# Estimating Soil Parameters from DESIS Images using Deep Learning

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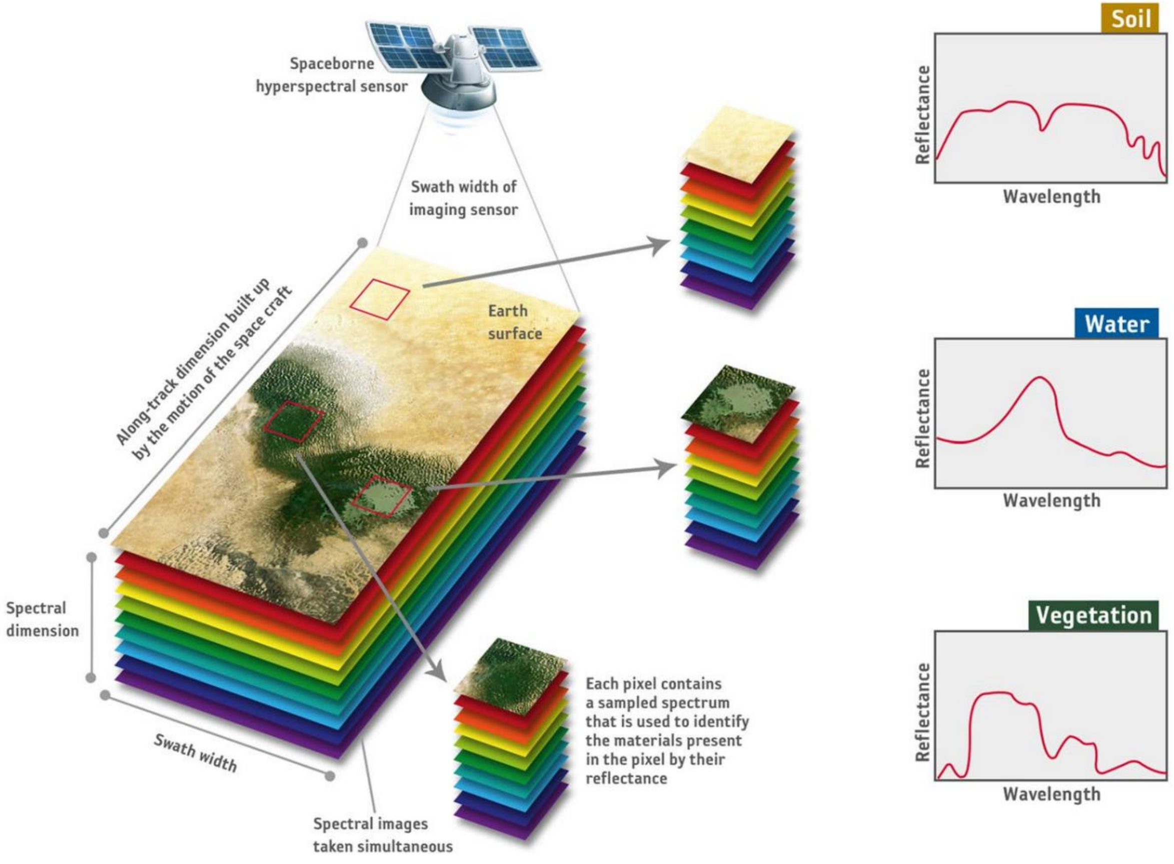
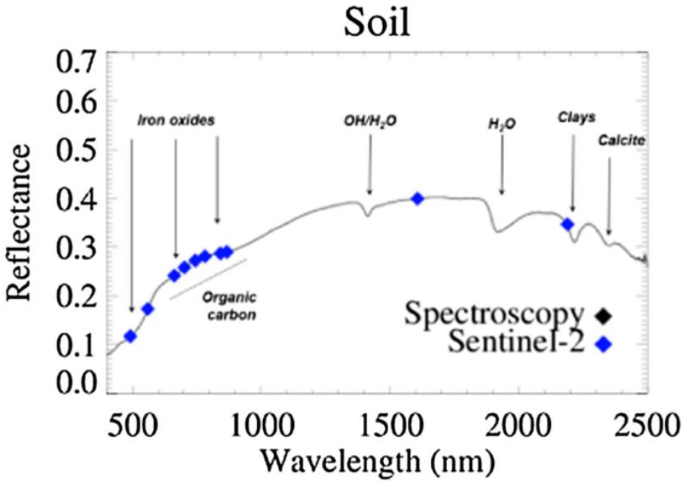
# Overview

- *Introduction*
- *Dataset*
- *Experiment Pipeline*
- *Data Selection, Preprocessing, Split*
- *Deep Learning methods*
- *Results (optional)*
- *Ablation study for soil texture*
- *Conclusions & Future Work*

# Introduction




Imaging spectroscopy




- *Spectral Reflectance could be used to estimate topsoil properties*
- *Hyperspectral Images could provide more detailed spectral information than multispectral ones*
- *Currently soil mapping using spectral reflectance is only conducted in small scales*
- *In this work, we use hyperspectral images (DESIS) to estimate soil parameter (Soil Organic Carbon) for a large area (Bavaria, Germany)*

Rast, Michael, and Thomas H. Painter. "Earth observation imaging spectroscopy for terrestrial systems: An overview of its history, techniques, and applications of its missions." Surveys in Geophysics 40.3 (2019): 303-331.

# Dataset

## *Soil property data*

- ***LFU (Bayerisches Landesamt für Umwelt):*** *2548 soil points information over the whole Bavaria, collected from 1953 to 2021, contain soil information like soil type, organic carbon, pH value, carbonate, etc.*

- ***LUCAS 2018 (Land Use and Coverage Area frame Survey):*** *18984 soil points information over the whole Europe, collected from 2018, contain soil information like pH value, organic carbon, CaCO3, P, N, K, land class, land usage, etc.*

## *Hyperspectral data*

- *DESIS (DLR Earth Sensing Imaging Spectrometer)*
  *spectral range: 400 – 1000 nm, spatial resolution: 30m,*
  *spectral resolution: 2.55nm*

# Experiment Pipeline

*L2A DESIS image*

↓

*Land Cover Mask*

↓

*Filter by NDVI*

↓

*Generate Temporal Composite*

↓

*SOC value & coordinates* → *Align Soil Samples with DESIS Composite*

↓

*Analyze with Soil Texture* ← *Soil Texture Map*

↓

*Data normalization and augmentation*

↓

*Train and test different frameworks*

↓

*Soil Organic Carbon Value*

# Data Selection, Preprocess, Split

***Soil Data Selection Criterion:***

- *only within Bavaria region (for LUCAS)*
- *land use is agriculture (for LUCAS)*
- *soil samples later than 2000 (for LFU)*
- *available DESIS images*

***1171 points:***
***1048 LFU, 123 LUCAS***

***755 points aligned with DESIS***

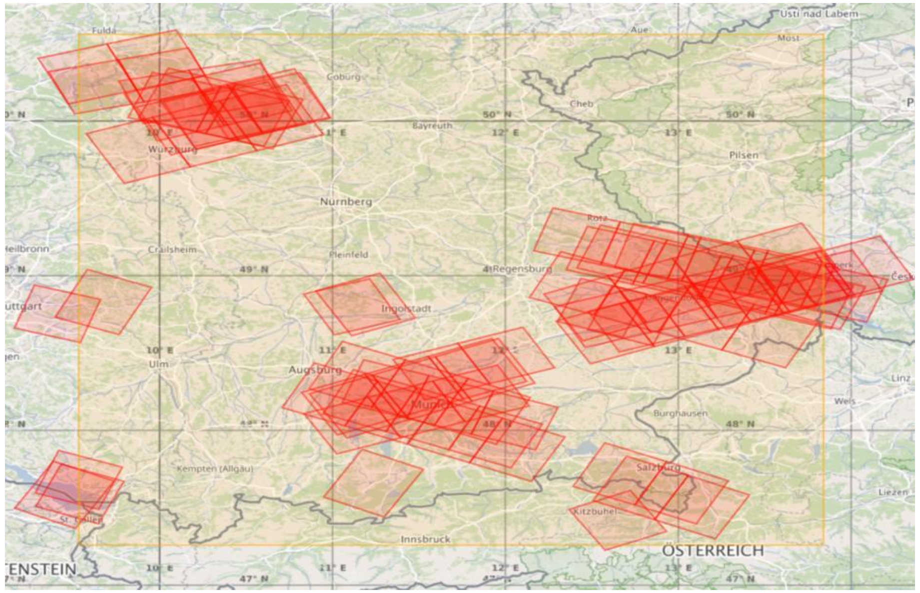
***Calibration: 595 points***

***Test: 160 points***

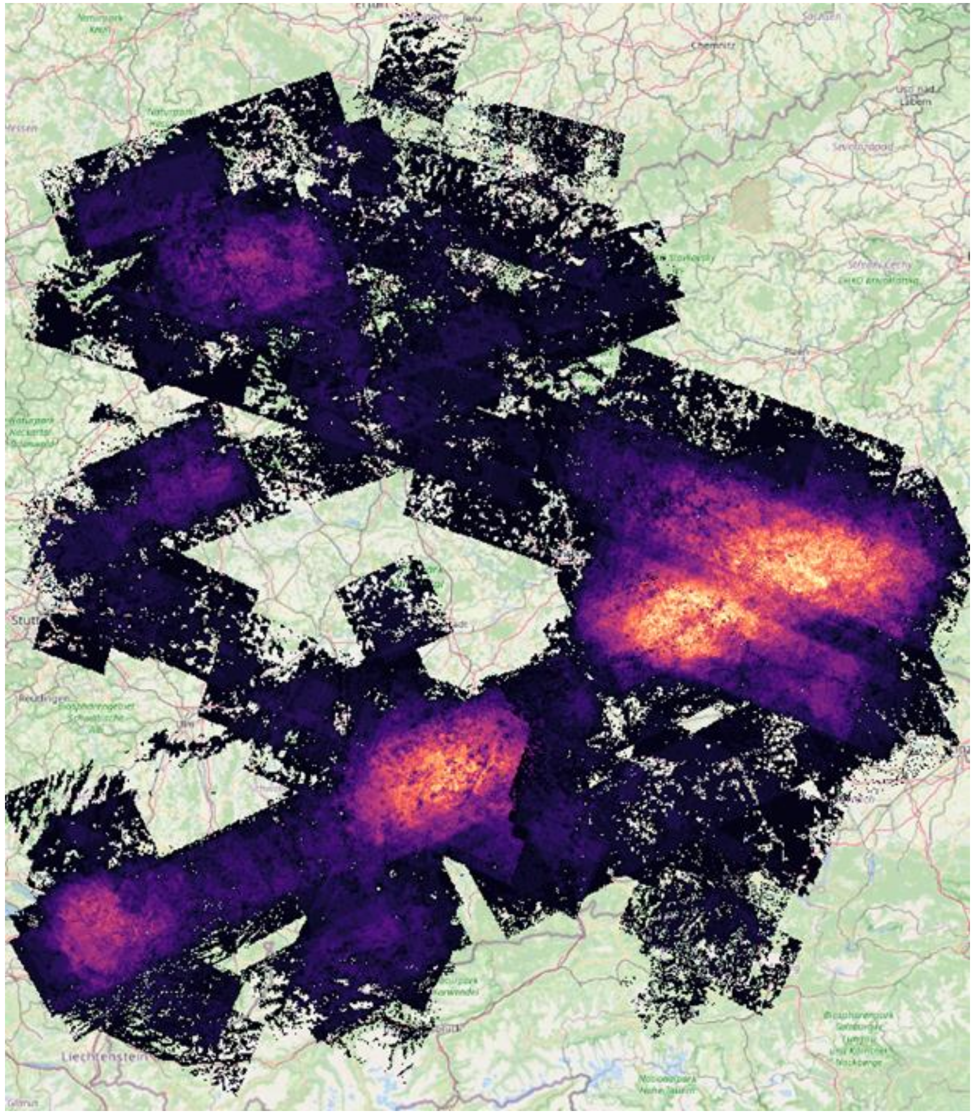
# Data Selection, Preprocess, Split

*Bavaria range:*
- *Latitude: 47.26N – 50.56N*
- *Longitude: 9.53E – 13.84E*

*In total,603 images in data portal. After data cleaning, 560 available images.*

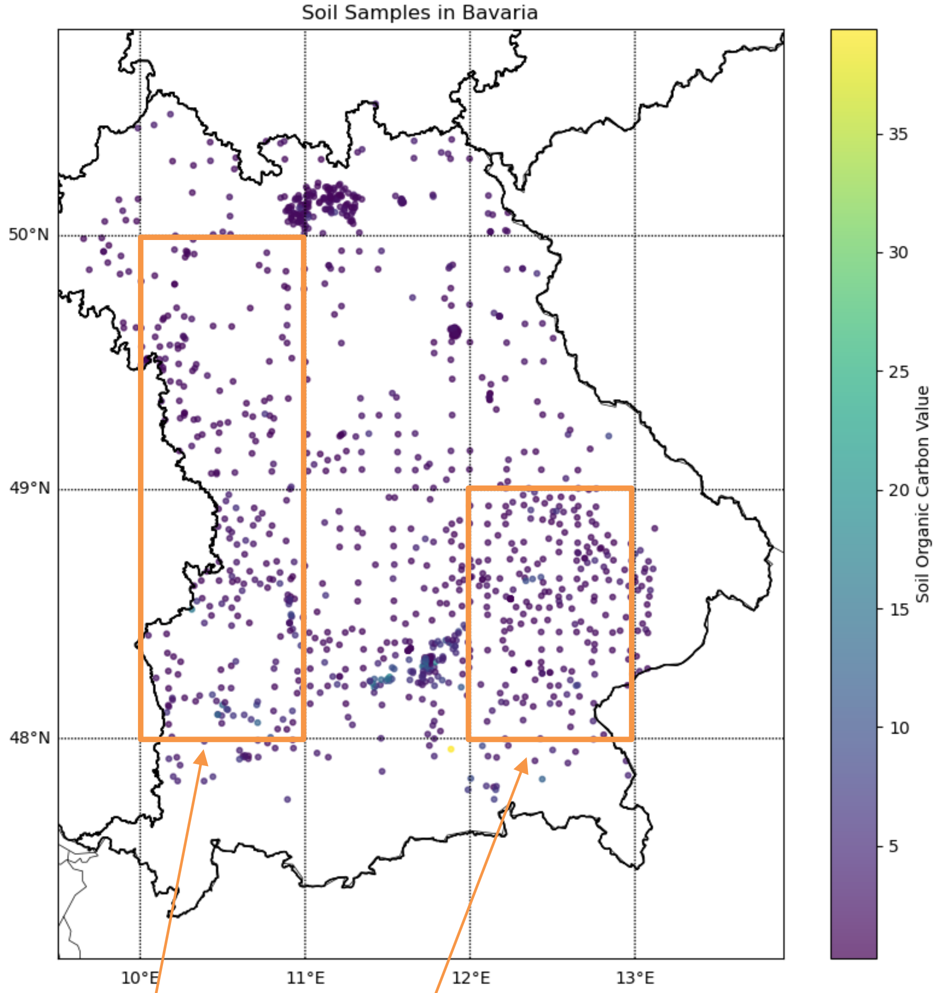


*100 DESIS images example in data portal*



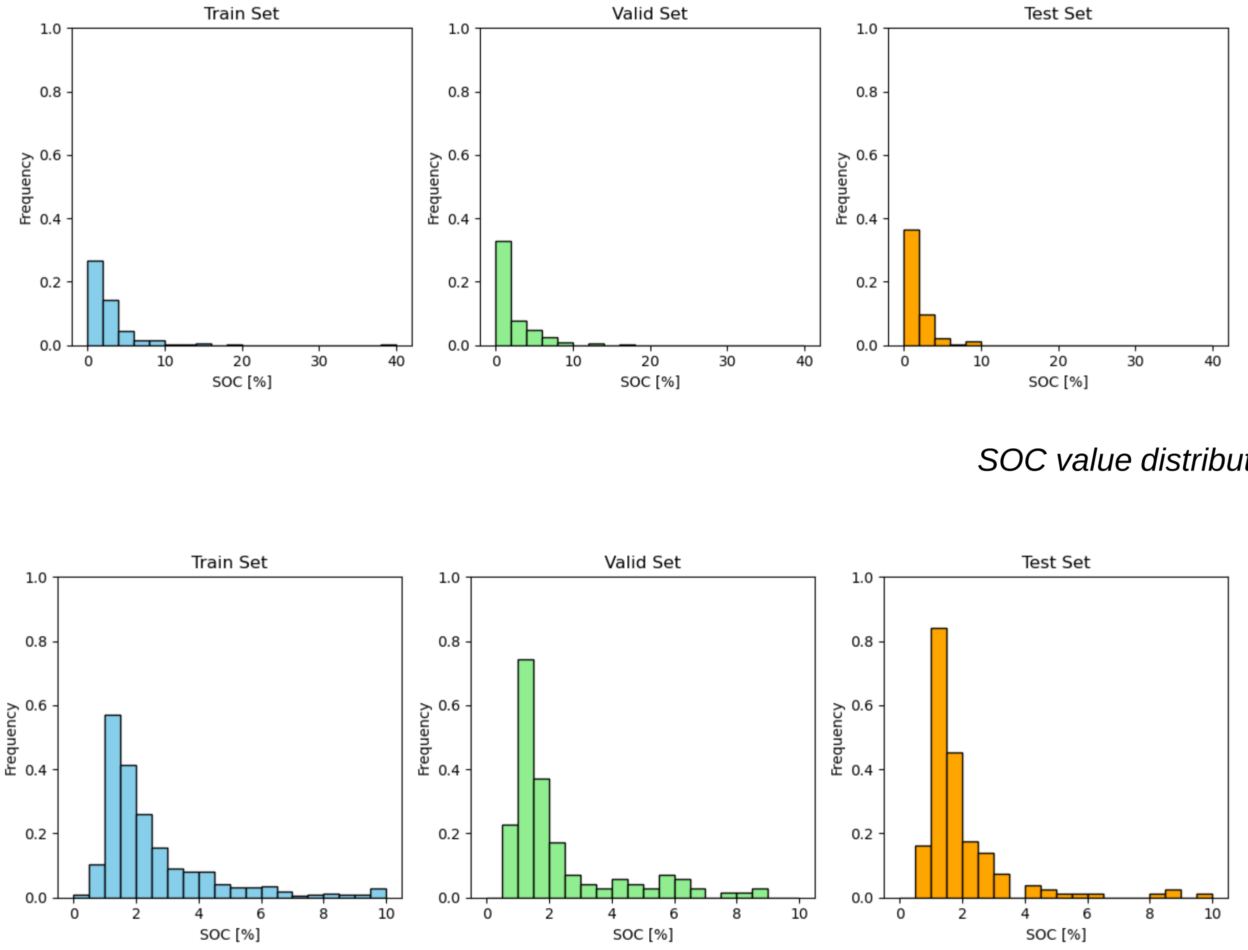
*DESIS frequency heat map in Bavaria*

# Data Selection, Preprocess, Split




*Valid Area*

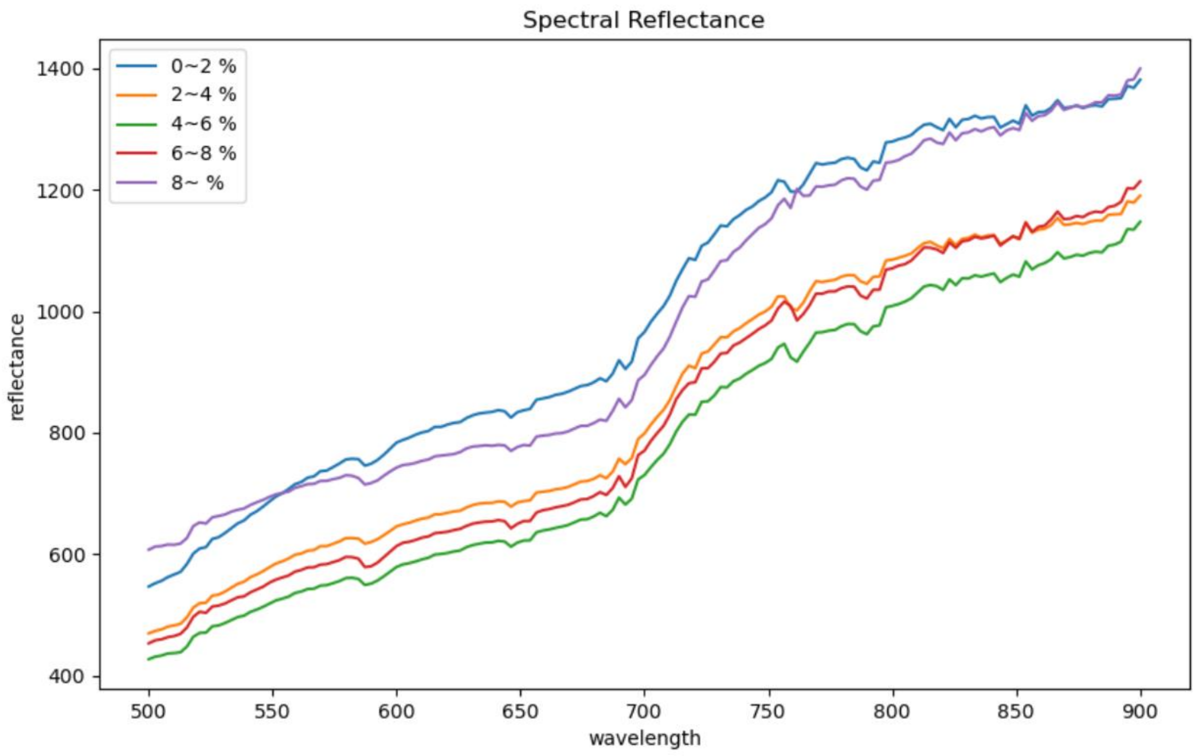
*Test Area*




*SOC value distribution*

# Data Selection, Preprocess, Split

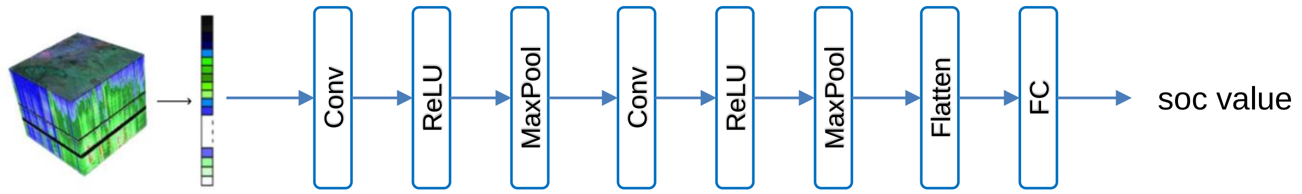
*Spectrum for different SOC value:*




*From the spectrum plots, different SOC values could show different spectral reflectance, which provides information for feeding the deep learning models*

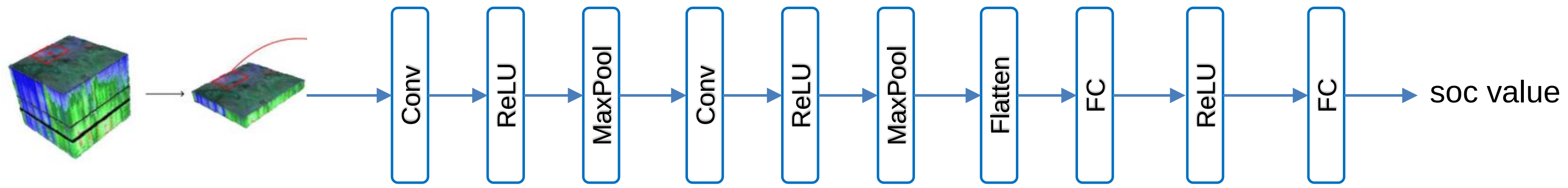
# Deep Learning Frameworks

*Spectral based: 1D CNN, RNN, LSTM, Self Attention*
*(The input image patch would be first averaged into a one-dimensional spectral vector)*




*1D CNN structure*

*Spatial based: 2D CNN*
*(The input image patch would be first converted into an image with 3 channels using PCA)*

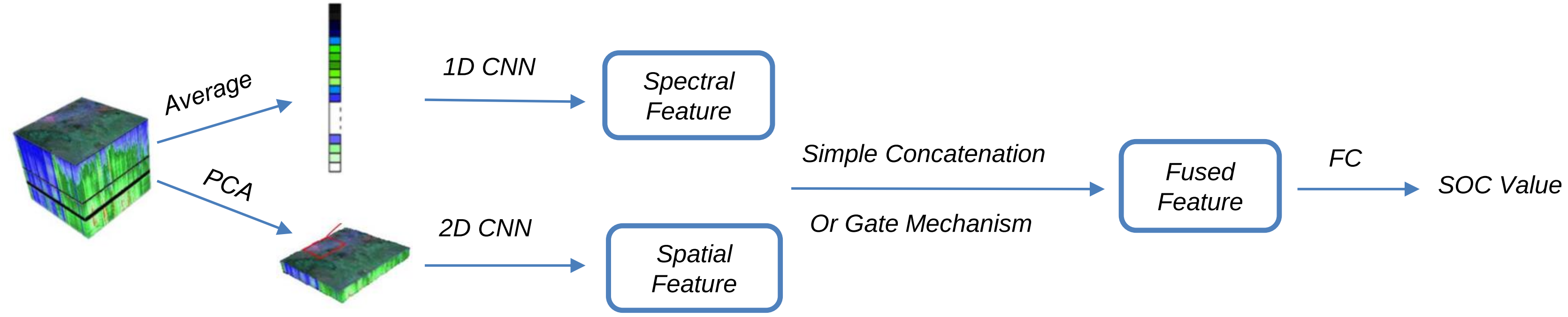



*2D CNN structure*

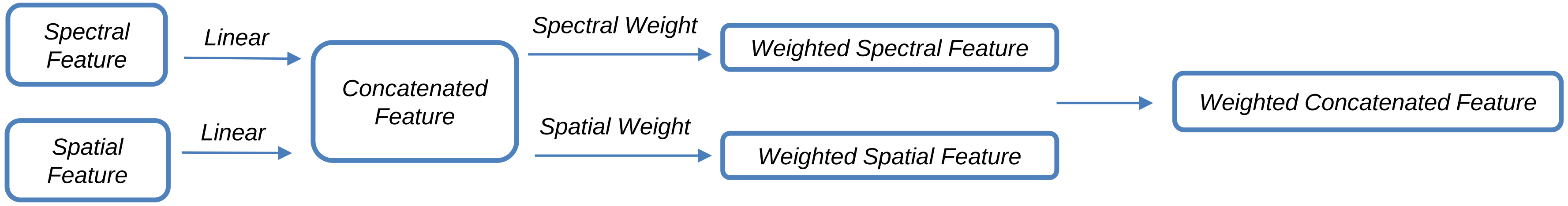

Chen, Yushi, et al. "Deep learning-based classification of hyperspectral data." IEEE Journal of Selected topics in applied earth observations and remote sensing 7.6 (2014): 2094-2107.

# Deep Learning frameworks

*Spectral + Spatial based: 1D CNN + 2D CNN (Concatenation), 1D CNN + 2D CNN (Gated Mechanism)*




*Gate Mechanism:*

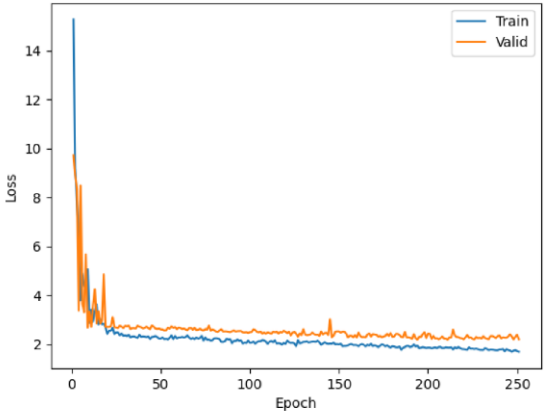



*( Spectral Weight + Spatial Weight = 1 )*

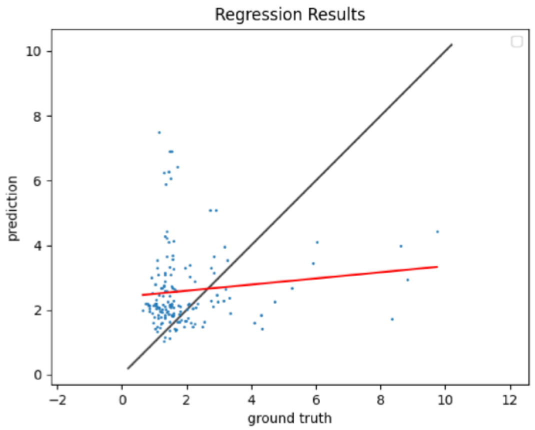
# Result ( Optional to present )

| *Framework* | *RMSE (Train)* | *RMSE(Valid)* | *RMSE(Test)* |
|---|---|---|---|
| *1D CNN* | *2.875* | *2.174* | *1.901* |
| *2D CNN* | *3.234* | *2.488* | *1.497* |
| *1D CNN + 2D CNN, Concatenation* | *0.934* | *2.455* | *2.453* |
| *1D CNN + 2D CNN, Gated fusion* | *3.194* | *2.489* | *1.485* |

*1D CNN*

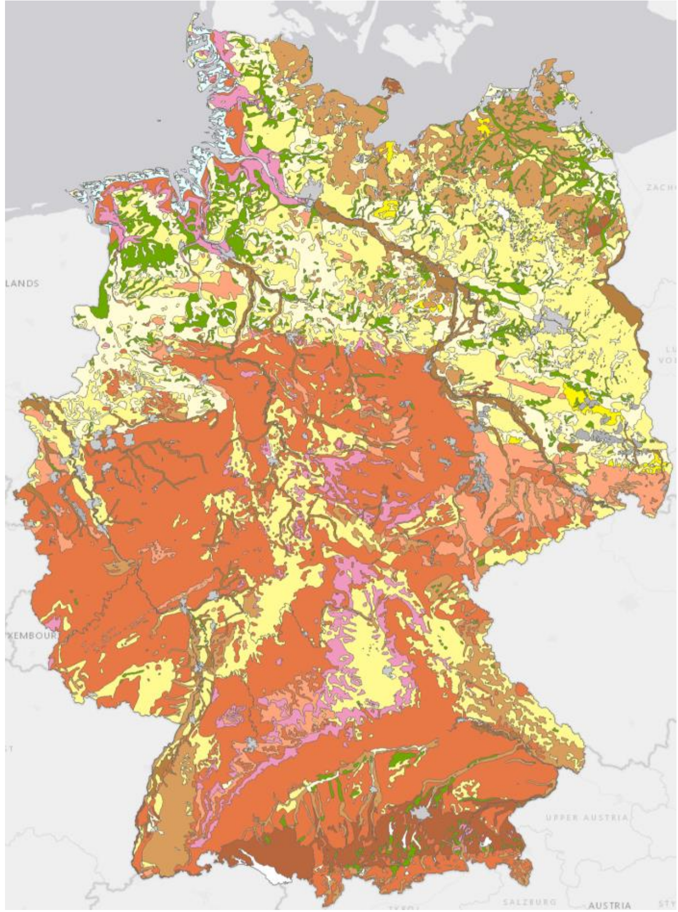



*Loss curve for train and valid*

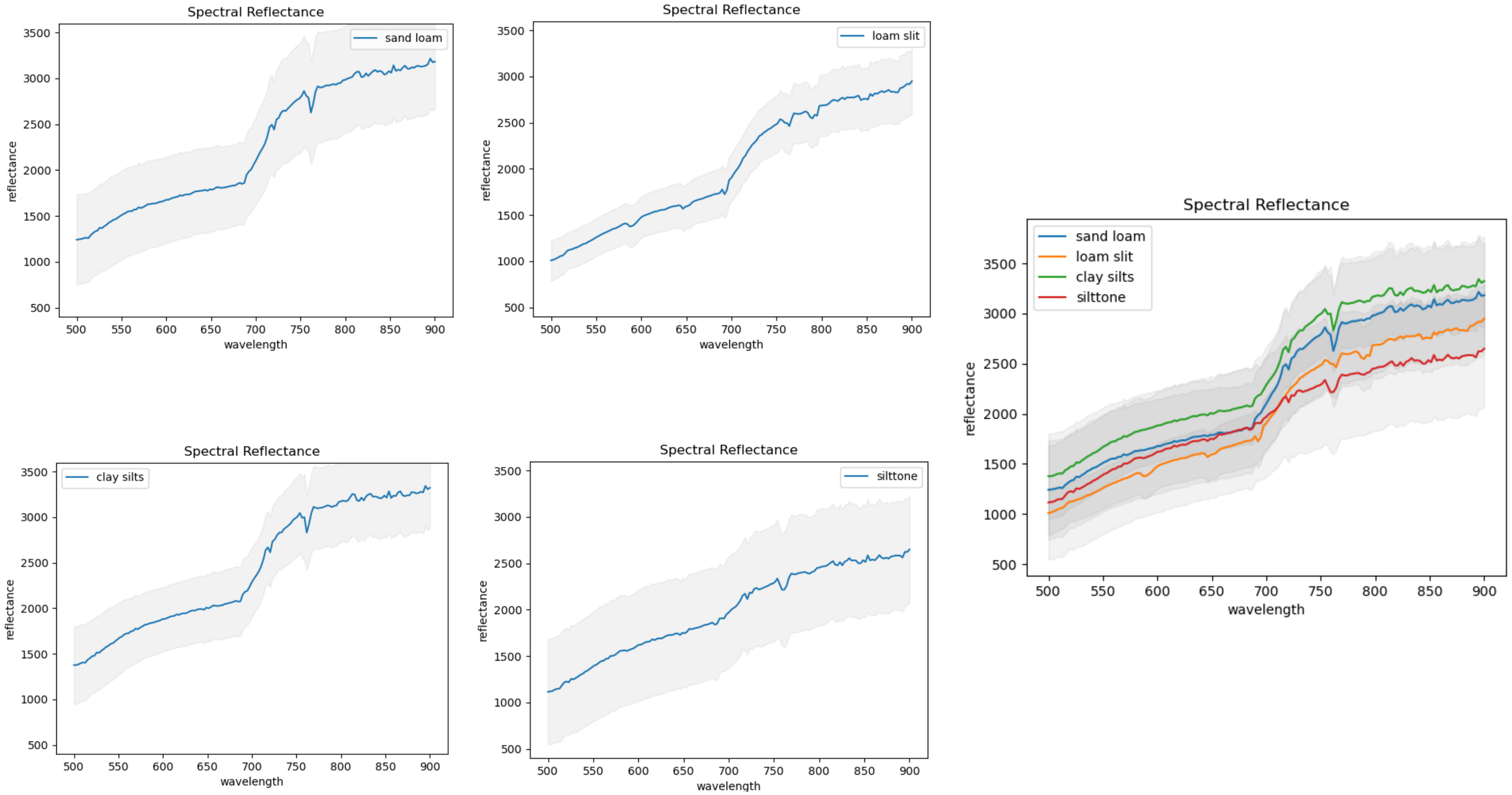



*Ground truth value and prediction for test [%]*

# Ablation Study: Spectrum for different soil texture



Soil Texture data from BGR
(Bundesanstalt für Geowissenschaften und Rohstoffe)




*Spectrum example*
*(sand loam, loam silt, clay silts, silttone)*

# Conclusion & Future Work

***Conclusions:***

- *Different SOC value range could show different spectrums from DESIS hyperspectral images*
- *Different soil textures could show different spectrums from DESIS images*
- *Deep Learning methods such as 1D CNN and 2D CNN could be implemented for SOC estimation, but the models would suffer from the imbalanced distribution for SOC distribution, especially the minority high SOC values (optional)*

***Future Work:***

- *Further tune the deep learning frameworks against the imbalanced distribution*
- *Incorporate soil texture data into the deep learning model*
- *Add spatial distance information among soil points for semi-supervised learning*

# Questions?