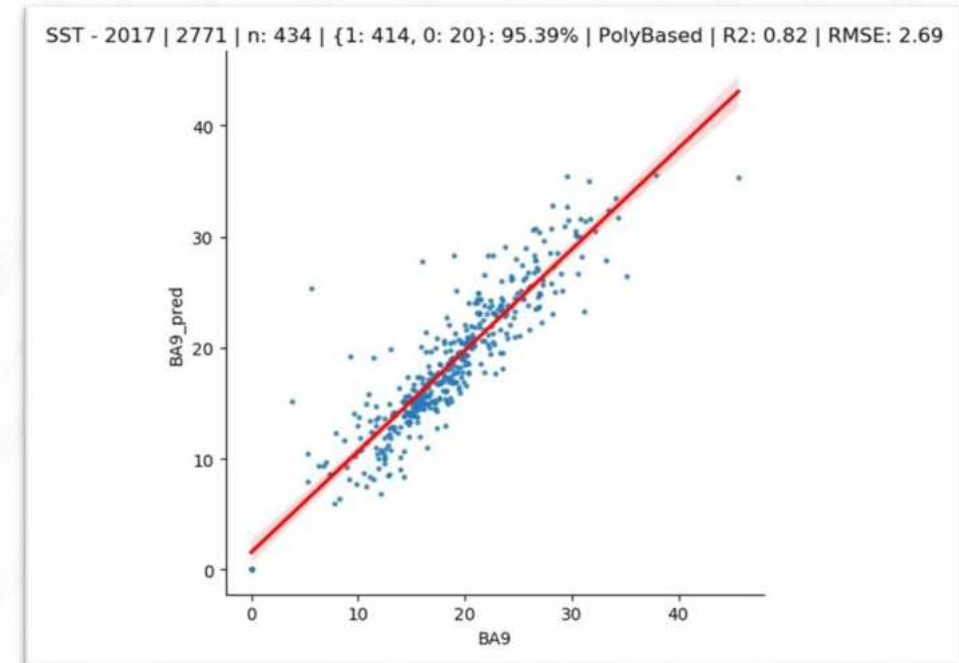
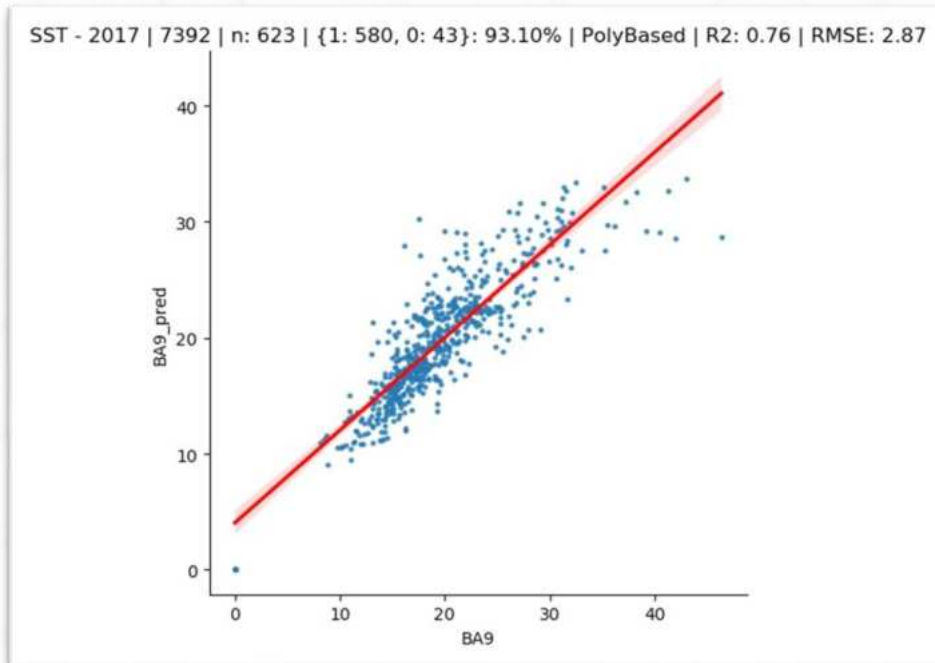


# Basal Area (BA) Prediction

- Basis for validation: Enhanced Forest Inventory (EFI) - based merchantable basal area (EFI BA9)
- Total number of EFI cells used for testing: 15570
- Number of BA values within 15% Range: 14326

Accuracy (15% Tolerance)

**92.01%**



# Canopy Height Model (CHM) Prediction using Sentinel-2 Imagery



- ✓ Accuracy ~**80%**
- ✓ Capable of generating CHM for large areas (for example, the entire province of New Brunswick)
- ✓ Predictions at 10m-by-10m pixels

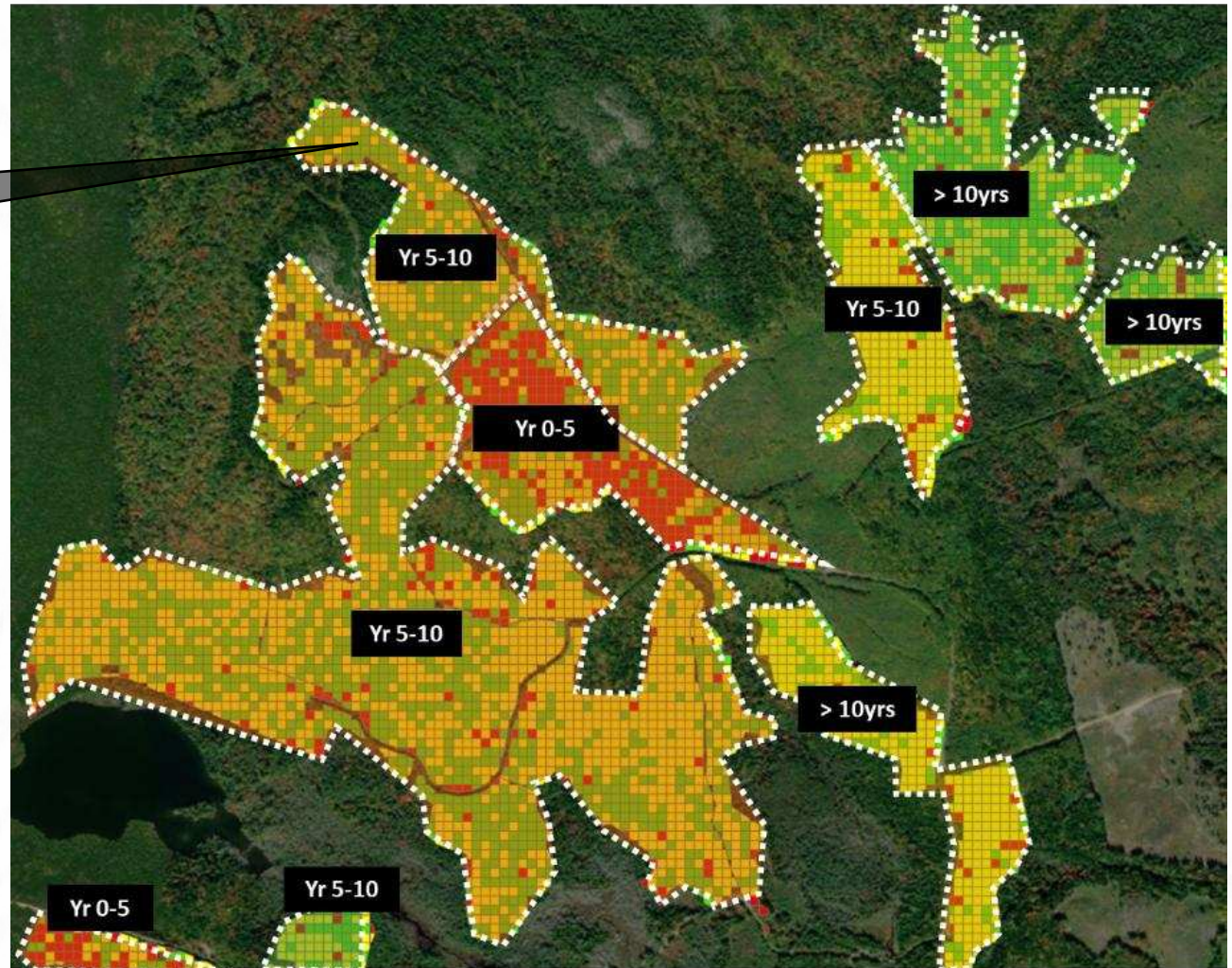
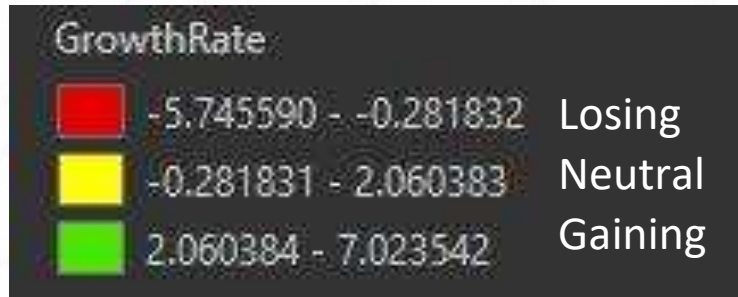
## Applications of CHM:

- Predict Basal Area
- Calculate Growth Rate
- Change Detection
- Calculate Above Ground Biomass (AGB)
- Carbon Stock Monitoring
- And other related forest health and management applications



# Periodic Annual Increment (PAI) Results

BA 2017: 22.44 m<sup>2</sup>  
BA 2021: 26.65 m<sup>2</sup>  
Growth: 1.4 m<sup>2</sup>



- TRL 8: The solution is fully developed and tested. All technical parts and processes are ready for use.



# Tree Vigor Predicting



- ✓ NHRI has developed a **vigor prediction tool** to monitor accidental damages to forests such as storms, spruce budworm, diseases, effect of herbicide applications, climate changes etc.

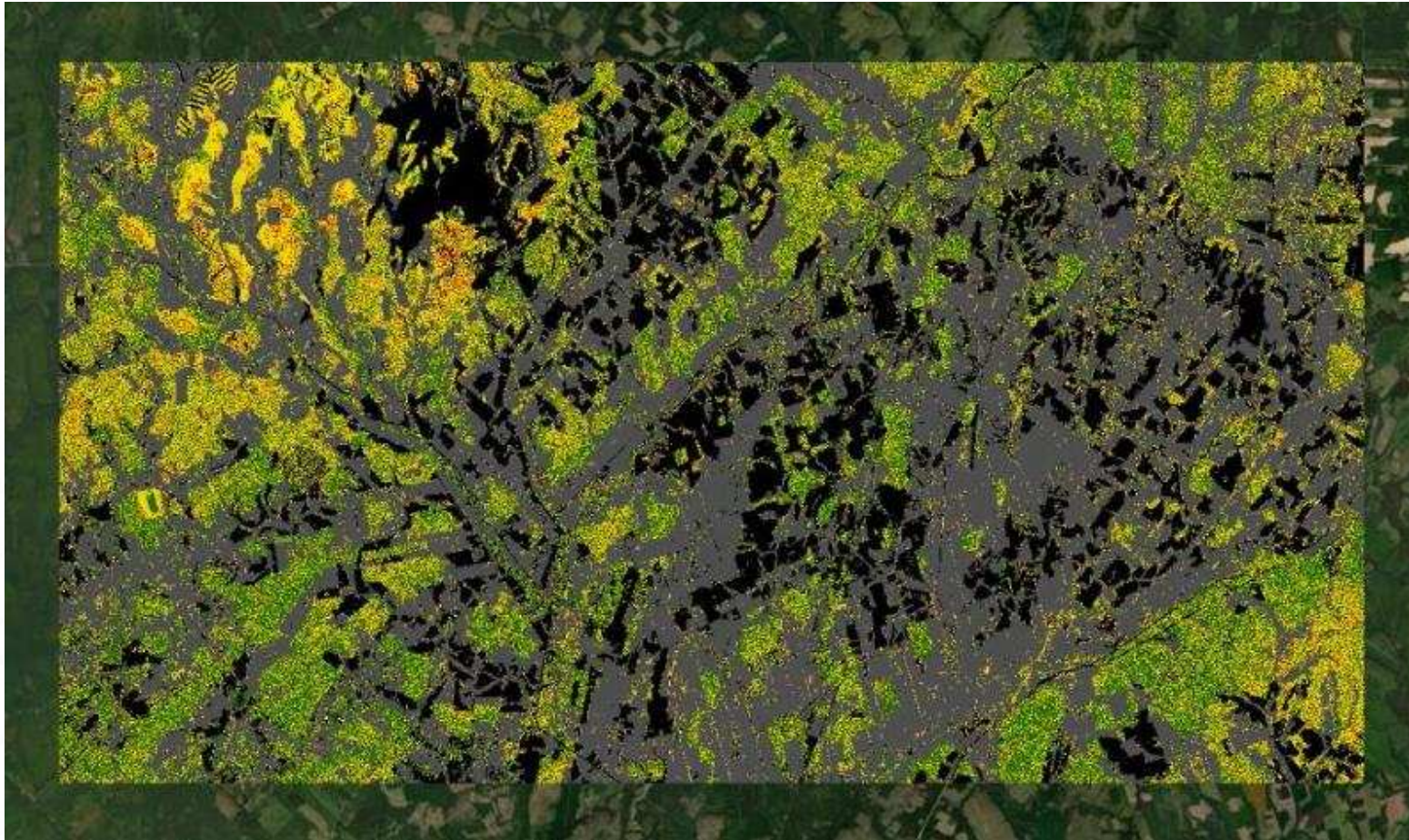


- ✓ As of March 2025, the technology readiness level (TRL) is at **6**, indicating that the technology has been **demonstrated** in a relevant forestry context and is **ready for further validation** and **scaling up**.

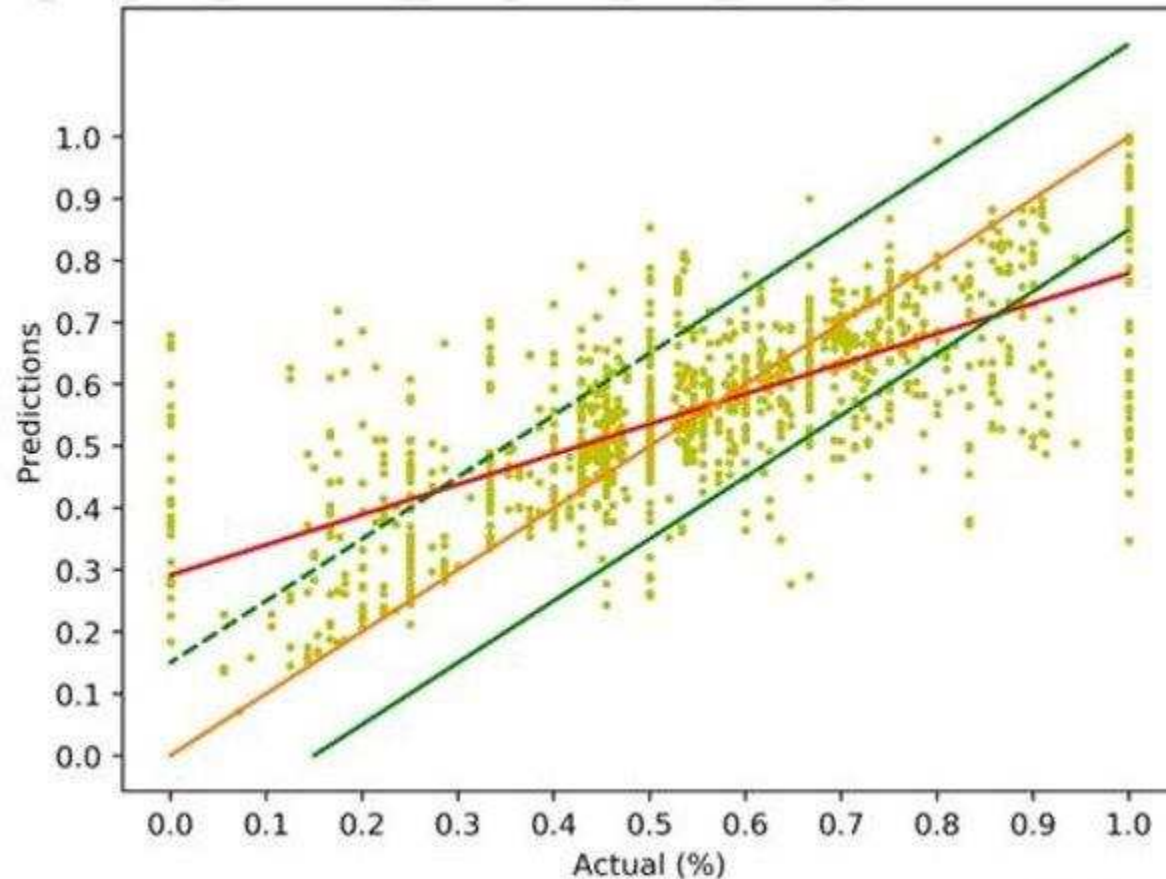


# Tree Vigor Predicting

$$\text{Vigor Index} = \frac{R1+R2}{R1+R2+R3+R4}$$



# Tree Vigor Prediction Validation (3/3)



$R^2 = 0.5062214$   
MeanSquaredError = 0.0255197

Total: 1135  
Pass: 844 (74.36 %)  
Fail: 291 (25.64 %)

— Regression  
— 1:1 Ratio  
- - Upper Control Limit  
- - Lower Control Limit

➤ TRL-6: Working to include more training data to improve accuracy



# NHRI's Ongoing AI-based Initiatives



# NHRI's Ongoing Initiatives

## ➤ Forest Biomass and Harvester Efficiency

### Challenge: Inefficient Hardwood Biomass Extraction



- Current harvesting methods are inefficient and costly for lower-value hardwood (e.g., small limbs unsuitable as roundwood).



- Up to 60% of usable hardwood biomass is left behind on harvested sites.



- Logistical challenges hinder efficient equipment deployment and material transport.



- High costs make biomass recovery uneconomical under current practices.



# NHRI's Ongoing Initiatives

## ➤ Forest Biomass and Harvester Efficiency

### Opportunity for Innovation



- Develop innovative forestry harvesting equipment to improve efficiency.



- Create logistical/data tools to optimize deployment of machinery and personnel.



- Increase recovery of biomass to support renewable energy and sustainable forest management.



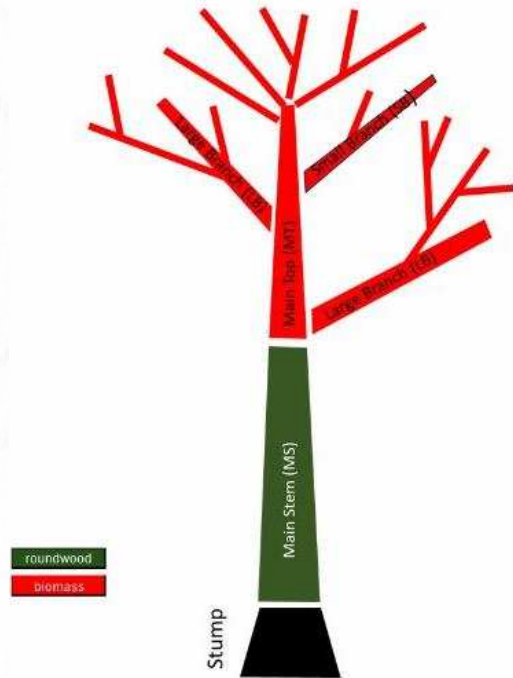
- Enhance cost-effectiveness and reduce waste in forest operations.



# NHRI's Ongoing Initiatives

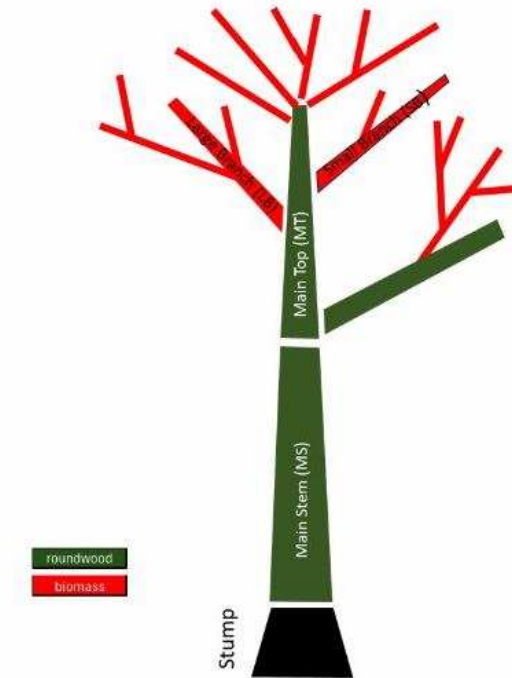
## ➤ Forest Biomass and Harvester Efficiency

LOW Utilization Scenario



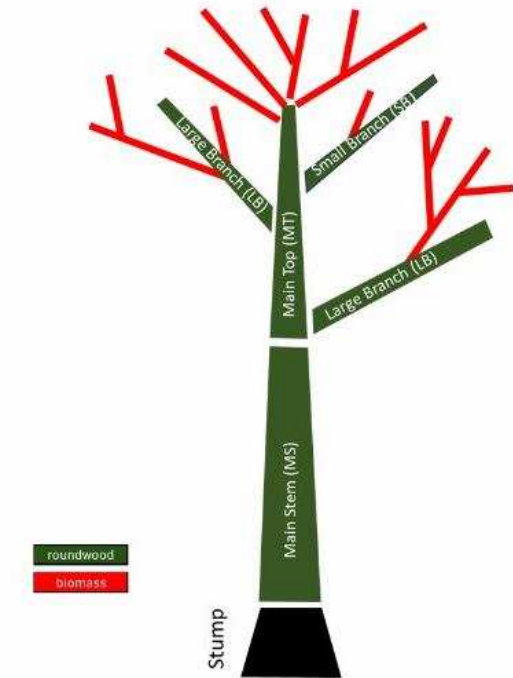
total value	lowest
processing cost	lowest
biomass recovery	highest
roundwood products GMV	lowest

MEDIUM Utilization Scenario



total value	medium
processing cost	medium
biomass recovery	medium
roundwood products GMV	medium

HIGH Utilization Scenario

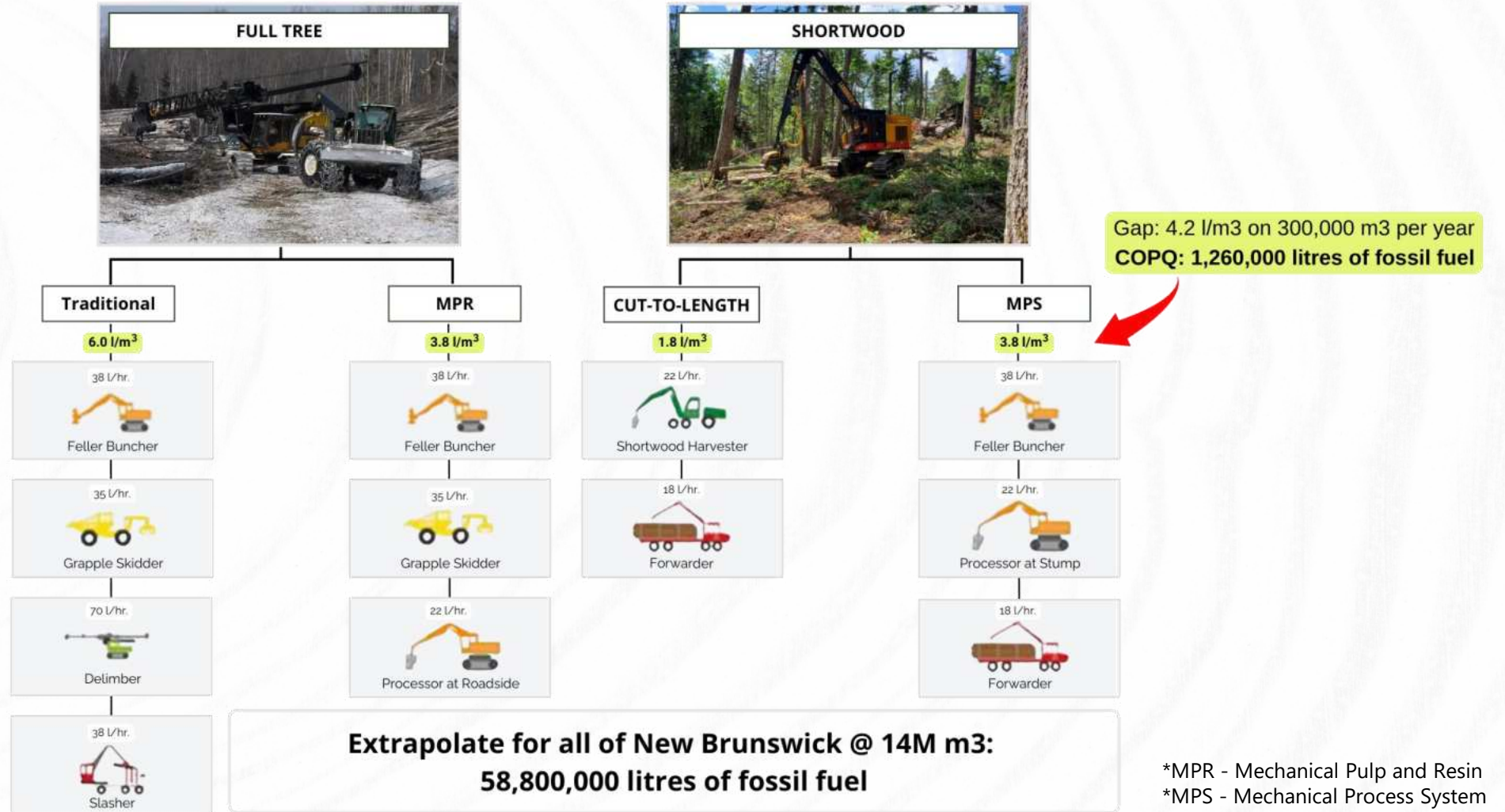


total value	highest
processing cost	highest
biomass recovery	lowest
roundwood products GMV	highest



# NHRI's Ongoing Initiatives

## ➤ Harvester Efficiency



\*MPR - Mechanical Pulp and Resin  
\*MPS - Mechanical Process System



# Objectives

- **Optimizing Harvesting for Sustainability: Reducing GHG Emissions and Enhancing Biomass Efficiency**

## **Real-Time Biomass Estimation:**

- Utilizing deep learning models to provide up-to-date estimates of biomass based on harvesting treatment and utilization standards.

## **Machine Learning for Productivity:**

- Predicting harvester productivity in mixed and hardwood stands using modified machine learning models.

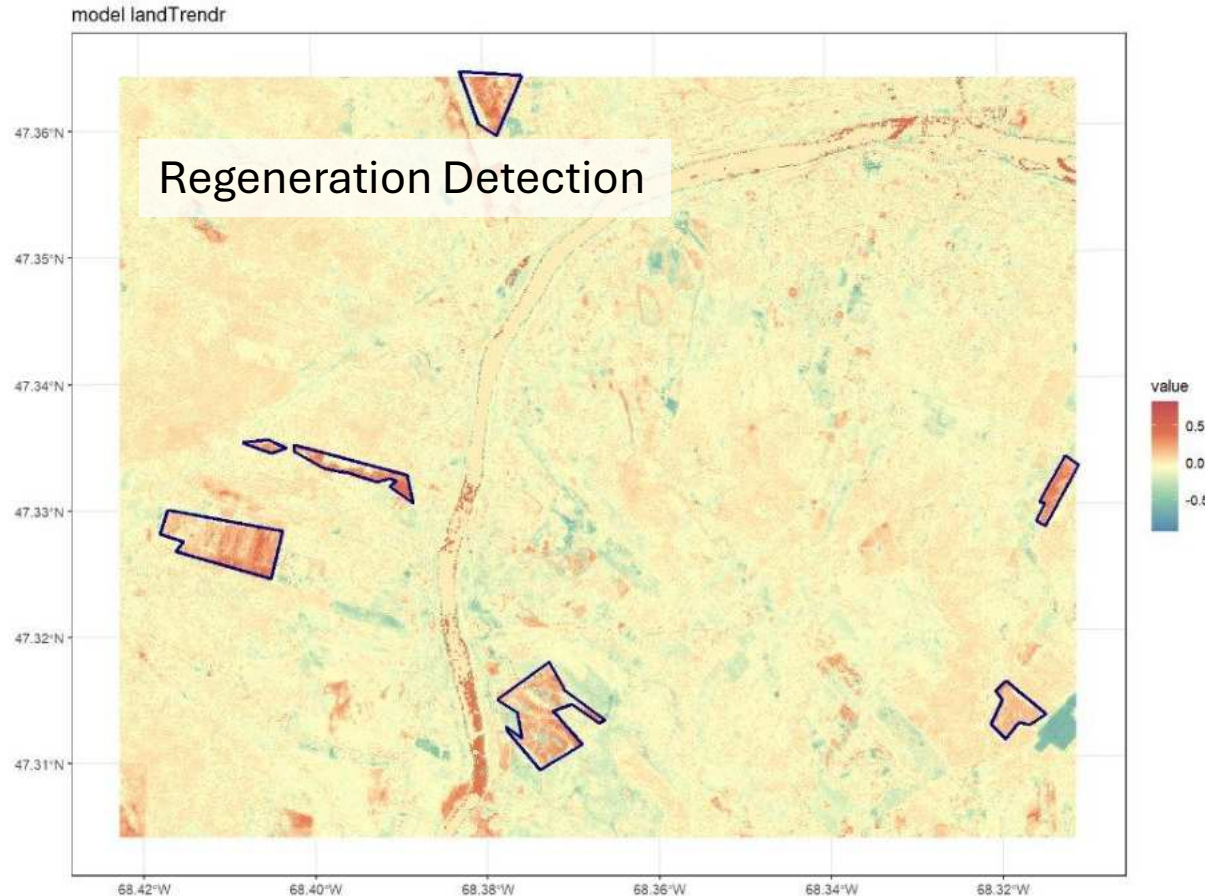
## **Impact on Greenhouse Gas Emissions:**

- By optimizing harvesting operations and increasing biomass extraction efficiency, the project will directly reduce the consumption of diesel fuel in forest machinery, leading to a significant reduction in greenhouse gas (GHG) emissions. We anticipate an annual reduction of up to **38,000 tonnes of carbon emissions.**



# Regeneration Detection and Characterization

## In Collaboration with CERFO



### Regeneration Characterization

- **Species groupings:** SW, HW, SW-HW, HW-SW, Commercial, Non-commercial
- **Density:** Very High, High, Moderate, Low, Very low



# Increase Sentinel-2 Image Resolution from 10m to 2.5m

- The developed AI Model increases Sentinel-2 Image resolution from 10m to 2.5m



# Increase DNR's Spot Image Resolution from 1.5m to 35cm

- The AI model will be trained using:
  - DNR's Spot imagery (1.5m)
  - DNR's Aerial imagery (15cm)



The trained AI Model will enhance Spot image resolution from 1.5m to 35cm.



# Conclusion

## ➤ A New Era for Forest Management: Precision Forestry is No Longer a Vision—It's Here

- ✓ AI-powered tool utilizing high-resolution satellite imagery for accurate predictions.
- ✓ Demonstrated high accuracy in pilot studies, validating its effectiveness.
- ✓ Solution is field-proven and ready for operational launch (TRL 6-9).
- ✓ Represents a major step forward in precision forestry technology.

With NHRI's cutting-edge AI and satellite-driven tools, we're redefining how forests are monitored, understood, and managed.

### **Our Tools Are Ready.**

- From partial harvest detection to species mapping and growth prediction—each solution is field-tested, scalable, and cost-effective.

### **Data-Driven Decisions = Better Forest Outcomes**

- Near real-time insights empower sustainable forestry, economic efficiency, and ecological resilience.

### **Let's Lead the Change Together.**

- Collaborate. Innovate. Grow smarter.
- **NHRI is ready!**



# Contact Us

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