Practical Applications of Remote Sensing Related to Pesticide Use

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Seminar outline

<u>Today we will:</u>

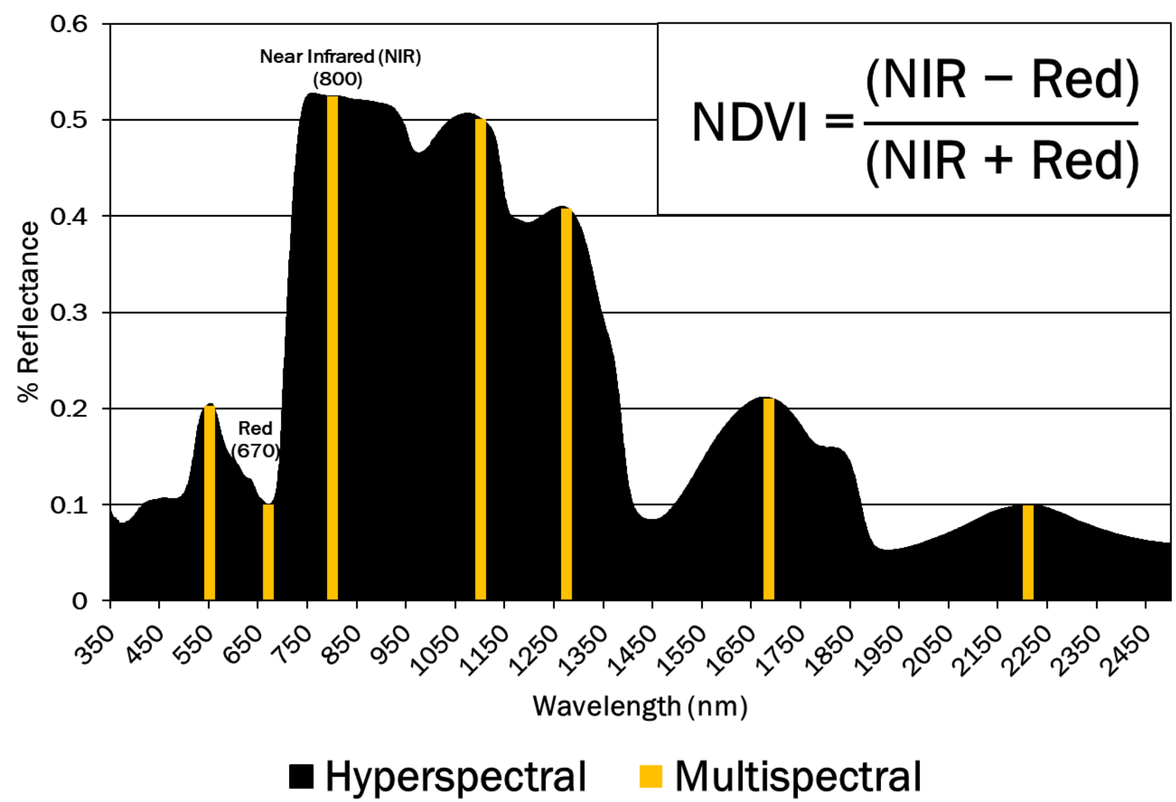
- Define remote sensing
- Briefly explore the technology and the theory
- Introduction to remote sensing capabilities (what can RS do?)
- Breakdown specific application of the technology (how has it been applied?)
- Connect these concepts to some research we are conducting at the Parma UI extension center
- Discuss some challenges associated with this technology

What is remote sensing?

- Two components:
  1. The measurement of reflected light
  2. Developing useful relationships from reflected light
- There are different types of remote sensing technology:
  - LiDAR (Light Detection and Ranging)
  - Optical remote sensing (RGB, Multispectral, and Hyperspectral)
- There are different types of sensor platforms:
  - Hand-held
  - Tractor mounted
  - Unmanned aerial vehicle, Plane or Helicopter mounted
  - Satellite

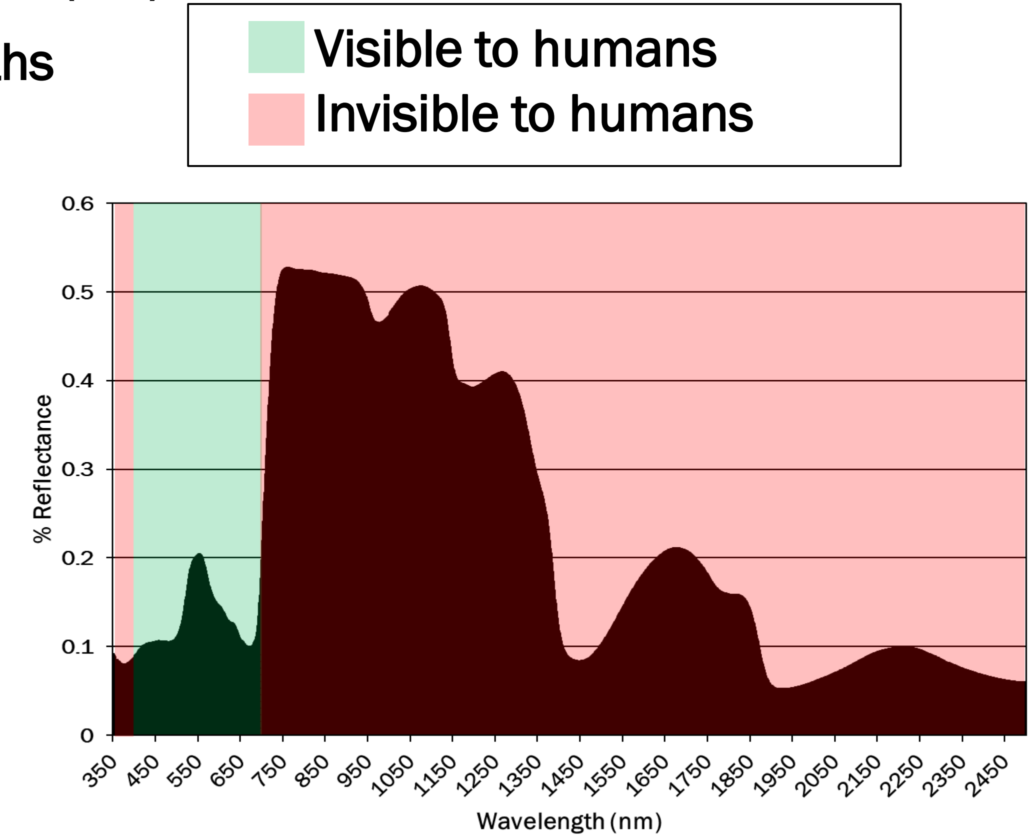
The examples I will introduce today utilize optical remote sensing

- Hyperspectral RS differs from multispectral RS in the <u>number</u> and <u>bandwidth</u> of measured wavelengths
- Spectral vegetation indices (NDVI) are calculated from multispectral or hyperspectral data
- Plants are highly reflective in the NIR region



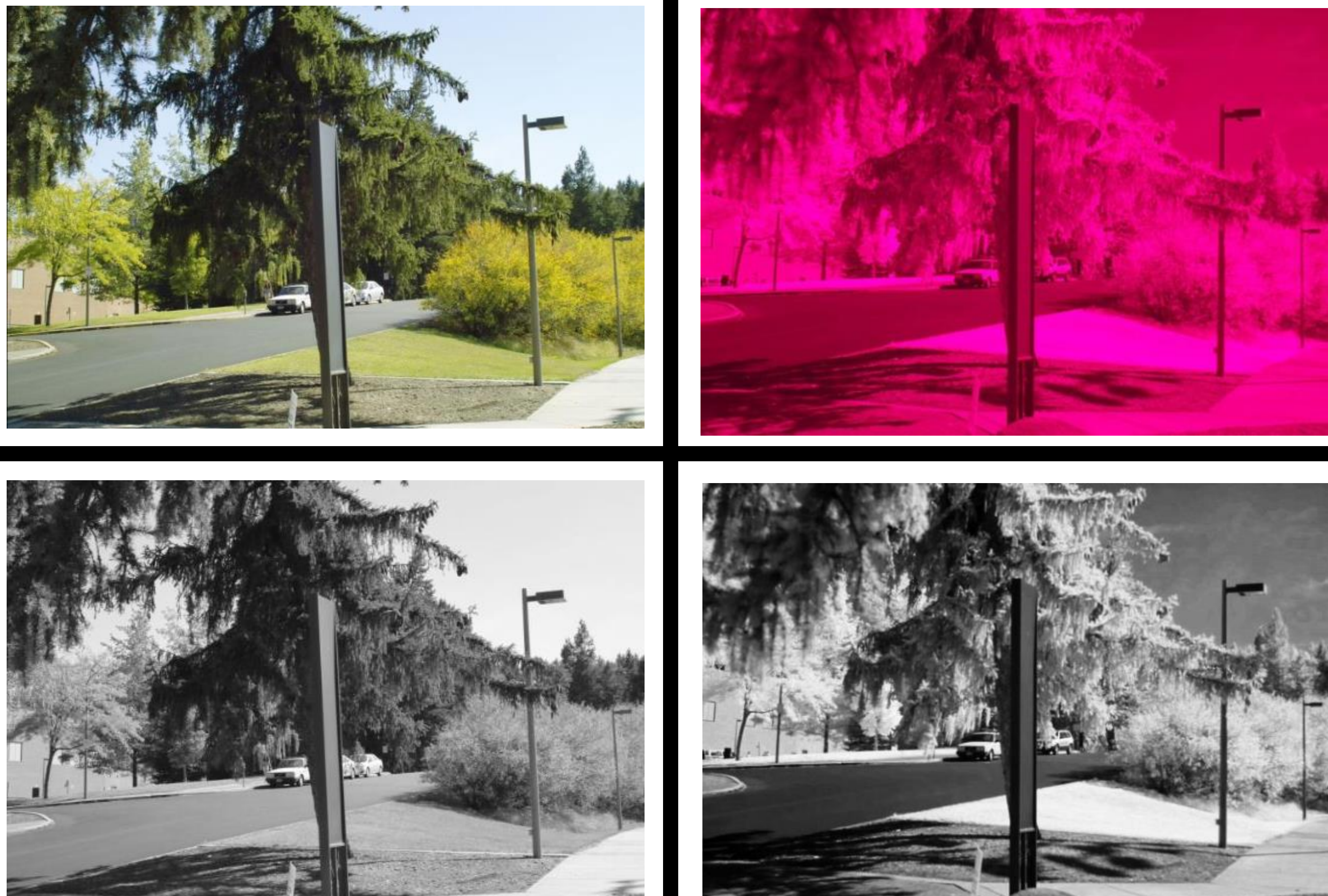
Imagine you take your goldfish for a walk in the park…

- Assuming you are not visually impaired, you can see wavelengths from 400 to 700 nanometers (nm)
- Goldfish can see wavelengths from 700 to 1000 nm



Visible (humans) | Near-infrared (Goldfish)

Color / Grayscale



*Pictures courtesy of Dr. Lee Vierling, Jyoti Jennewein, and UI NRS 472 class

1) Remote sensing has been used to distinguish between plant species

Practical application A: Precision herbicide spraying

<u>Example:</u> Automated weed control in organic row crops using thermal micro-dosing (Zhang et al. 2012)

- Location: California, USA
- Scenario: Manual labor is in short supply and is expensive
- Proposed solution: Used a tractor mounted hyperspectral sensor and a prototype application platform to spray heated food-grade oil (160 ºC) onto weeds but not tomatoes
- An example of species identification in real time

*Image source: Zhang et al. 2012

Practical application A: Precision herbicide spraying

- Results: Over 93% of black nightshade (*Solanum nigrum*) and redroot pigweed (*Amaranthus retroflexus*) were controlled 15 days post spray
- Only 2.4% of the tomato plants received significant damage
- Practical use: precision herbicide sprays may reduce herbicide use (and save money)

So the technology works, but how practical is that tractor implement?

Application platforms have made significant advancements in recent years

AVO – the weeding robot

- Autonomous
- Solar powered
- Light weight
- Controlled by smart phone

The company claims:

- Uses up to 90% less herbicide
- 30% less expensive than standard treatments
- Detection accuracy >85%

*Image source: www.ecorobotix.com

*Image source: www.naio-technologies.com

Practical application B: Monitoring of invasive plant species

<u>Example:</u> Mapping and monitoring invasive plant species in the Greater Yellowstone Area

- Location: Idaho, Montana, and Wyoming, USA
- Scenario: Invasive plant species are a threat to the Greater Yellowstone ecosystem because they displace native species and disrupt wildlife habitat. Invasive species are widespread and difficult to control
- Proposed solution: Map the current location of invasive species using remote sensing and geographical information systems (GIS) to identify at risk areas
- Invasive species include: Leafy Spurge (*Euphorbia esula*), Hoary Cress (*Lepidium draba*), and Spotted Knapweed (*Centaurea maculosa*)

Yellowstone National Park ID, MT, WY

Plan Your Visit ▼ Learn About the Park ▼ Get Involved ▼ INFO ALERTS MAPS CALENDAR RESERVE

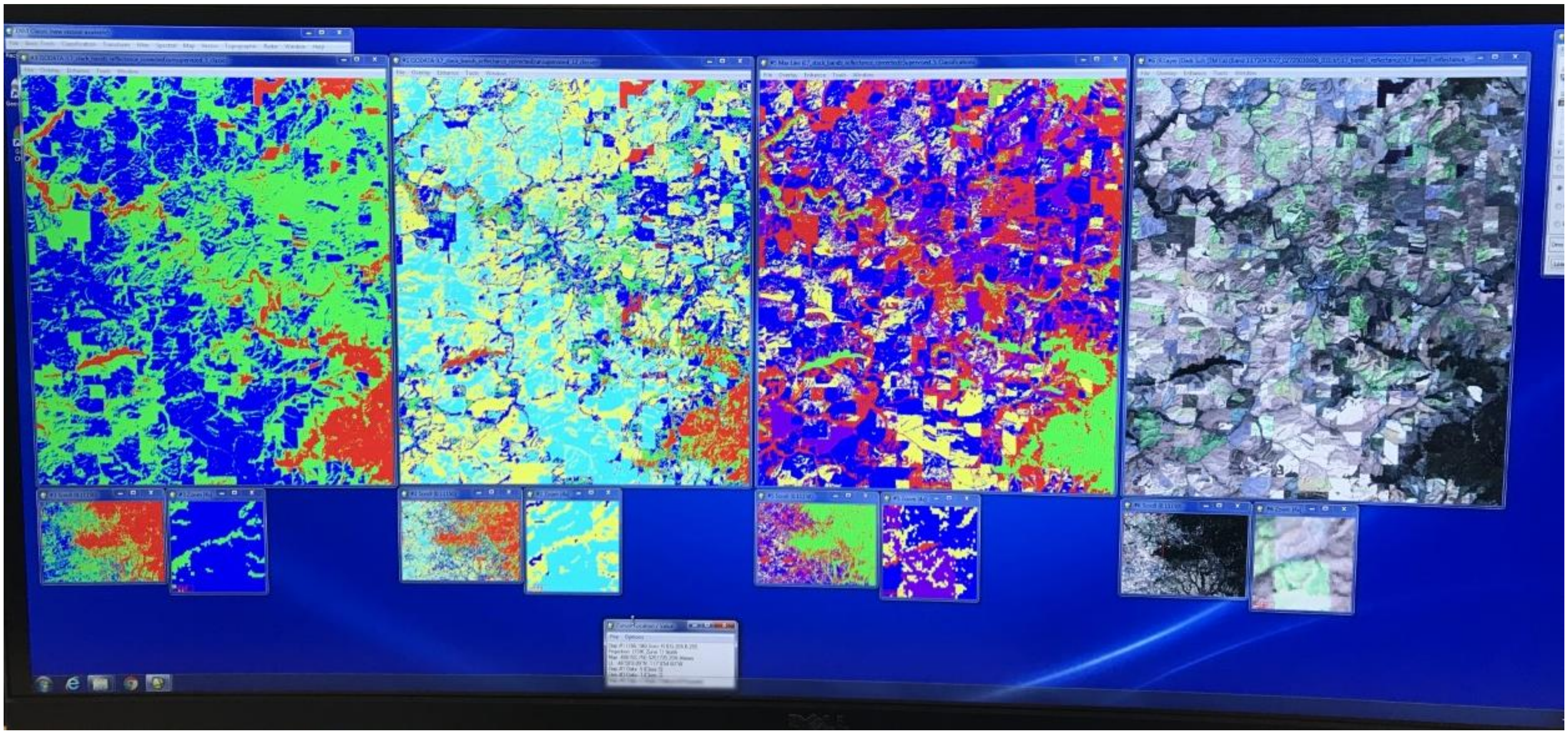
NPS.gov / Park Home / Learn About the Park / Nature / Plants / Invasive Plants

Invasive Plants

Yellowstone works to prevent the spread of invasive plant species, which can displace native species, change vegetation communities, affect fire frequency, and impact food for wildlife.

NPS/Pat Perrotti

*Image source: www.nps.gov



Practical application B: Monitoring of invasive plant species

Example: Mapping and monitoring invasive plant species in the Greater Yellowstone Area

- Results: Several invasive plant species were mapped with reasonable accuracy
- Practical use: remote sensing can be used to proactively manage invasive weeds and effectively allocate limited resources

2) Remote sensing has been used to diagnose and map plant stress

Application A: Identification and mapping of herbicide damage

Example: Hyperspectral sensing for early detection of soybean injury from dicamba (Huang et al. 2016)

- Location: Mississippi, USA
- Scenario: Dicamba drift onto non-target crops is a major concern in the Midwest because it is highly active (even small doses) on susceptible crops
- Proposed solution: Evaluate the usefulness of remote sensing to detect soybean damage from dicamba
- Results: Dicamba treated soybean could be distinguished from untreated soybean with an accuracy ranging from 76 to 86%
- Practical use: The ability to map herbicide damage may help in crop insurance claims

Application B: Assess insect damage at a regional scale

Example: Mapping the damage of armyworm (*Mythimna separate*) in maize at a regional scale (Zhang et al. 2016)

- Location: Hebei Providence, China
- Scenario: A significant rainfall event (continuous rainfall for 15 days) coincided with the emergence of armyworm larvae and resulted in an severe insect outbreak in 2012
- Proposed solution: Map armyworm damage in maize at a regional scale to most effectively employ limited resources

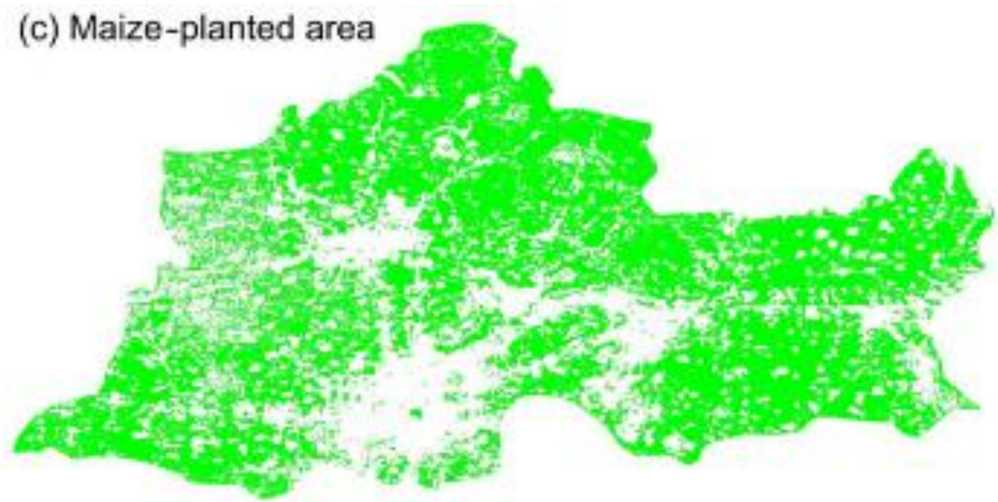


*Image source: Zhang et al. 2016

Application B: Assess insect damage at a regional scale

Example: Mapping the damage of armyworm (*Mythimna separate*) in maize at a regional scale (Zhang et al. 2016)

- Results: Maize damage severity was mapped with an accuracy of 79%
- Practical use: Mapping of insect damage early on may help effectively allocate limited resources to limit insect dissemination

Application C: Remote diagnosis and mapping of plant disease

Example: Cotton root rot mapping using multispectral and hyperspectral imagery (Yang et al. 2010)

- Location: Texas, USA
- Scenario: Cotton root rot results in plant death and significantly reduced crop yield
- Proposed solution: Early diagnosis and mapping of cotton root rot may assist in remedial measures

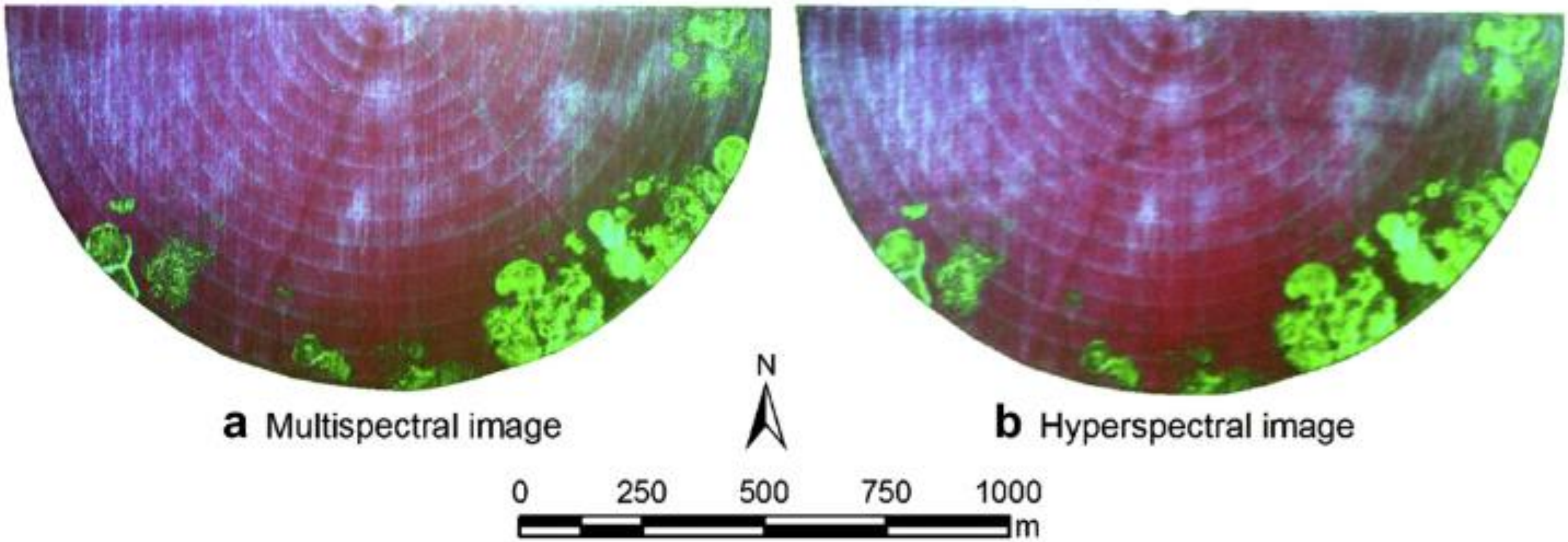


*Image source: Yang et al. 2010

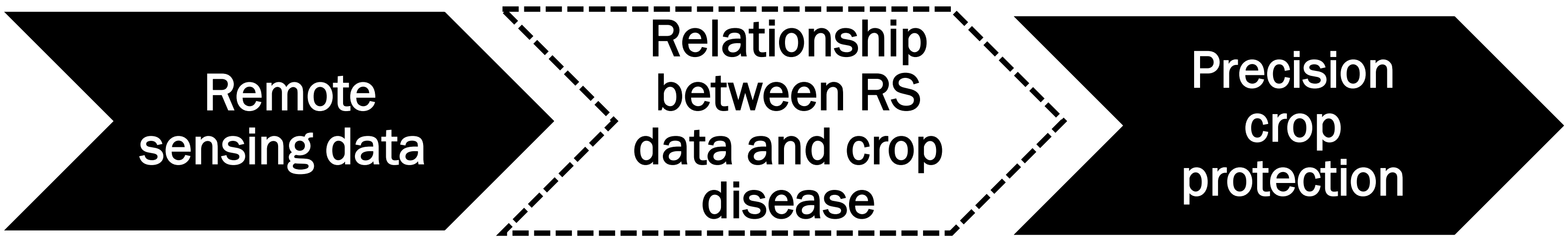
Application C: Remote diagnosis and mapping of plant disease

Example: Cotton root rot mapping using multispectral and hyperspectral imagery (Yang et al. 2010)

- Results: Cotton root rot could be mapped using multispectral and hyperspectral remote sensing with an accuracy above 95%
- Practical use: The ability to diagnose and map plant disease could, in some cases, allow for precision crop protection

Remote sensing is a precursor to precision crop protection

- Need information about where and when a disease occurs



- This relationship has been established is isolated scientific studies for some plants and some diseases
- There is a need to interpret the results of all studies collectively
- There is a need for further research (new crops and new diseases)

Onion pink root is a challenge to local growers

- Caused by the soilborne fungus, *Setophoma terrestris*
- It is limiting to both total yield and bulb size of susceptible cultivars (25%+ yield reduction in the present study)
- Pink root is not new to the region but remains a challenge because:
  - It is widespread: identified in 108 out of 139 (78%) soil samples collected from different locations in Southwest Idaho (Woodhall unpublished)
  - Can colonize numerous plant species but is particularly pathogenic to onion
  - Management options are limited

Soil fumigation is the most widely used method to control onion pink root

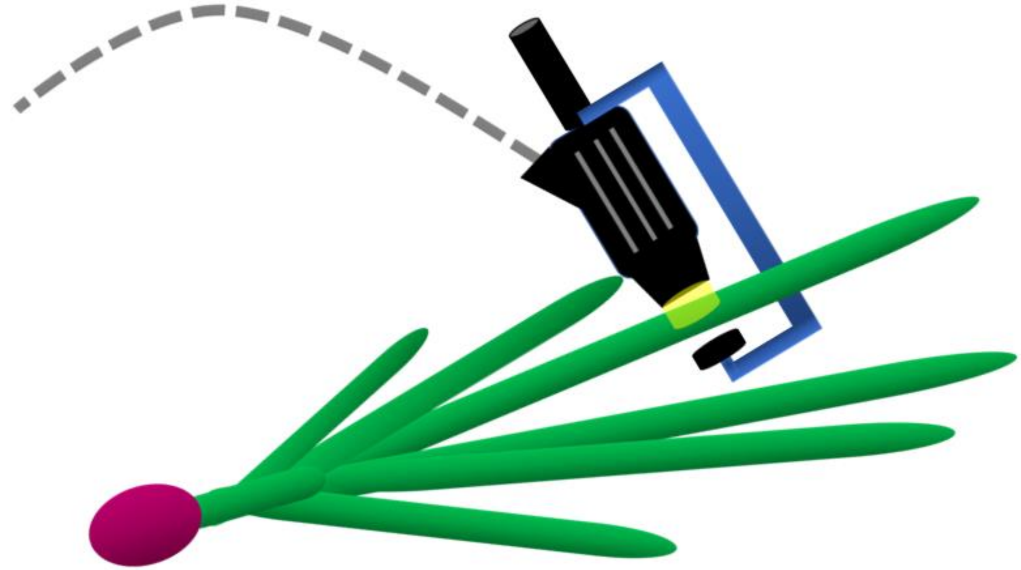
- Soil fumigation is nonideal due to:
  - Cost (~$600 per hectare)
  - Its effect on nontarget organisms (nonspecific)
  - Potential adverse effects to human health and the environment
- There has been recent interest is exploring the use of advanced technologies, like remote sensing, to support onion pest management decision making in the Treasure Valley (Murray et al. 2018)
- The remote detection and mapping of pink root "hot spots" in the field may allow for a more structured and direct approach to soil fumigation and tolerant genotype selection.

To evaluate the usefulness of remote sensing to detect pink root, we designed a field experiment

- Primary objectives:
  - Manifest high levels of disease for study
  - Impose water and nitrogen stress (similar visual symptoms) for comparison
- Used red cultivar with intermediate resistance (yellow cultivar was included in 2019)
- Four treatments were utilized in this study:

Treatment	Fumigation	Nitrogen fertilizer	Irrigation
1. High disease	None	134.5 kg ha^{-1}	Normal
2. Low disease	Chloropicrin 37.4 L ha^{-1}	134.5 kg ha^{-1}	Normal
3. Non-fertilized	Chloropicrin 37.4 L ha^{-1}	None	Normal
4. Reduced water	Chloropicrin 37.4 L ha^{-1}	134.5 kg ha^{-1}	Reduced

Corresponding reflectance measurements were taken weekly with a hand-held hyperspectral sensor



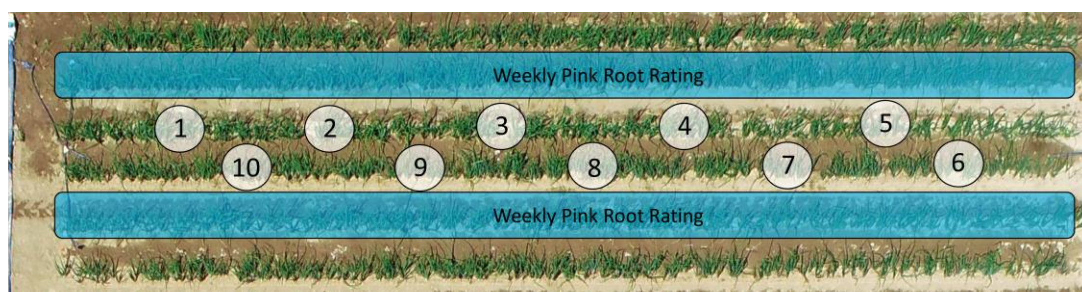


*Image courtesy of Jerry Neufeld

Results

- We tested 41 published Spectral vegetation indices (SVI) including NDVI and determined that each characterized the stress treatments in a similar manner at the canopy level
- Some parameter was having a dominating affect
- We found that onion biomass is closely related to SVI value (R^2= 0.68 to 0.83 depending on which SVI was used) as opposed to a particular crop stress
- This is likely because biomass is related to the fraction of leaf area
- Therefore, in scenarios where the crop canopy does not completely cover the soil, SVI value is primarily a measure of the fraction of leaf area or leaf area index (LAI)

NDVI meaning depends on the fraction of vegetation cover

*Image courtesy of Dr. Jae Ryu

NDVI meaning depends on the fraction of vegetation cover

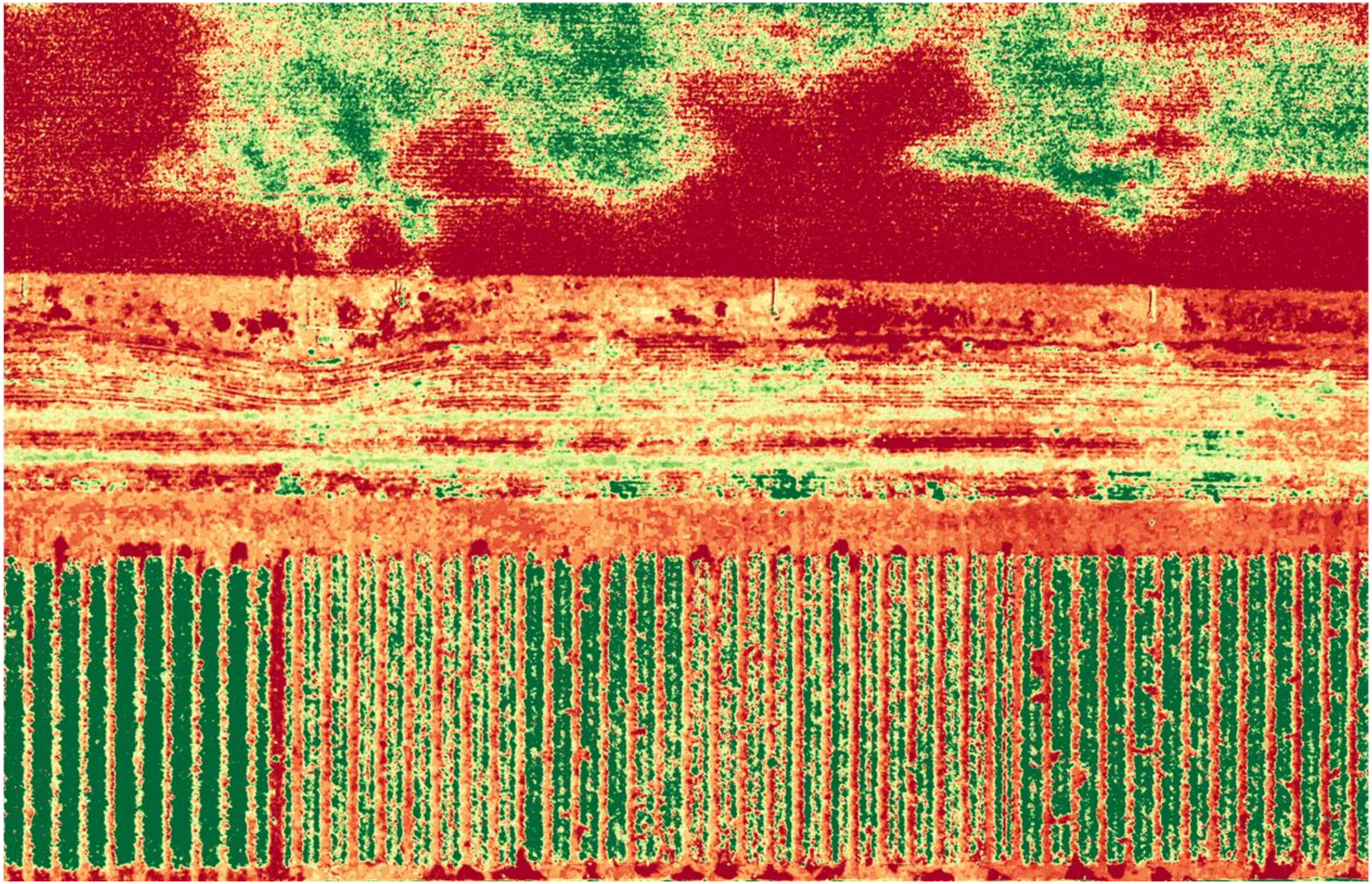


*Image courtesy of Dr. Jae Ryu

Remote disease diagnosis is a challenge due to the similarity of stress symptoms

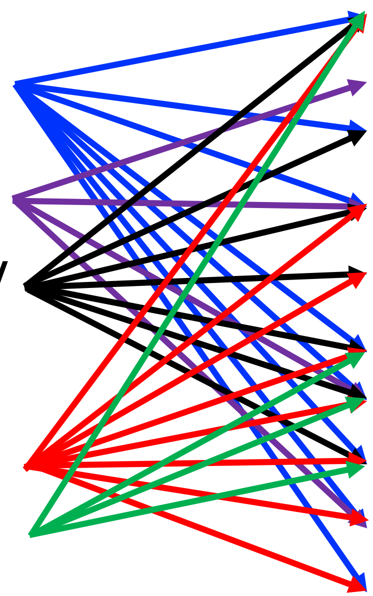
Stresses

Abiotic:

- Drought/water stress
- Frost
- Mineral deficiency or toxicity

Biotic:

- Disease
- Insect damage



Plant Responses

- Stomatal closure
- Freezing
- Increased respiration
- Decreased chlorophyll
- Altered pigments
- Altered biochemistry
- Photosynthetic inhibition
- Altered growth (e.g. LAI)
- Altered leaf angle
- Altered water content

*Adapted from a figure by Jones and Vaughan, 2010

Conclusions

- Remote sensing can be used to:

1. Distinguish between plant species
2. Diagnose and map plant stress

- In some situations, this allows for:

1. Precision herbicide application
2. Monitoring of invasive plant species
3. Mapping herbicide damage
4. Regional mapping of insect damage
5. The diagnosis and mapping of plant disease

- However, there are still some challenges, particularly with the use of SVIs to account for plant stress
- There is a need for more research and for results from isolated scientific studies to be interpreted collectively

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Thank you!

If you wish to discuss these topics further or have any other questions, email me at:

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