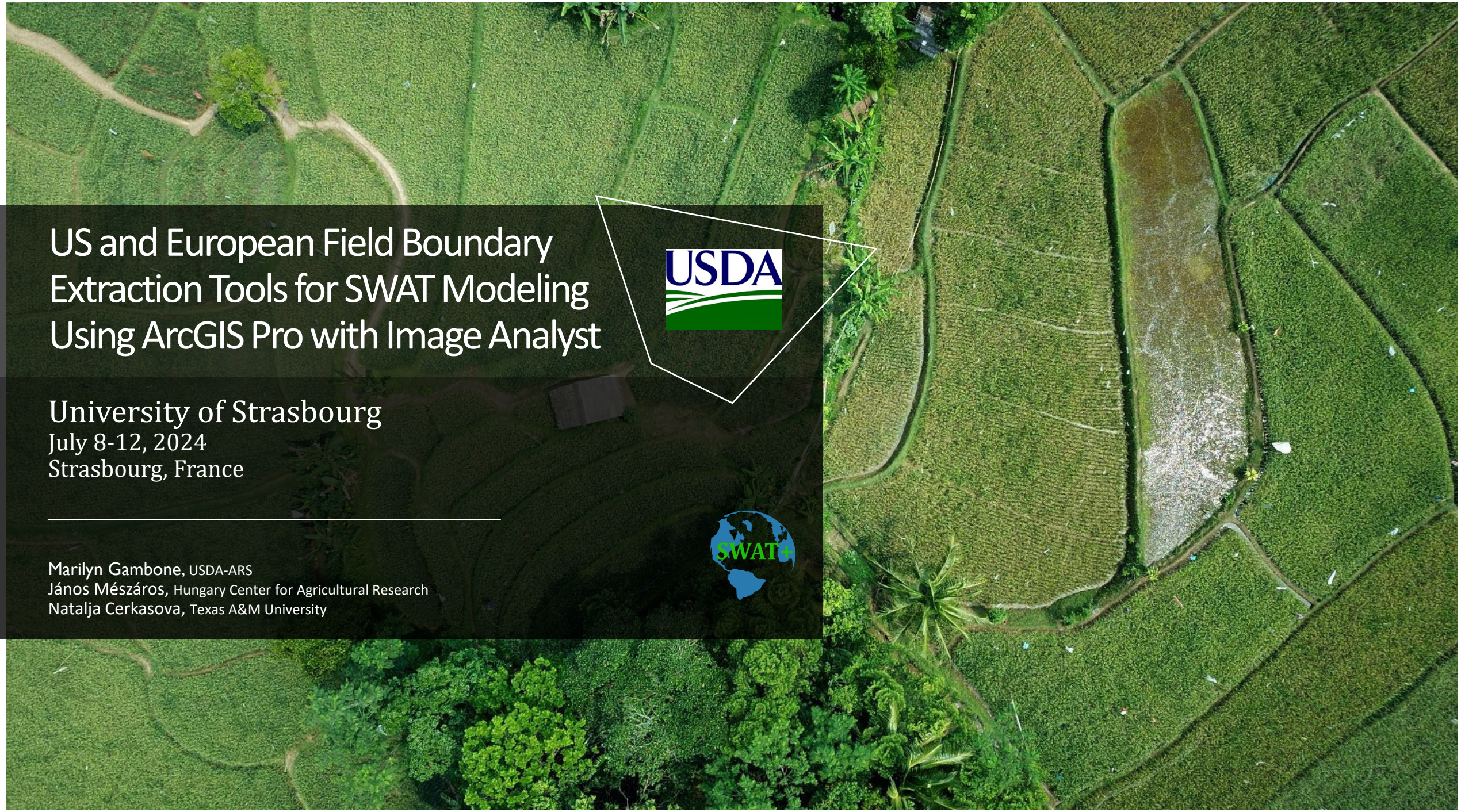

US and European Field Boundary Extraction Tools for SWAT Modeling Using ArcGIS Pro with Image Analyst

University of Strasbourg
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Strasbourg, France

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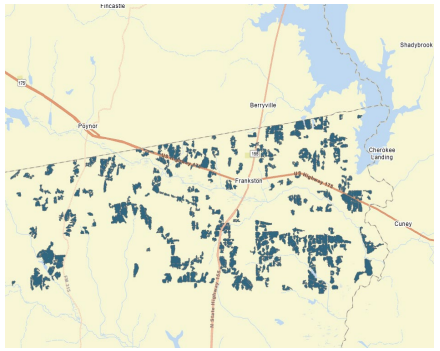
Natalja Cerkasova, Texas A&M University

The Problems

Lack of Field Boundary Data

Field boundary data are usually private or proprietary



Sparse data

Those available do not cover entire area of interest (pastures, grassland)

Boundary edge problems

Difficult to determine edge boundaries, e.g., between pastures and grassland (herbaceous)

Digitizing Problems

Manual digitization can be labor-intensive and error-prone

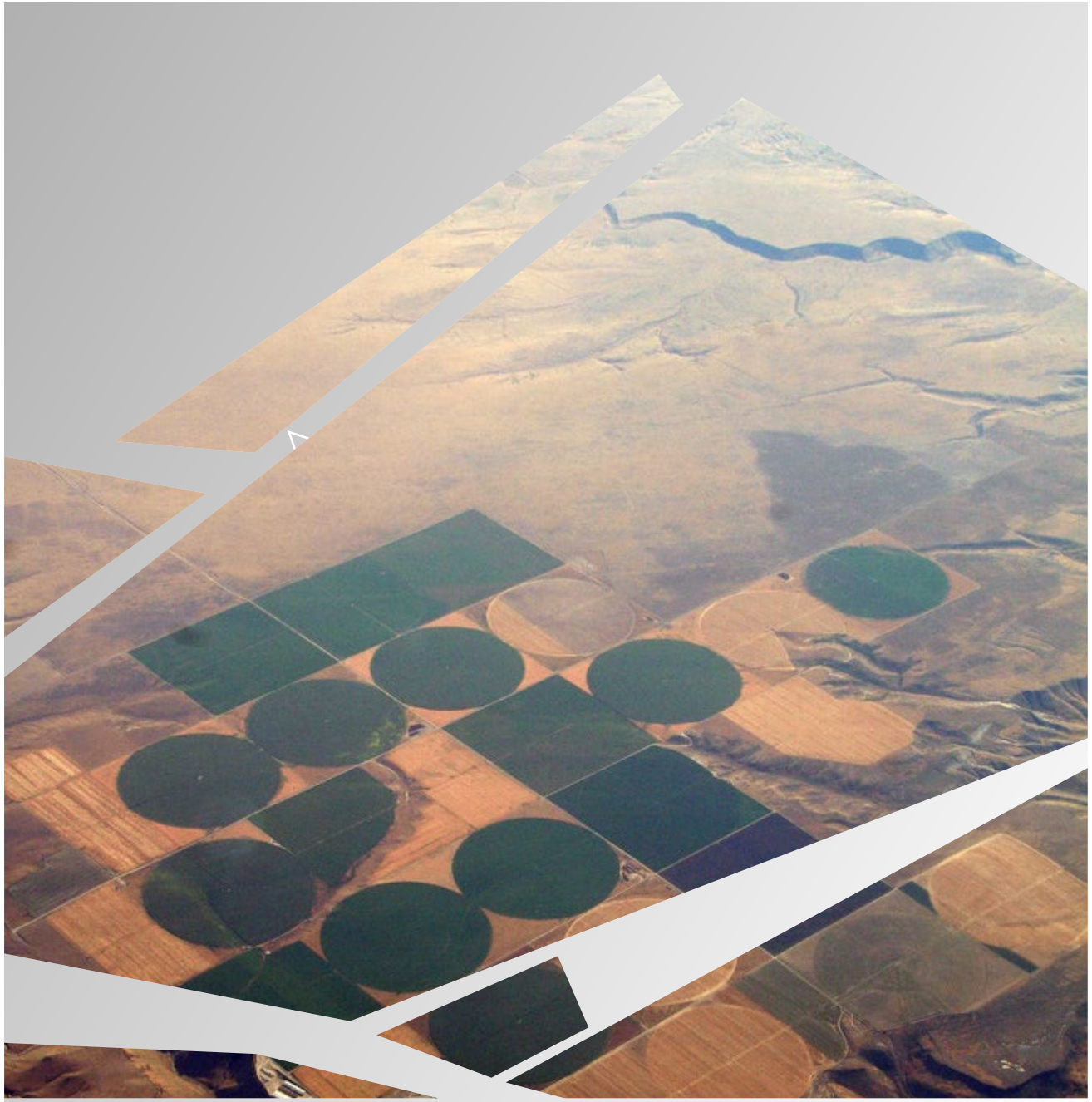
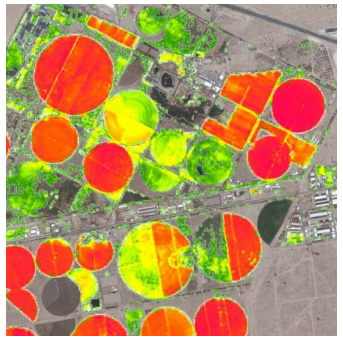


Photo Credit: *https://live.staticflickr.com/4090/5155933746_999df2c378_b.jpg*

Proposed Solution



- Deep Learning
- Train Deep Learning models using high resolution satellite imageries

Photo Credit: *https://live.staticflickr.com/4090/5155933746_999df2c378_b.jpg*

Use ArcGIS Pro

With Image Analyst Extension

Photo Credit: *https://geospatialtraining.com/wp-content/uploads/2016/07/arcgispro2.png*

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Deep Learning Models

Using ArcGIS Pro with Image Analyst

Photo Credit: *https://dronevideoaerialphotography.com/wp-content/uploads/2018/09/02_Services_Agriculture.jpg*

Issues with Deep Learning Models

- Deep learning methods require specialized hardware making their implementation difficult to achieve.
- Satellite imageries involve large number of images as well as high pixel counts, making them computationally expensive to analyze.
- Deep learning models require a huge volume of **training data** which are difficult to obtain.
- Unlike ArcGIS Pro, high-powered-computers (HPC) and open-source algorithms could not handle big satellite imageries. We needed to break up a single satellite imagery into multiple "chunks" so the open-source algorithms could analyze them, thereby increasing the complexity of extracting the edge boundaries. We haven't been successful to date in training the model using HPC.

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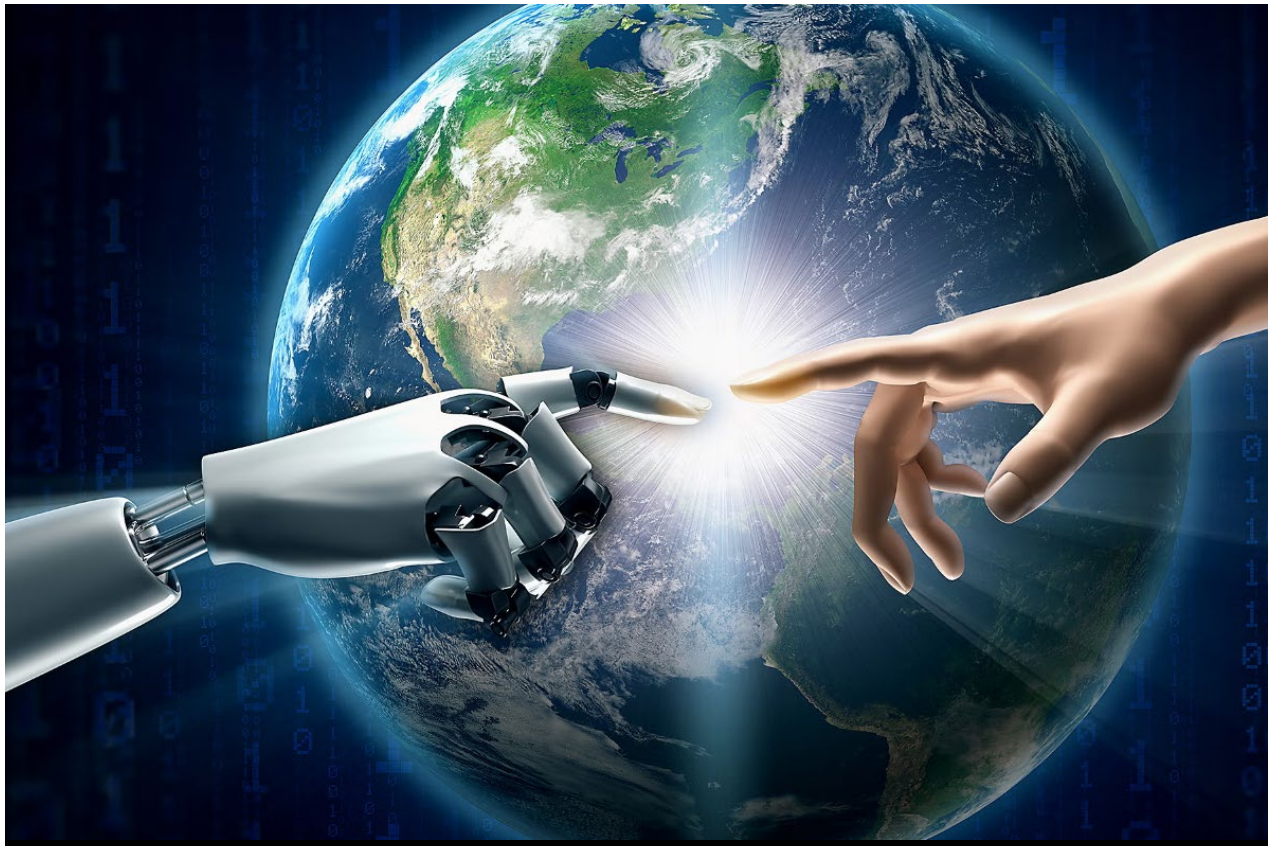

ArcGIS Pro with Image Analyst

For Deep Learning Models

Photo Credit: *https://static.independent.co.uk/s3fs-public/thumbnails/image/2017/01/11/12/artificial-intelligence-3.jpg*

Pre-trained Models

- Instantly extract features using your own satellite imageries
- Eliminates the need to create your own training data and develop models

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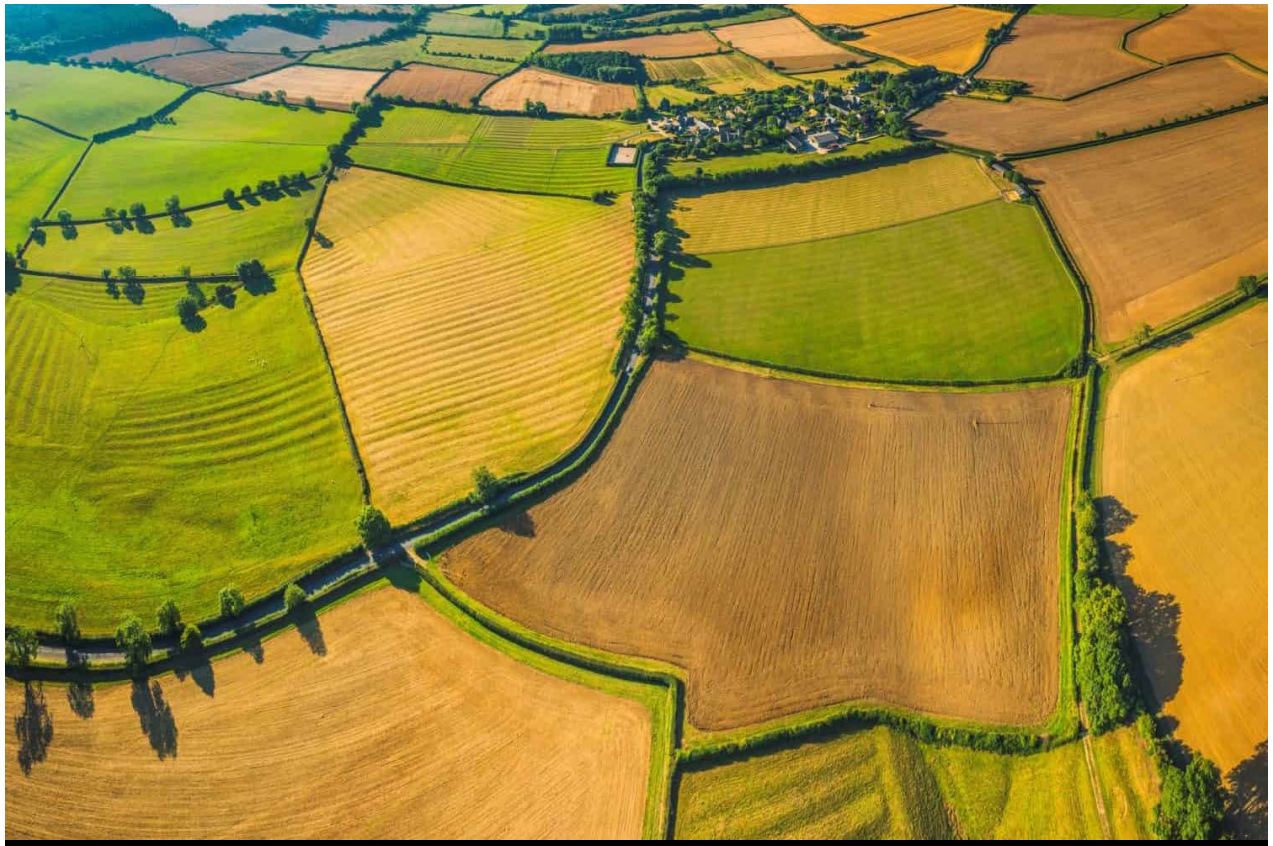

ArcGIS Pro with Image Analyst

Pre-trained Field Boundary Extraction Tool for US

Photo Credit: *https://foodtank.com/wp-content/uploads/2017/08/iStock-485627208-e1501593235134.jpg*

SWAT Farm Model

- Used Holistically-Nested Edge Detection (HED) model
- Used National Agricultural Imagery Program (NAIP) orthographic images at ~1-meter resolution (*https://nrcs.app.box.com/v/naip*)
- Trained on 10,682 polygon samples from Bell County, Texas
- Model accuracy: 72%

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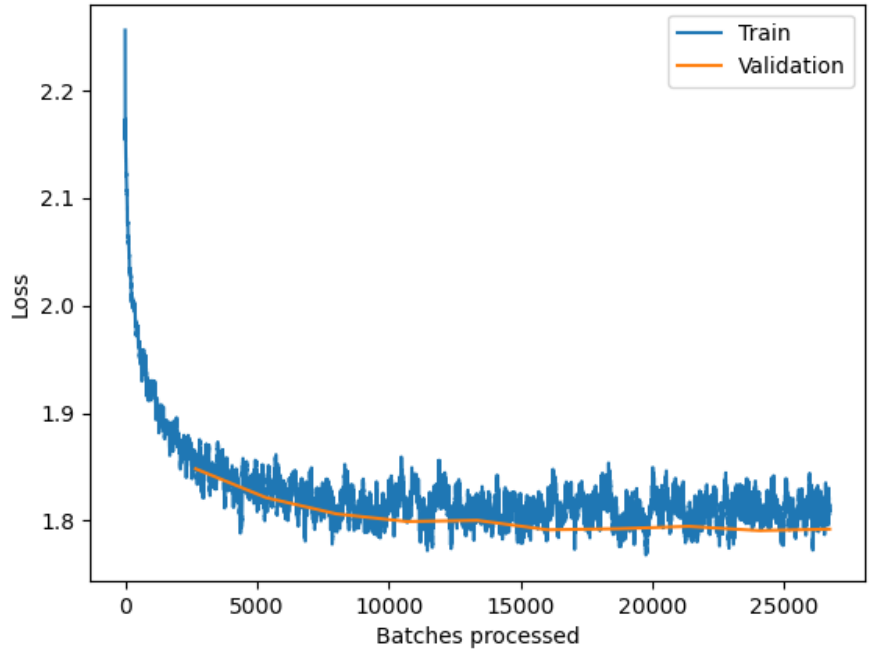
SWAT Farm HED Model Validation Graph

HEDEdgeDetector

Backbone: resnet34

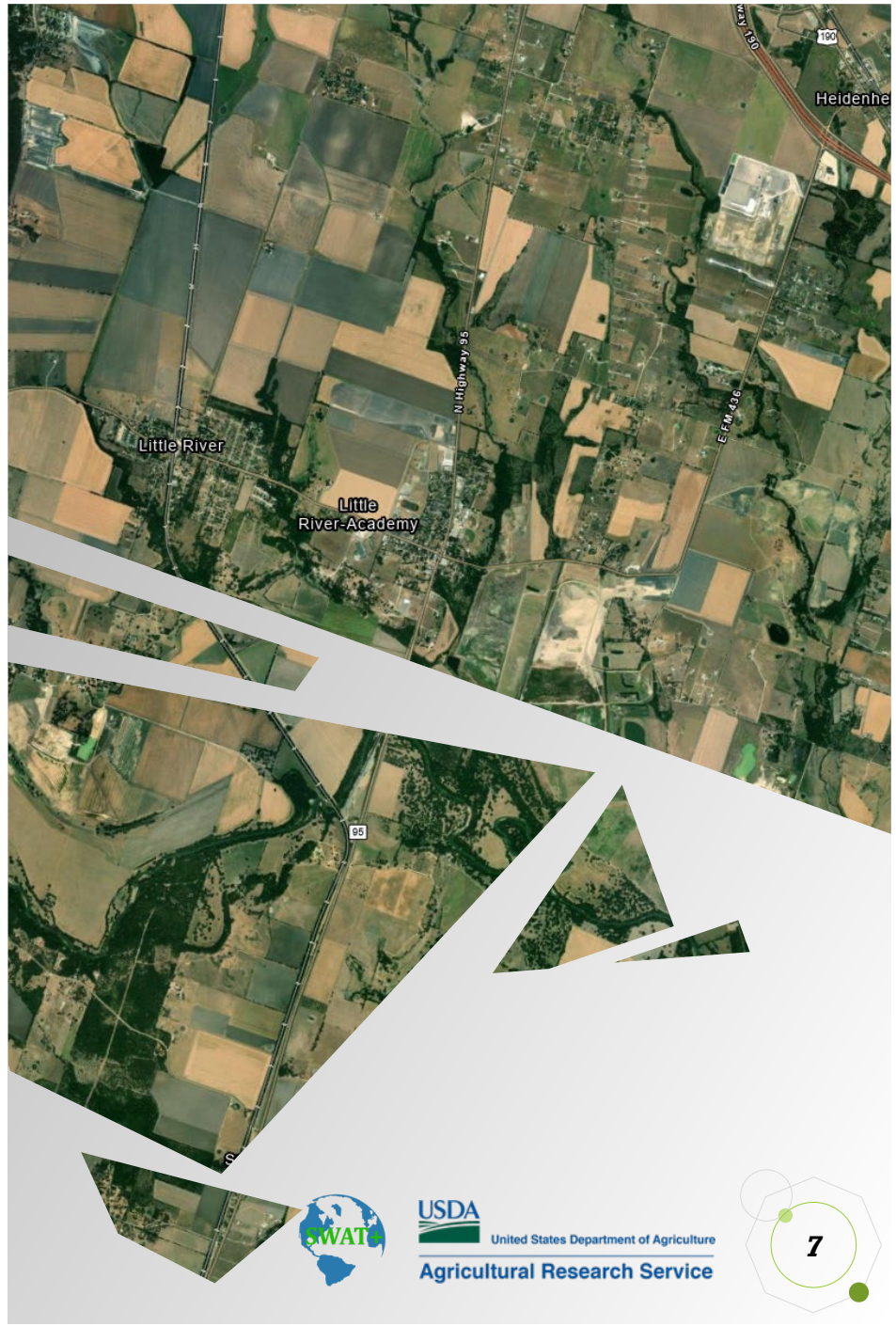
Learning Rate: slice('2.5119e-04', '2.5119e-03', None)

Training and Validation loss



Analysis of the model

Accuracy: 7.2080e-01



How it Works…

1 Raster Data Preparation (NAIP)

- **Contrast enhancement**: Use Stretch (Sigmoid type-Level 6) raster function to enhance edges
- **Noise reduction**: Apply Convolution (Smooth 3x3) raster function

2 Classify Pixels Using Deep Learning

- Run the *SwatFarmHedModel.dlpk* using your satellite image as input
- Convert the output raster to polygon

3 Post-Processing – ArcGIS Pro

- Add area (acre) field; Calculate Geometry
- Select and export features >= 2.4 acres (this is your field boundaries)
- Overlay streets, rivers other water bodies
- Run Multipart to Singlepart function
- Eliminate polygon parts < 0.5 acre (mostly noise)
- Recalculate Geometry for area
- Filter the fields again; delete fields < 2.4 acres (10,000 sq meters)
- Simplify and smooth polygons to remove jagged edges

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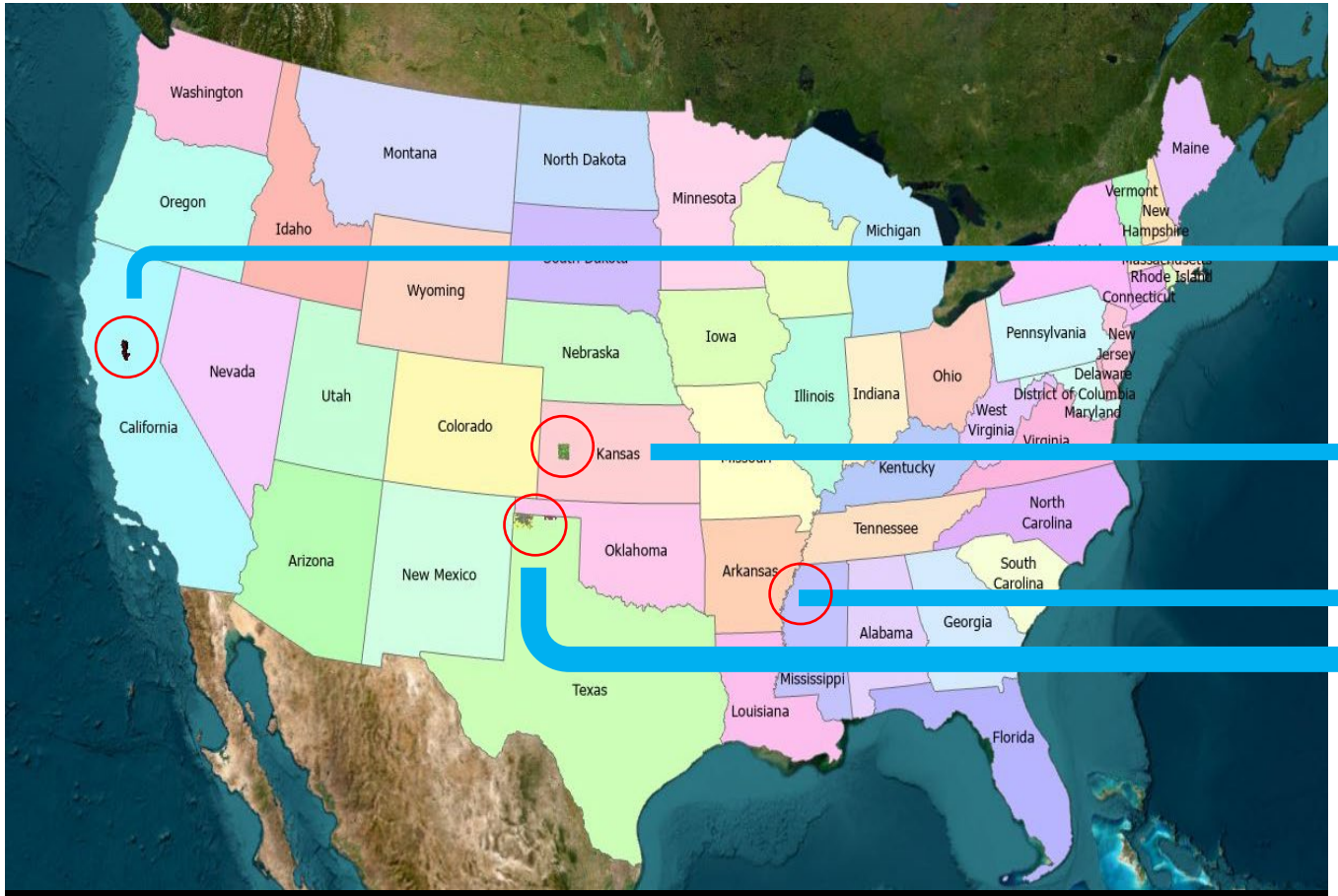
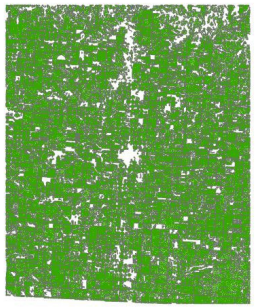


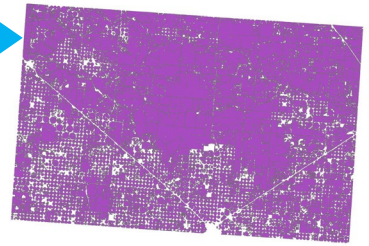
US Model Output

Post-Processed Polygons

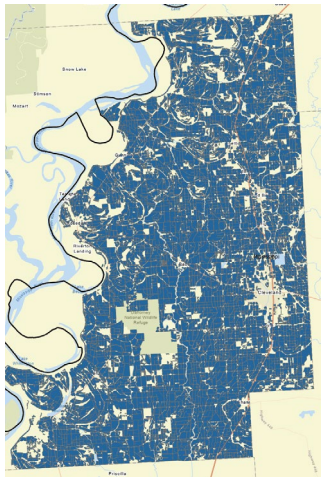
Sutter County, **California**

Scott County, **Kansas**





Dallam County, **Texas**



Bolivar County, Mississippi

Photo Credit: *https://i.pinimg.com/originals/63/cd/4e/63cd4e2fa82a66741af93229aa3dd13b.jpg*

Photo Credit: *https://gisgeography.com/hungary-map/#Satellite-Map*

Hungary Field Boundary Model

ArcGIS Pro with Image Analyst

Pre-trained Field Boundary Extraction Tool for Europe

Hungary Field Boundary Tool

- Used Holistically-Nested Edge Detection (HED) model algorithms
- Used 2018 Sentinel-2 imagery, with spectral bands B, G, R, NIR (in that order) and spatial resolution of 10 m/pixel using Hungarian national coordinate system (EPSG 23700)
- Used the Northwest part of the country for Autumn season in training the model
- Trained the model using 2,318 manually digitized samples
- Model Accuracy: 78.5%

Photo Credit: *https://www.amazingarchitecture.com/photos/5/BORD%20Architectural%20Studio/Sauska%20Winery/Sauska_Winery_BORD_Architectural_Studio_Hungary_001.jpg*

SWAT+ USDA United States Department of Agriculture Agricultural Research Service

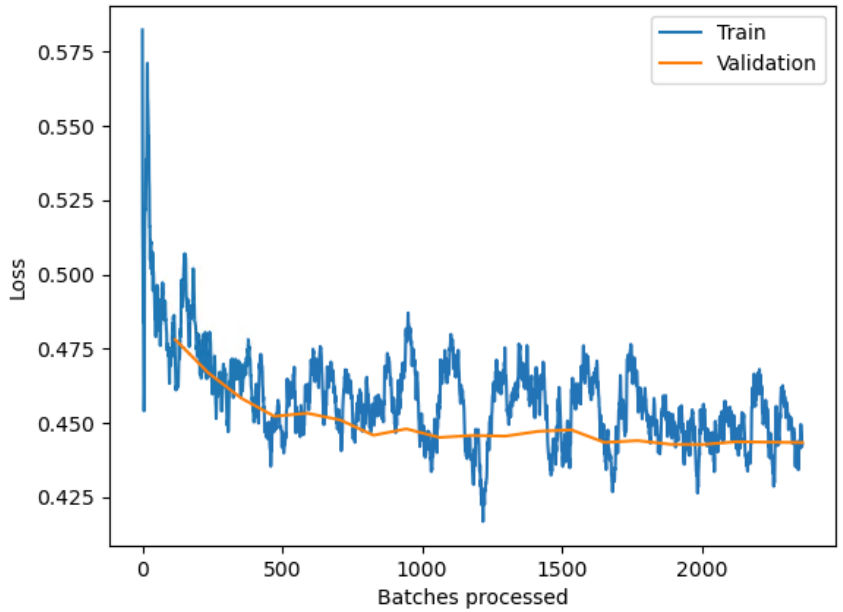
Hungary HED Model Validation Graph

HEDEdgeDetector

Backbone: resnet34

Learning Rate: slice('2.5119e-04', '2.5119e-03', None)

Training and Validation loss



Analysis of the model

Accuracy: 7.8517e-01

Sample Results

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Agricultural Research Service

How it Works…

1 Raster Data Preparation

- Satellite-2 imagery don't have as much noise as the NAIP imagery;
- Used as is

2 Classify Pixels Using Deep Learning

- Selected the coordinate system Hungary: EPSG 23700 (Hungarian National Coordinate System)
- Convert output raster to polygon

3 Post-Processing – ArcGIS Pro

- Add area (acre) field; Calculate Geometry
- Select and export features >= 2.4 acres (this is your field boundaries)
- Eliminate polygon parts < 0.5 acre (mostly noise)
- Recalculate Geometry for area
- Filter the fields again; delete fields < 2.4 acres (10,000 sq meters)
- Simplify and smooth polygons to remove jagged edges

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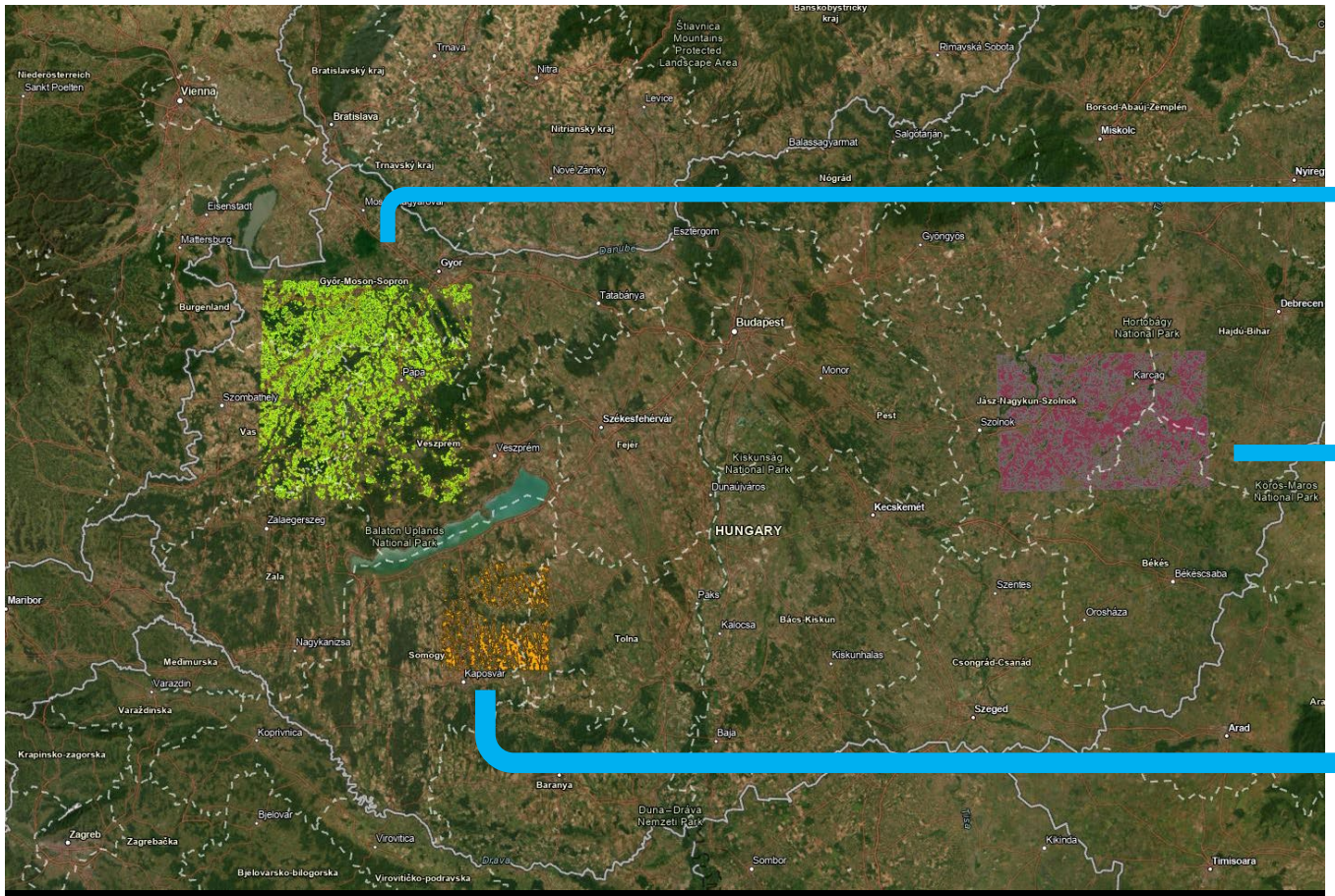
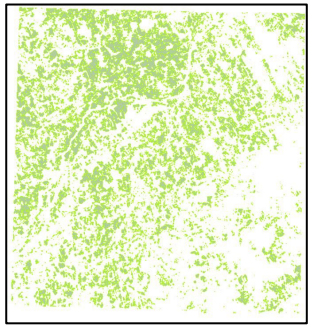
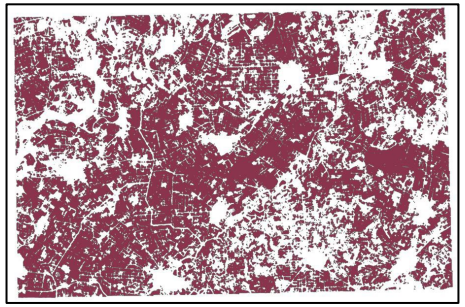


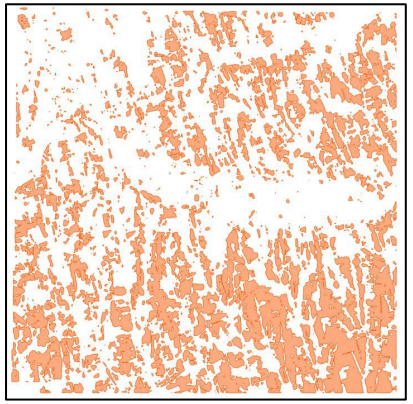
Northwest Hungary



East Hungary



Southwest Hungary



Hungary Model Output

Post-Processed Polygons

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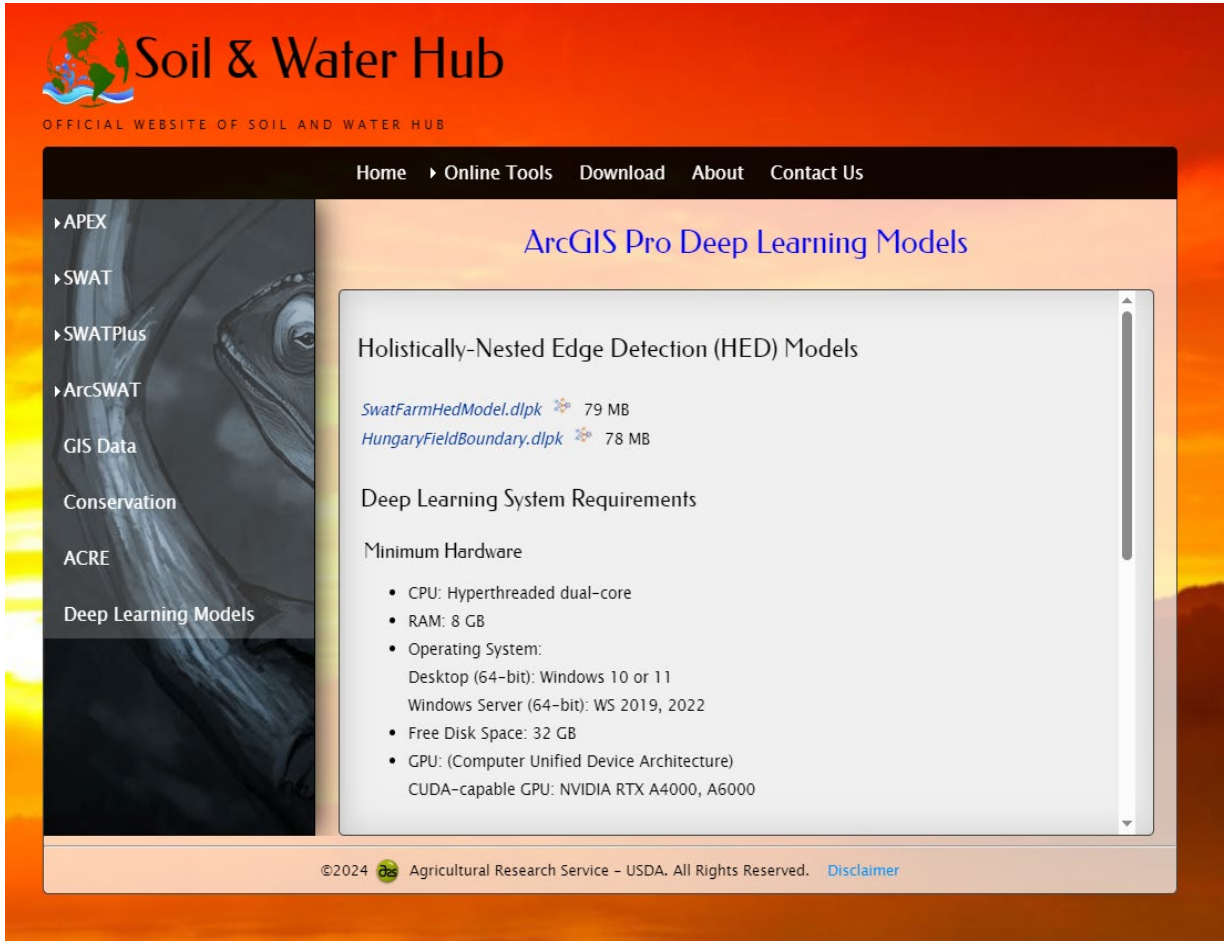
Where to Download the Field Boundary Tools

https://soilandwaterhub.brc.tamus.edu



Best Practices

Photo Credit: *https://www.adventurouskate.com/wp-content/uploads/2016/10/DSCF9925.jpg*

How much training data?

The more, the better; create samples for entire area of interest if possible (e.g., county)

Size of chips

Size >= 400px *(the larger the chips, the more context it provides when training the model)*

Number of chips

# of chips = between 400 and 40,000 depending on the size of area of interest

Summary

Field Boundary Extraction Tools for SWAT Modelling

- Using the deep learning methods we employed in the United States, we were able to extract field boundaries for Hungary. We were not able to test other parts of Europe due to lack of access to satellite imageries from other European countries.
- Most available edge detecting algorithms fail to adequately predict the edges of adjacent fields resulting in multiple fields being bounded as a single field. This increases the post-processing tasks of separating them into individual fields.
- The accuracy of the model increases by increasing the number of training data.

Photo Credit: *https://smapse.com/storage/2018/09/832-70139.jpg*

Thank You

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Grassland Soil and Water Research Laboratory : USDA ARS