Invasive Species Monitoring with Remote Sensing

Part 3: Mapping Invasive Grassland Plant Species with Hyperspectral Remote Sensing

Hamed Gholizadeh, Oklahoma State University

August 28, 2024

Part 3 – Trainers

Hamed Gholizadeh

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Oklahoma State University

Sativa Cruz

Applied Scientist

BAER/NASA Ames Research Center

Prerequisites

- Fundamentals of Remote Sensing

Training Outline

Part 1

An Introduction to the Monitoring of Invasive Species with Remote Sensing Tools

August 14, 2024

10-11:30 PT (1-2:30pm ET)

Part 2

Monitoring of Aquatic Invasive Species with Remote Sensing

August 21, 2024

10-11:30 PT (1-2:30pm ET)

Part 3

Monitoring Invasive Grassland Species with Hyperspectral Remote Sensing

August 28, 2024

10-11:30 PT (1-2:30pm ET)

Homework

Opens August 28 – Due September 11 – Posted on Training Webpage

A certificate of completion will be awarded to those who attend all live sessions and complete the homework assignment(s) before the given due date.

Training Learning Objectives

By the end of this training attendees will be able to:

- Recognize the extent and impacts of invasive species on biodiversity and a changing climate.
- Identify the types of remote sensing data and products that can be used for invasive species mapping and monitoring.
- Explore key considerations, benefits and limitations of remote sensing data sets for invasive species.
- Identify where to access remote sensing data for monitoring invasive species and mapping relevant habitat and climate variables.
- Evaluate remote sensing methods used to monitor aquatic and grassland invasive plant species.

How to Ask Questions

- Please put your questions in the Questions box and we will address them at the end of the webinar.
- Feel free to enter your questions as we go. We will try to get to all of the questions during the Q&A session after the webinar.
- The remainder of the questions will be answered in the Q&A document, which will be posted to the training website about a week after the training.

National Aeronautics and Space Administration

Invasive Species Monitoring with Remote Sensing

Part 3: Mapping Invasive Grassland Plant Species with Hyperspectral Remote Sensing

Hamed Gholizadeh, Oklahoma State University

August 28, 2024

Objectives

- Describe the key challenges of monitoring invasive plants in grassland ecosystems using field-based techniques
- Compare the key benefits of remote sensing techniques for mapping invasive plants compared to field-based techniques
- Identify applications of airborne hyperspectral data for mapping invasive plants in grasslands
- Identify limitations of remote sensing for mapping invasive plants

Outline

- Background on remote sensing of invasive plants
- Case study: Using hyperspectral remote sensing to map an invasive plant in grasslands
- Data availability considerations for mapping invasive plants using remote sensing

Background

Example: Remote Mapping of Invasive Water Hyacinth Using Color Infrared Photography (1975)

Figure adapted from Rouse, et al. (1975)

Figure adapted from Kleinschroth, et al., *Ambio* (2021)

Unique Role of Remote Sensing: Spatiotemporal Data Collection with Consistent Format

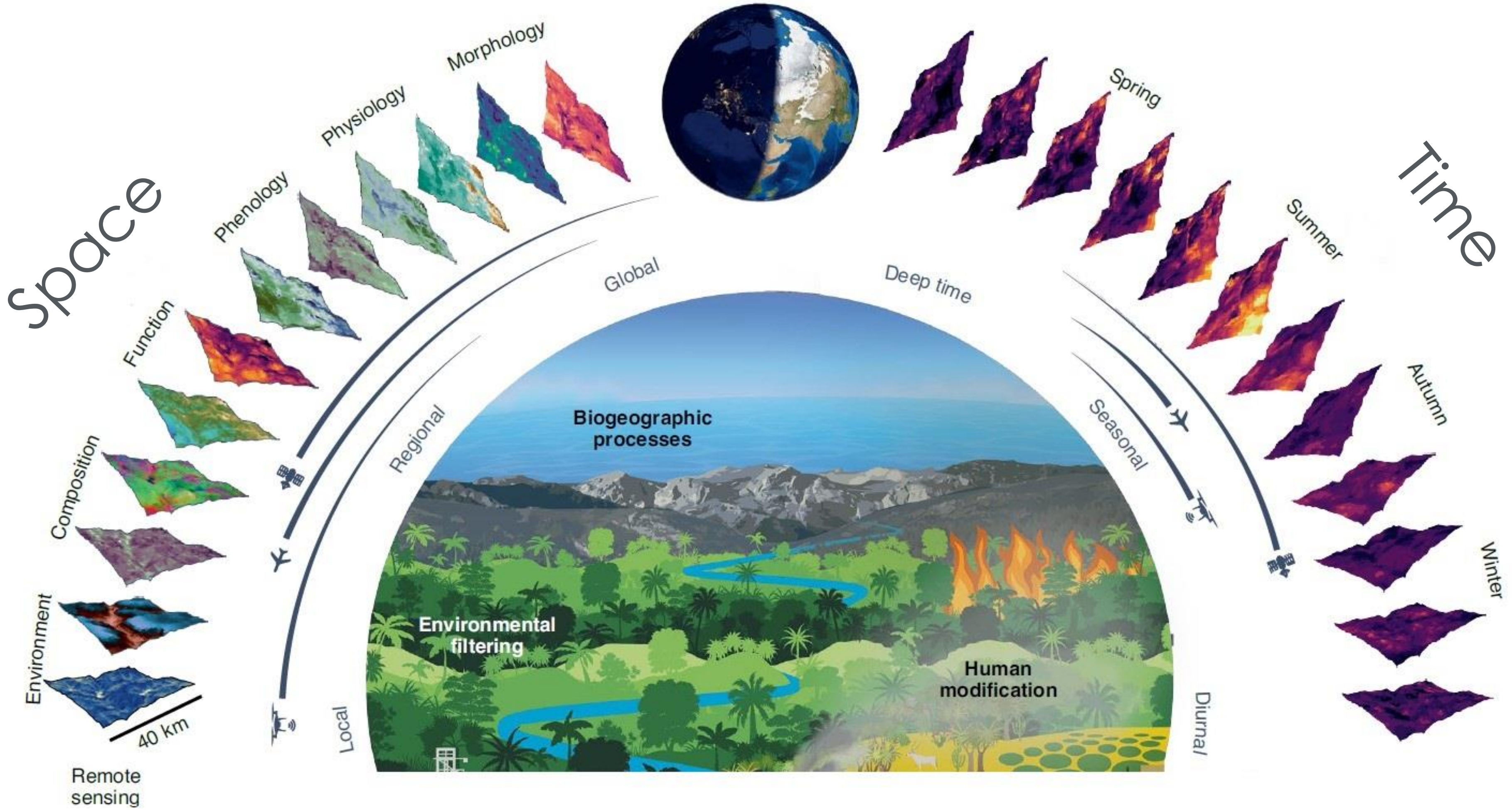

Figure adapted from Cavender-Bares, et al., *Nature Ecology and Evolution* (2022)

How Can Remote Sensing Help Us Monitor Invasive Plants?

- Mapping the occurrence of invasive plants (or direct mapping)
- Providing useful data for predicting distribution of invasive plants (or indirect mapping)
- Assessing the impacts of invasive plants

How Can Remote Sensing Help Us Monitor Invasive Plants?

- **Mapping the occurrence of invasive plants (or direct mapping; the focus of this talk)**
- Providing useful data for predicting distribution of invasive plants (or indirect mapping)
- Assessing the impacts of invasive species

But remote mapping of invasive plants is not necessarily simple…

A Conversation: Remote Sensing Scientist to Applications Partner

Remote sensing scientist

"Would you like to work together and use remote sensing to study invasive plants in your grassland?"

Landowners, managers, ecologists, NGOs, …

"Sure, can you help me detect individual cheatgrass plants?"

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"Hmm, I would love to, but these plants are too small to detect remotely …"

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"Hmm, I would love to, but these plants are too small to detect remotely ..."

Landowners, managers, ecologists, NGOs, ...

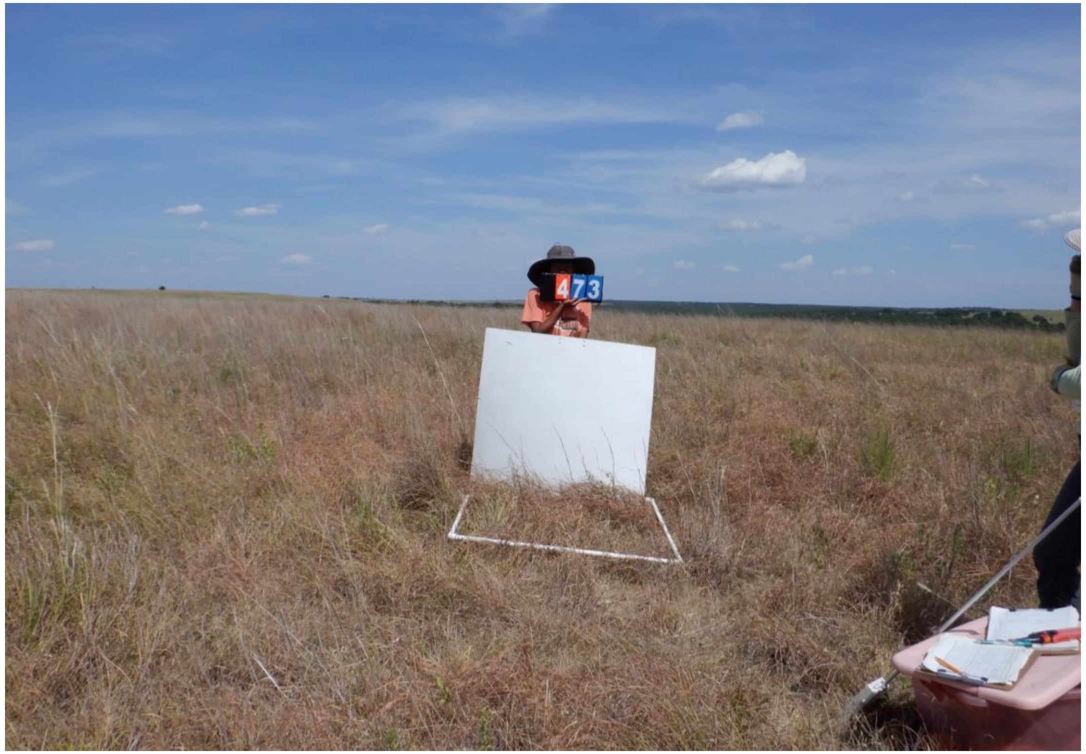
"Sure, can you help me detect individual cheatgrass plants?"

"Oh, you mean remote sensing cannot help us study invasive plants?"

Effective Mapping of Invasive Plants Depends on…

1. Contrasting seasonal phenology of invasive plants vs. native plants (requires remote sensing data with fine temporal resolution)

Native plant community



Invasive plant community

Joseph H. William Tallgrass Prairie Preserve (date: July 2022)

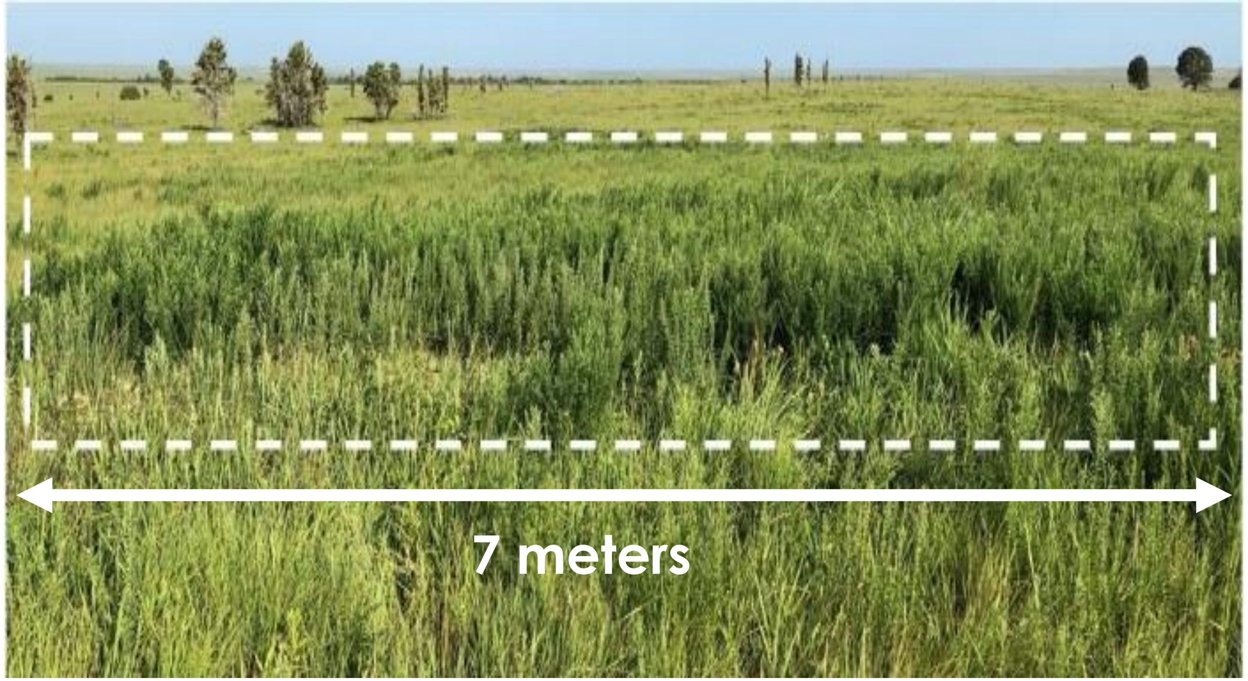
Effective Mapping of Invasive Plants Depends on…

2. Distinct biochemical, physiological, and structural characteristics (or functional traits) of invasive plants vs. native plants (requires remote sensing data with fine spectral resolution)

Effective Mapping of Invasive Plants Depends on…

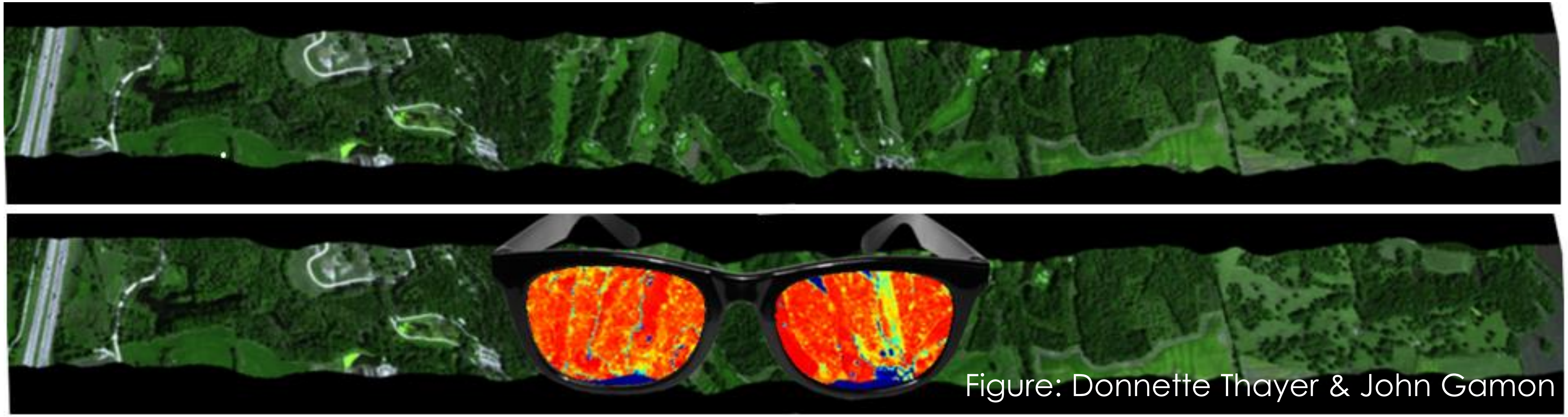
3. Prevalence of invasive plants in the study area (access to remote sensing data with fine spatial resolution is ideal)

Large and homogeneous patches (easier to map)

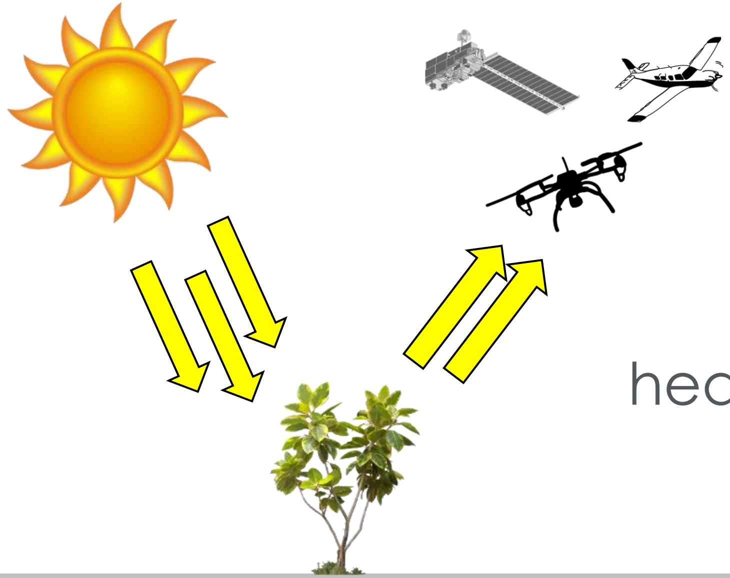


Small patches (challenging to map)

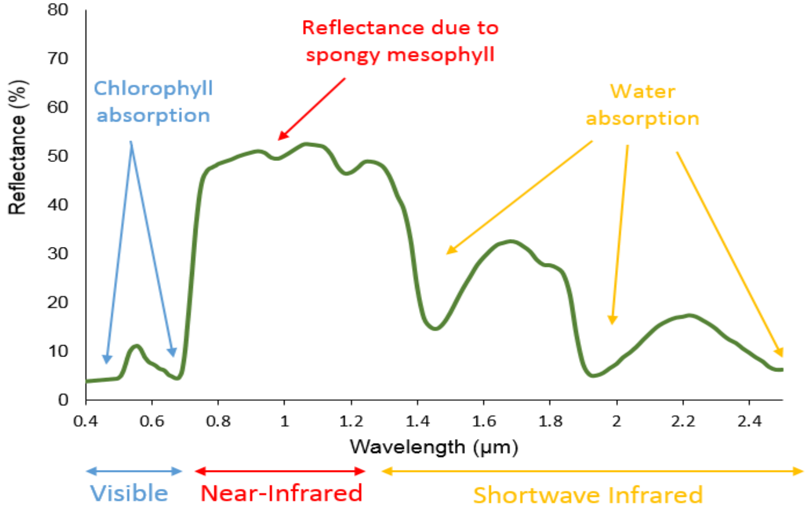
Hyperspectral Remote Sensing (Imaging Spectroscopy)



Optical Remote Sensing of Plants

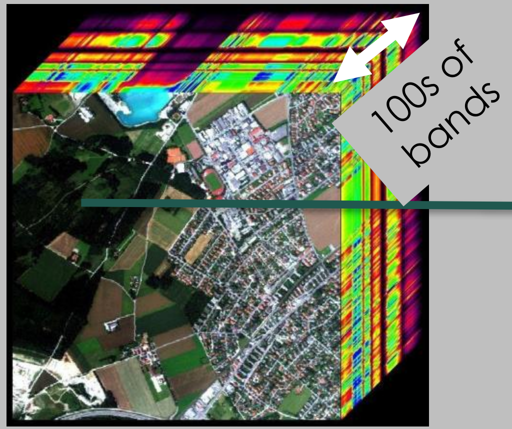


Reflectance of
healthy green vegetation

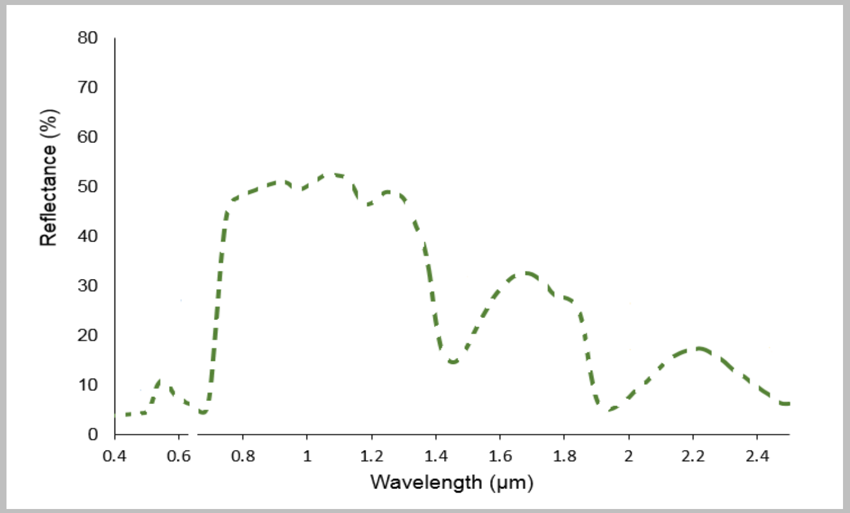


http://gsp.humboldt.edu/

Hyperspectral imaging



Pre-processing



Case Study: Using hyperspectral remote sensing to map an invasive plant in grasslands

The invasive *Lespedeza cuneata*
(*L. cuneata*; also known as "sericea")

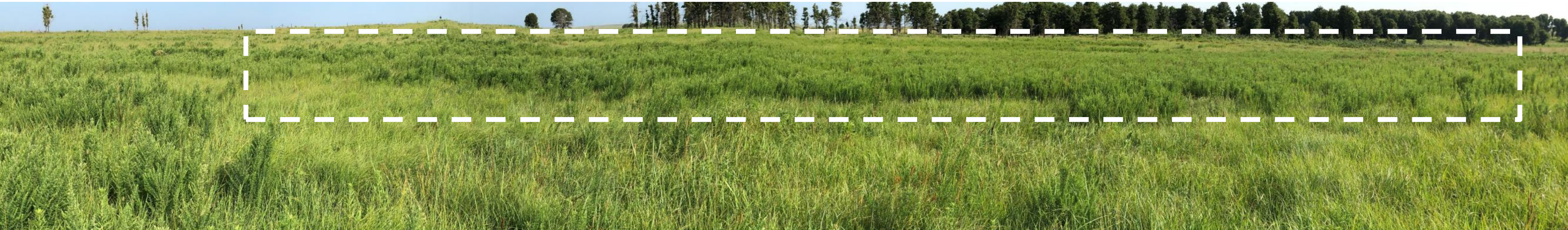
L. cuneata (also known as “sericea”)

L. cuneata (also known as "sericea")

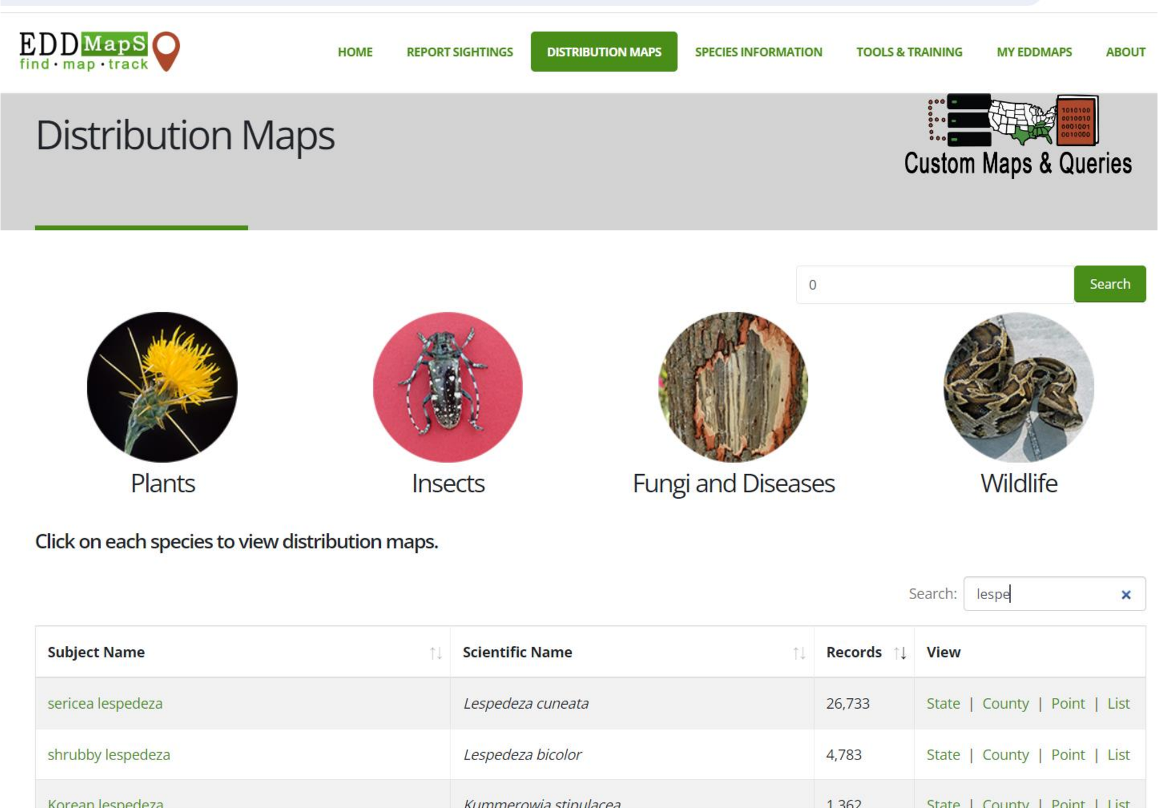
"The top nightmare plant"
"Greedy grass"
"Fiendish"

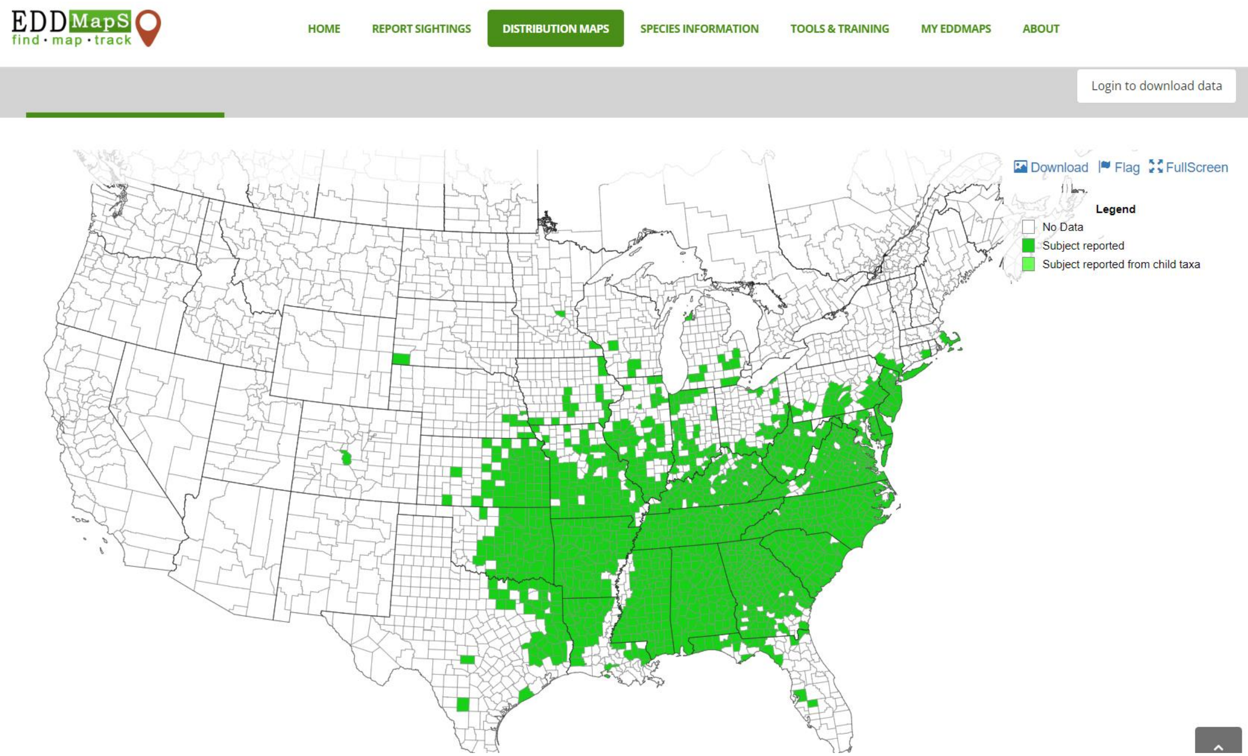
"Managing L. cuneata represents our greatest annual land management cost and we need strategies with high conservation benefit that minimize cost and collateral damage"

Robert Hamilton, the Director of The Nature Conservancy's Tallgrass Initiative



Distribution Maps for *L. cuneata*





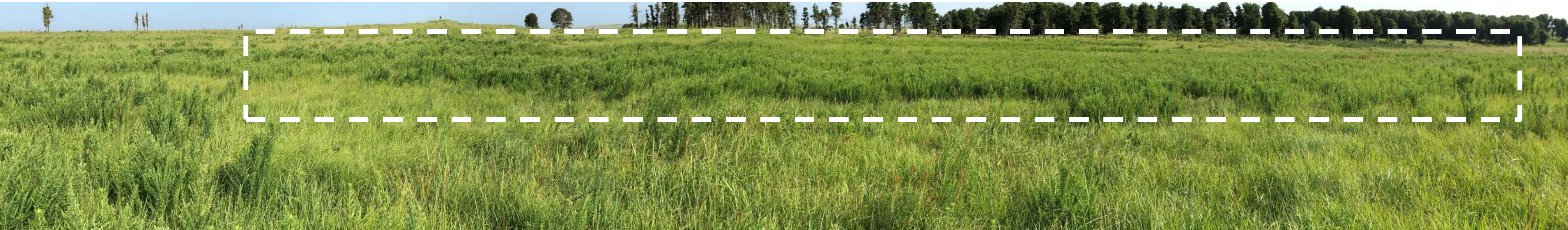
U.S. Counties where *L. cuneata* has been reported

Go to https://www.eddmaps.org/distribution/

Some Background on *L. Cuneata* in the U.S.

Brought to the U.S. in the 1890s:

- As a cheap forage
- To control soil erosion



But What Makes *L. cuneata* Invasive?

Prolific seed producer

Tolerates drought

Reproduces under poor soil conditions

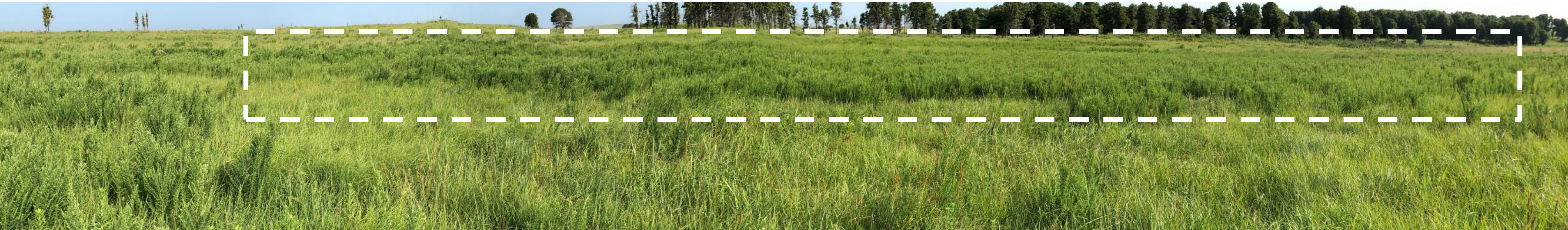
A nitrogen-fixing legume

→ These are also characteristics of a good forage!

Taller than most co-occurring native plants

High concentrations of phenolics, specifically condensed tannins

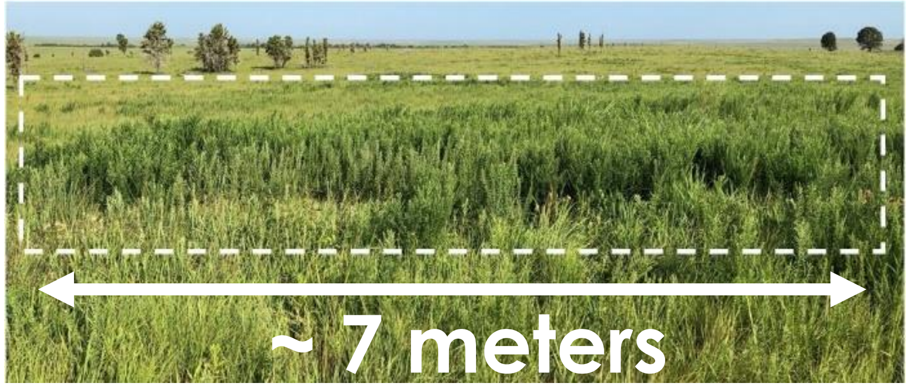
→ avoidance by grazing animals



Challenges for Remote Mapping of *L. cuneata*: Spatial Scale Mismatch

Small canopy size of
each individual *L. cuneata* plant

Small size of *L. cuneata* patches relative to the
Spatial resolution of common
remote sensing data
(e.g., Landsat 8/9, MODIS)



Challenges for Remote Mapping of *L. cuneata:* Limited Temporal Resolution

One way to detect *L. cuneata* is based on its contrasting seasonal phenology compared to native plants.

Following this approach requires data with fine temporal resolution (but we did not have such data).

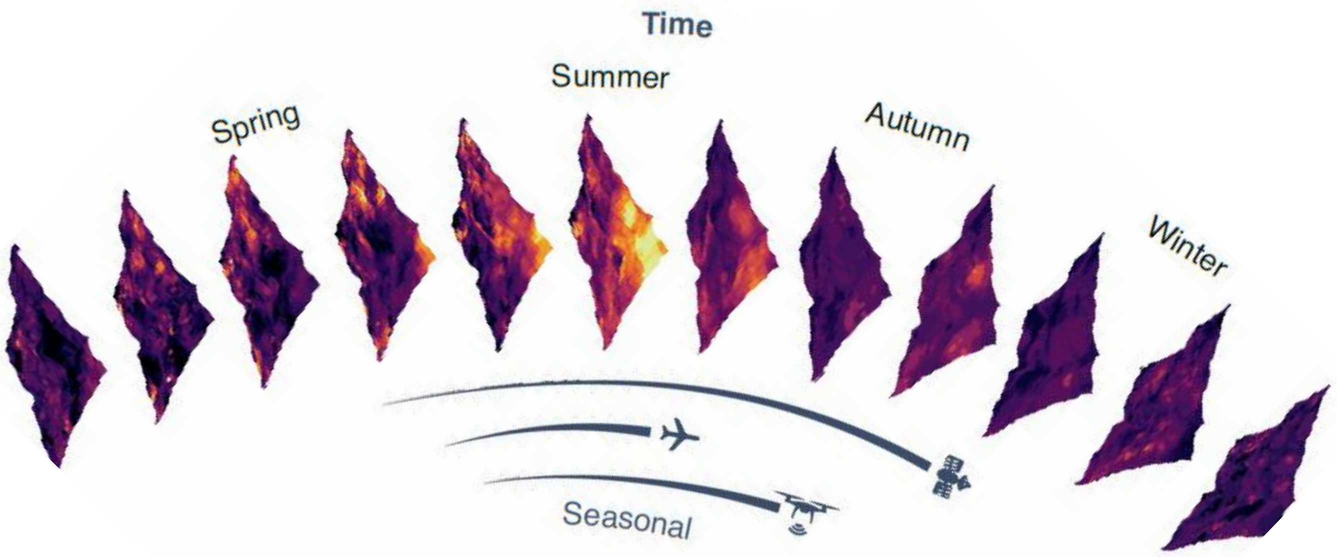


Figure adapted from Cavender-Bares, et al., *Nature Ecology and Evolution* (2022)

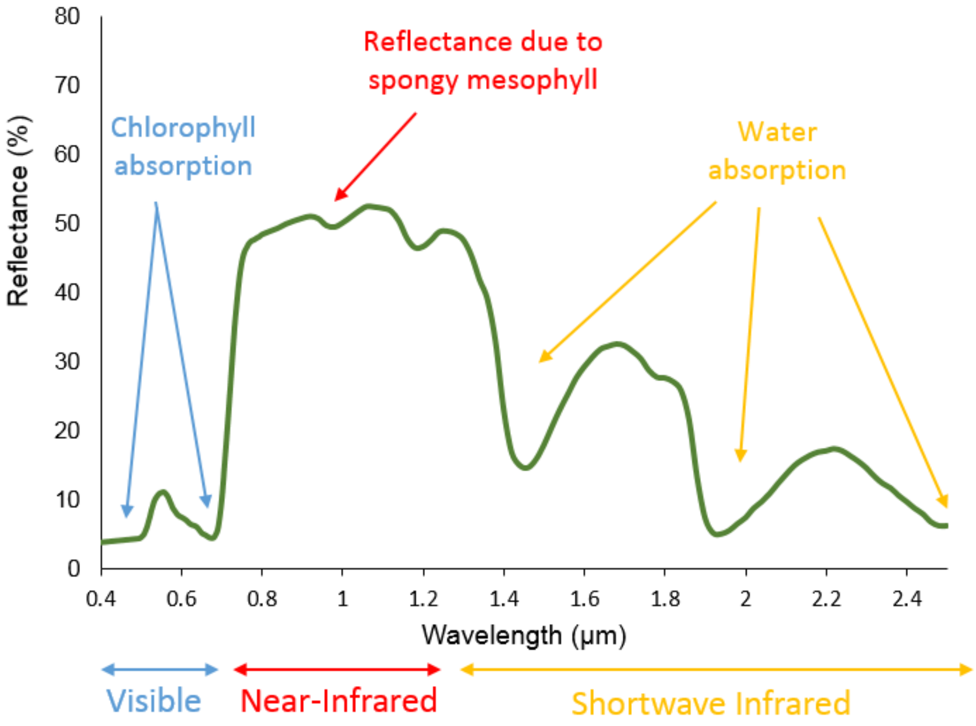
How Did We Overcome These Challenges?

- We used airborne hyperspectral data with spatial resolution of 1 meter.
- In other words, we used data with fine spectral/spatial resolution.

Key Hypothesis:

Depending on their functional traits, plants can display different spectral signatures in remotely sensed data.

L. cuneata has specific *remotely-observable* functional traits (e.g., higher total nitrogen content) that can be used to distinguish it from co-occurring native species in hyperspectral data.



http://gsp.humboldt.edu/

Our Approach for Remote Mapping of *L. cuneata*

- Step 1: Identified remotely-observable vegetation functional traits that distinguish *L. cuneata* from co-occurring native species.

- Step 2: Used these key vegetation functional traits to develop a robust method for remote detection of *L. cuneata* invasion.

Measuring Vegetation Functional Traits

Field Data collection – Collecting foliage samples

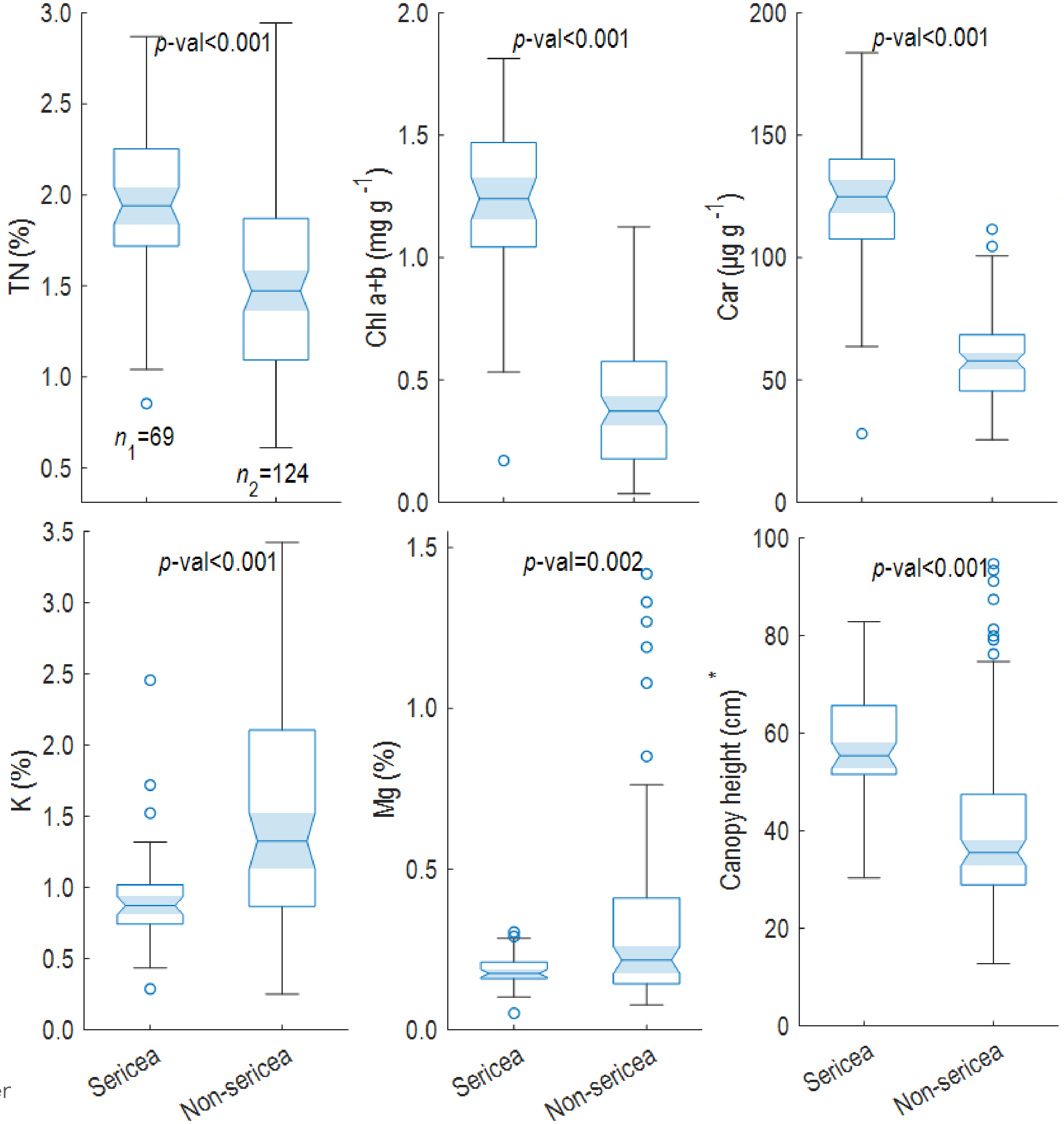

Flash-freezing foliage samples


Measuring plant height

Functional Trait	Relevance
Total nitrogen (TN)	*Photosynthetic capacity*
Chlorophyll a+b (Chl ab)	*Light capture*
Total carotenoids (Car)	*Light capture; photoprotection*
Total phenolic content (TPC)	*Defense*
Phosphorus (P)	*Micro- and macro-nutrient; metabolic processes*
Calcium (Ca)	
Potassium (K)	
Magnesium (Mg)	
Iron (Fe)	
Zinc (Zn)	
Leaf mass per area (LMA)	*Leaf and canopy structure*
Canopy height	

Step 1: Identifying remotely-observable vegetation functional traits that distinguish *L. cuneata* from co-occurring native species

TN: Total nitrogen
Chl a+b: Chlorophyll a+b
Car: Carotenoid
K: Potassium
Mg: Magnisium



Step 2a: Remote estimation of functional traits using a data-driven model

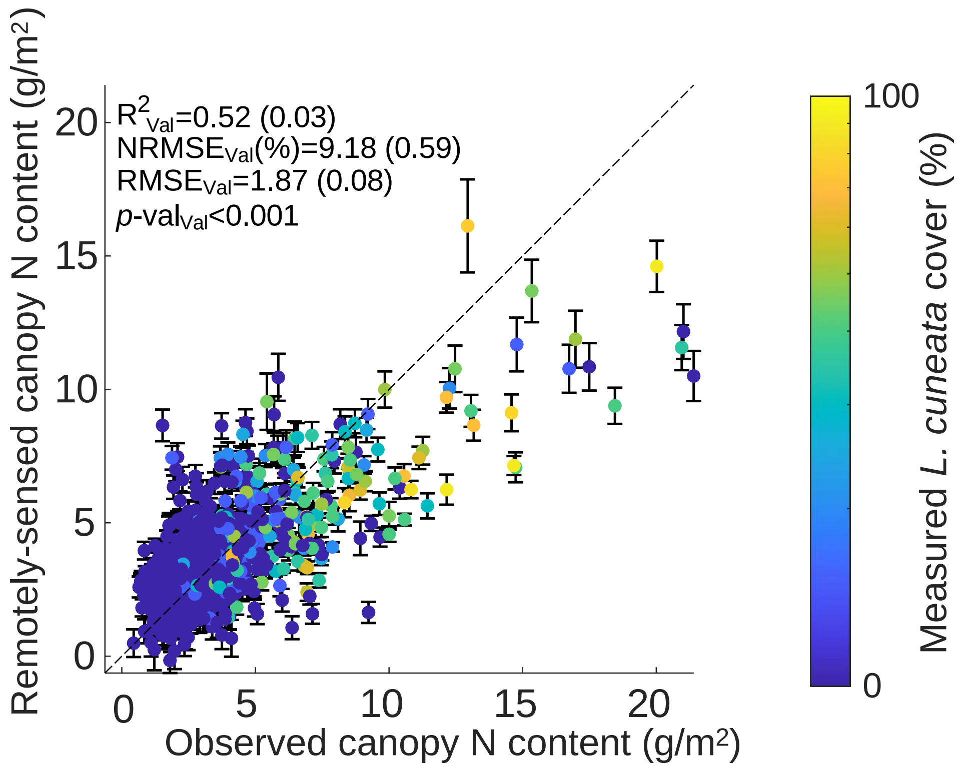
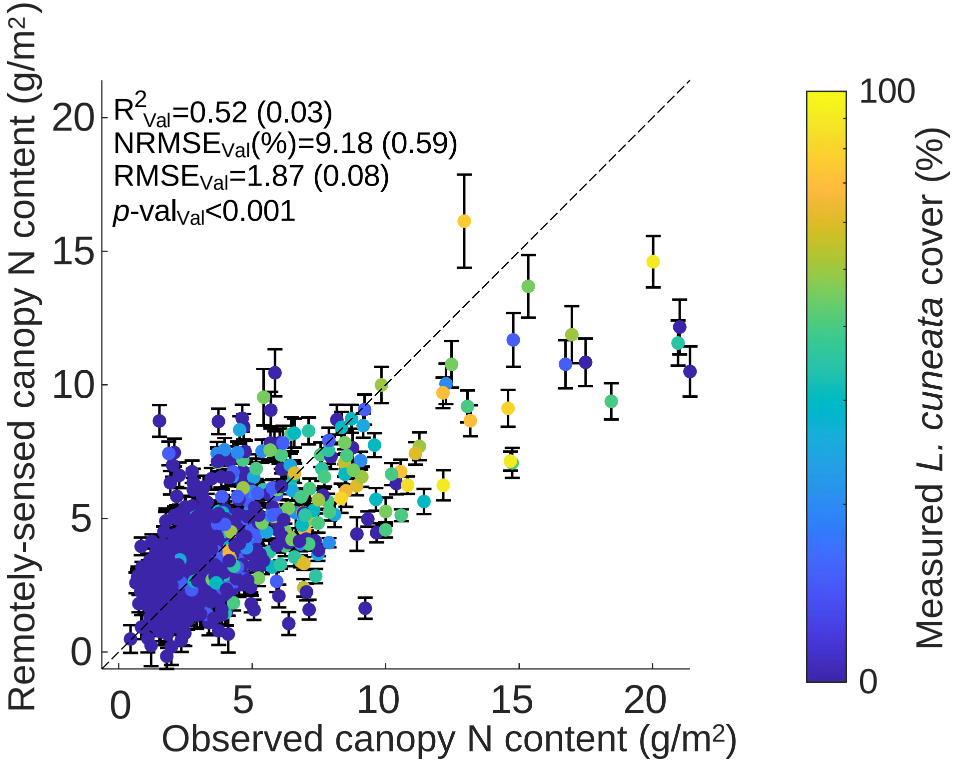
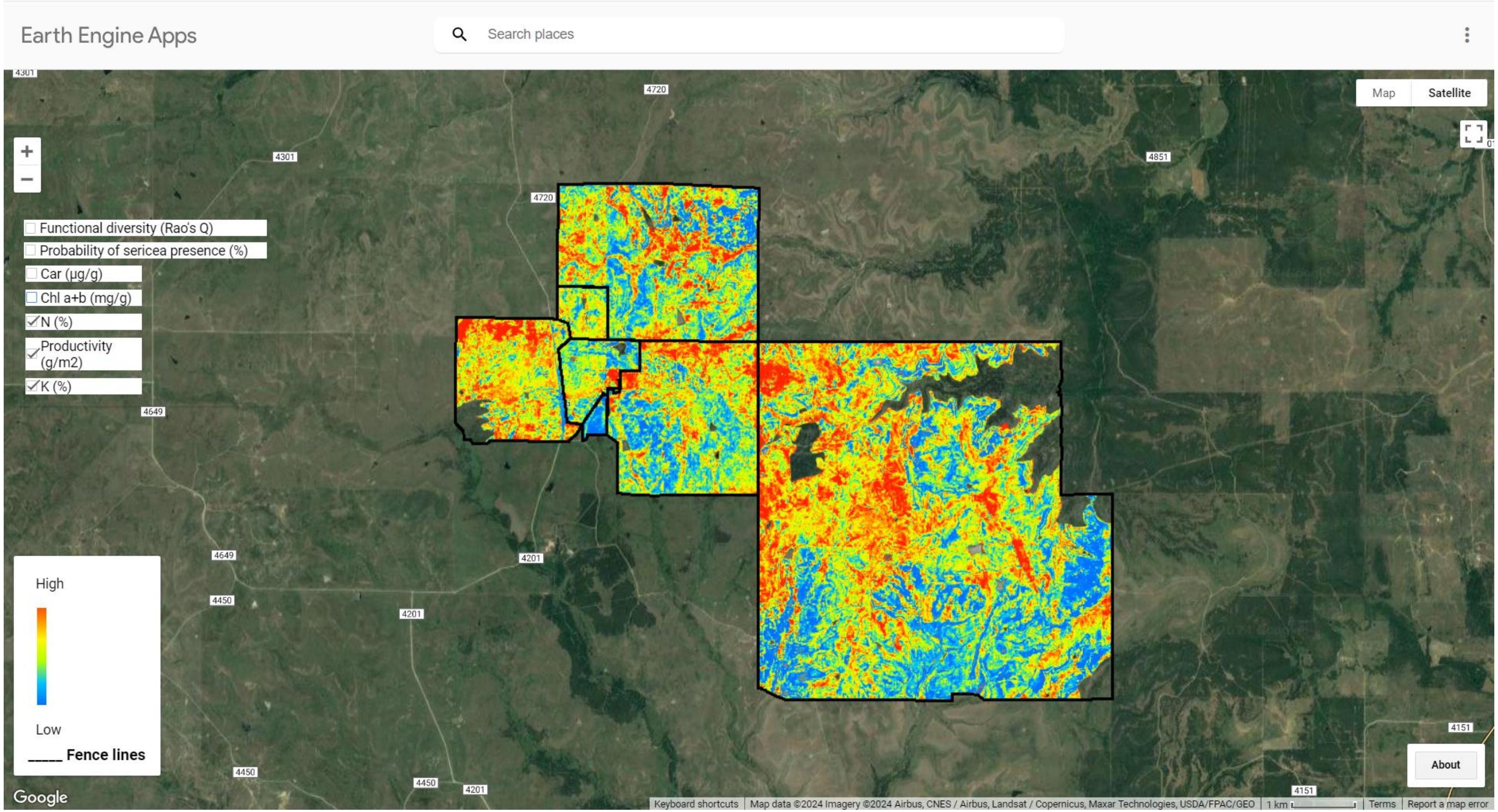


Figure adapted from Gholizadeh, et al., *Remote Sensing of Environment* (2024)

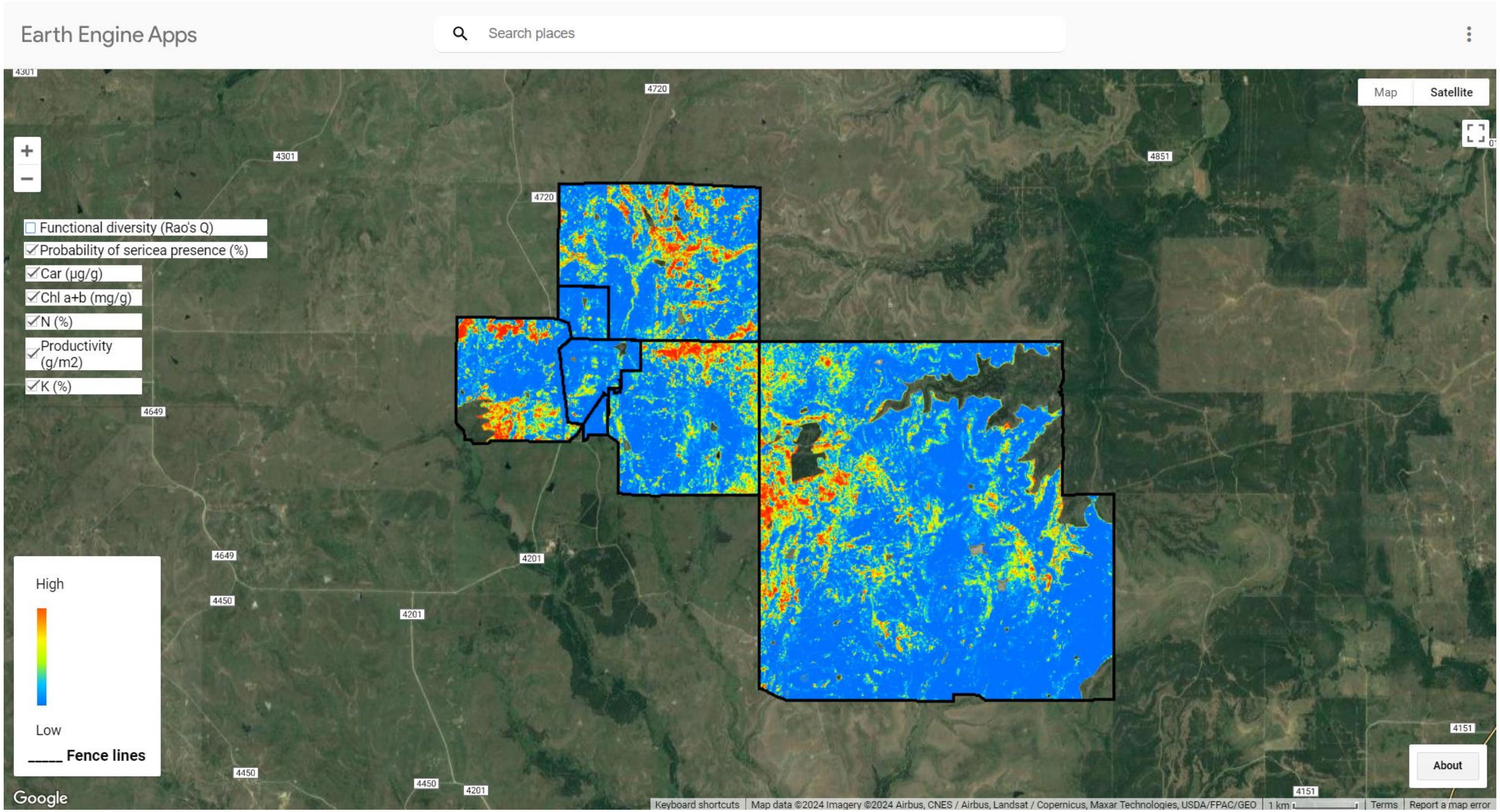
Step 2a: Remote estimation of functional traits using a data-driven model



Output from Step 2a

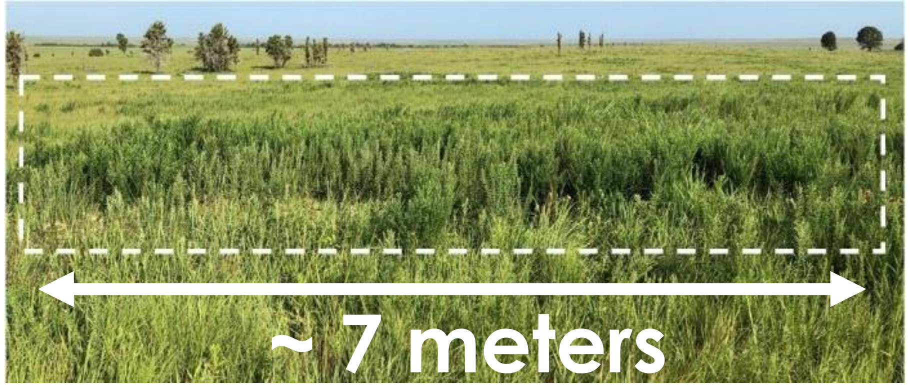


Step 2b: Estimating *L. cuneata* Abundance



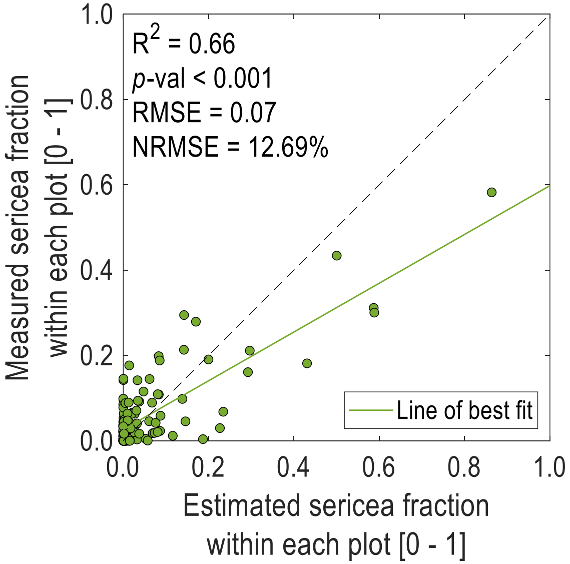
The Accuracy of *L. cuneata* Detection

Scenario 1: When *L. cuneata* forms large patches



		Map: Sericea	Map: Non-sericea	Map: Total	Producer's accuracy
Field	Sericea	33	3	36	91.5% (±4.8%)
Field	Non-sericea	2	40	42	96.2% (±2.2%)
Field	Total	35	43	78	
User's accuracy		95.5% (±2.4%)	93.1% (±3.5%)		
Overall accuracy		94.0% (±2.0%)			
Kappa		0.87 (±0.04)			

Scenario 2: When *L. cuneata* is mixed with native plants



Gholizadeh, et al., *Remote Sensing of Environment* (2022)

What future possibilities does hyperspectral sensing provide?

Improving Decision-making

Opportunities for using hyperspectral observations to develop effective management practices to control invasive plants

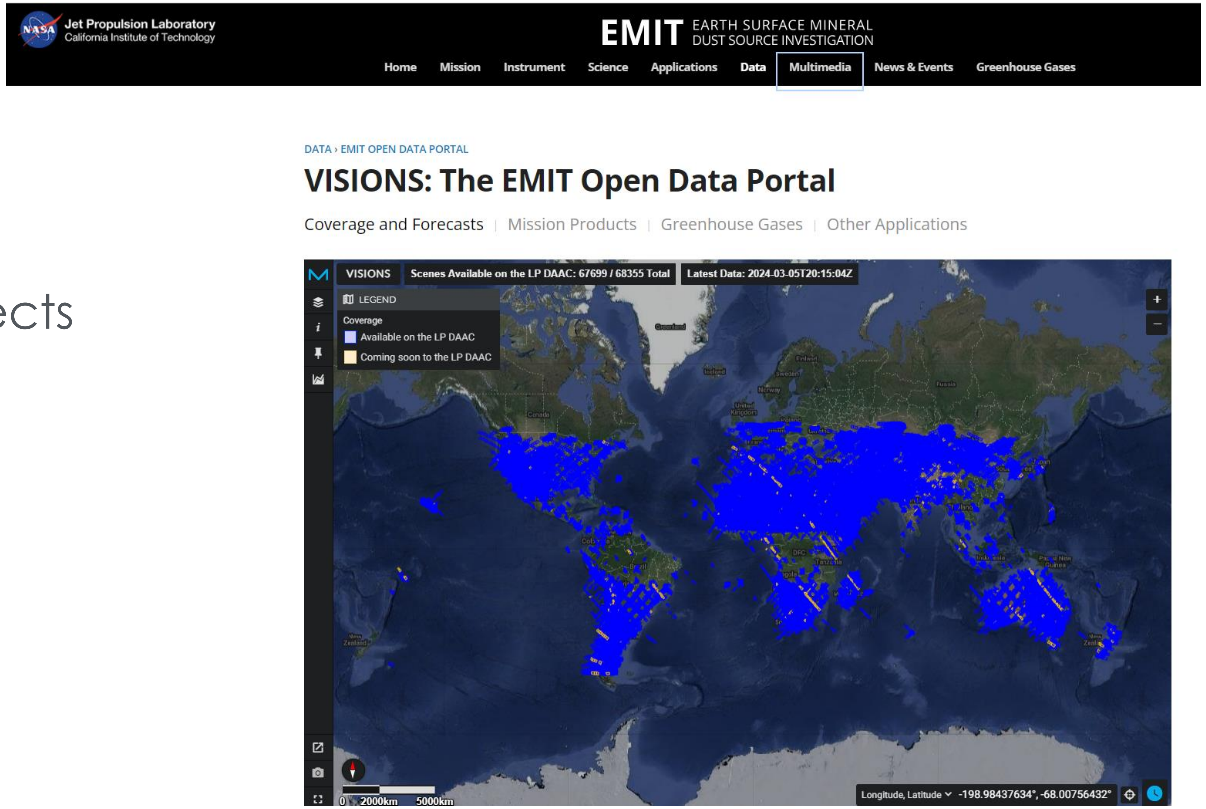
Data availability considerations

Hyperspectral Data Availability Considerations

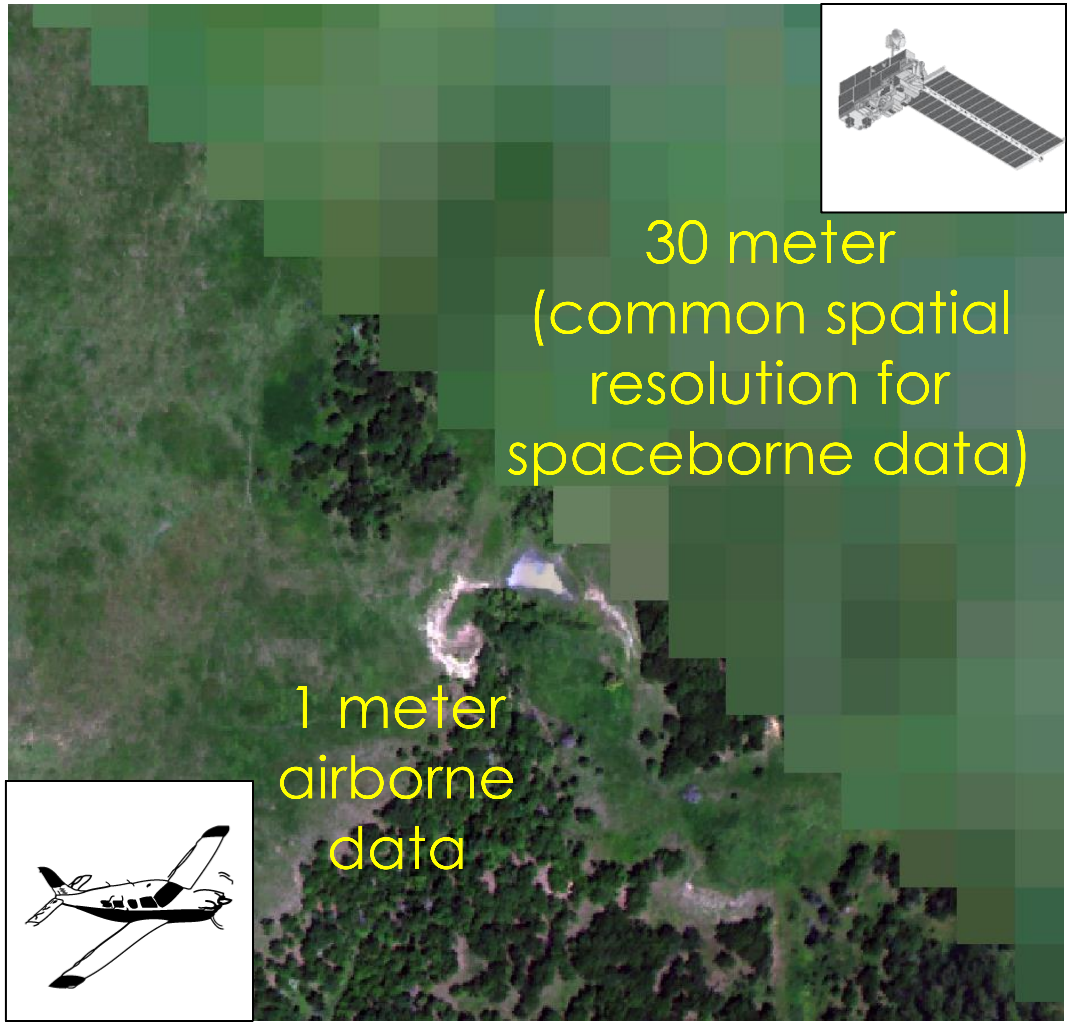
- We used airborne hyperspectral data
- Airborne campaigns are costly
- Limited spatial coverage
- Coarse temporal resolution
- Overall, limited availability of airborne hyperspectral data

Spaceborne Hyperspectral Data

- Currently, there are only a few operational spaceborne hyperspectral imagers.
- For example, NASA's EMIT sensor aboard ISS collects hyperspectral data with near-global coverage.
- However, the spatial resolution of spaceborne hyperspectral data is coarse (30-60 m) to map some invasive plants, especially in grasslands.

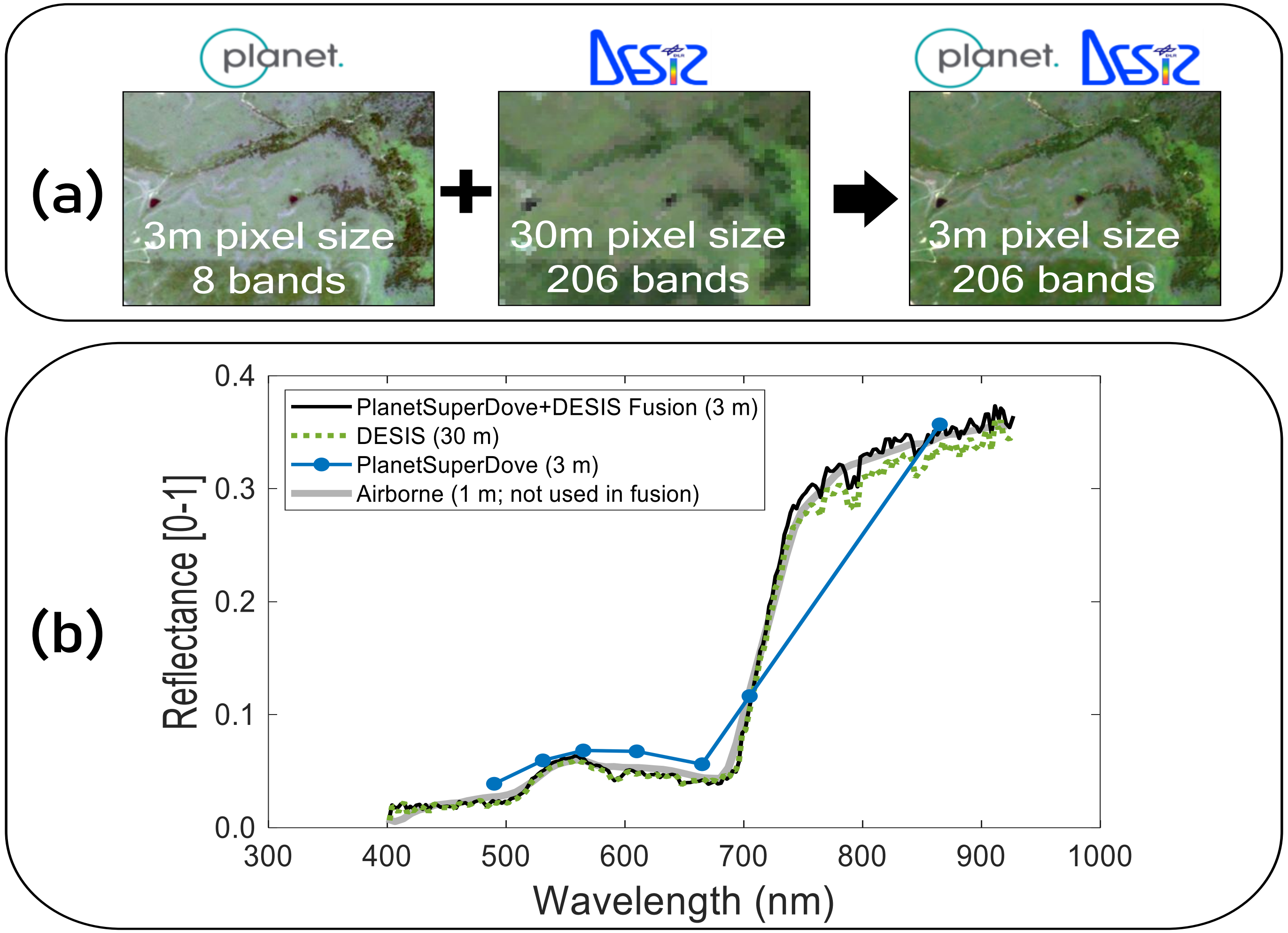


https://earth.jpl.nasa.gov/emit/data/data-portal/coverage-and-forecasts/


30 meter
(common spatial
resolution for
spaceborne data)
1 meter
airborne
data

Addressing Data Availability Limitations Example: Image Fusion

Some of these limitations can be resolved by combining (or fusing) remotely sensed data.



Part 3:
Summary

Summary

- Unique role of remote sensing to map invasive plants
  - Unlike field-based techniques, we can use remote sensing to collect data across large spatial domains and over time with consistent format

- Limitations
  - Scale mismatch
  - Data availability (e.g., airborne hyperspectral data)

- We need large scale integration of expertise to improve decision-making activities.

Invasive Species Monitoring with Remote Sensing Summary

- Introduced the extent and impacts of invasive species on biodiversity and a changing climate.
- Established that remote sensing can be used to map and monitor invasive species.
- Identified different types of remote sensing data and products that can be used for invasive species mapping and monitoring.
- Described key considerations, benefits and limitations of remote sensing of invasive species.
- Reviewed in greater detail remote sensing and field methods used to monitor aquatic and grassland invasive plant species.

Homework and Certificates

- **Homework:**
  - One homework assignment
  - Opens on 08/28/2024
  - Access from the training webpage
  - Answers must be submitted via Google Forms
  - **Due by 09/11/2024**

- **Certificate of Completion:**
  - Attend all three live webinars (attendance is recorded automatically)
  - Complete the homework assignment by the deadline
  - You will receive a certificate via email approximately two months after completion of the course.

Contact Information

Trainers:

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Thank You!