Comparative Analysis of Aspen Leaf Miner Detection and Severity Assessment in Interior Alaska Using Multi-Resolution Remote Sensing

Sumana Sahoo, PhD Student

Dr Santosh Panda, Associate Professor of GIS

UAF INSTITUTE OF AGRICULTURE, NATURAL RESOURCES & EXTENSION
University of Alaska Fairbanks

UAF DEPARTMENT OF NATURAL RESOURCES AND ENVIRONMENT
University of Alaska Fairbanks
COLLEGE OF NATURAL SCIENCE & MATHEMATICS

USDA NIFA
United States Department of Agriculture
National Institute of Food and Agriculture

Insect Damage Survey in Alaska's Forests

Who?

- U.S. Forest Service Forest Health Protection program
- Alaska Division of Forestry and Fire Protection
- State, private, and tribal stakeholders
- Citizen scientists - iNaturalist

How?

- Annual Reports and Dashboards
  - Aerial detection surveys
  - Ground detection surveys
- Remote Sensing (under research and development)

Why?

- Forest resource management
- Economic and ecological values
- Early detection and mitigation

Challenges?

- Incomplete coverage
- Resource intensive
- Weather constraints
- Data Integration
- Delayed reporting

References: (Insects and Diseases of Alaskan Forests, 2008), (Forest Health Conditions in Alaska,2019,2020)

Major Insect Outbreaks

Interior

- Aspen Leafminer

- Birch Leafminer

- Spruce Beetle

Southcentral

- Spruce Beetle

Southeast

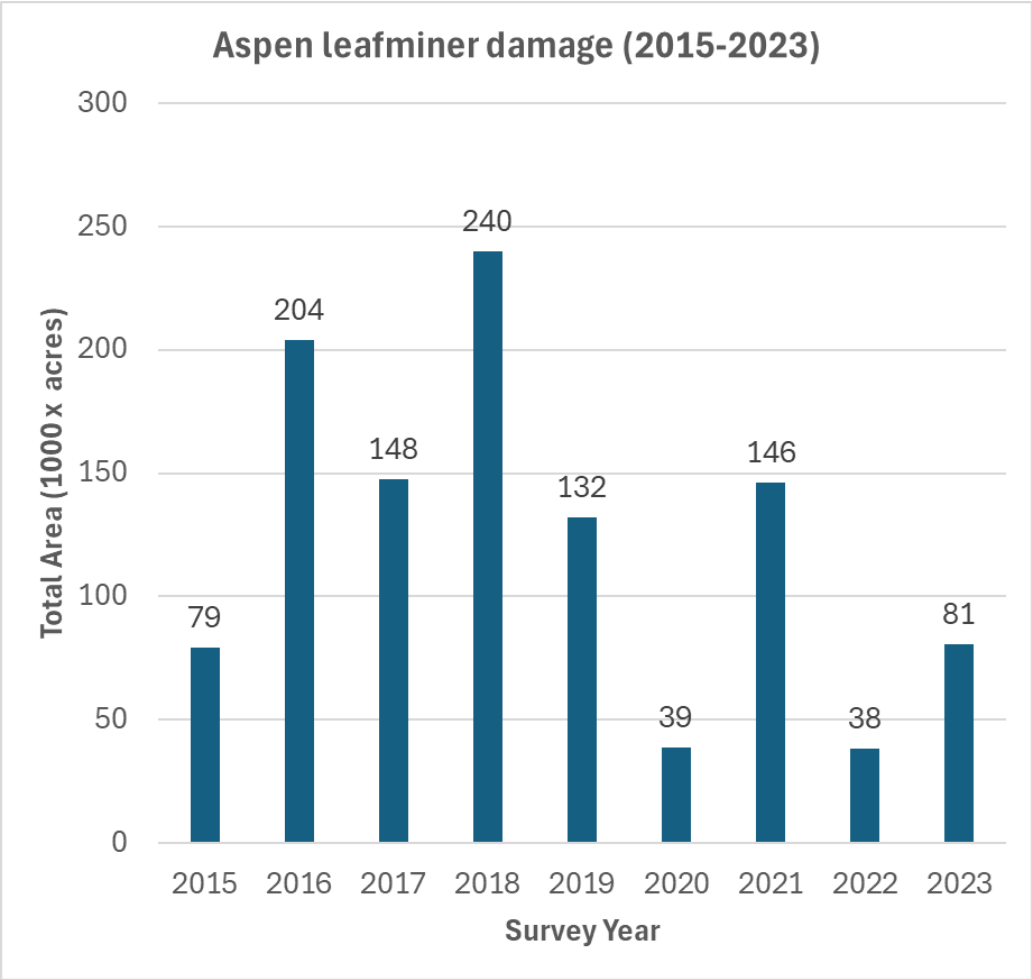
- Western Blackheaded Budworm

- Needle Blight

References: (Forest Health Conditions in Alaska, 2023);Picture credits: Forest Health Protection, Forest Service, USDA, Alaska Region

Need for Research on ALM Detection

- Late 1970s : first recorded outbreak in Alaska
- 2002 – Present: Major multi-year outbreak in Interior Alaska
- 2022 - 2023, defoliation increased from 38,000 to 80,600 acres
- Hotspots:
  - Tanana Valley State Forest : ~ 55,600 acres
  - Along Parks Highway between Fairbanks and Nenana: ~20,200 acres
- Second outbreak in Alaska's recorded history, damage > 500,000 acres
- Affect leaf photosynthetic capacity, potentially stunting tree growth and increasing vulnerability to other stressors.
- Recent changes in fire regime – successional deciduous dominance



References: (Wagner & Doak, 2013), (Wagner et al., 2020),(Ruess et al., 2021), (Forest Health Conditions in Alaska, 2019,2020,2021,2022,2023)

Aspen Leaf Miner (ALM) Life cycle

Window for Early Detection

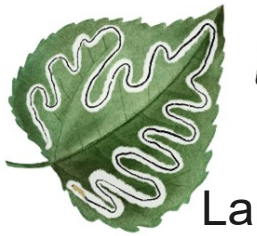
Early to mid May
Eggs are laid on the edges of young aspen leaves.
Adults then fold leaf edges to shelter them until hatching

Egg Stage

Mid to late May
Larvae hatch

Larval Stage

Late May to June
Larval feeding or "mining" of the epidermal tissue



Pupal Stage

June to July
Pupation occurs within mines

Adult Stage

Late August-September
Adults emerge.
Univoltine
(1generation/year)

September -April
Adults overwinter

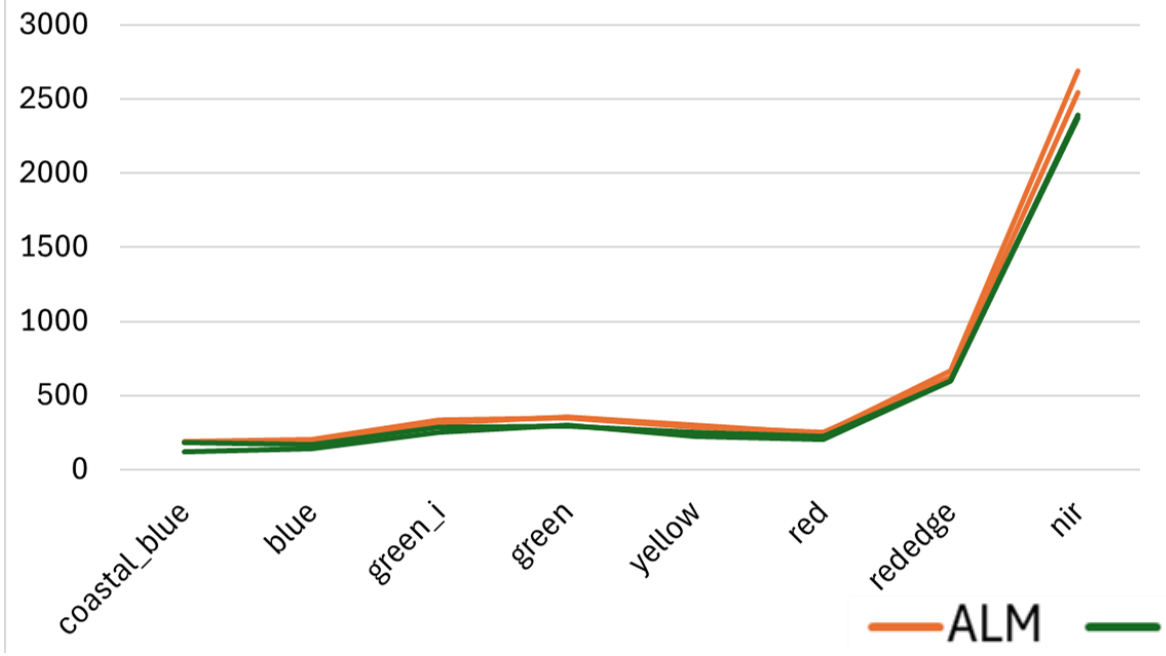
Window for Severity Assessment

References: www.fs.usda.gov (R10, forest and grassland health); www.forestry.gov.yk.ca

Remote Sensing of Aspen Leaf Miner in Alaska

Literature	Challenges
High-resolution imagery (Douglas., 2008) • Quickbird (2.4 m resolution) • Spectral metrics: Normalized Difference Vegetation Index • Validated : USFS Aerial Detection survey and ground investigations	• Unavailability of high-resolution data • Extrapolating results beyond study areas reduced prediction accuracy • Minor difference in NIR • Detection only • No severity assessment

PlanetScope (3m)



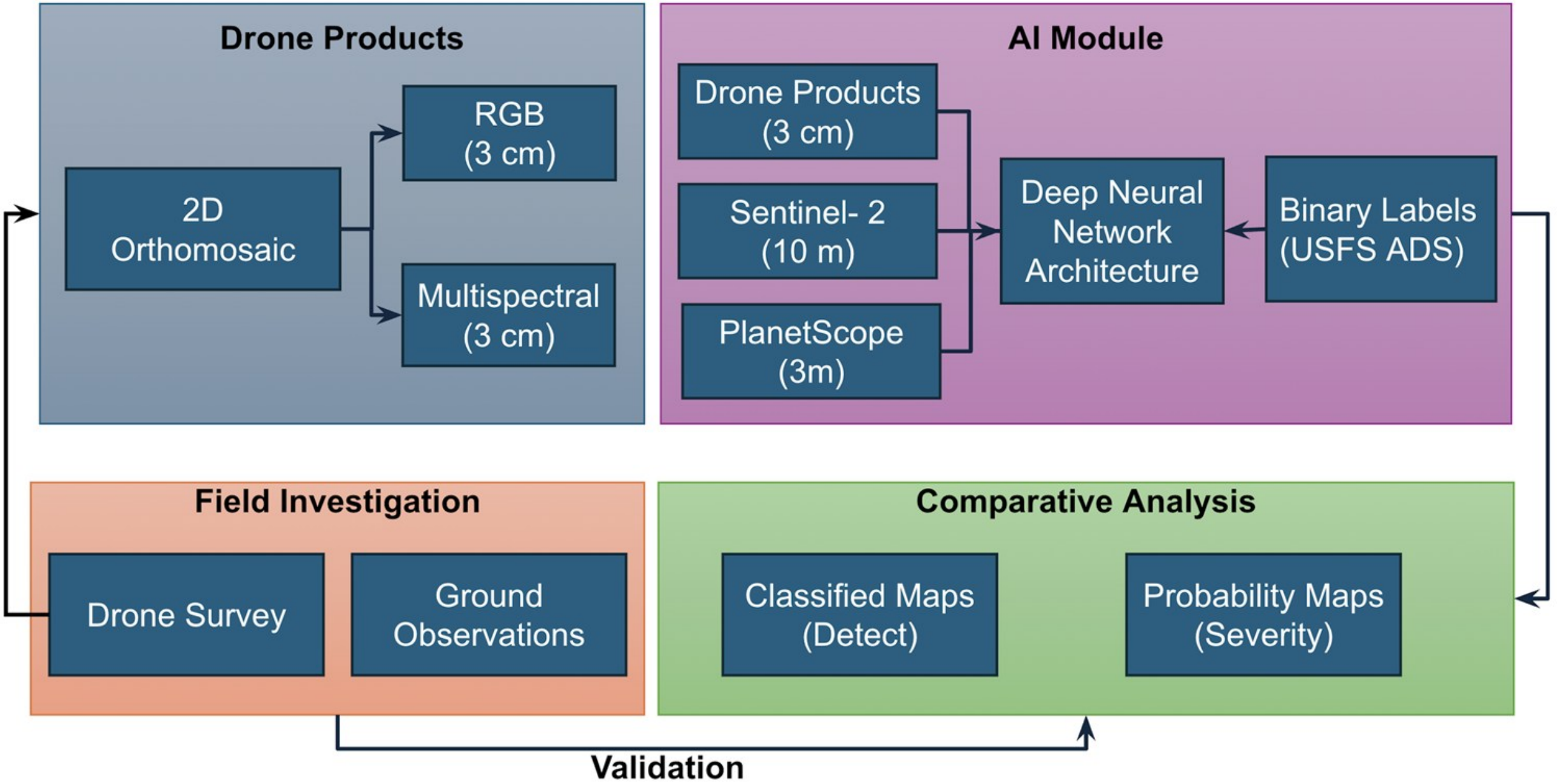
Sentinel -2 Multi Spectral Instrument (10m)

ALM NO_ALM

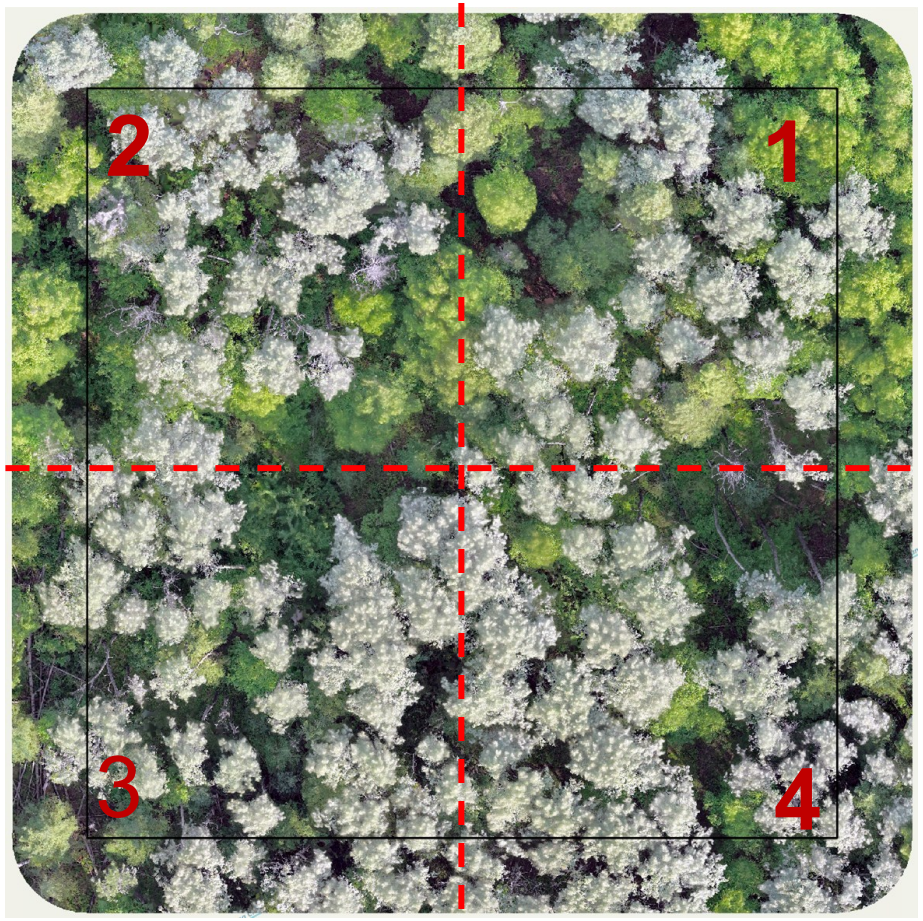
Why deep learning?

	Machine Learning	Deep Learning
Input	Structured Data (e.g. tabular)	Unstructured Data (e.g. Image)
Feature Engineering	Manual, Site-specific	Automatic, Generalizable
Data Volume	Low Volume • Good for low spatial resolution data • Smaller region for analysis	High volume • Good for high spatial resolution data • Larger region for analysis
Interpretability	Spectral relations are better captured than spatial relations	Captures both spectral and spatial relations (neighborhood)
Adaptation Methods	Retrain from scratch or adjust thresholds	Transfer learning with fine-tuning
Cross-Site Performance	Often degrades without retraining	Maintains performance with minor updates

Methodology



Summer Field Investigations

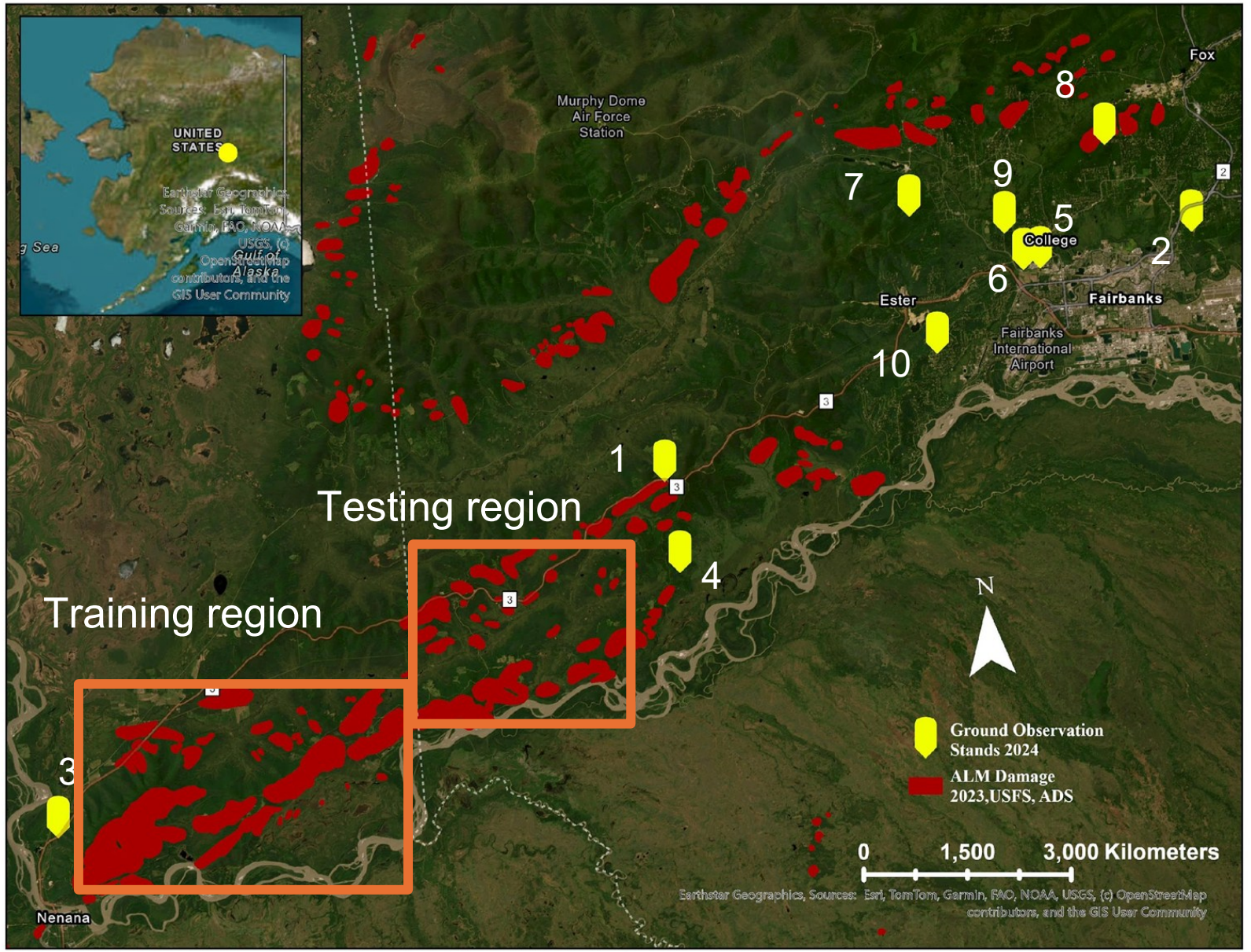


- Stand Name: Parks Highway, Mile 339
- Type of Stand (Age): Medium
- Dominant Species: Aspen, Spruce, Alder
- Understory Species: Spruce, Alder, Birch
- Notes: Mature aspen and spruce

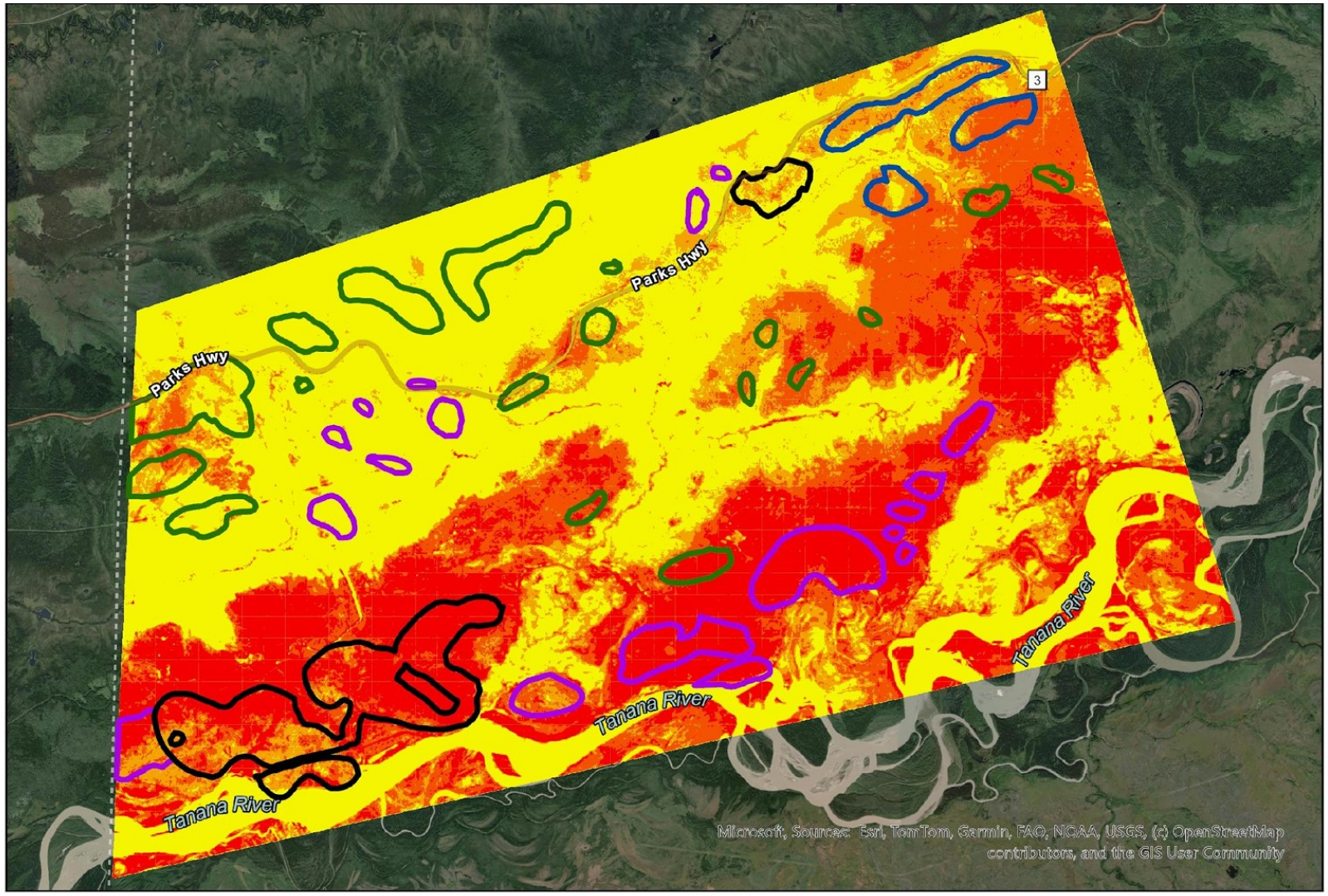
Quadrant Number	Canopy Cover (%)	Species	#	Range of DBH (inches)	Height (meter)	ALM Severity
1	90.64	Aspen	>30	6.69-13.7	17	Severe
		Spruce	>30	2.72-22.6	5-16	
		Alder	>30	3.82	5	
		Birch	<10	5	--	
2	87.5	Aspen	>30	6.84-12.5	20.5	Moderate
		Spruce	>30	1.48-16.7	3-23.7	
		Alder	~10	1.79	--	
		Birch	~15	5.17	--	
3	95.9	Aspen	15-20	8.0-13.4	21	Severe
		Spruce	>30	2.1-10	5-14.9	
		Alder	~10	2.15	--	
		Birch	~10	4.87	--	
4	95.9	Aspen	>30	10.1-8.52	18.1	Severe
		Spruce	>30	2.34-11.75	5-14.9	
		Alder	~10	3	--	
		Birch	<10	5.95	--	

Summer Field Investigation for Validation

1. Parks Highway, Mile 338
2. Skyline Ridge After Hours Trail
3. Nenana, FAA Hill Road
4. Crispy Aspen, BCEF
5. University of Alaska Fairbanks - Reichardt
6. UAF Equinox Trail
7. Ester Dome
8. Birch Hill
9. Miller Hill Rd
10. Chena Ridge



Preliminary Results - Detection + Severity Assessment



ALM 2023, USFS ADS

- Light (4-10%)
- Moderate (11-29%)
- Severe (30-50%)
- Very Severe (>50%)

ALM Detection 2023

- 0.01 - 0.23 ((Light)
- 0.24 - 0.46 (Moderate)
- 0.47 - 0.7 (Severe)
- 0.71 - 0.93 (Very Severe)

Training Parameters	
Model	U-Net architecture with a ResNet50 encoder
Input	PlanetScope (3m) 8-band image tile
Tile size	256*256
Labels	ADS Binary mask (ALM, No ALM)
Loss Function	Dice +Binary Cross Entropy
Metric	IOU & Dice Coefficients

Conclusions

- **Climate Impact:** Climate change and altered fire regimes are increasing deciduous forest coverage in Alaska, while warming temperatures favor insect populations, including deciduous defoliators.
- **Detection Challenges:** Aspen leafminer detection via remote sensing remains understudied, with minimal spectral differences (especially in NIR bands) limiting conventional detection methods.
- **Advanced Solutions:** Deep learning approaches (particularly CNN models) show promise for detecting subtle spectral variations caused by leafminer damage.
- **Management Applications:** Early detection and severity assessment tools are needed to support forest managers and complement existing survey methods, specifically using moderate to high-resolution imagery products.

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Thank You

Sumana Sahoo
Email: sshaoo2@alaska.edu