# Tillage – Monitoring, Reporting and Verification

Deep learning based field level classification of tillage intensity to facilitate remote monitoring and verification of sustainable cropland practices

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Overview

- Background on tillage, intensity and measurement
- Ground truth data and satellite imagery
- The model and early results
- Next steps
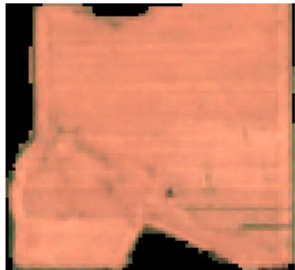
Background

Tillage

Preparation of soil for planting of next crop, and weed suppression by digging, mixing, overturning and loosening.

Impacts

- Increases wind and water erosion
- Increases exposure to direct sunlight, heat and evaporation
- Decreases soil organic matter
- Removes microbial food source
- Gradual decline in soil health and productivity
- Increases mechanical field operations
- Increases reliance on fertilisers

Background

Purpose of MRV

- Carbon credit platforms - carbon certificates and credits
- Agri-businesses - supply chain transparency
- Governments - verifying farm reported data to unlock payments (UK Environmental Land Management Scheme)

→ Reducing the number of required in-field inspections

Background

Classifying tillage intensity

1. Depth of tillage
2. Residue percentage

Residue percentage

The fraction of the soil surface covered by crop residue, shortly after planting.

- No Till (> 30% crop residue cover)
- Min Till (15 to 30% crop residue cover)
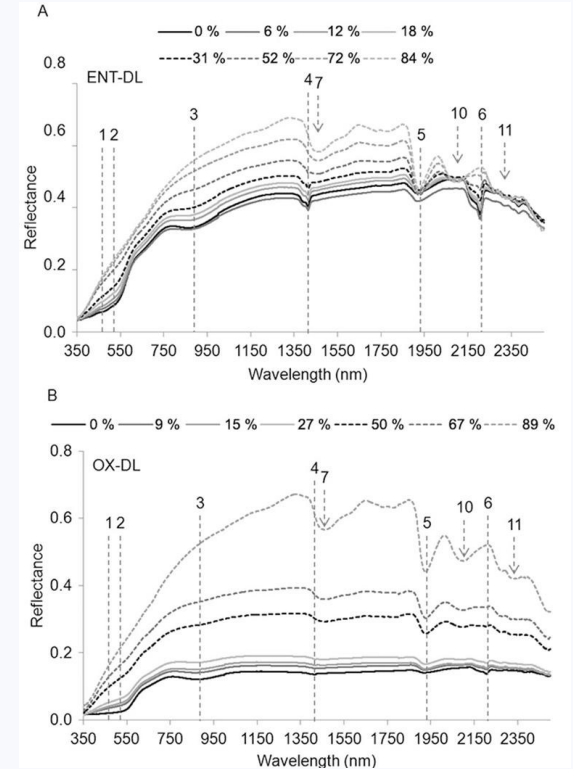- Conventional Till (< 15% crop residue cover)

No Till

Min Till

Conventional

Background

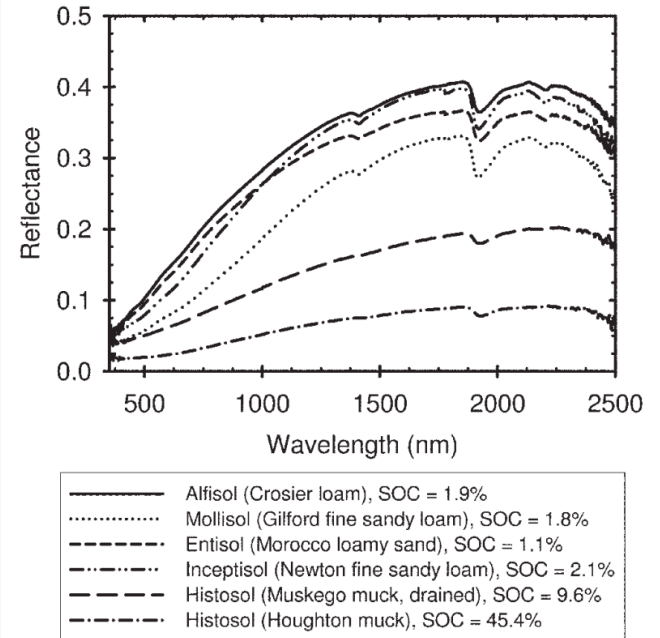Lab experiments on spectral properties of crop residue, soil and moisture

- Higher crop residue % on top of soil generally results in higher reflectance

Demattê, José AM, et al. "Assessment of sugarcane harvesting residue effects on soil spectral behavior." *Scientia Agricola* 73 (2016): 159-168.

Background

Lab experiments on spectral properties of crop residue, soil and moisture

● Higher crop residue % on top of soil generally results in higher reflectance

● Soil type has a large impact on reflectance

Serbin, Guy, et al. "Effect of soil spectral properties on remote sensing of crop residue cover." *Soil Science Society of America Journal* 73.5 (2009): 1545-1558.

Background

Lab experiments on spectral properties of crop residue, soil and moisture

- Higher crop residue % on top of soil generally results in higher reflectance

- Soil type has a large impact on reflectance

- Moisture content impacts reflectance - higher relative water content results in lower reflectance

Quemada, Miguel, and Craig ST Daughtry. "Spectral indices to improve crop residue cover estimation under varying moisture conditions." *Remote Sensing* 8.8 (2016): 660.
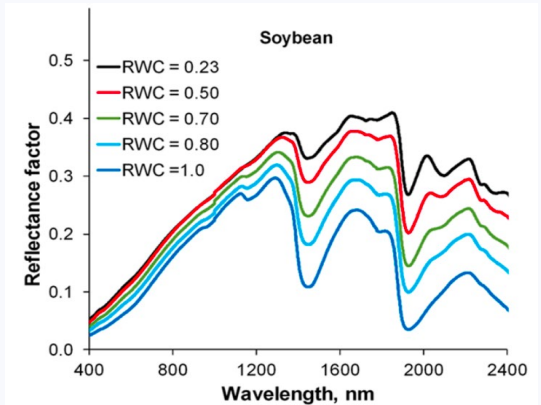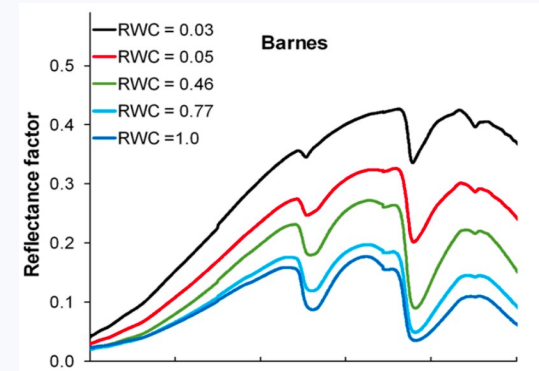
Background

Sentinel-2

- Spectral signature can help detect differences in residue % (SWIR bands are particularly important, as used in Normalised difference tillage index), but reflectance is affected by moisture

Sentinel-1

- Can be used to estimate moisture content
- Helps determine surface roughness

Bauer-Marschallinger, Bernhard, et al. "Toward global soil moisture monitoring with Sentinel-1: Harnessing assets and overcoming obstacles." *IEEE Transactions on Geoscience and Remote Sensing* 57.1 (2018): 520-539.

Baghdadi, Nicolas, et al. "Potential of Sentinel-1 images for estimating the soil roughness over bare agricultural soils." *Water* 10.2 (2018): 131.

Ground truth data

➔ Training data for tillage verification is very rare
➔ Farm reported operations available in some instances

Large scale ground truth data collection

● Focus UK and USA (> 10,000 and 5,000 respectively)
● Standard operating procedure for data collectors
● Fulcrum App for consistent standardised data
● Revisits
● 2021/22 and ongoing

Data includes

● Tillage type, residue %, crop type
● Photos of every field
● Drone imagery for 10% of all fields
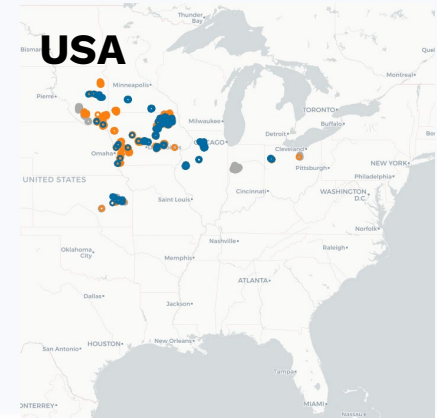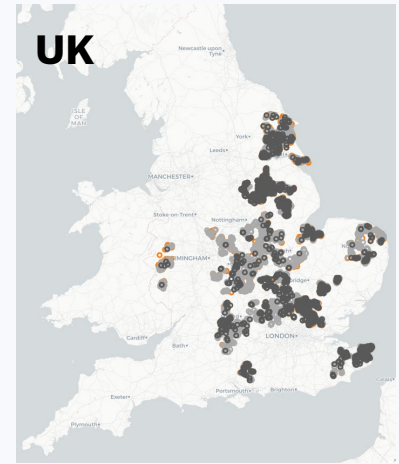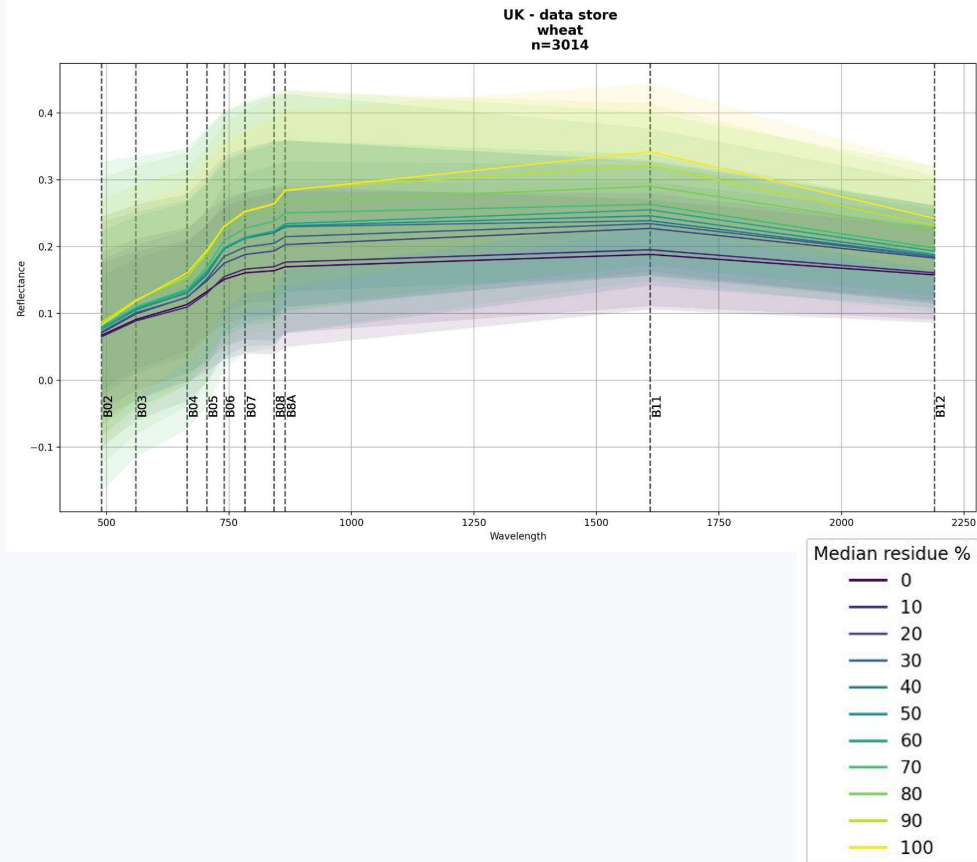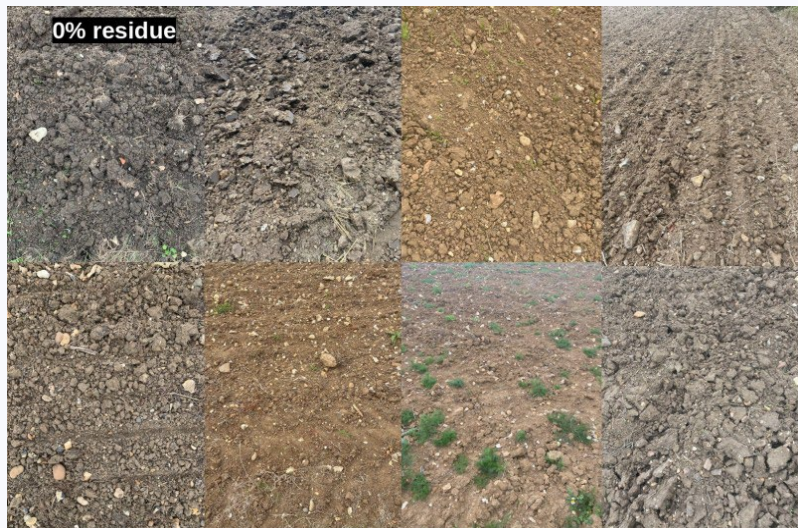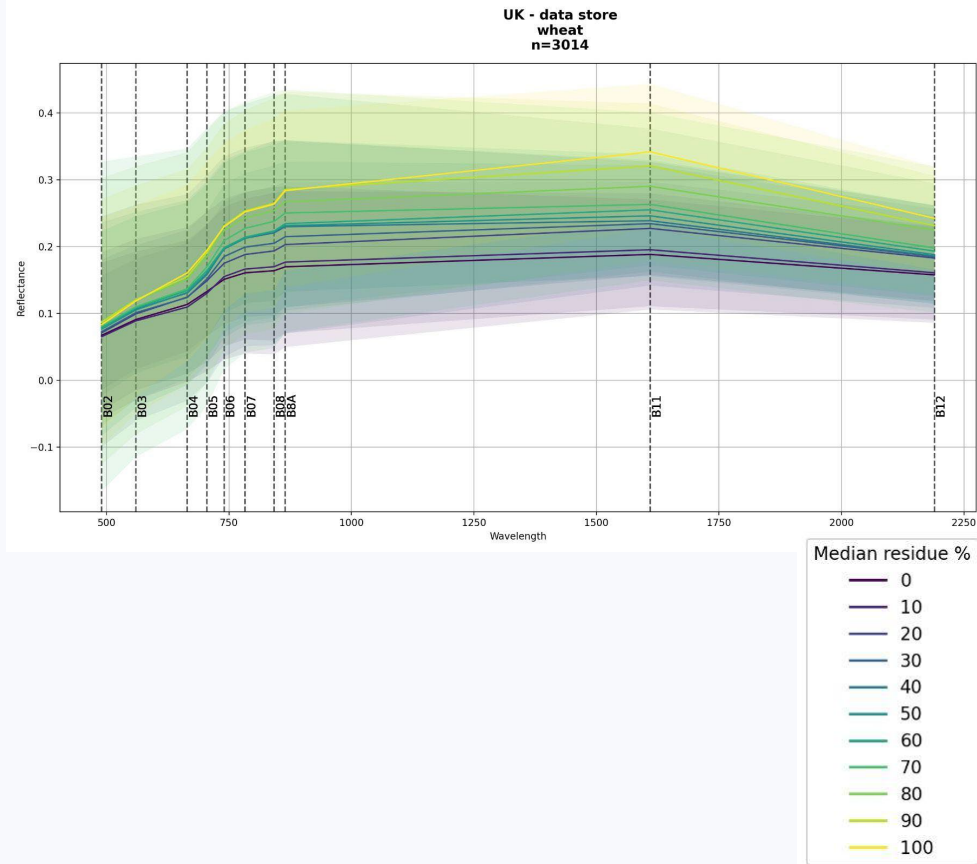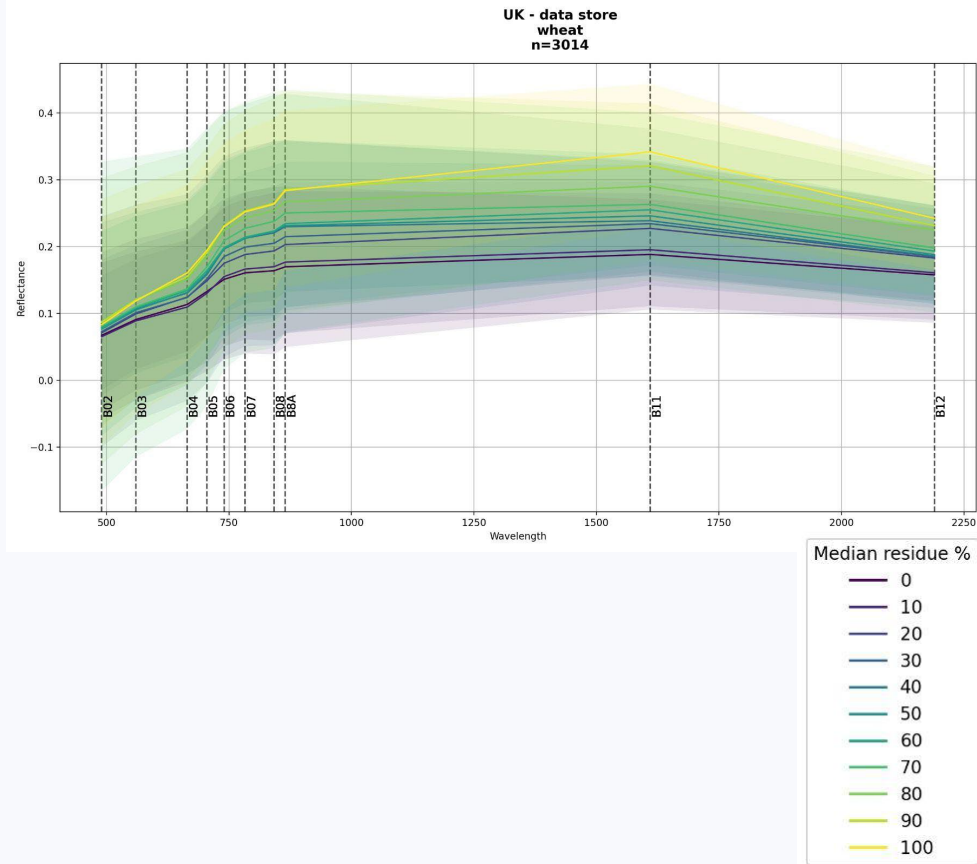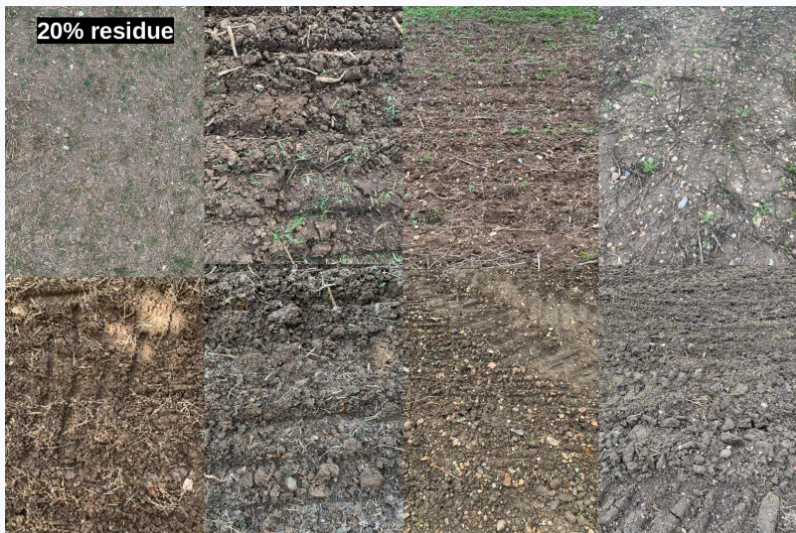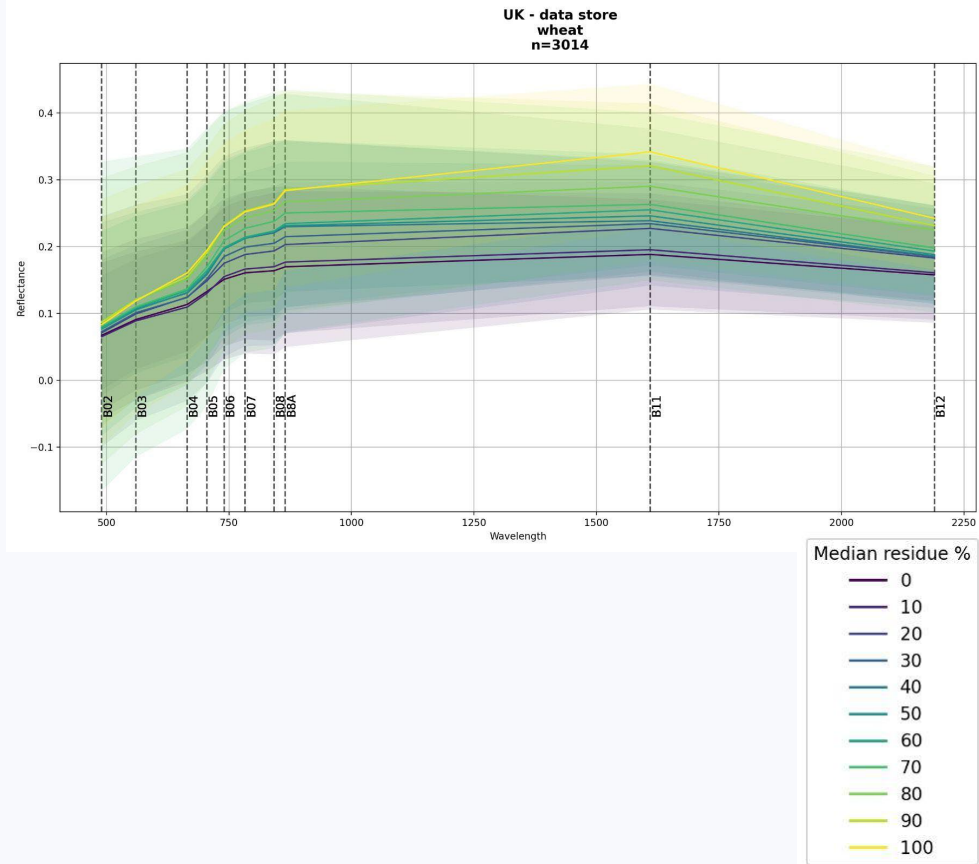
UK

USA

Ground truth data

0% residue

UK - data store
wheat
n=3014

Median residue %
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Ground truth data

10% residue

UK - data store
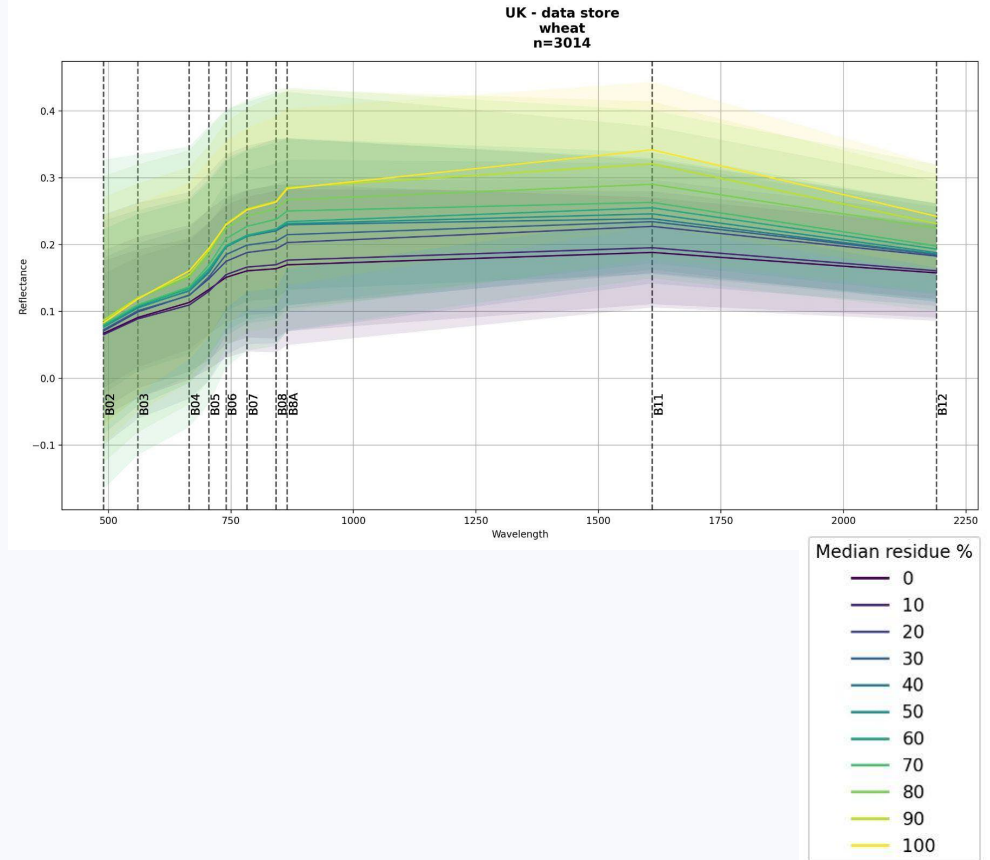wheat
n=3014

Median residue %
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Ground truth data

Ground truth data

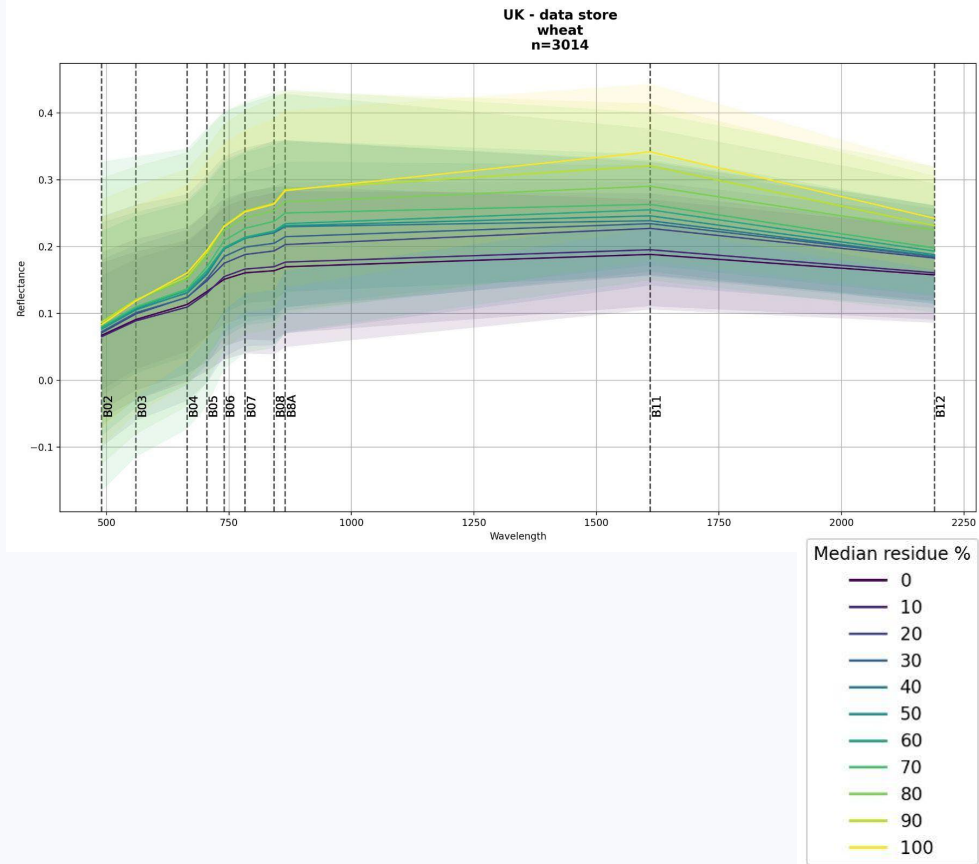30% residue

UK - data store
wheat
n=3014

Ground truth data

40% residue

UK - data store
wheat
n=3014

Median residue %
— 0
— 10
— 20
— 30
— 40
— 50
— 60
— 70
— 80
— 90
— 100

Ground truth data

Ground truth data

60% residue

UK - data store
wheat
n=3014

Median residue %
— 0
— 10
— 20
— 30
— 40
— 50
— 60
— 70
— 80
— 90
— 100

Ground truth data

70% residue

UK - data store
wheat
n=3014

Ground truth data

80% residue

UK - data store
wheat
n=3014

Median residue %
- 0
- 10
- 20
- 30
- 40
- 50
- 60
- 70
- 80
- 90
- 100

Ground truth data

90% residue
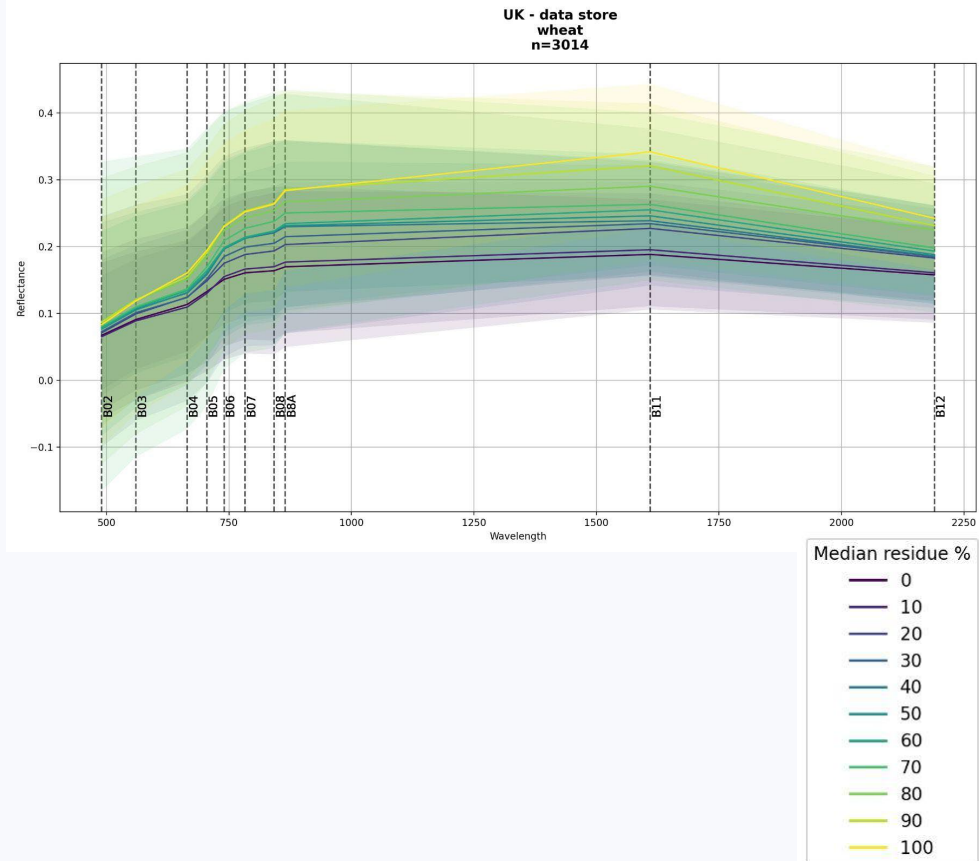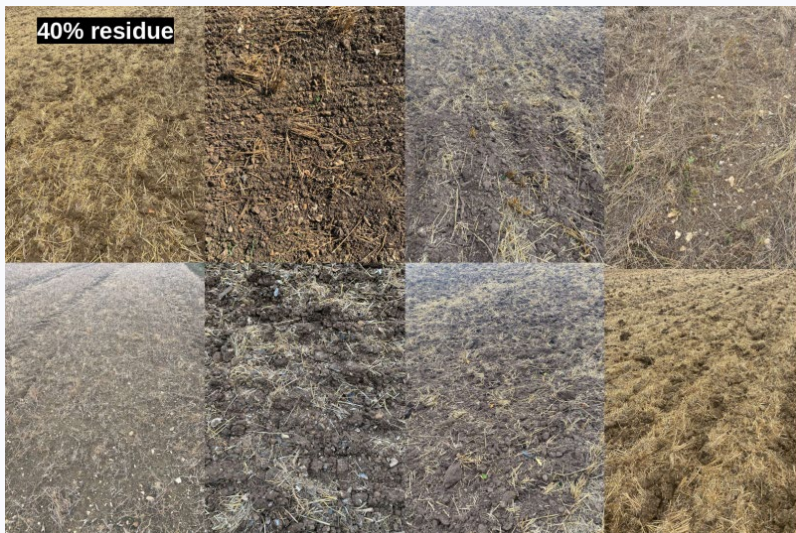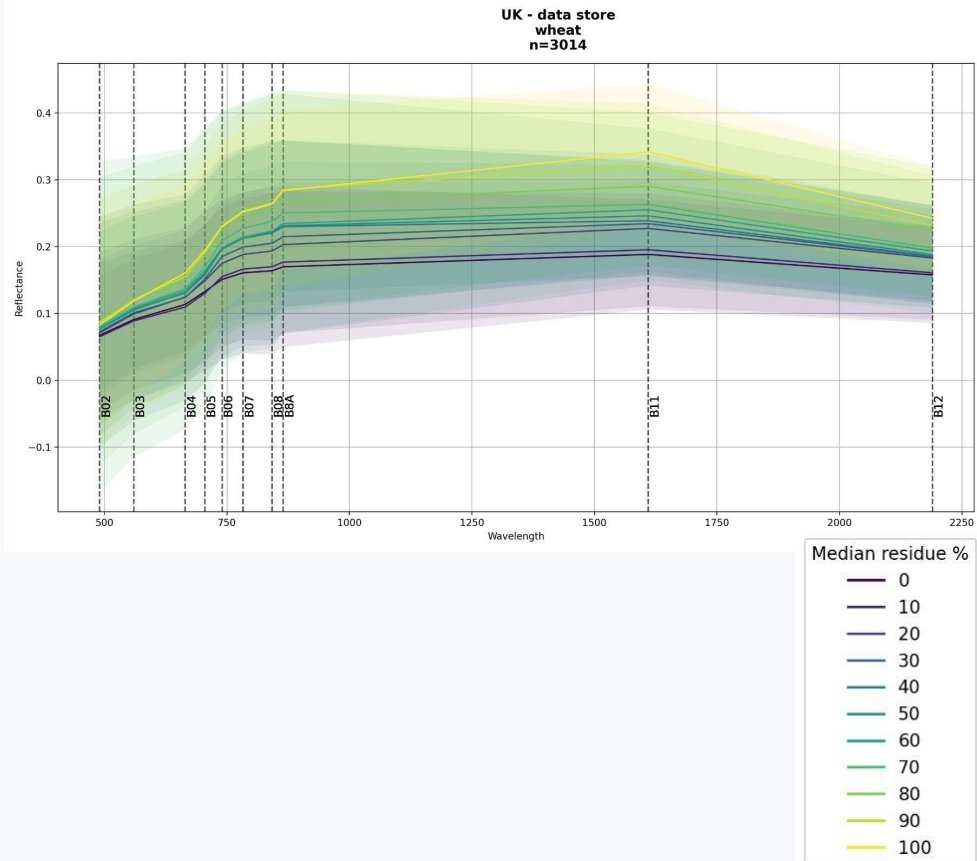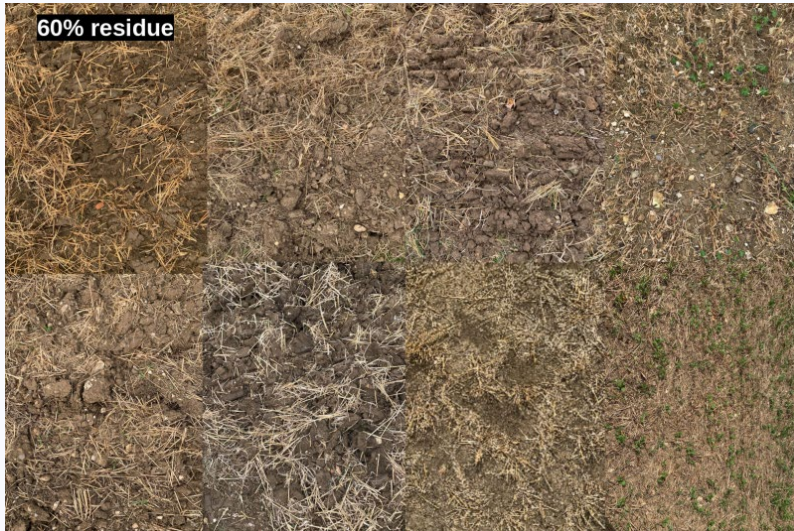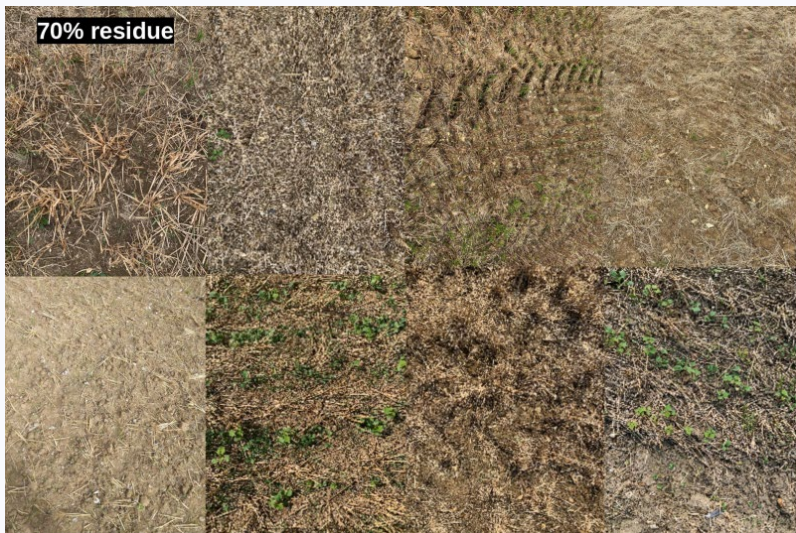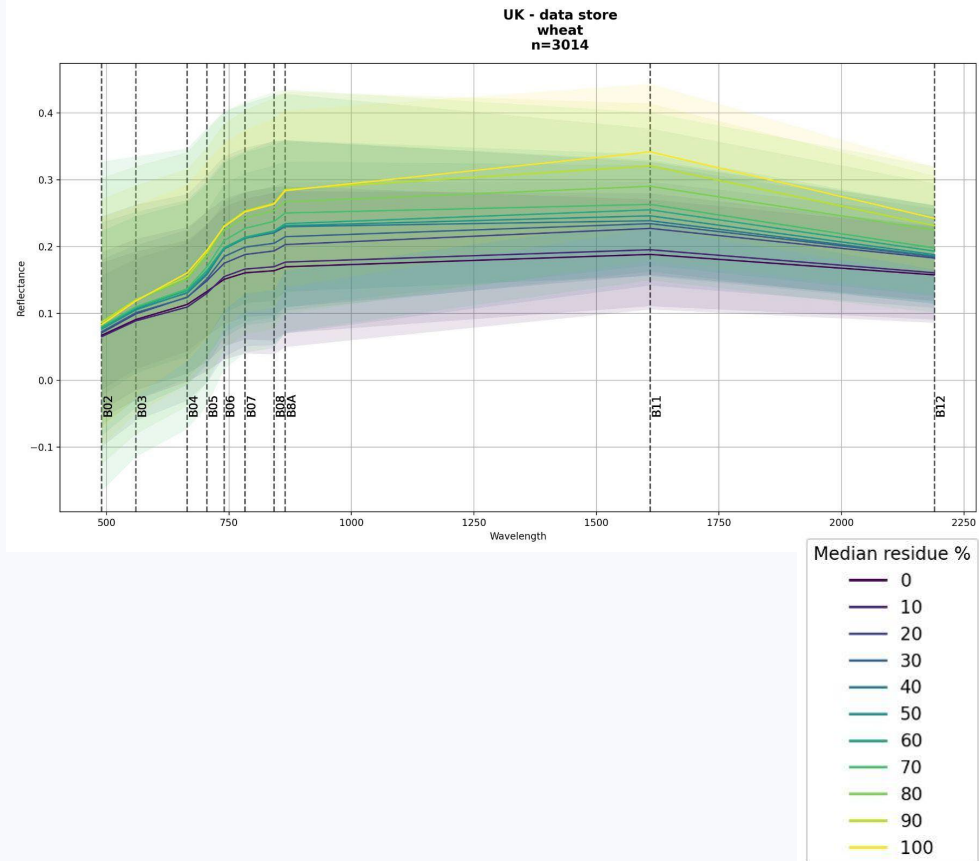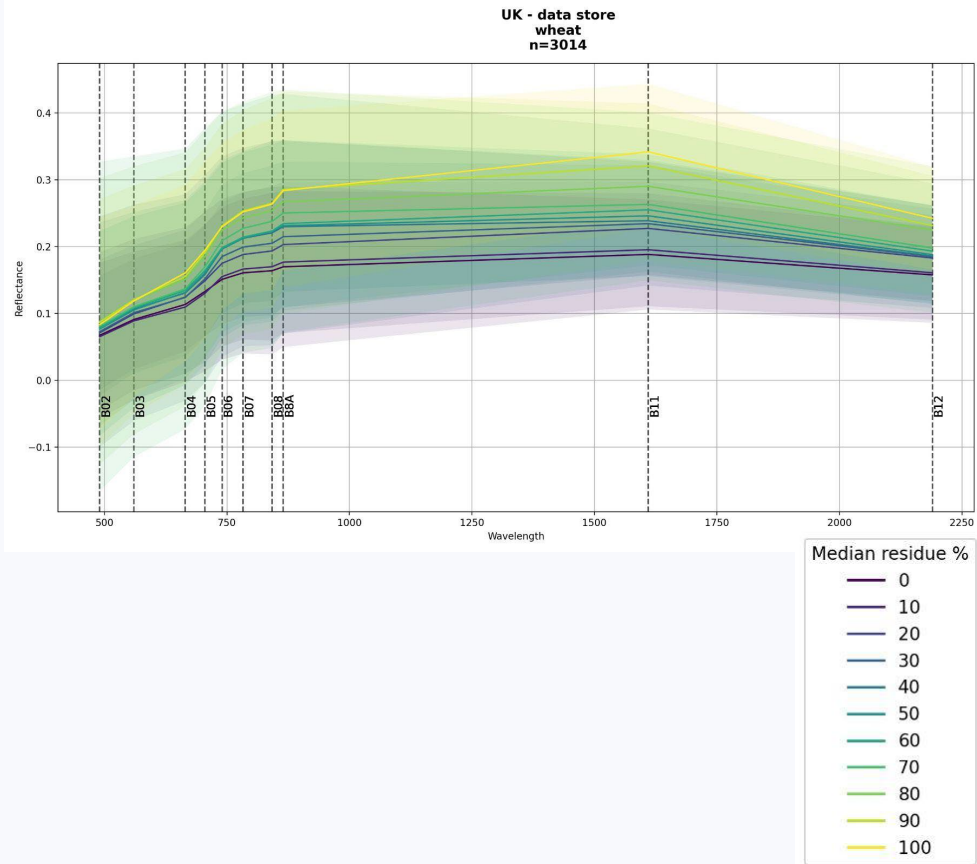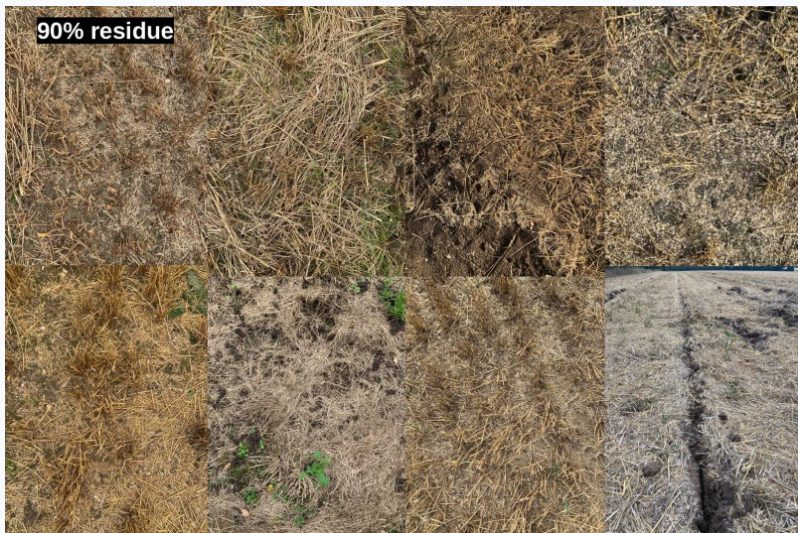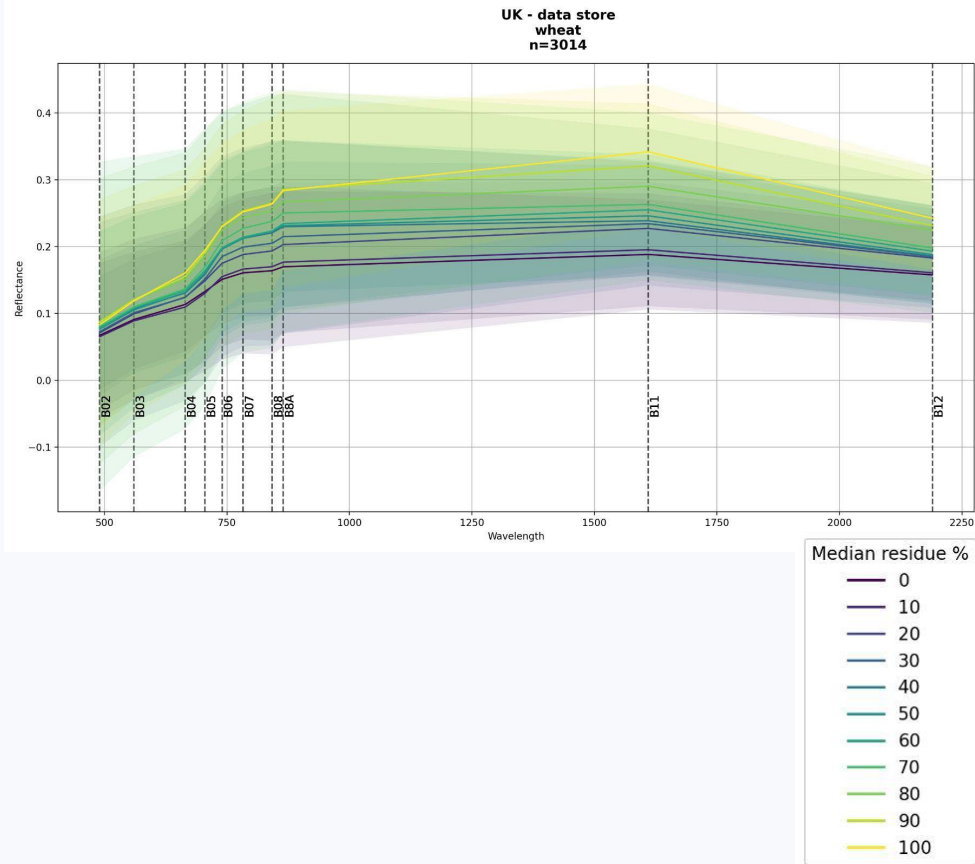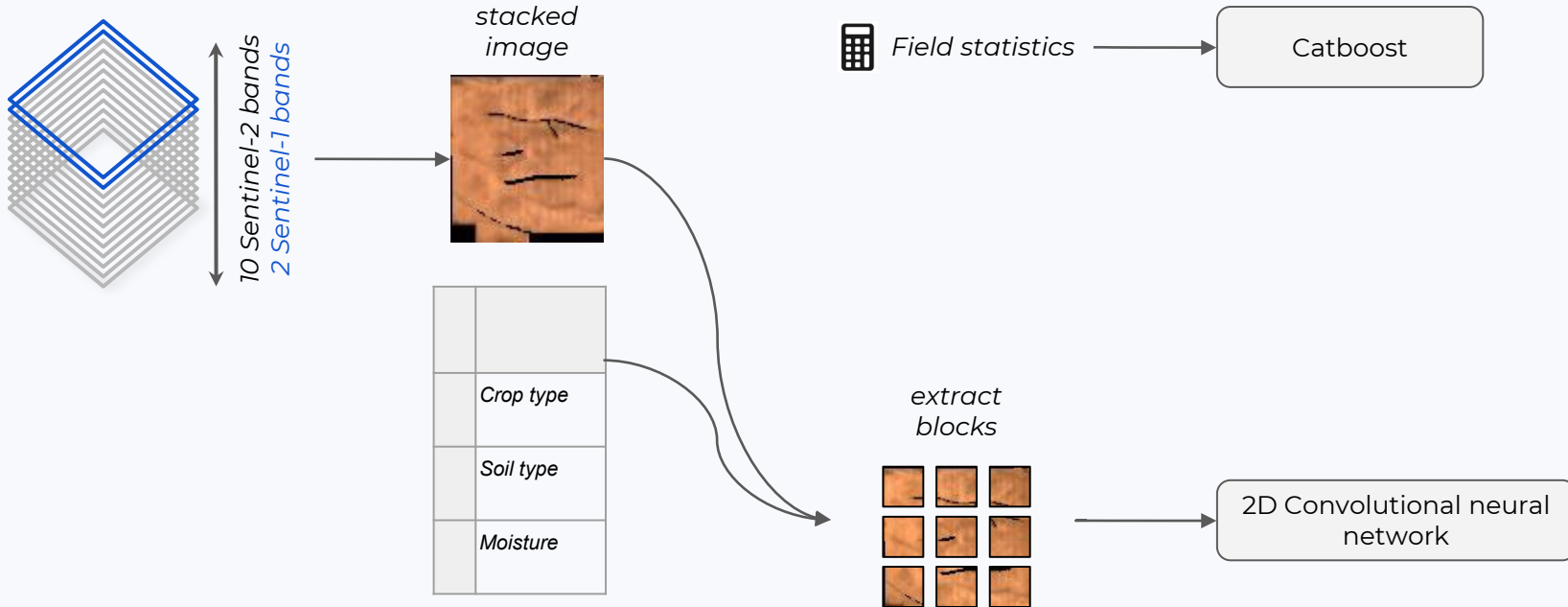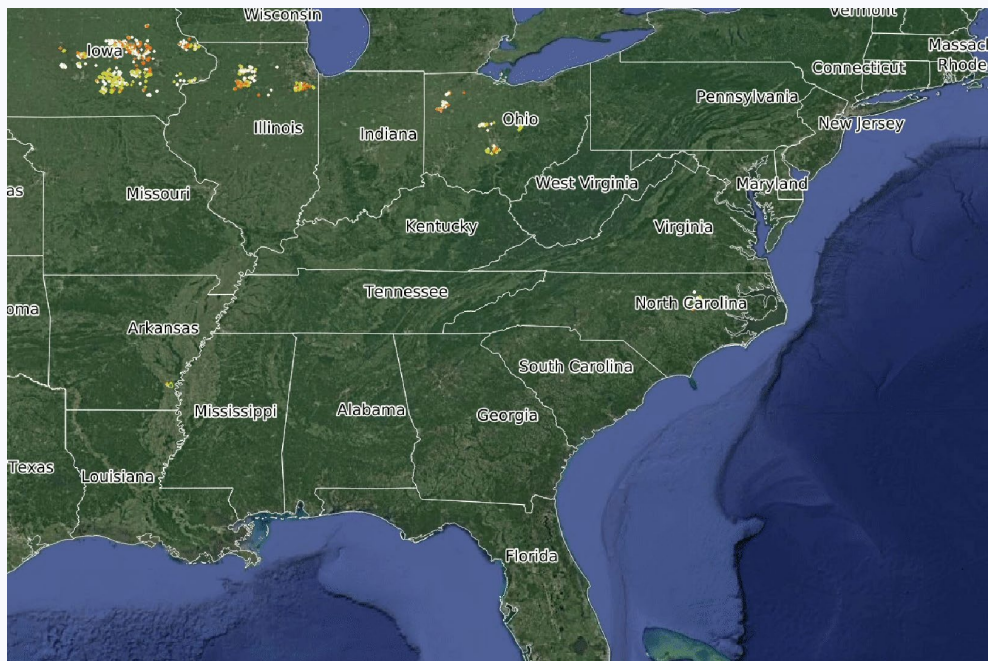
Ground truth data

Data preparation

- Field boundary detection from ground truth point data
- Collect Sentinel-1 and Sentinel-2 imagery for each field
  - Sentinel-2 cloud detection, segmentation and removal
- Remove fields with *NDVI > 0.3* - too much live vegetation to distinguish residue
- Additional categorical data per field
  - Crop type - from ground truth, or from crop-type-classification model for unvisited fields
  - Soil type - Soil Survey Geographic Database (SSURGO) USA
  - Moisture - ERA5, ECMWF Climate Reanalysis
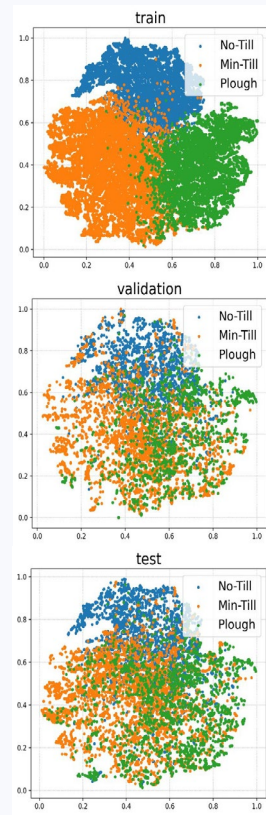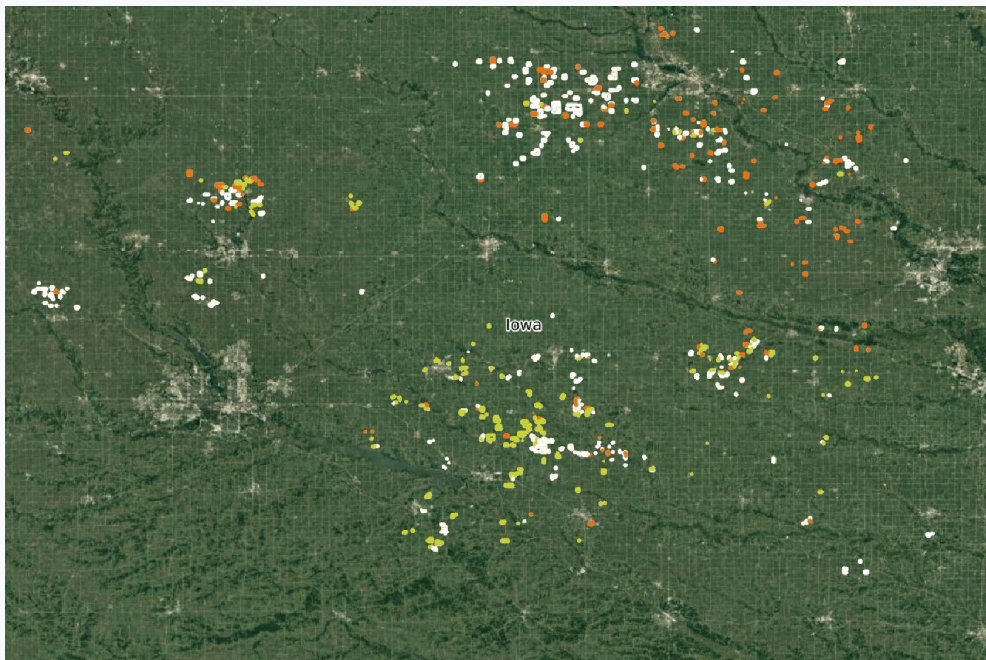- Data balancing and augmentation
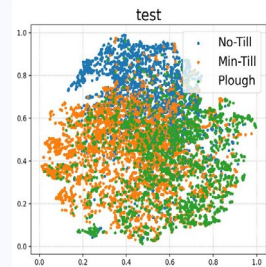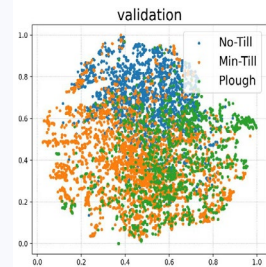 - rotation, flipping

Model overview

stacked image

10 Sentinel-2 bands
2 Sentinel-1 bands

Field statistics → Catboost

	Crop type
	Soil type
	Moisture

extract blocks

→ 2D Convolutional neural network
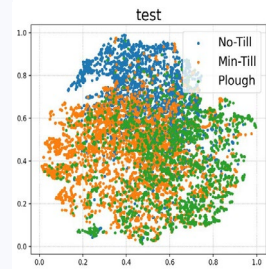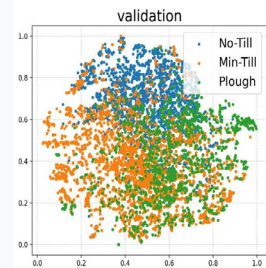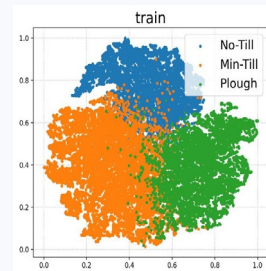
Results

Results

train

validation

test
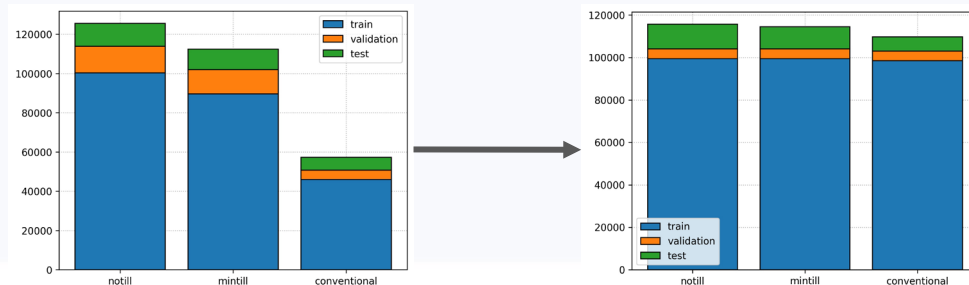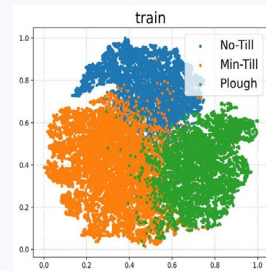
Results
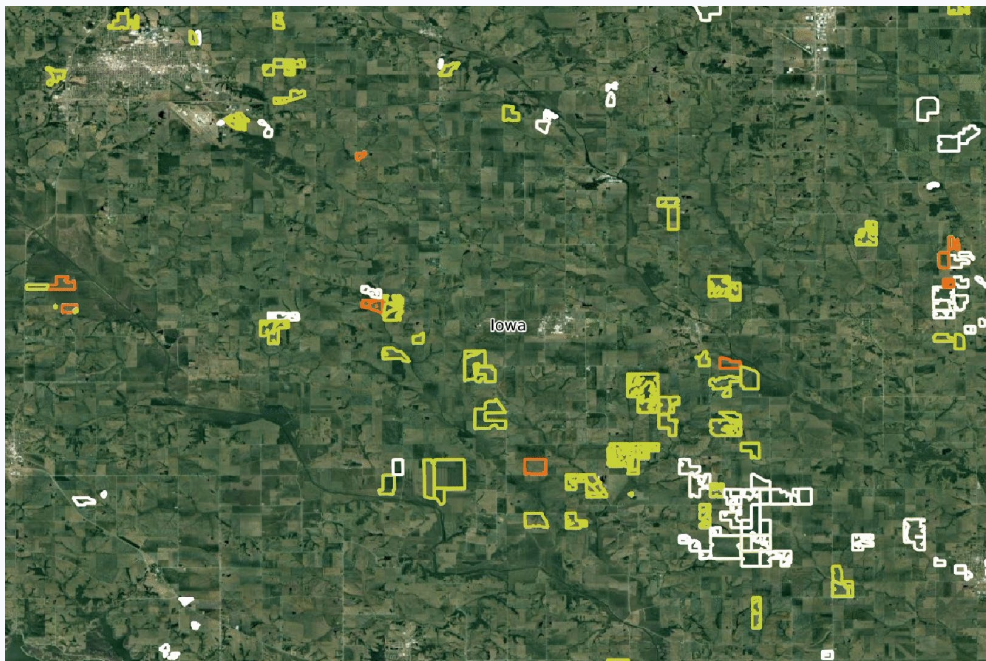
t-SNE plots

Next steps

- Ongoing data collection
- Expanding geographies
- Experiments
  - Clustering of GT data to identify outliers and noise
  - HLS - but not as replacement for Sentinel-2
  - Moisture from ERA5 or derive from Sentinel-1
  - Continuing to develop model architecture
- Time-series analysis

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