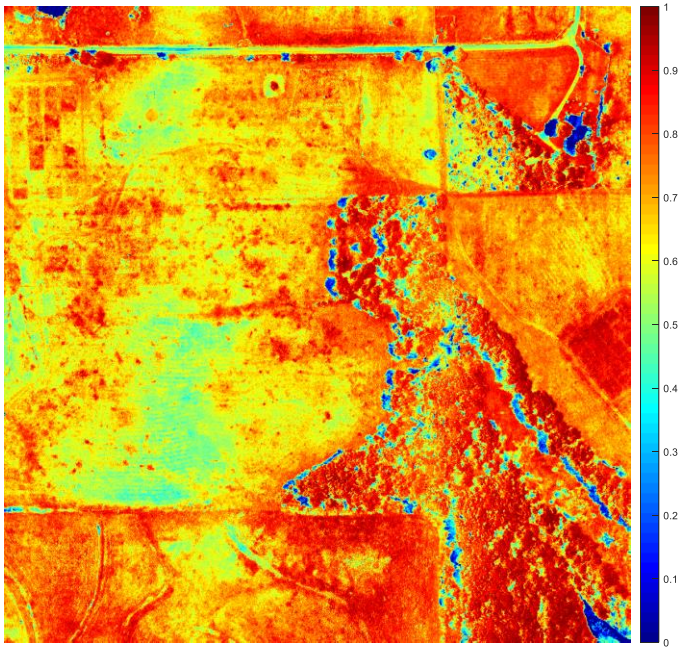
Radiometric Correction of Digital UAS Multispectral Imagery Using Free and Open Satellite Surface Reflectance Images



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Outline

I. **Introduction**

II. Comparison of Remote Sensing Data at Different Spatial Resolutions (Landsat 8 OLI, Sentinel 2 MSI, and NEON Phase One)

III. Satellite-based Empirical Radiometric Inter-Calibration

IV. Validation of identified Radiometric Inter-Calibration functions using high-resolution NEON data

V. Conclusions & Future Work

Introduction

Motivations

- Accurate and low-cost high-resolution multispectral field observations are critical to applications including precision agriculture and disaster damage assessment (e.g., hail, tornados, fire, etc.);
- Spatiotemporal enrichment of existing free and open satellite remote sensing data at low spatial resolution (Landsat 8 OLI, Sentinel 2 MSI) using high resolution uncalibrated UAS data.

Contributions

- Proposed novel methods for radiometric correction of high resolution digital UAS multispectral orthomosaic maps using free and open satellite surface reflectance images;
- Generated high-resolution UAS images of calibrated reflectance and derived products (e.g., NDVI) using the identified mapping functions to facilitate the examination of higher resolution features and inferences which are crucial for applications including vegetation monitoring and disaster damage tracking;
- Validation of the generated UAS calibrated SR images using high-resolution (1 m/pix) NEON surface reflectance images acquired by manned aircraft over a 32 subplot hay field (10 × 10 m).

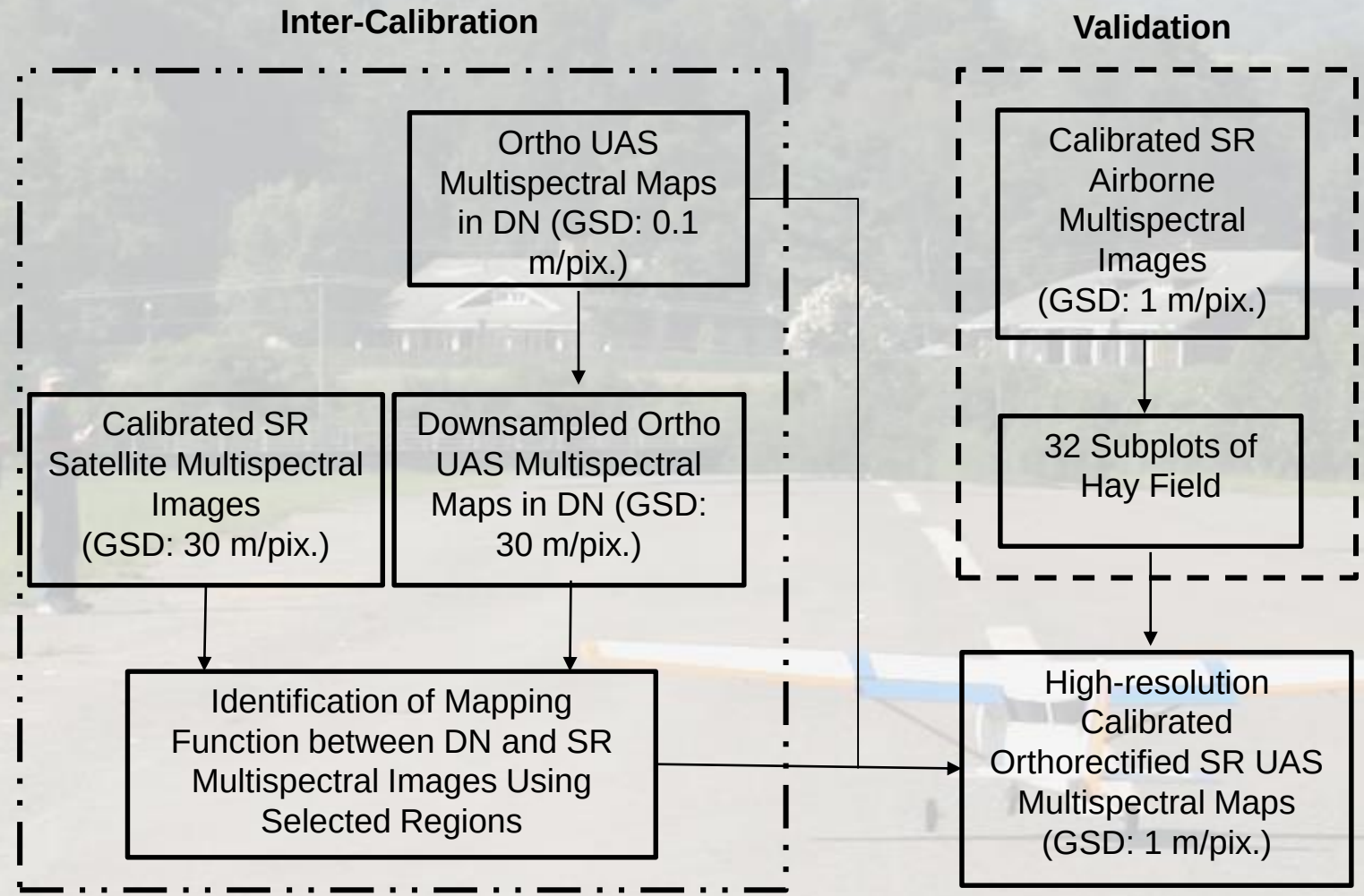
KHawk UAS Platform

The NIR band from the modified multispectral camera and the R,G, and B bands from the unmodified true color camera are used to prevent noise in the visible bands due to NIR leakage.

Sensing Payload: PeauPro82 RGB Camera and modified multispectral (R,G,NIR) Camera

	Bands	FWHM Wavelength (nm)	Peak Wavelength (nm)
OLI	Blue	452.02 – 512.06	482.04
	Green	532.74 – 590.07	561.41
	Red	635.85 – 673.32	654.59
	NIR	850.54 – 878.79	864.67
GoPro Hero 4 True Color	Blue	398.7 – 505.5	458.5
	Green	475.9 – 602.9	532.9
	Red	583.9 – 710	627.6
GoPro Hero 4 Modified Multispectral	NIR	825.4 – 880	852.7

Workflow


Inter-Calibration
Validation
Ortho UAS Multispectral Maps in DN (GSD: 0.1 m/pix.)
Calibrated SR Satellite Multispectral Images (GSD: 30 m/pix.)
Downsampled Ortho UAS Multispectral Maps in DN (GSD: 30 m/pix.)
Identification of Mapping Function between DN and SR Multispectral Images Using Selected Regions
Calibrated SR Airborne Multispectral Images (GSD: 1 m/pix.)
32 Subplots of Hay Field
High-resolution Calibrated Orthorectified SR UAS Multispectral Maps (GSD: 1 m/pix.)

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Remote Sensing System Description

Description	KHawk UAS GoPro	NEON Phase One	Sentinel 2 MSI	Landsat 8 OLI
Platform Type	UAS	Aircraft	Satellite	Satellite
Revisit Times	< 1 day	1 year	5 days	16 days
Bands	4	426	13	9
Spatial Resolution	0.1 m/pix	1 m/pix	10 m/pix	30 m/pix

KHawk UAS

NEON Aircraft

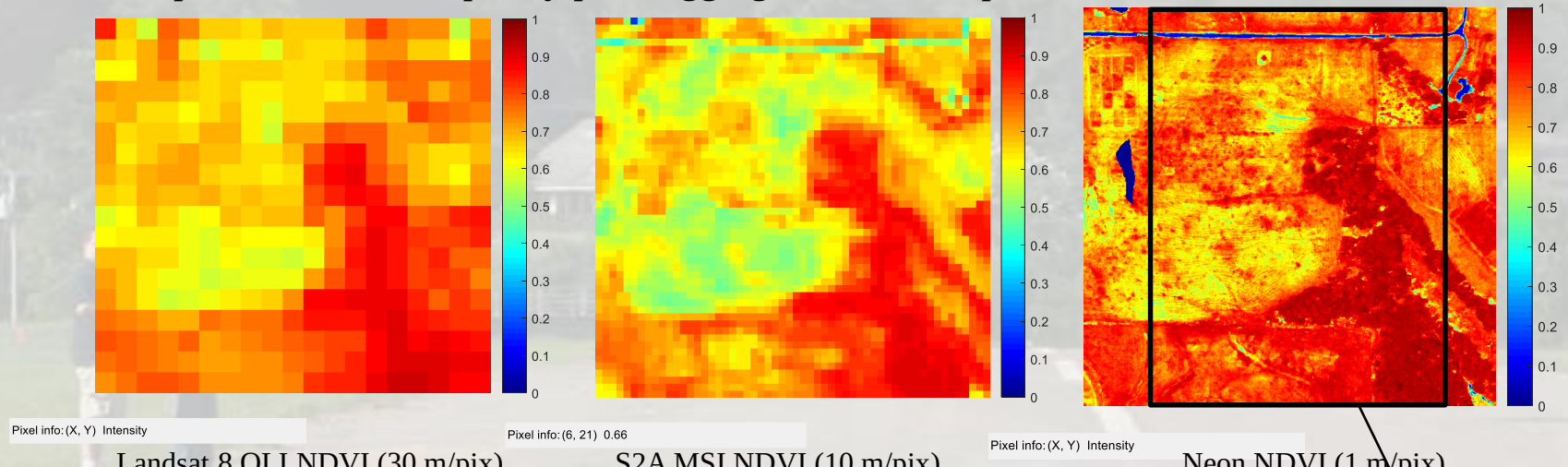
Landsat 8

https://www.neonscience.org/data-collection/airborne-remote-sensing

https://www.usgs.gov/land-resources/nli/landsat/landsat-8?qt-science_support_page_related_con=0#qt-science_support_page_related_con

Landsat 8 OLI, Sentinel 2A MSI, and NEON Comparison

The Sentinel 2A MSI Image (10 m/pix) and the Neon NDVI image (1 m/pix.) are sampled later to 30 m/pix by pixel aggregation for comparison.



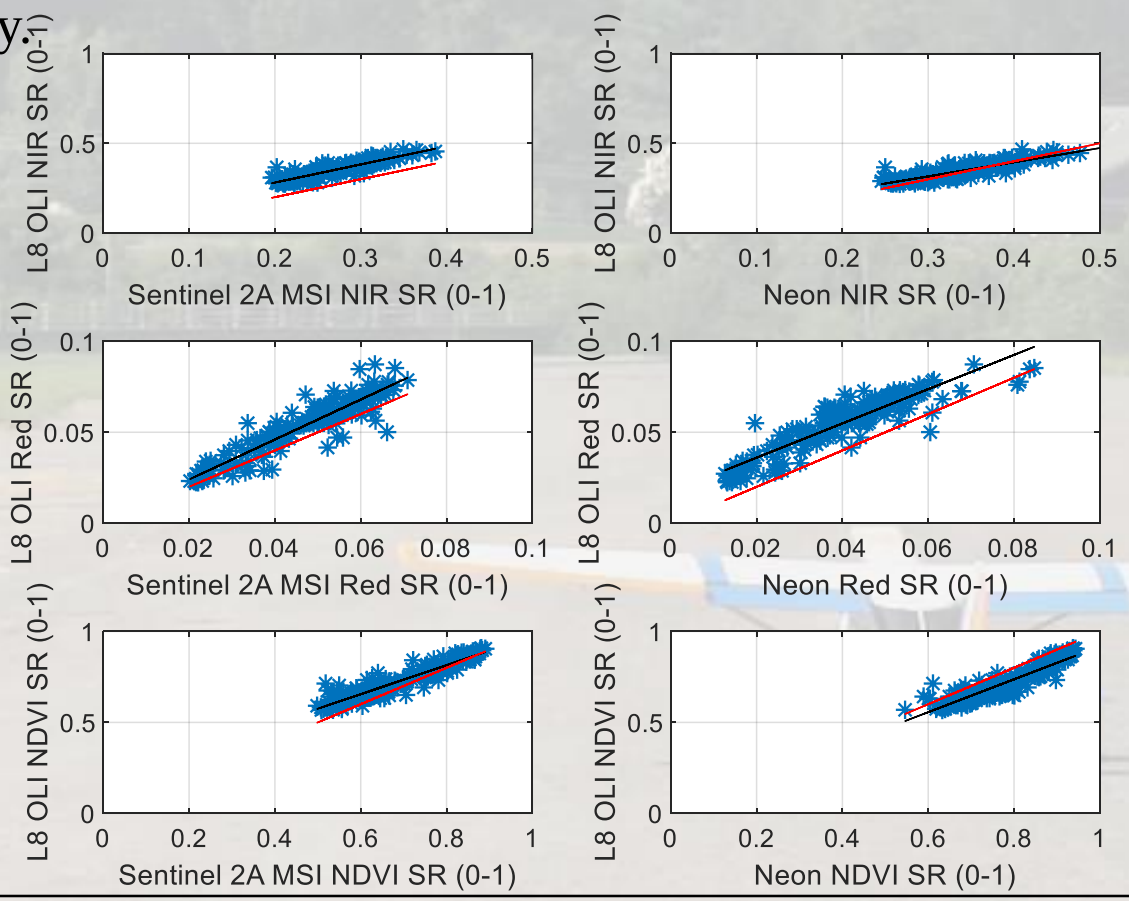
Landsat 8 OLI NDVI (30 m/pix) S2A MSI NDVI (10 m/pix) Neon NDVI (1 m/pix)

2D Correlation

Platform	NIR	Red	NDVI
S2A-L8	0.9207	0.9313	0.9417
NEON-L8	0.8972	0.9091	0.9207

Landsat 8 OLI, Sentinel 2A MSI, and NEON Comparison

The reflectance values of multispectral imagery remain about the same at different spatial resolutions (30 m to 1 m) for regions with vegetation homogeneity.



The red line represents "y = x".

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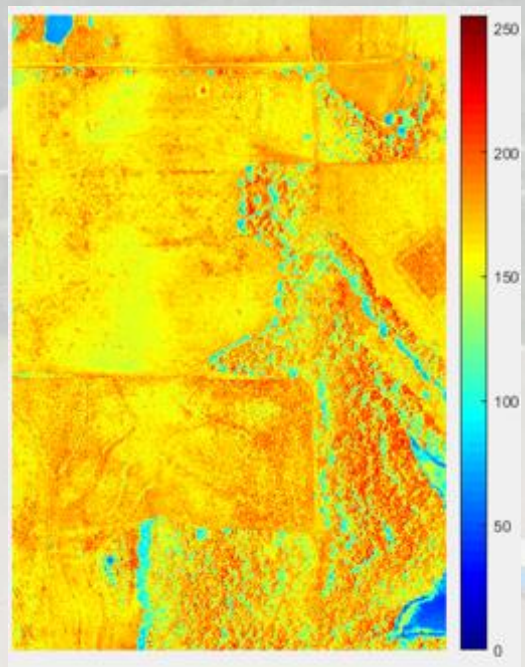
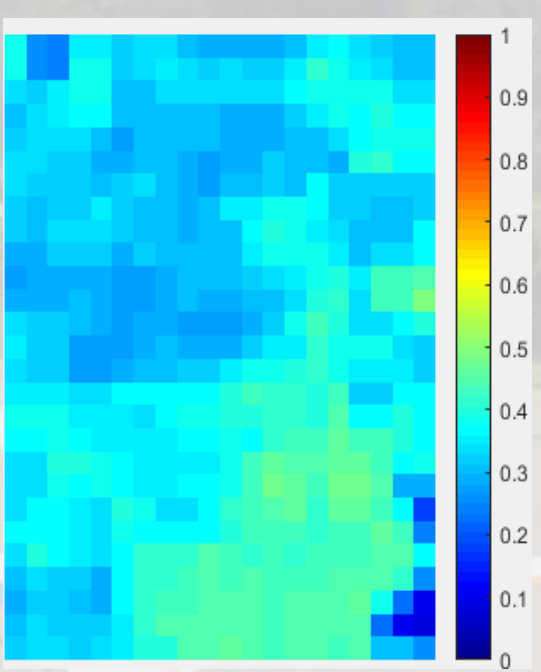
Uncalibrated UAS DN Maps and Calibrated L8 SR Images

- The orthorectified KHawk DN maps, RGB (L), NIR (M), and calibrated L8 OLI NIR SR (R) maps are shown below.

KHawk UAS RGB DN Map
(GSD: 0.1 m/pix)



KHawk UAS NIR DN Map
(GSD: 0.1 m/pix)

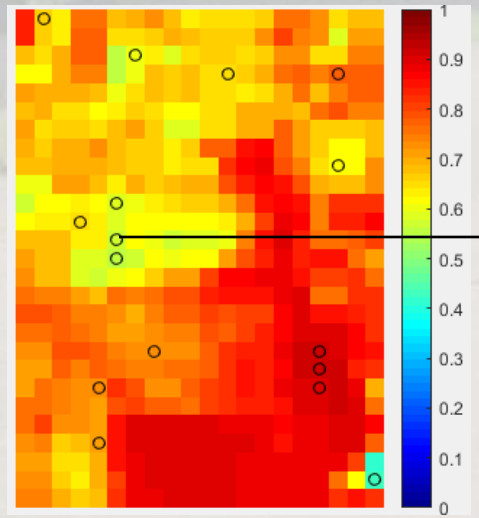


L8 OLI NIR SR Map
(GSD: 30 m/pix)

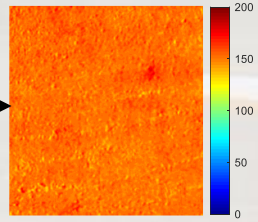
Satellite-based Empirical Radiometric Inter-Calibration (SERI)

The SERI method involves three steps:

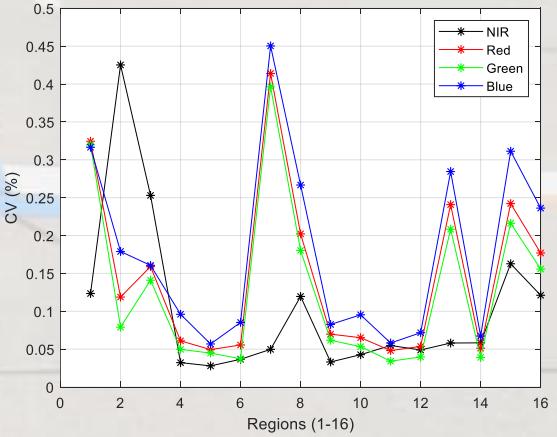
- Pixel-aggregation of the UAS DN maps to match the spatial resolution of the reference image (L8 SR);
- Extract regions from the scene that represent the range of the reflectance values of each respective spectral band;
  - The extracted regions should also exhibit low vegetation variability in smaller scales:
- Identification of the correction function between the UAS DN mean values and the L8 SR values corresponding to the extracted regions.



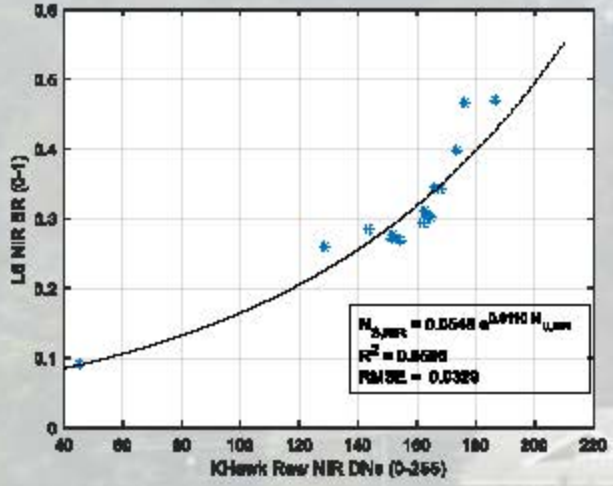
Extracted Regions (black circles) shown on the L8 NDVI image

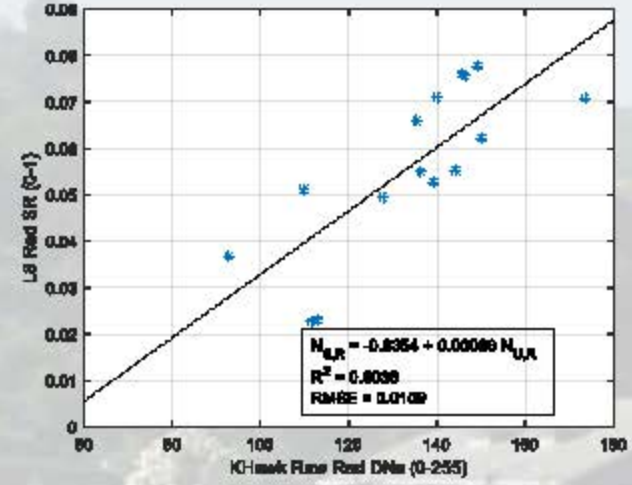


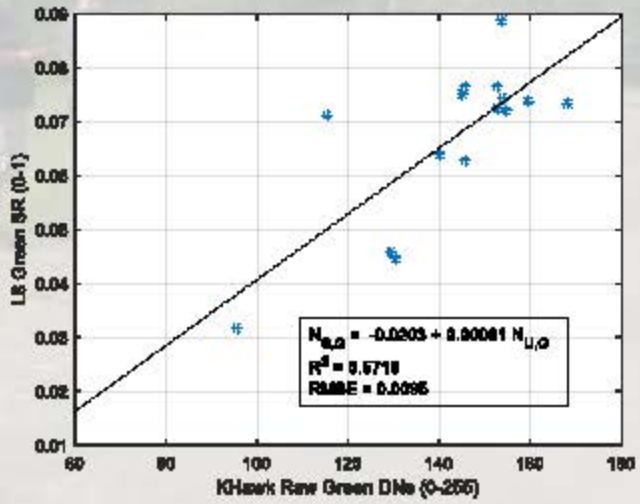
High-resolution view of one of the extracted regions

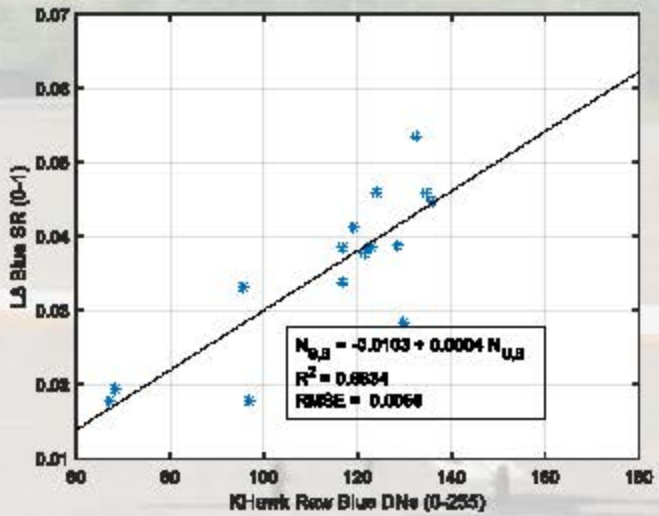


Coefficient of Variation of small-scale features for each regions


L8 NIR SR (0-1)
KHawk Raw NIR DNs (0-255)


L8 Red SR (0-1)
KHawk Raw Red DNs (0-255)


L8 Green SR (0-1)
KHawk Raw Green DNs (0-255)


L8 Blue SR (0-1)
KHawk Raw Blue DNs (0-255)

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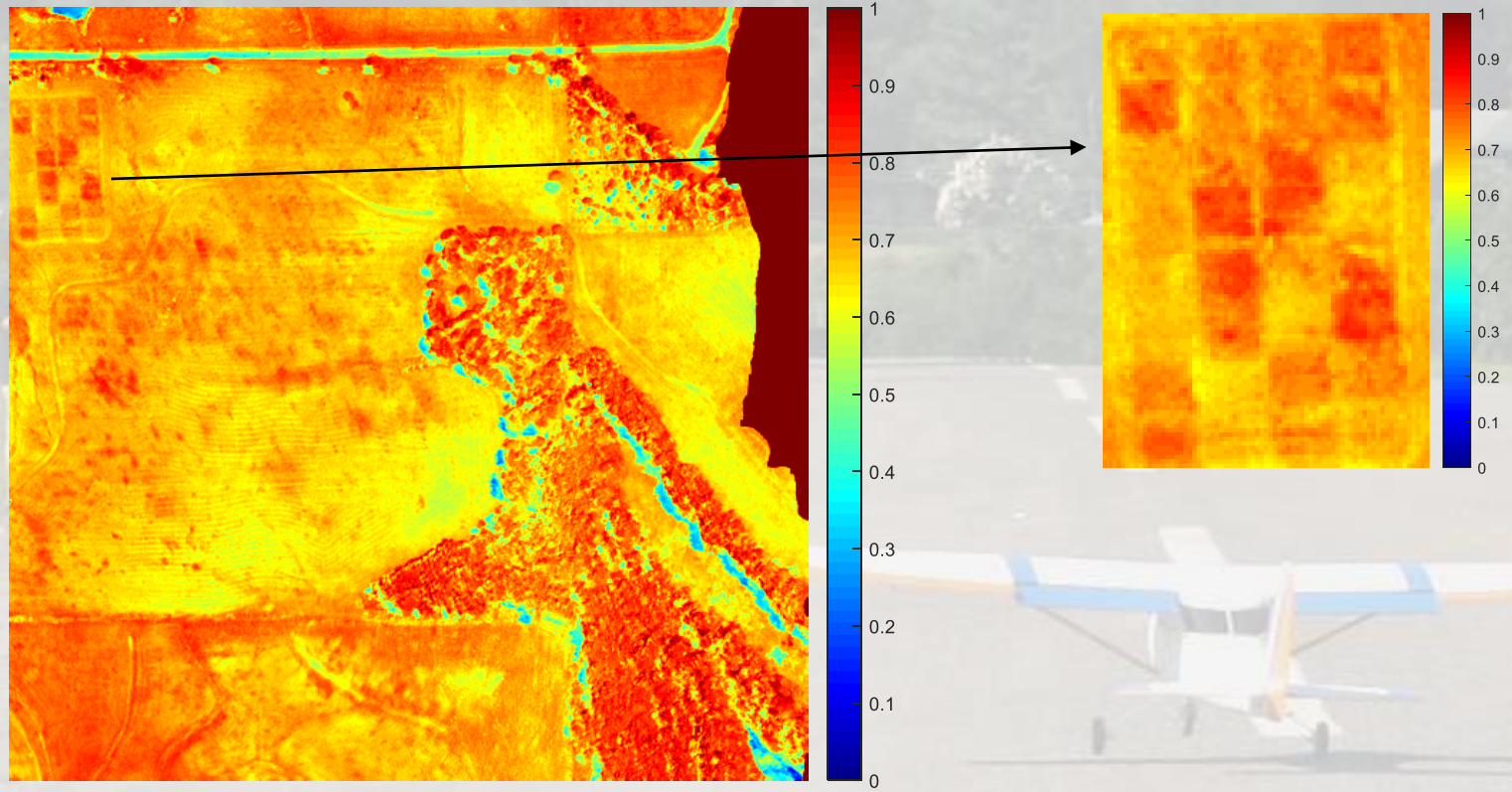
Validation using Selected Hay Field

- At the start of our studies in 2000, the field was dominated by introduced C3 hay-grasses, Bromus inermis (Smooth Brome) and Schedonorus arundinaceus (Tall Fescue).

https://foster.ku.edu/long-term-studies-secondary-succession-and-community-assembly-prairie-forest-ecotone-eastern-kansas

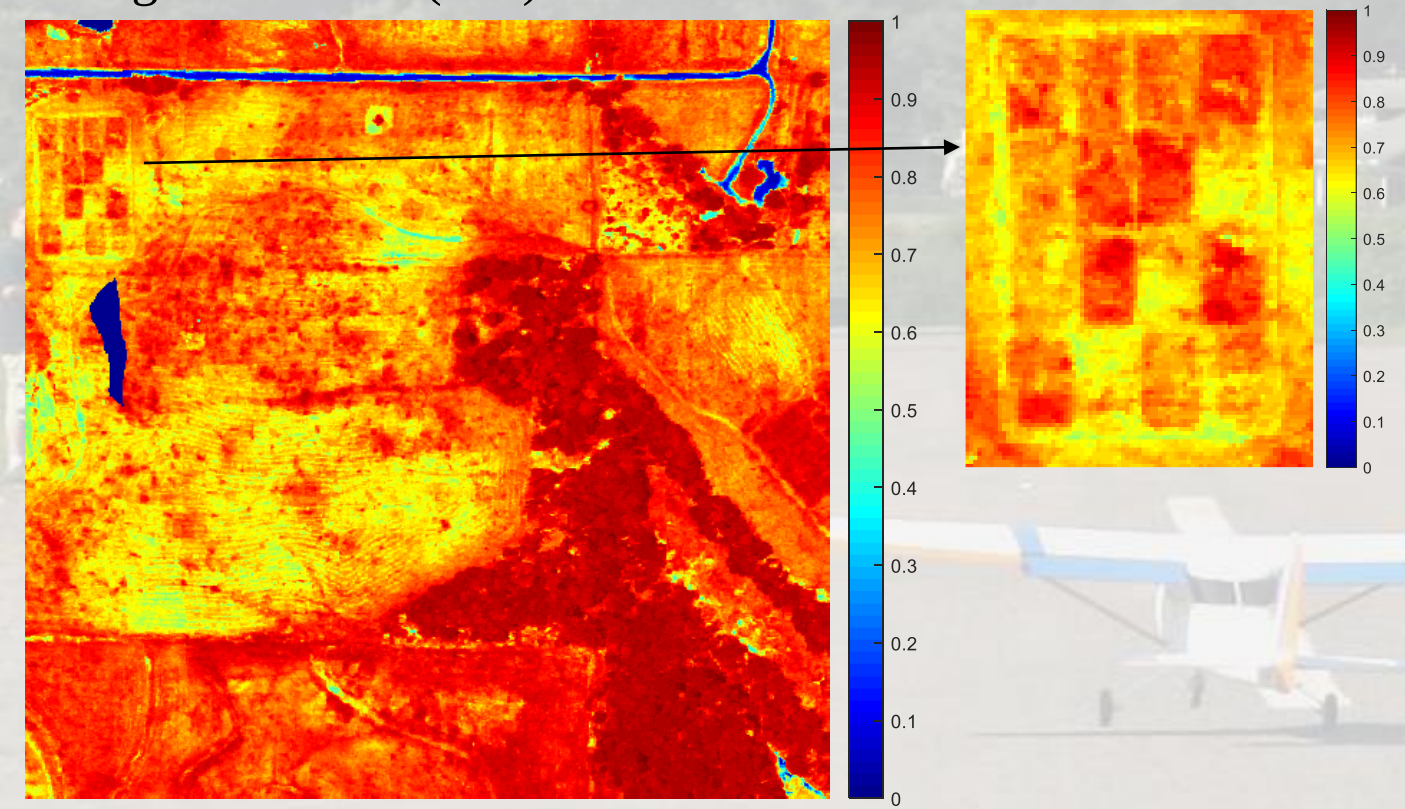
High-Resolution KHawk NDVI Map (1 m/pix)

- Validation at selected research hay field (32 subplots with each 10 × 10 meter)
  - 4 subplots each row and 8 subplots each column.



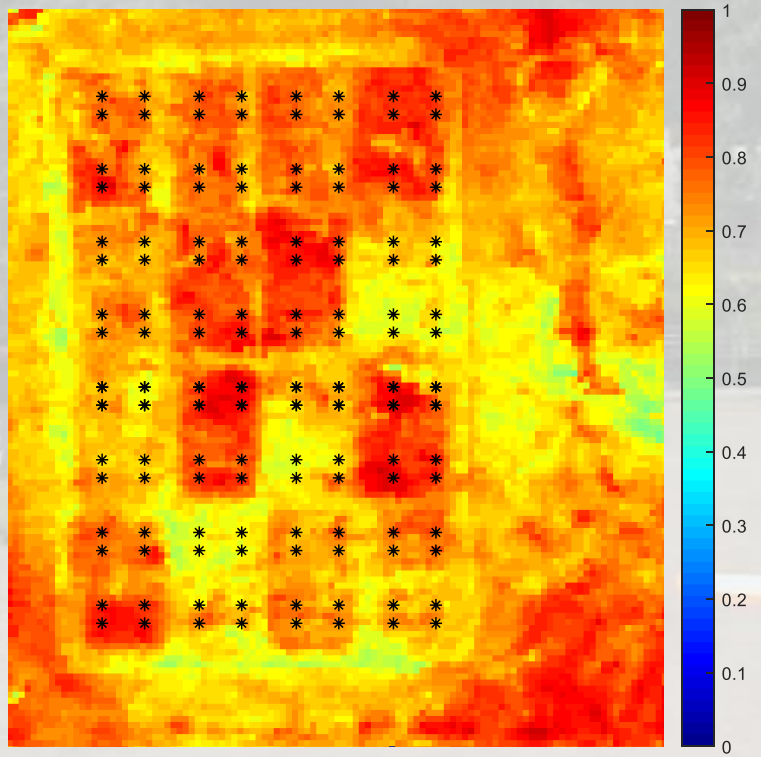
High-Resolution NEON NDVI Map (1 m/pix)

- Ground truth from NEON data for validation of calibrated UAS map at high resolution (1 m).

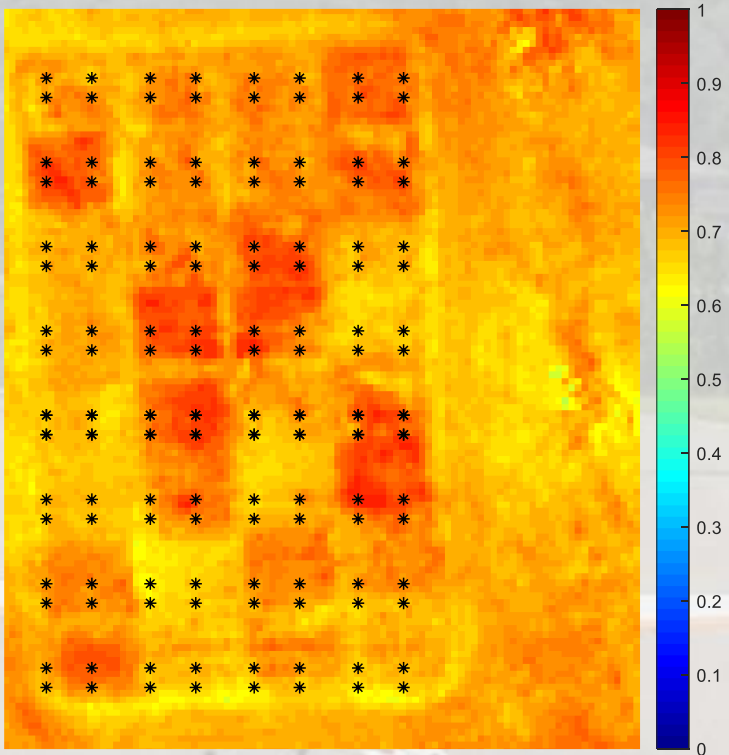


Analysis Using 32 sub-plot Hay Field

- The average reflectance and NDVI within each selected subplot are compared between UAS and NEON data.



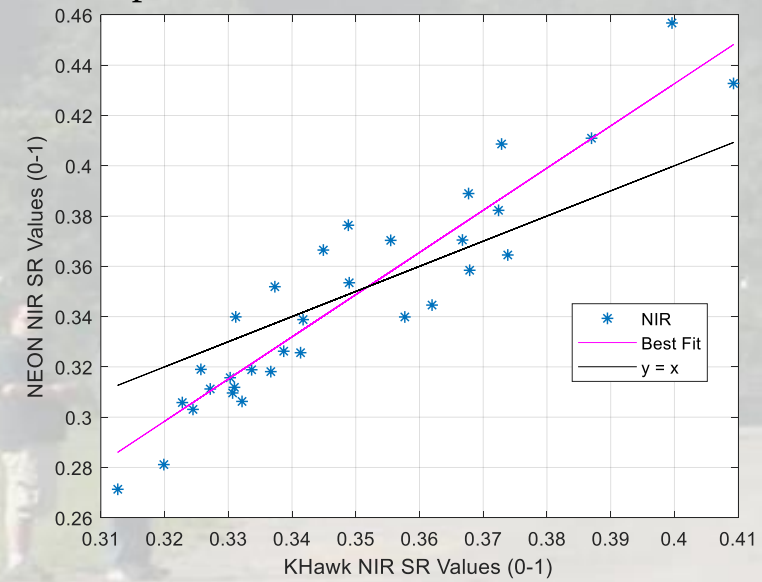
NEON NDVI at 1 m

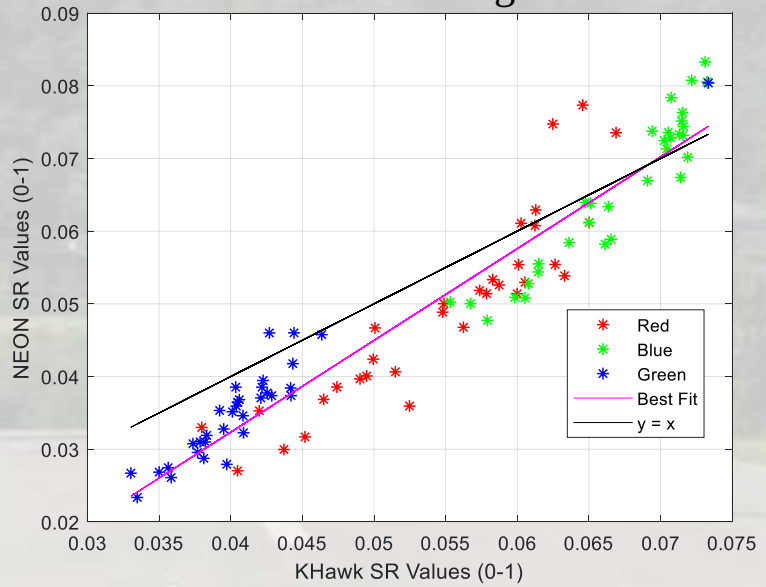


KHawk NDVI at 1 m

Analysis Using 32 sub-plot Hay Field

- The NIR band and visible spectrum reflectance values predicted by the KHawk UAS map are compared with the measured reflectance values observed in the NEON image.





Band	R^2	RMSE
NIR	0.7237	0.0153
Visible (RGB Combined)	0.8165	0.0071

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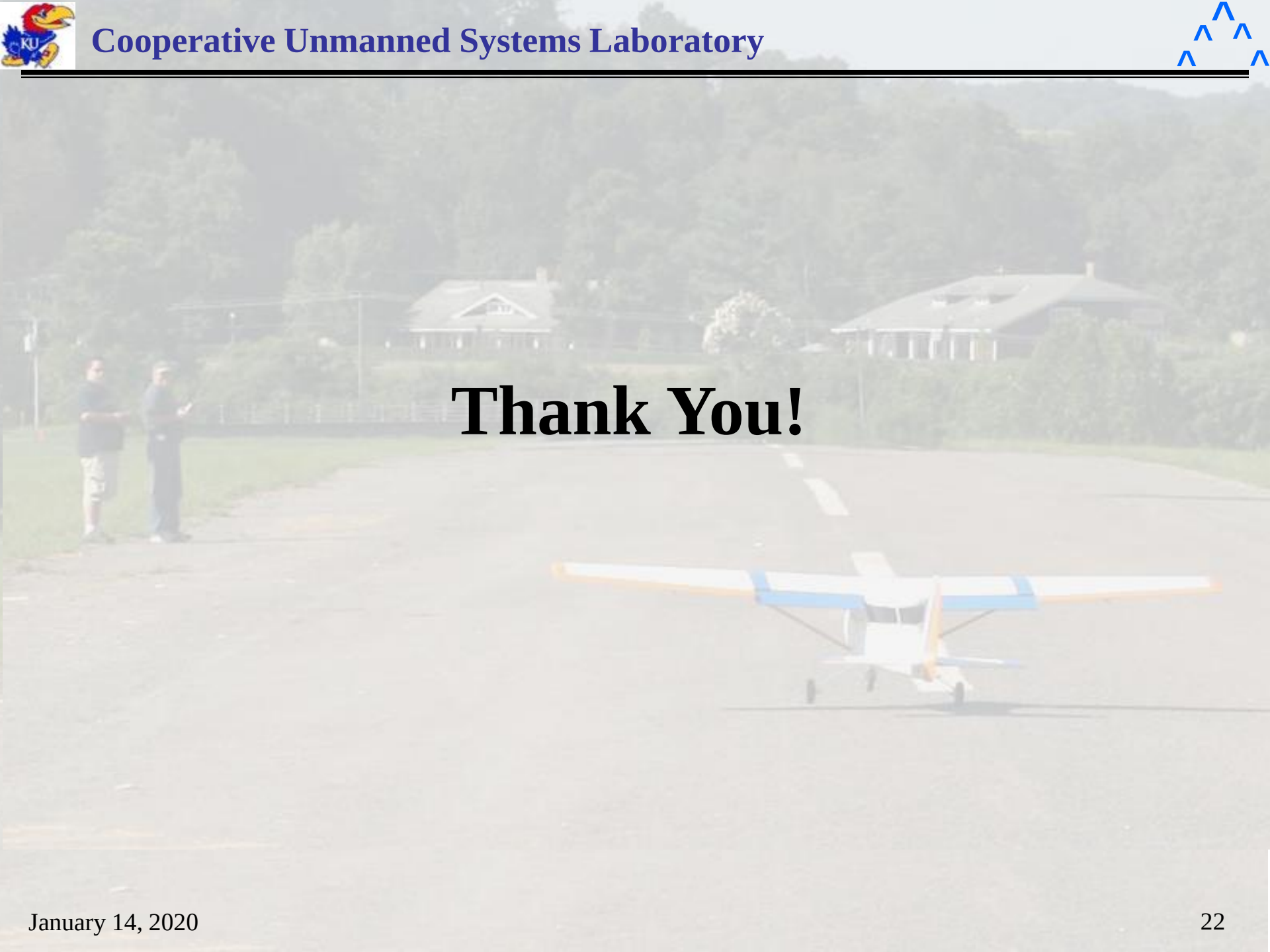
Conclusions

- For the ROI the spectral values at different resolutions: 1, 10, and 30 m/pix demonstrated a high correlation of **~ 90 %** indicating that the vegetation showed low variability, therefore, validating the idea of using low-resolution L8 SR images to inter-calibrate the downsampled UAS DN maps;
- The developed SERI for DN-SR calibration showed low RMSE of 0.033 for the NIR band and 0.011, 0.0005, and 0,0059 for the R,G, and B bands respectively;
- Finally, the calibrated KHawk SR images were compared to high-resolution airborne NEON images to validated the proposed inter-calibration technique;
- A 32 sub-plot Hay field was used to perform this comparison which should very good correlation of R^2 = 0.724 for the NIR band and R^2 = 0.817 for the visible bands;

Future Work

- Test our proposed algorithm on different data sets and different ROI;
- Conduct flight tests for NDVI-time series analysis and perform comprehensive analysis with corresponding L8 OLI images over different days and times.



Thank You!