Remote Sensing for Agricultural Applications: Principles and Techniques (2023-2024)
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Lecture 7: *In situ* Reflectance Measurements

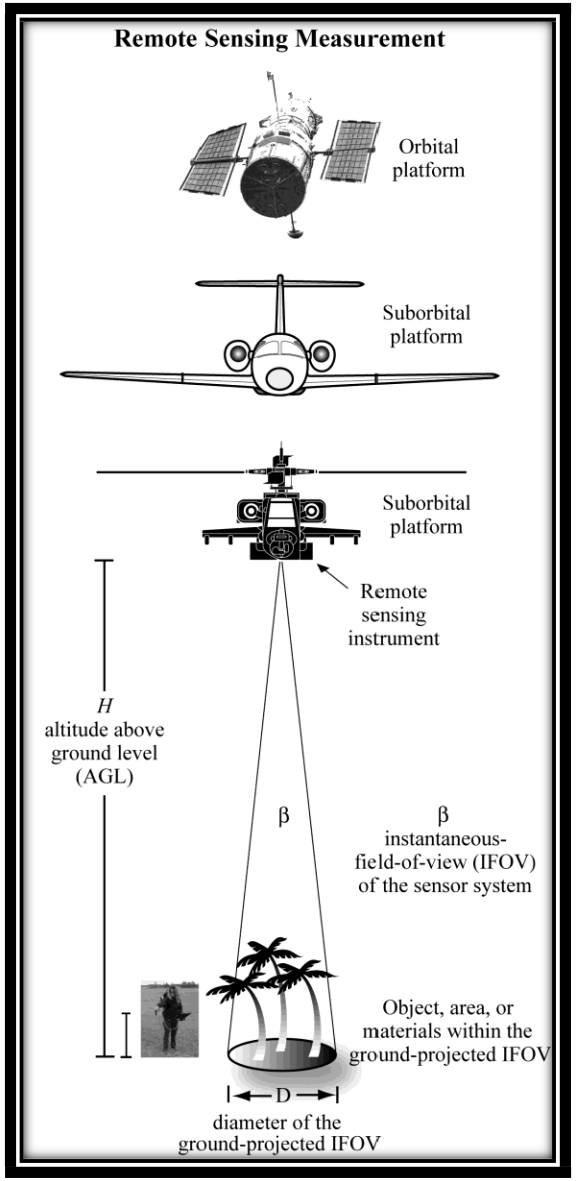


November 22, 2023

Outline

- **Purposes of *in situ* reflectance measurements**
- **Instruments for *in situ* measurements**
- **Potential issues encountered in measurements**
- **Reflectance measurements for image calibration**

Remote sensing at different scales

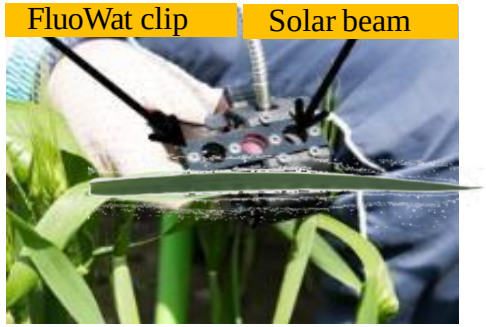


- **Acquisition of remotely sensed data may be needed at different scales**
- **When do you need to work on the ground?**
  - **Flexible scheduling**
  - **Cal/val**
  - **…?**

Jensen (2006)

What are *in situ* reflectance measurements?

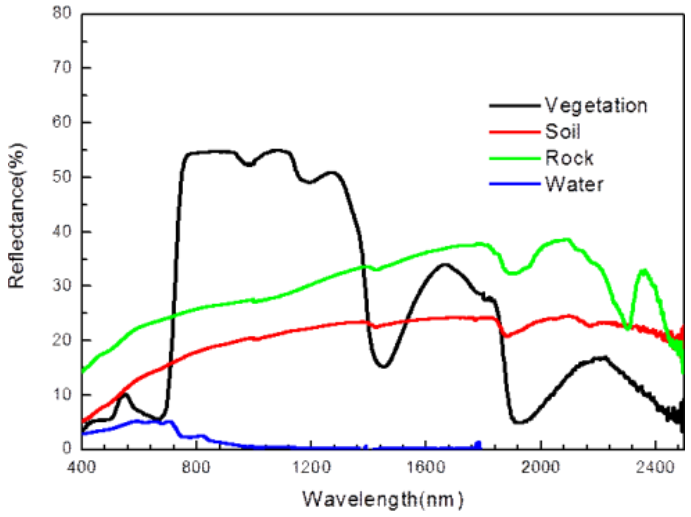
- **Reflectance spectra obtained in the field using a portable spectroradiometer**
- **Fundamental data for the subject of field spectrometry**



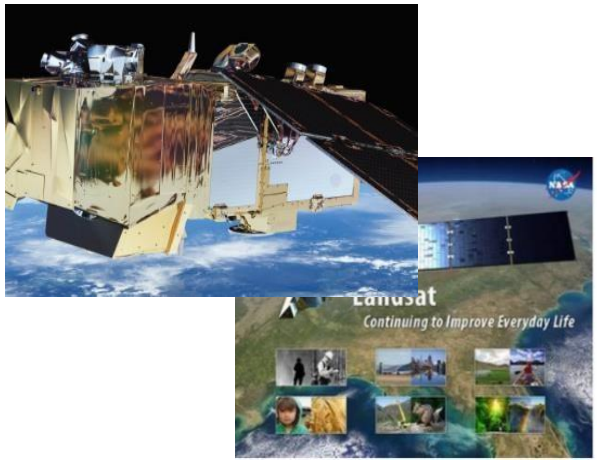
Q1: Why do we collect data in the field rather than all in the lab?

What is field spectrometry used for?

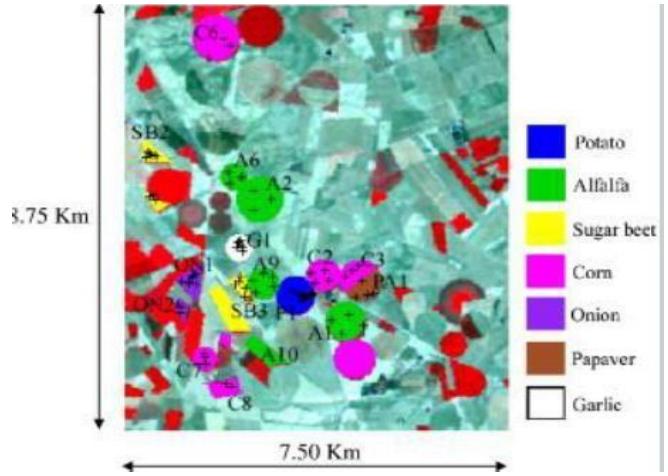
- **Characterizing the reflectance of natural surfaces in the field**
- **Supporting the vicarious calibration of aircraft and satellite sensors**
- **Performing pilot studies to understand how/if materials can be identified using remote sensing**
- **Guiding the collection of *in situ* reflectance measurements**



Reflectance of different surface meterials



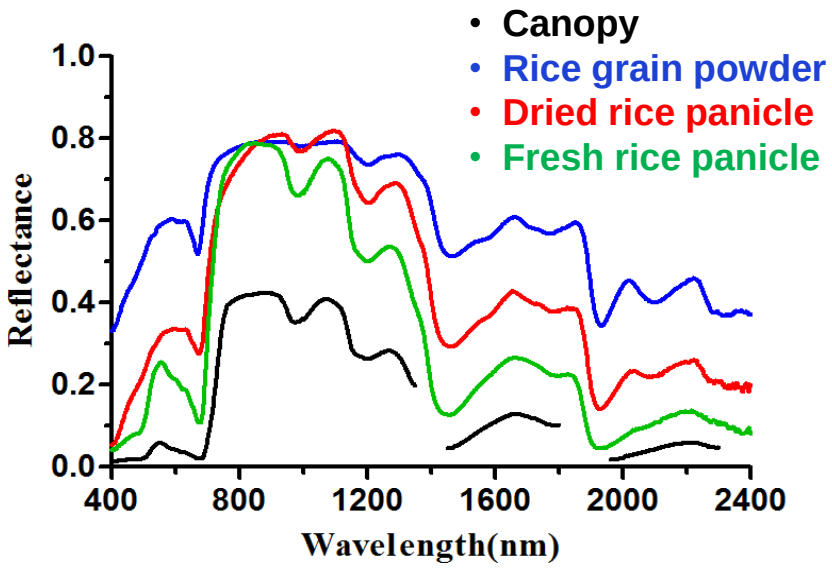
Calibration of aircraft and satellite instruments

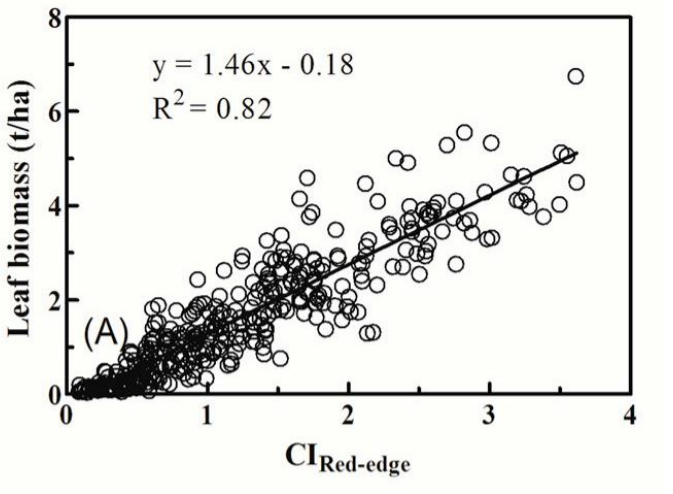


Identification of crop types

Why do we collect *in situ* data?

- To **correct data geometrically and radiometrically**, so that it is easier to compare remotely sensed data obtained on different dates.
- To **develop spectral libraries** for identifying targets of interest
- To **build models** for quantifying biophysical and biochemical properties (e.g., LAI, biomass, chlorophyll)





Cheng et al., (2017). RS, 9, 319

Spectroradiometer

- **A device used to collect spectral measurements**
- **Most widely used models:**
  - **ASD FieldSpec series**
  - **Spectral evolution PSM series**
  - **Ocean Optics**
  - **GER 1500**

ASD
FieldSpec 4

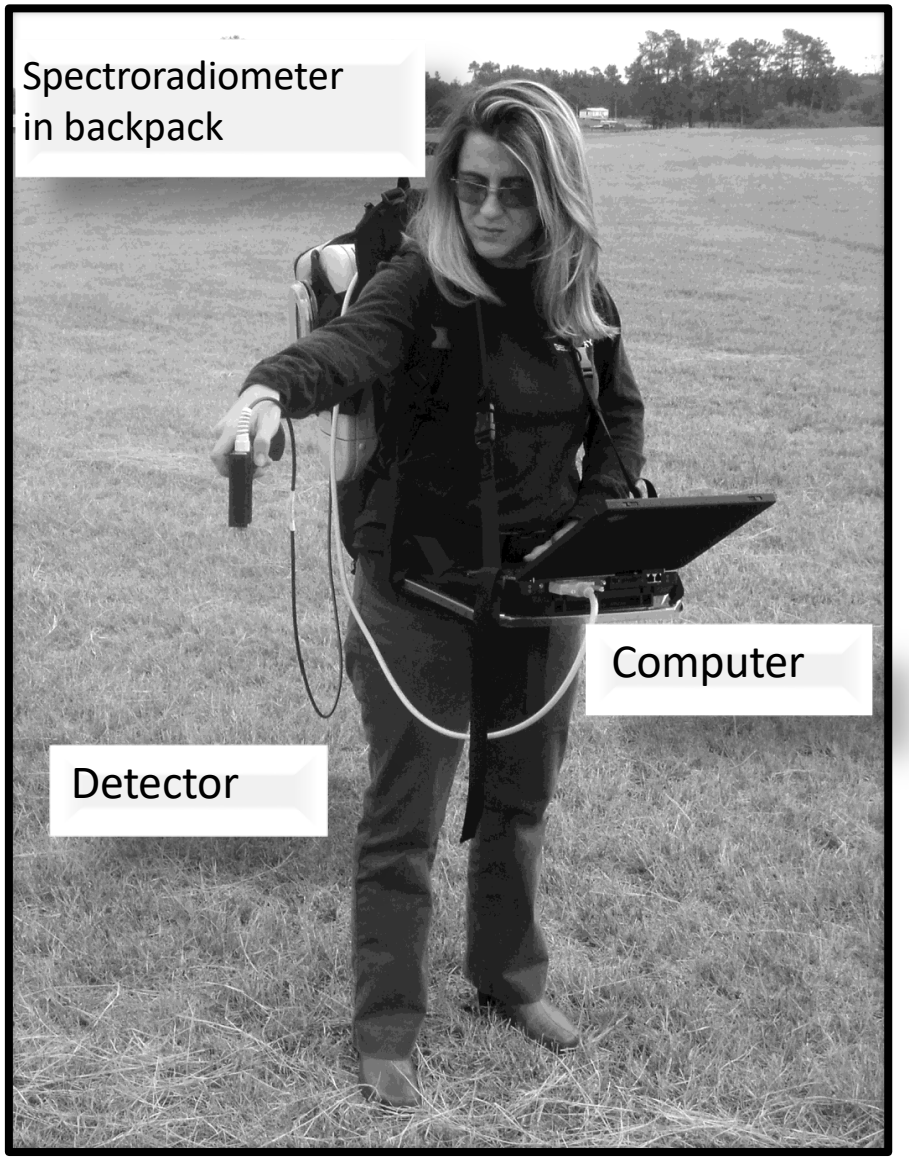
Spectral Evolution
PSM-3500

QE Pro
Ocean Optics

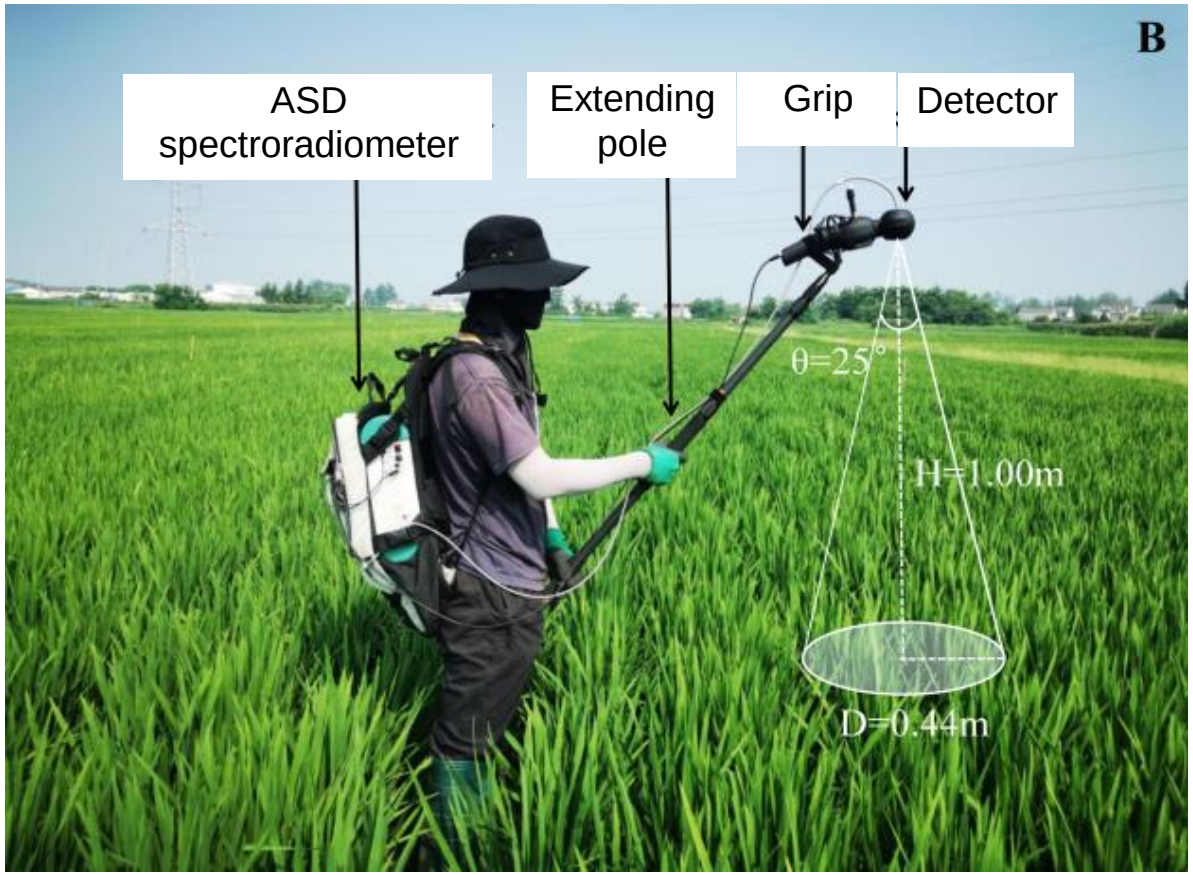
GER 1500

Q2: Which one to use?

Spectral Reflectance Measurement using a Spectroradiometer

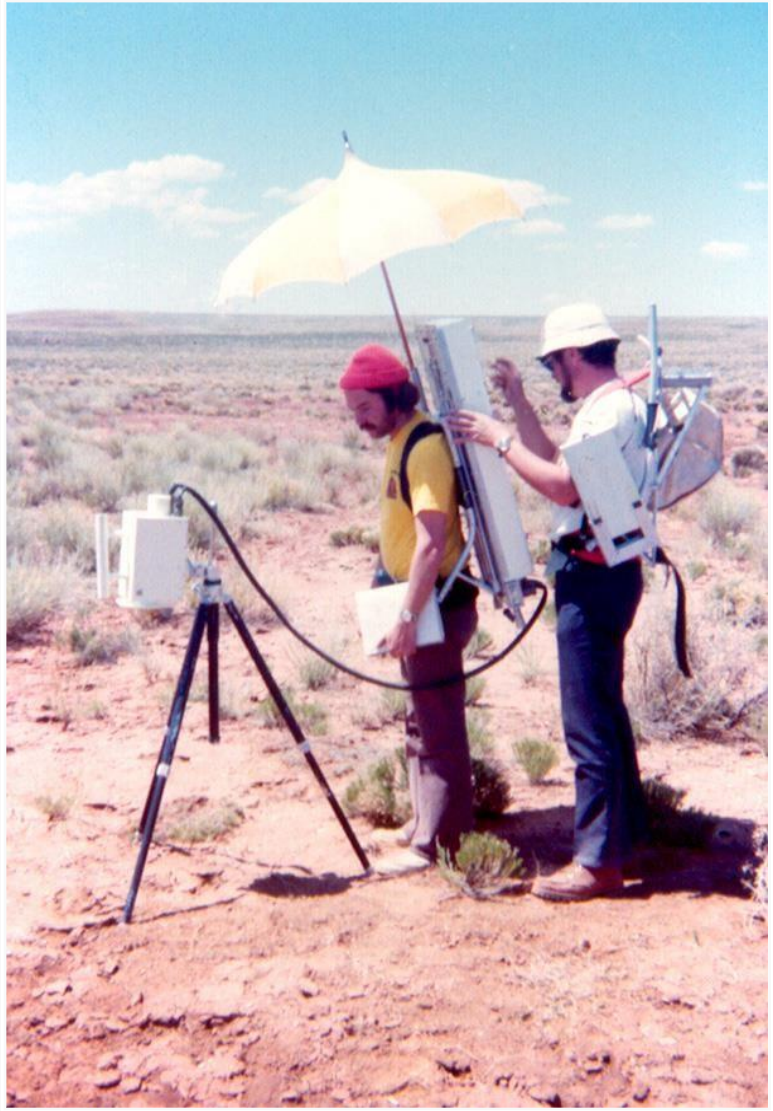


Jensen (2006)



Xue Bowen & Cheng Yuxin, 2022

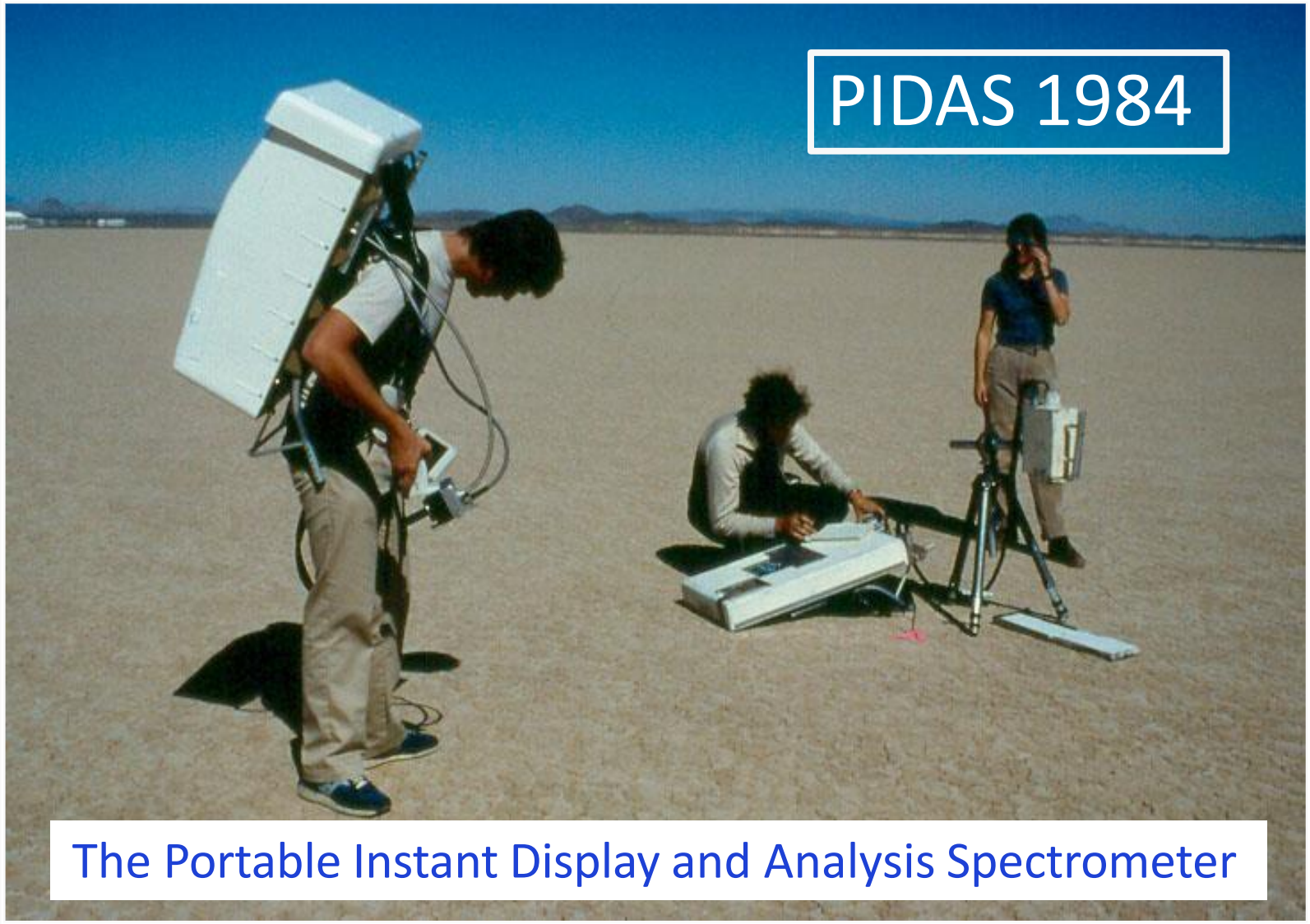
The First Portable Field Reflectance Spectrometer



- **It collected radiance and reflectance simultaneously.**
- **It required 2 min to take a sample spectrum and another 2 min to take a reference spectrum.**

PFRS 1974

Picture from Dr. Susan Ustin's lecture materials.



◆ It still took about 0.5 min to take a spectrum and it weighted ~90 lbs.

Picture from Dr. Susan Ustin's lecture materials.

Milton et al. (2009), RSE, 113, S92-S109.

Above-canopy measurements remain a major unsolved problem in some cases

Within a greenhouse

Pictures from Dr. Wang and Jin from Institute of Crop Science, CAAS

picture from Dr. Susan Ustin's lecture materials.

Canopy height > 2m

Q3: How high is good enough?

Commonly used spectroradiometers

Some examples of current field spectroradiometers.

Spectroradiometer	Spectral region		Optical input [a]		Sensing method		Integral data storage [b]	Wireless comms	Comment	Manufacturer [f]
	VNIR 350–1000 nm [c]	SWIR 1000–2500 nm [d]	Lens	Fibre-optic	Single-beam	Dual-beam [e]				
FieldSpec HandHeld	•		•		•					Analytical Spectral Devices Incorporated (http://www.asdi.com/)
ASD FieldSpec Pro FR	•	•		•	•					
ASD FieldSpec3	•	•		•	•			•	The FieldSpec3 is a development of the FieldSpec Pro FR.	
Ocean Optics HR4000/USB2000	•			•	•				Miniature spectroradiometer. Modular system with a wide range of optional accessories.	Ocean Optics (http://www.oceanoptics.com/)
UniSpec-SC	•			•	•					PP Systems (http://www.ppsystems.com/)
UniSpec-DC	•			•		•				
GER1500	•		•		•	•	•			Spectra Vista Corporation (http://www.spectravista.com/)
GER2600	•	•	•		•					
GER3700	•	•	•		•					
SVC HR-1024	•	•	•		•		•	•	Employs a PDA with sunlight-readable screen	
PIMA SP [g]		•			•		•		On-board data processing for mineral identification	Integrated Spectronics (http://www.intspec.com/)

- Instrumentation technologies have improved since then.

Milton et al. (2009), RSE, 113, S92-S109.

Spectral reflectance of a target material

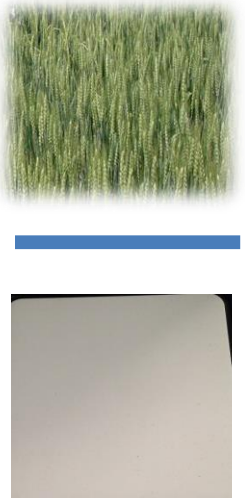
- The reflectance measured in the field is bidirectional reflectance factor (BRF).
- Spectral reflectance of a target material:

$$\rho_T = \frac{L_T}{L_r} \times k$$

L_T: Radiance from the target

k: k is often close to 1

L_r: Radiance from a reference panel



- L_T and L_r should be collected under the same conditions (atmospheric and illumination).

Reference materials

- Spectralon targets
  - Diffuse reflectance properties
  - Durable and washable
  - Available in a range of reflectance (10%-99%)

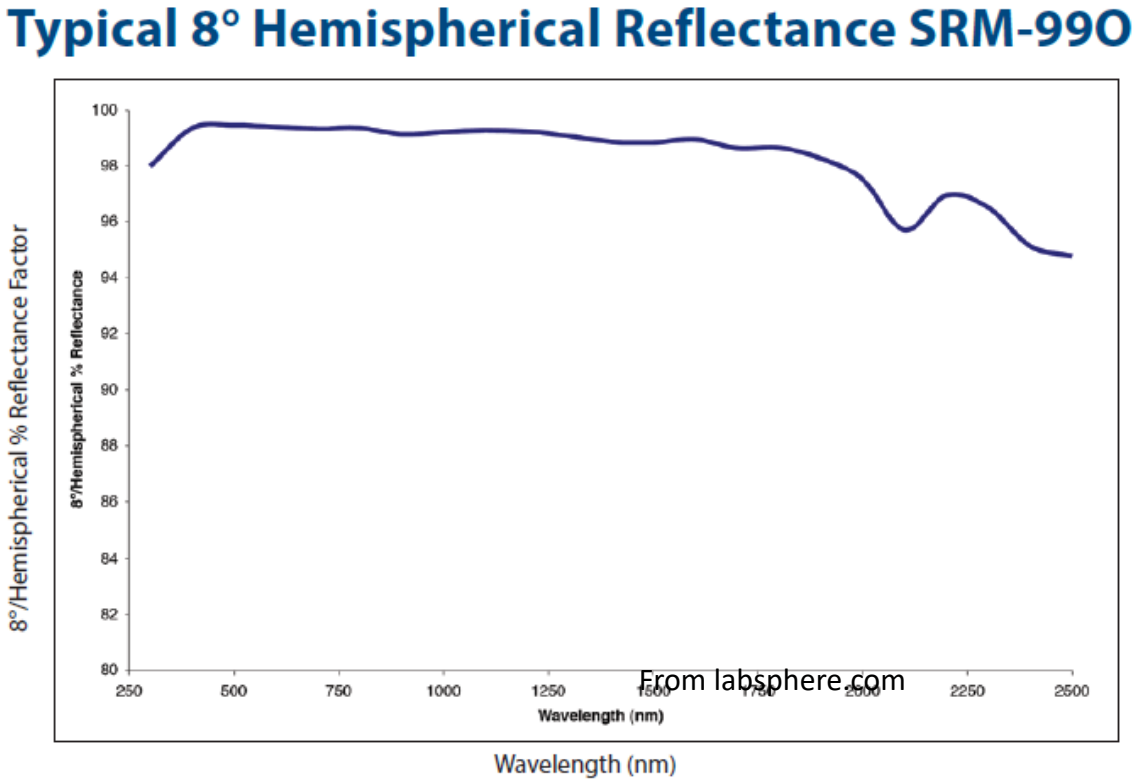
Labsphere^{TM} Spectralon panels

A typical reference panel

12.5x12.5 cm

A diffuse white panel in a case

99% reflectance (some claim it as 100%)

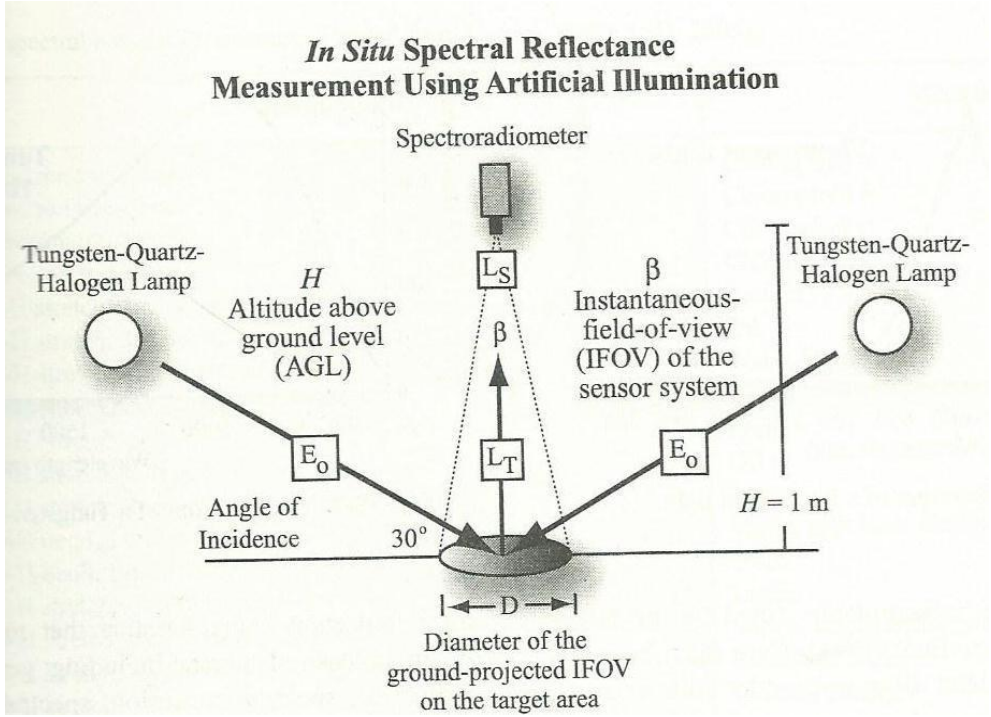


From labsphere.com

A smooth reflectance curve is preferred for calibration panels.

Viewing geometry

- To avoid the BRDF issue, position your detector to view the target at nadir (view angle = 0°) and take measurements at noon (solar angle = min).

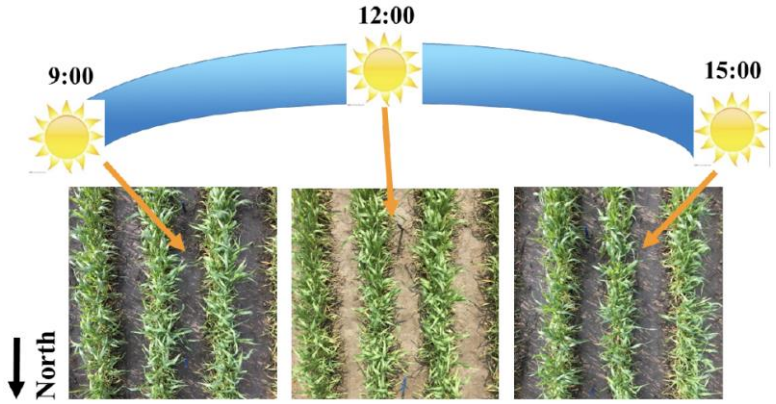


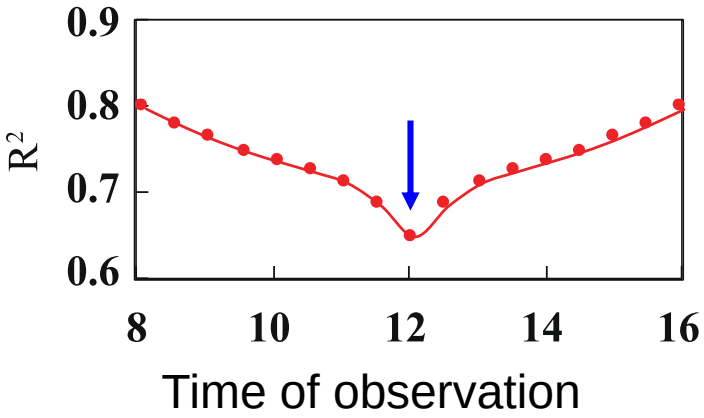
$$D = 2 \times H \times tan\,(\beta/2)$$

Care for students: Off-noon observing to avoid soil effect

Sampling at noon in the rice paddy. Caution: HOT

- **Is it mandatory to take spectral measurements at noon?**
  No!
- **Adjusting the sun-target-sensor geometry is the key**
  - **oblique observations (sensor)**
  - **off-noon observations (sun)**
- **For north-south row oriented crops, the exposure of soil to the sensor is the highest at noon.**

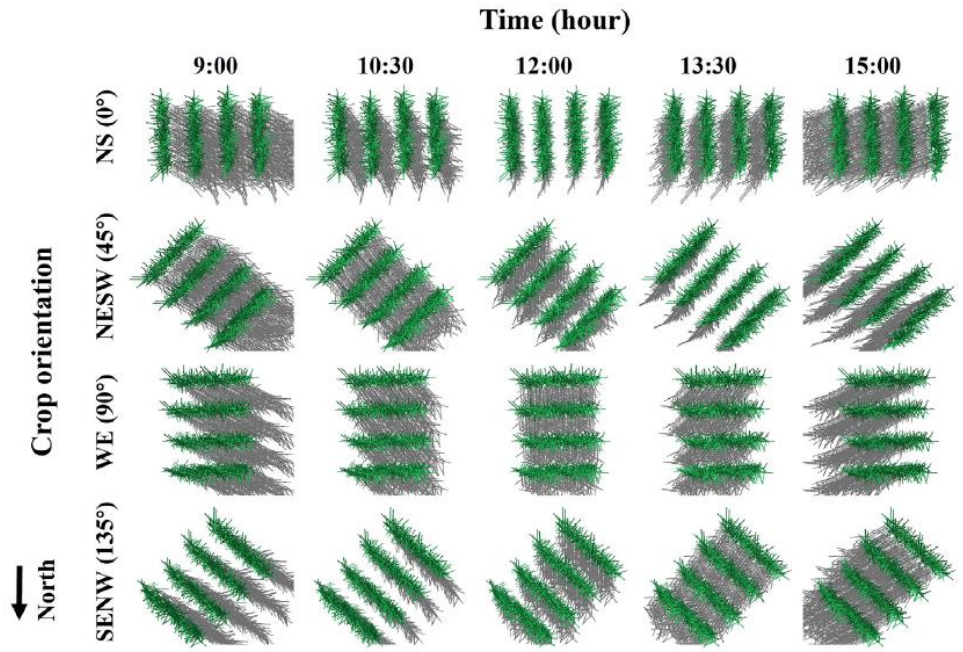




Li et al. (2020). RSE, 2020, 248, 111985

Off-noon sensing to avoid soil effect

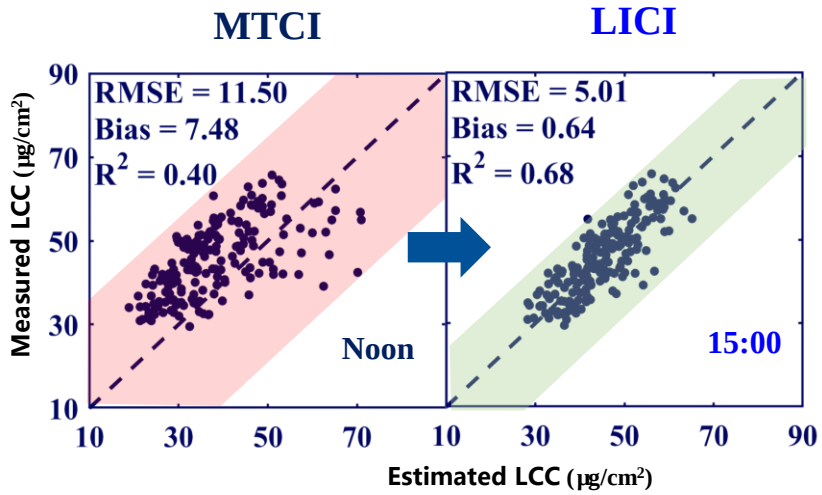
- Developed an off-noon observing approach for reducing the contribution of sunlit soil to canopy reflectance
- Generated synthetic datasets to cover a range of planting scenarios
- Off-noon data exhibited higher accuracies in LCC estimation than noon data



$$MTCI = \frac{R_{754} - R_{709}}{R_{709} - R_{681}}$$

Novel VI

$$LICI = \frac{R_{735}}{R_{720}} - \left(\frac{R_{573} - R_{680}}{R_{573} + R_{680}}\right)$$

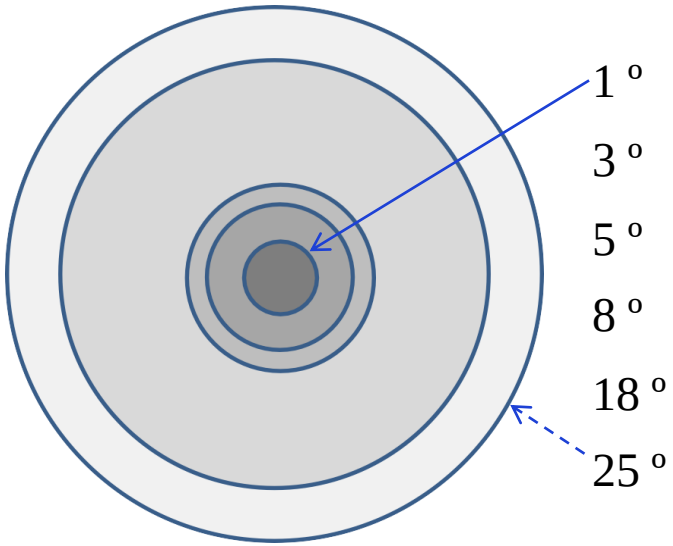


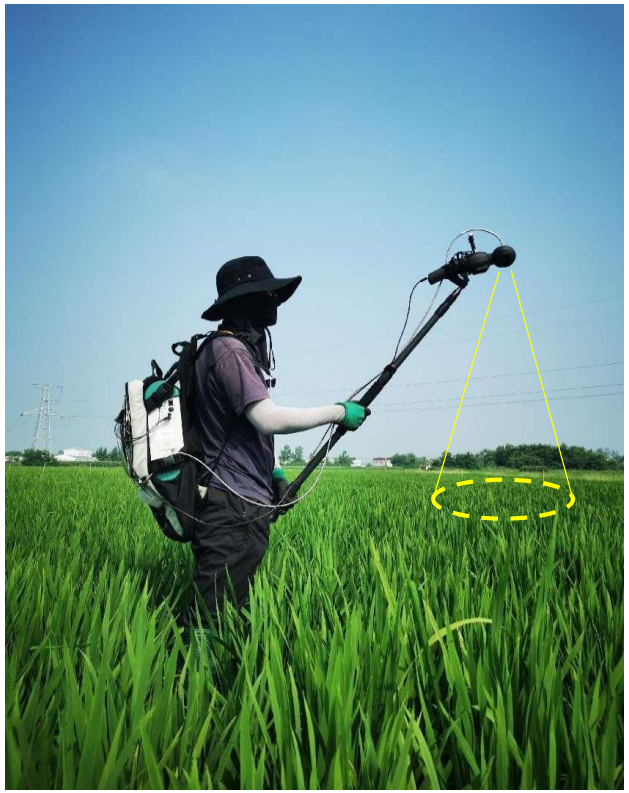
RMSE reduced by 57%

Li et al. (2020). RSE, 2020, 248, 111985

Field of view (FOV)

- Calculate the fields of view for a range of foreoptics (H = 1 m):





- The FOV determines what can be sensed by the spectroradiometer.

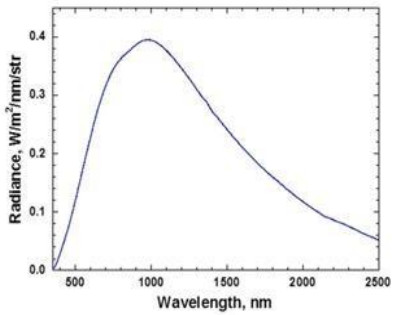
Q4: How to estimate the FOV?

Accessories for reflectance measurements

- **Foreoptics limiting the FOV from 1 ºto 25 º**

- **Leaf clip for reflectance (black panel) and transmittance measurements (white panel) (Do not cook the leaf!)**

- **Illuminator reflectance lamp (artificial light source)**



Figures from asdi.com

Accessories for reflectance measurements

- Fiber optical cables
  - Connect the detector and the core part
  - Can be extended

- Fiber checker magnifiers
  - Help to check the number of fibers

Figures from asdi.com

Environmental conditions

- **Cloud**
  - **The reference spectrum and the target spectrum should be collected under the same conditions**
  - **Although some references indicate it is acceptable to take canopy reflectance spectra on cloudy days (with stable cloud conditions), it is recommended to collect canopy spectra on clear days to avoid the cloud effects**
- **Wind**
  - **More difficult to handle**
  - **Modifies the amount of vegetation, shadow, soil within the IFOV of the spectradiometer**

Q5: when is it suitable for collecting in situ reflectance measurements?

Problems Associated with *In Situ* Data Collection

Method-produced errors will be introduced, if we use biased procedures:

- Sampling design does not capture the spatial variability of the target of interest
- Improper operation of spectroradiometers
- Uncalibrated spectroradiometers

Capture the spatial variation to measure the crop population, not a single leaf.

Q6: What needs to be covered in the FOV on the ground?

Ground preparation for airborne flights

Pictures are from Dr. Susan Ustin's lecture materials.

① **Locate objects visible in images**

- **Road intersections**
- **Structures**

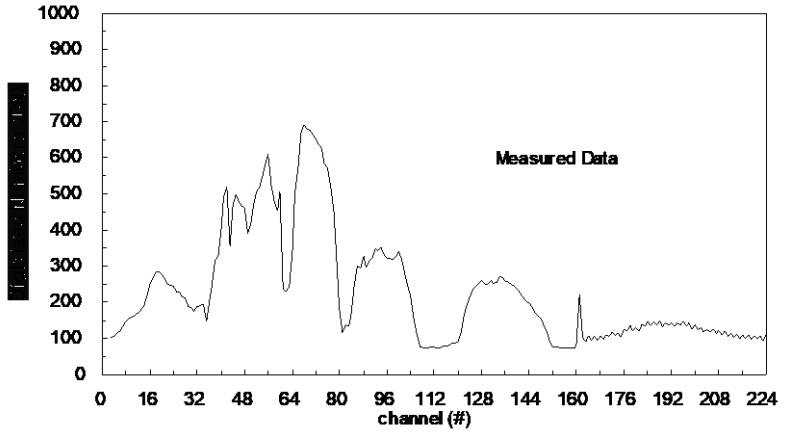
② **Record their coordinates using a RTK:**

Identify geolocation and calibration targets:

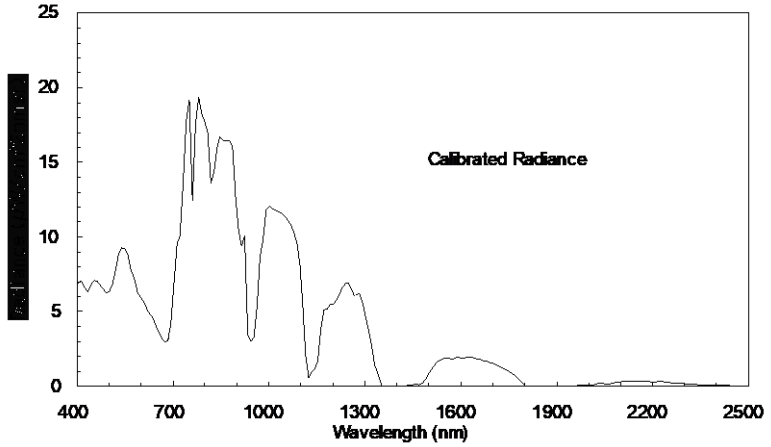
- **Large areas**
- **Homogeneous**
- **Dark and bright spectrally invariant targets**
- **Can be used for 2nd stage spectral improvement**

Image calibration

Measured Uncalibrated Data (DN)

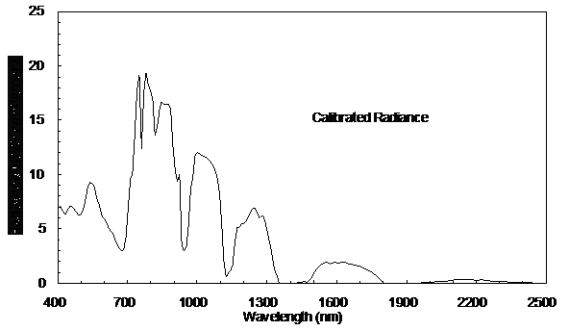


Instrument Calibration to Radiance (removes instrument noise)



Calibrated Radiance

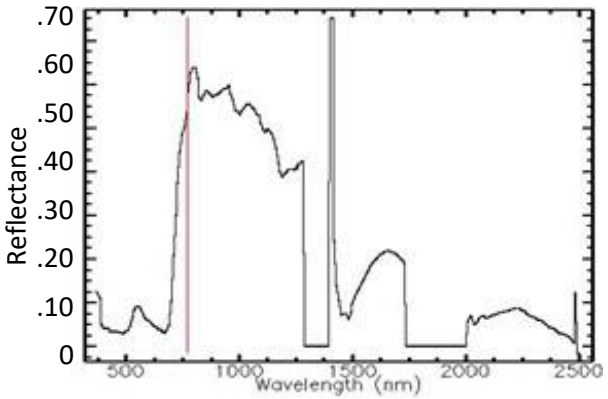
Image calibration



Calibrated Radiance

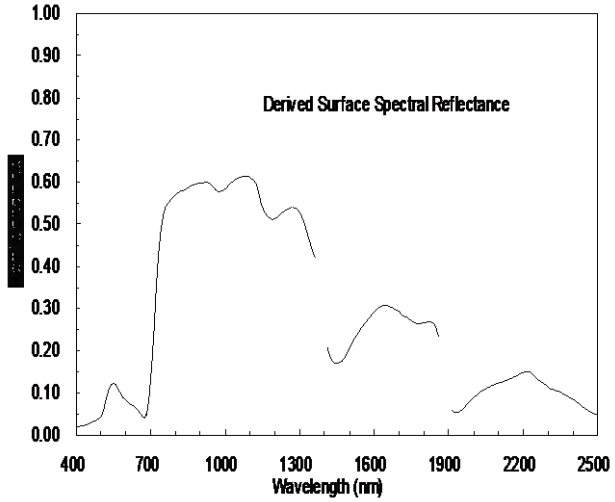
This step uses *in situ* reflectance measurements from calibration targets.

Atmospheric correction



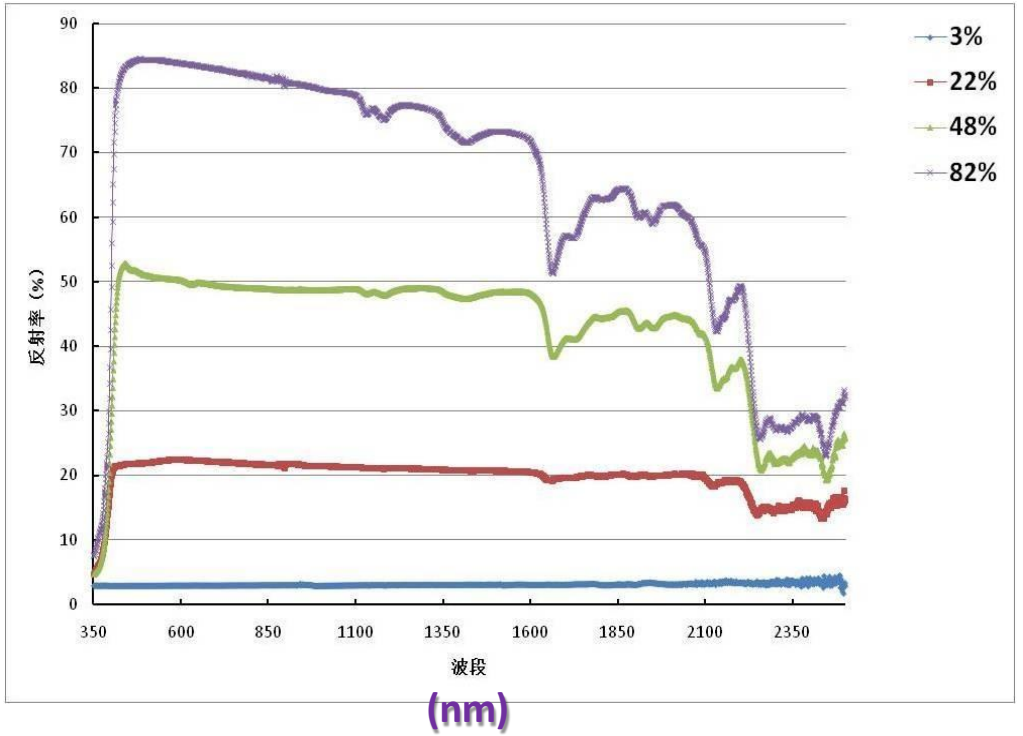
Reflectance spectrum (overall shape correct but still has some noise in spectrum)

2nd stage calibration (noise reduction)



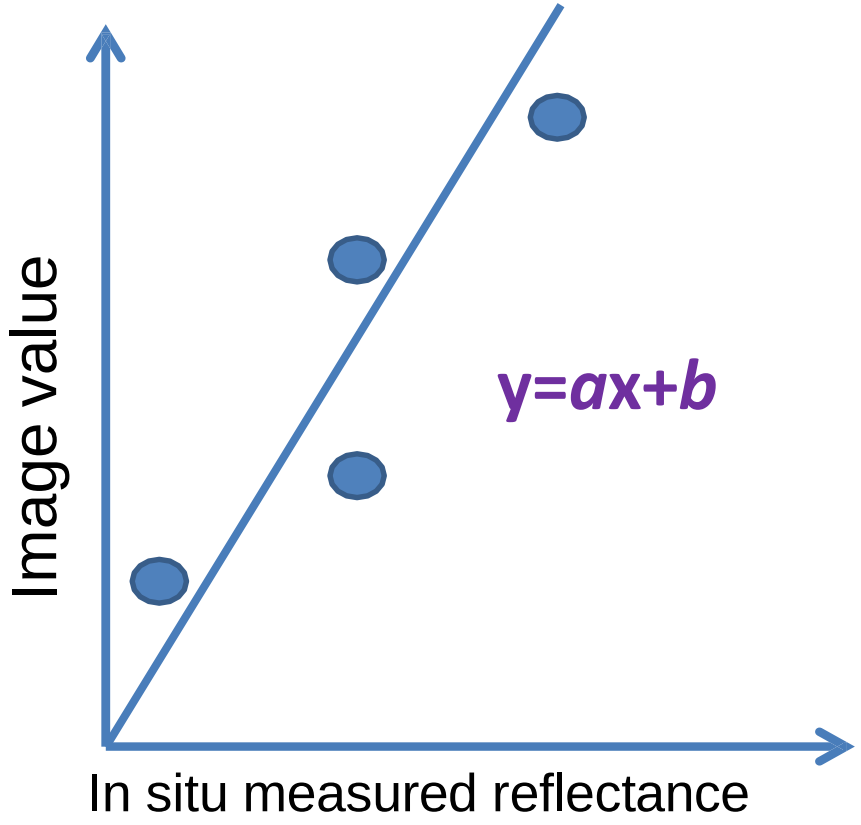
Calibrated Reflectance

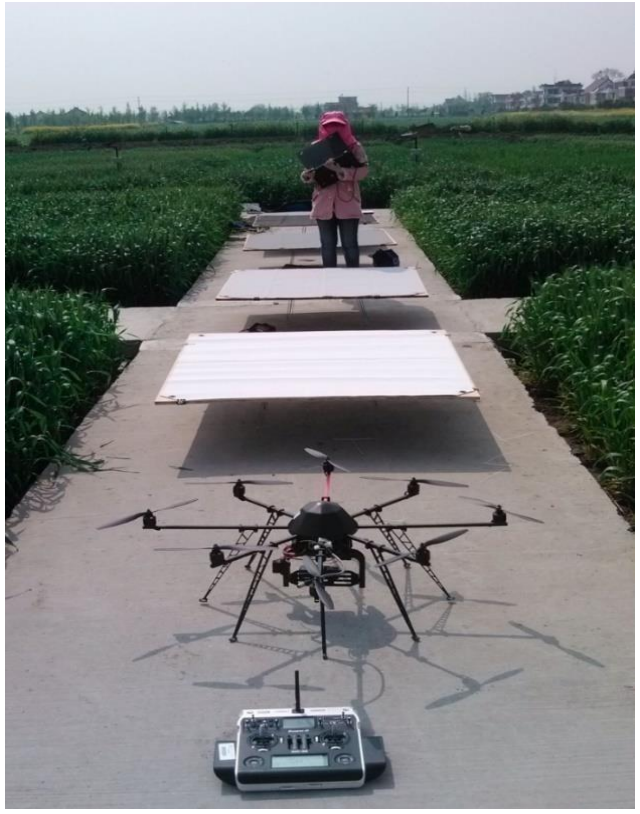
Fabric targets for calibrating multispectral data



Type 822 target fabric (1.2x1.2 m) in the Rugao Experimental field

Reference panels for image calibration





Empirical line calibration for a particular band

Further reading

- RSE textbook Chapter 15