Field Boundary Extraction

Using ArcGIS Pro with Image Analyst
In SWAT Modelling

June 26-30, 2023 Aarhus, Denmark

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Field Boundaries determine HRUs in SWAT Modelling

Importance of field boundaries in SWAT Modelling

- Used in identifying land use/land cover classification in a watershed (e.g., cropland, pastures, grassland)
- Specific soil, irrigation, tiles, slope, area, and other DEM properties are determined on a field-level scale
- All fields having similar properties are then grouped into HRUs and used as input for SWAT modelling

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The Problems

Lack of Field Boundary Data

Field boundary data are usually private or proprietary

Sparse data

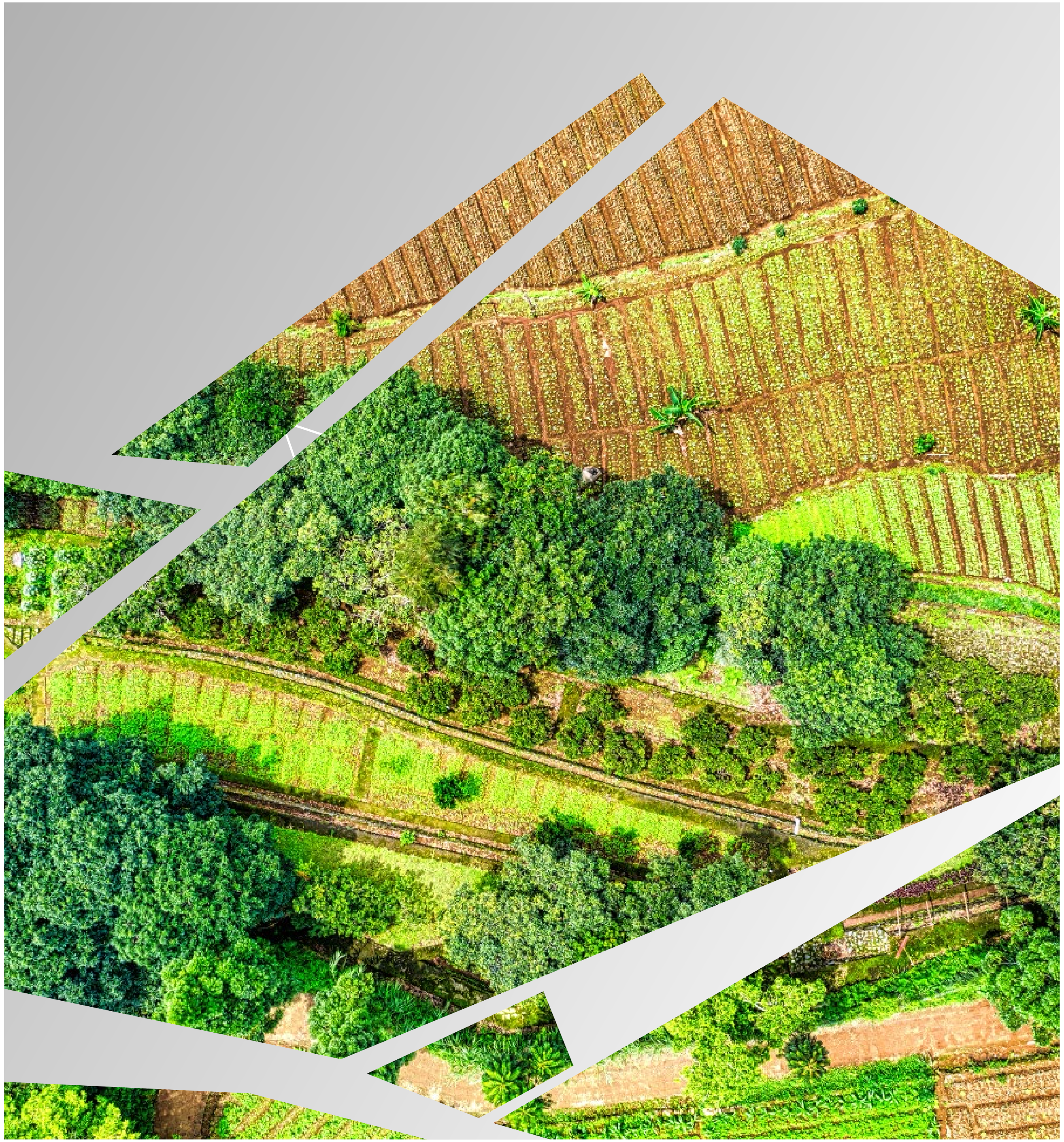
Those available do not cover entire area of interest (pastures, grassland)

Boundary edge problems

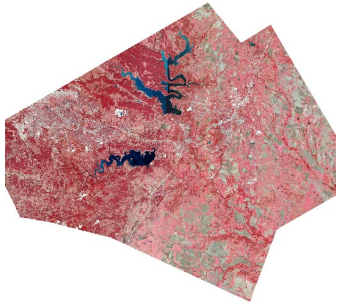
Difficult to determine edge boundaries, e.g., between pastures and grassland (herbaceous)

Digitizing Problems

Manual digitization can be labor-intensive and error-prone



The Solution



- Deep Learning
- Train Deep Learning models using orthographic satellite imageries

Use ArcGIS Pro

With Image Analyst Extension

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System Requirements

Minimum Hardware

- **CPU**: Hyperthreaded dual-core (actual: 56 and 64-cores)
- **RAM**: 8 GB (actual: 1TB and 256 GB)
- **Operating System**: Windows (64-bit) 10 or 11 or Windows Server (64-bit) 2016, 2019, 2022
- **Free Disk Space**: 32 GB (actual: 12/15 TB)
- **GPU**: CUDA (Compute Unified Device Architecture)-capable GPU: RTX A4000, A6000

*Note: ArcGIS Pro does not support **AMD** GPUs since these do not have CUDA—a proprietary technology of **NVIDIA**.*

Software

- NVIDIA CUDA Toolkit: https://developer.nvidia.com/cuda-downloads
- .NET Desktop Runtime: version 6.0.5 or higher: https://dotnet.microsoft.com/en-us/download
- Visual Studio 2019 (licensed version)
- ArcGIS Deep Learning Framework (same version as your installed ArcGIS Pro): https://github.com/Esri/deep-learning-frameworks

3-Stage Approach in Field Boundary Extraction

1 Pre-process Satellite Imagery

- Download from NAIP https://datagateway.nrcs.usda.gov/
- Download by County (filename contains County FIP code)
- Convert MrSid format to PNG or TIFF format using *XY Coordinate System:*

  USA_Contiguous_Albers_Equal_Area_Conic_USGS_version
- Clip the NAIP imagery using *Clip Raster* tool and store converted raster in a file geodatabase

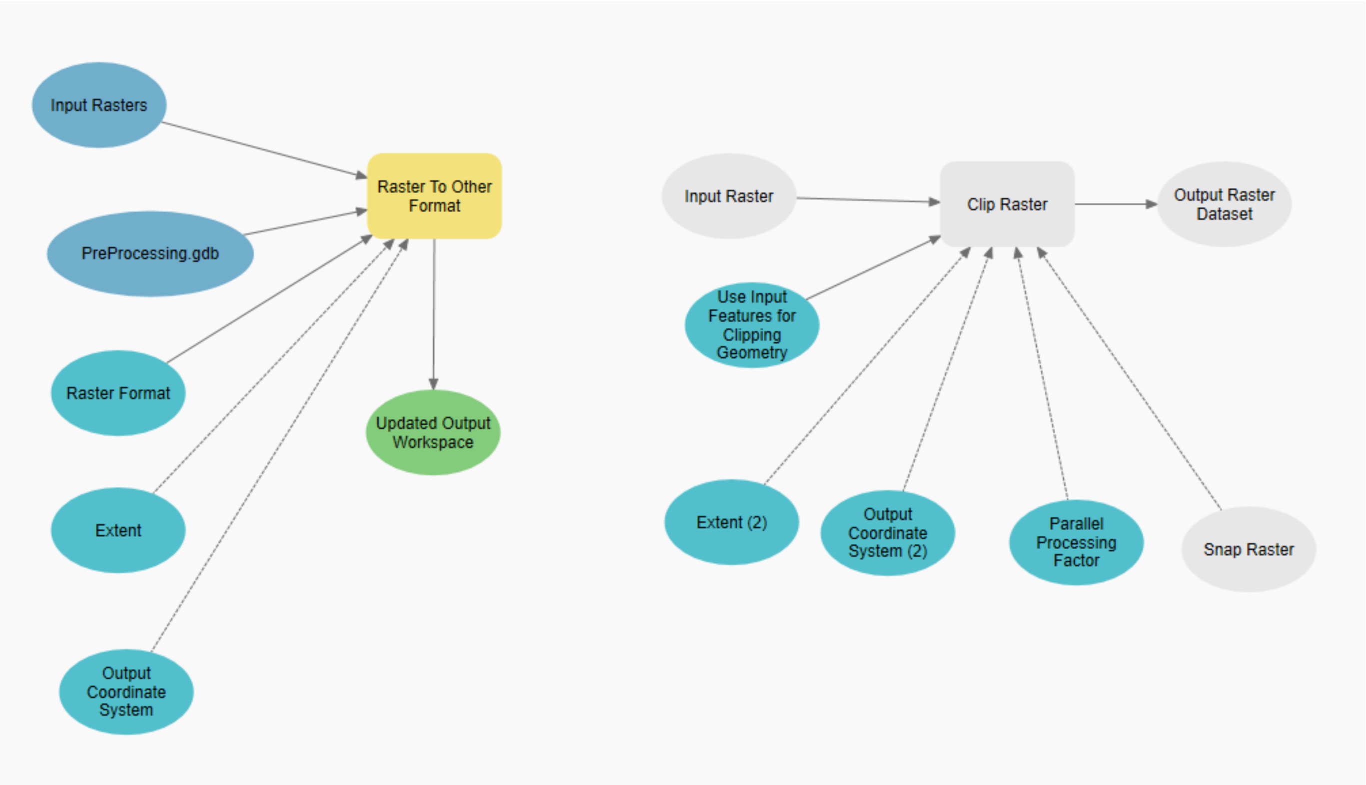
2 Training Samples Manager (Image Analyst)

- Cover entire county as much as you can
- Create a **binary** schema of classes for **HED** model type:
  - Field (classvalue=1)
  - NonField (classvalue=0)
- Digitize Field class samples or
- Import from other shapefile/polygons; must include “classvalue” and “count” columns

3 Train Data and Model

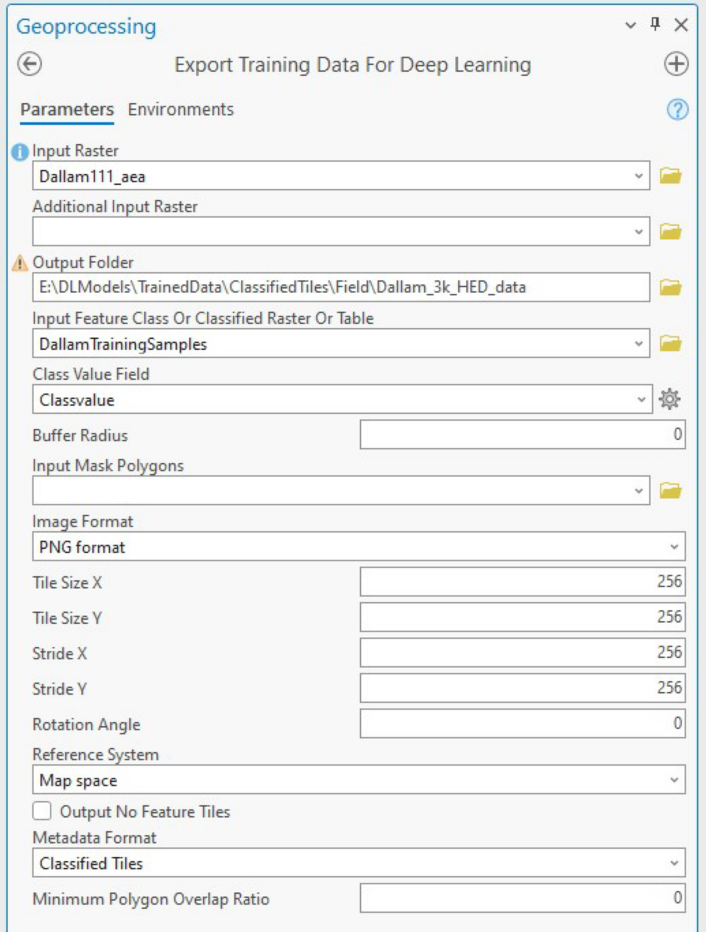
- Use *Export training data for deep learning* tool (output folders containing image chips)
- Use Holistically-Nested Edge Detection (**HED**) model with ResNet-18 as backbone model in *Train Deep Learning Model* tool
- Output trained model is applied to satellite imageries in the boundary extraction stage using *Classify Pixels for Deep Learning* tool

Pre-Processing using ModelBuilder

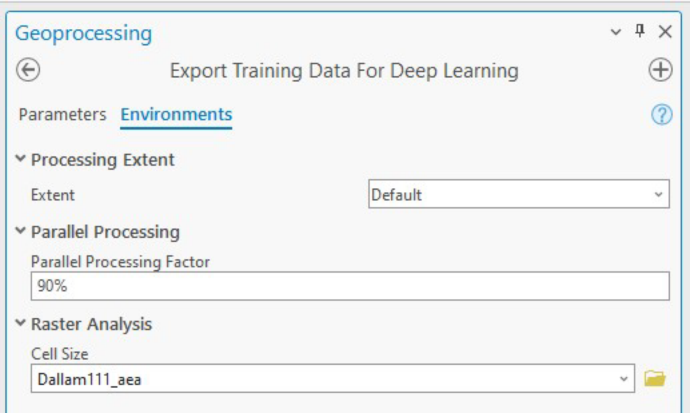


Export Training Data for Deep Learning

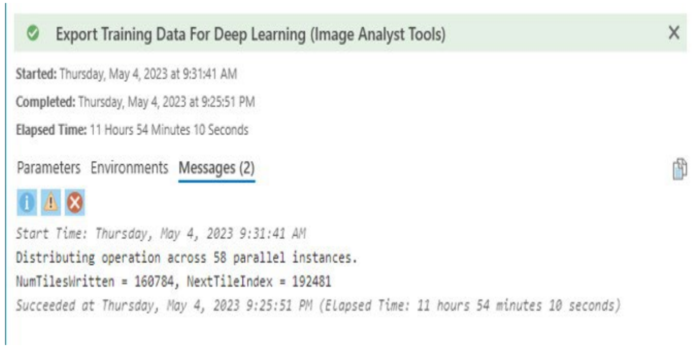
- Parameters



- Environment



- Messages



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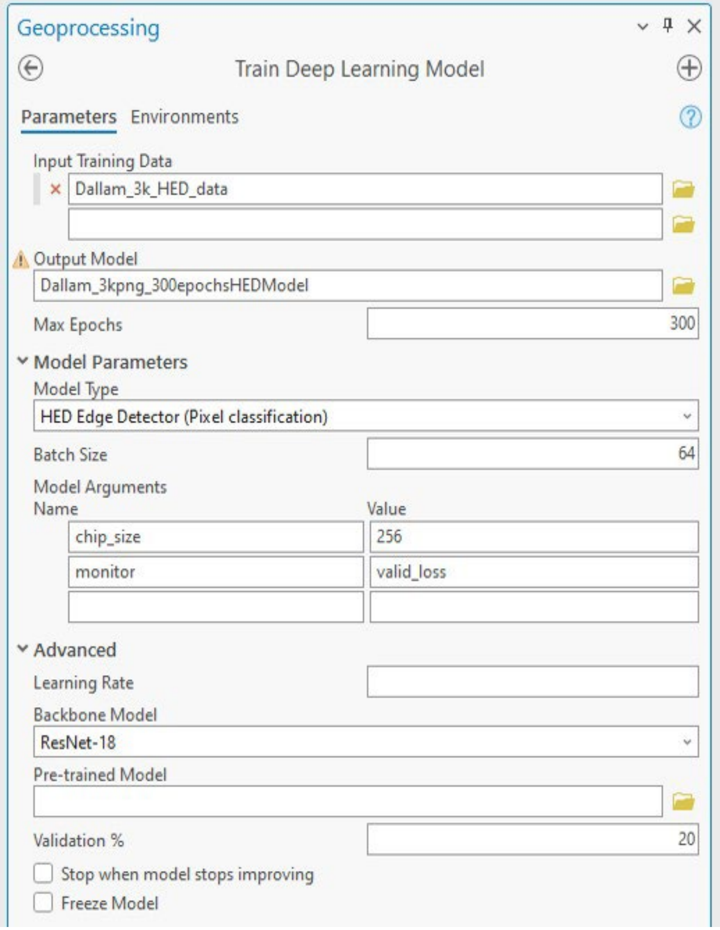
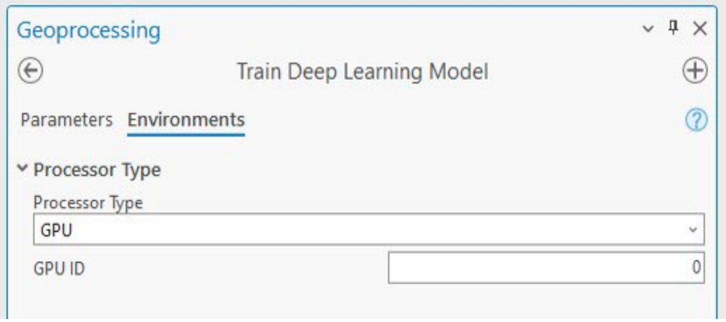
Train Deep Learning Model: Holistically-Nested Edge Detector (HED)

- Parameters



- Environment



- Settings for # of epochs: 300
- Power outage cut it down to 85 epochs
- Model Accuracy: 75.84%
- Hardware:
  - 56-core CPU
  - 1 NVIDIA RTX A6000 GPU (48GB RAM)
  - 1 TB RAM

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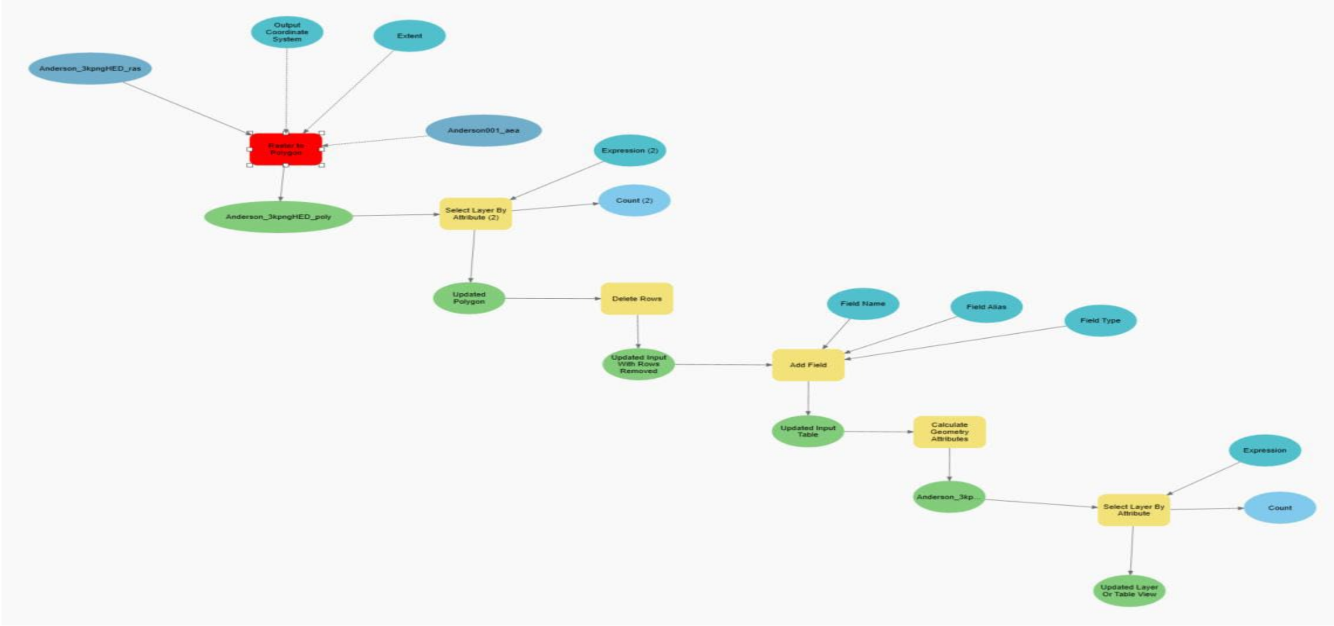
Post-Processing using ModelBuilder



Convert Raster to Polygon:

- Add needed attributes (area, state/county names, etc.)
- Delete polygons based on thresholds (small areas)

Current Bottleneck: *Raster to Polygon* tool = poor performance (sequential processing)
Requested ESRI to add parallel and GPU processing for this tool.

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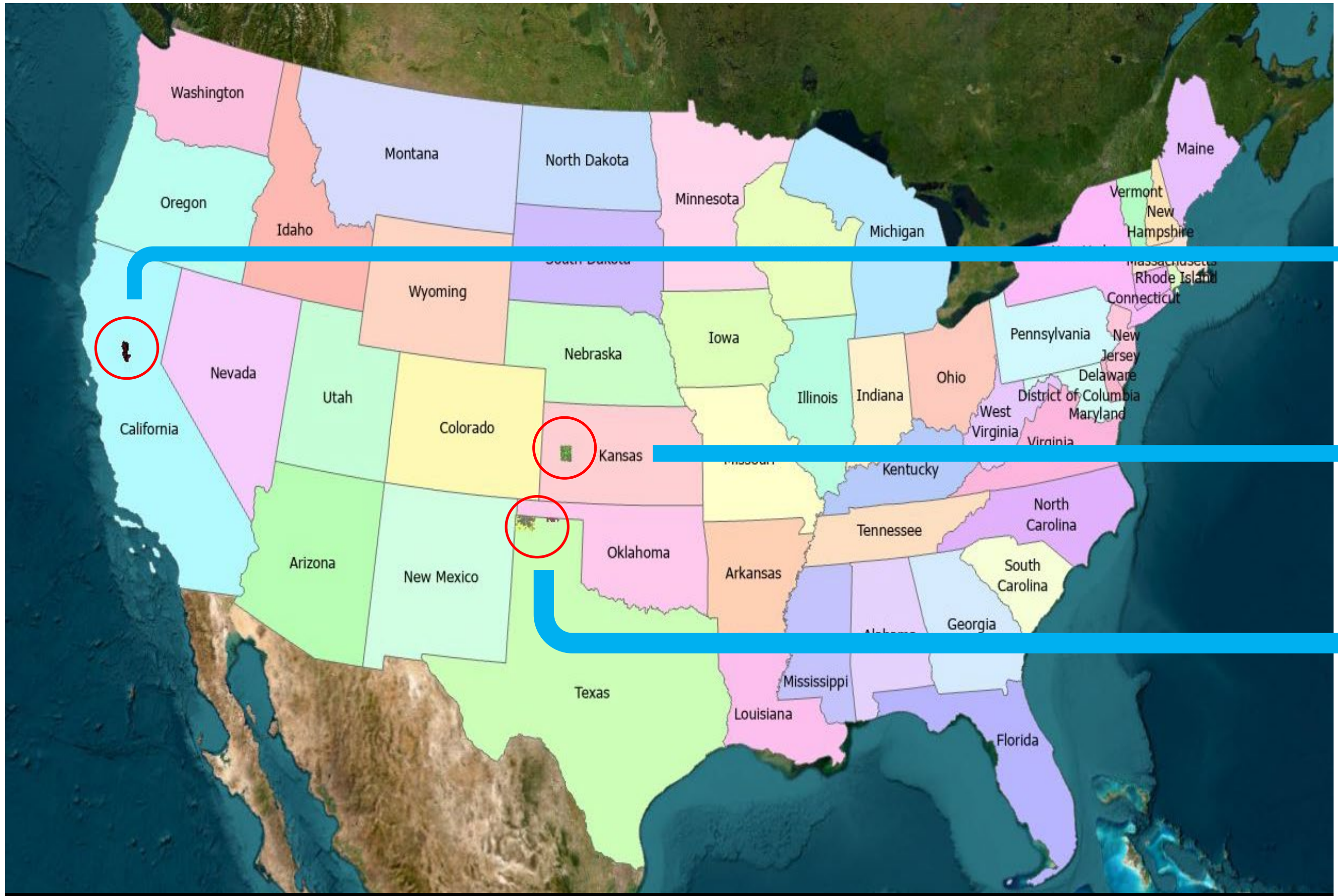
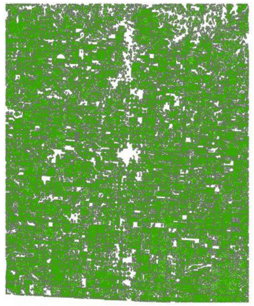


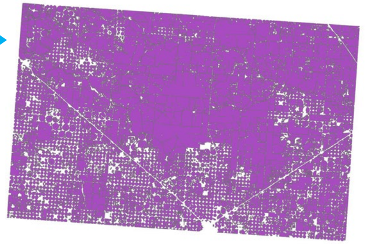
Model Output

Post-Processed Polygons

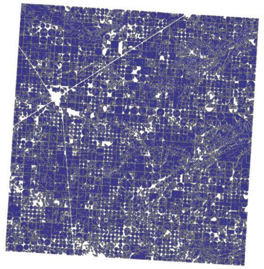
Sutter County, **California**

Scott County, **Kansas**

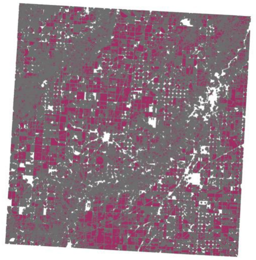




Dallam County, **Texas**



Sherman County, **Texas**



Hansford County, **Texas**

Bell County, **Texas**

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Attribute Table

Final Field Boundary Table

FID	Shape	FUID	Shape_Leng	Shape_Area	AreaAcres	HUC12	HUC8	HucName	State	County	FIPS
0	Polygon	4048401001	2067.46	44648.49	11.0328	120702011001	12070201	Stampede Creek	Texas	Bell	48027
1	Polygon	4048508002	3773.18	49878.93	12.3253	120702011001	12070201	Stampede Creek	Texas	Bell	48027
2	Polygon	4048624004	10179.449	99827.464	24.6678	120702011001	12070201	Stampede Creek	Texas	Bell	48027
3	Polygon	4048650001	20664.562	258159.70	63.792	120702011001	12070201	Stampede Creek	Texas	Bell	48027
4	Polygon	4048764001	171940.17	2048457.220	506.182	120702011001	12070201	Stampede Creek	Texas	Bell	48027

Best Practices

https://www.sophiesworld.net/wp-content/uploads/2010/06/IMG_9021.jpg

How much training data?

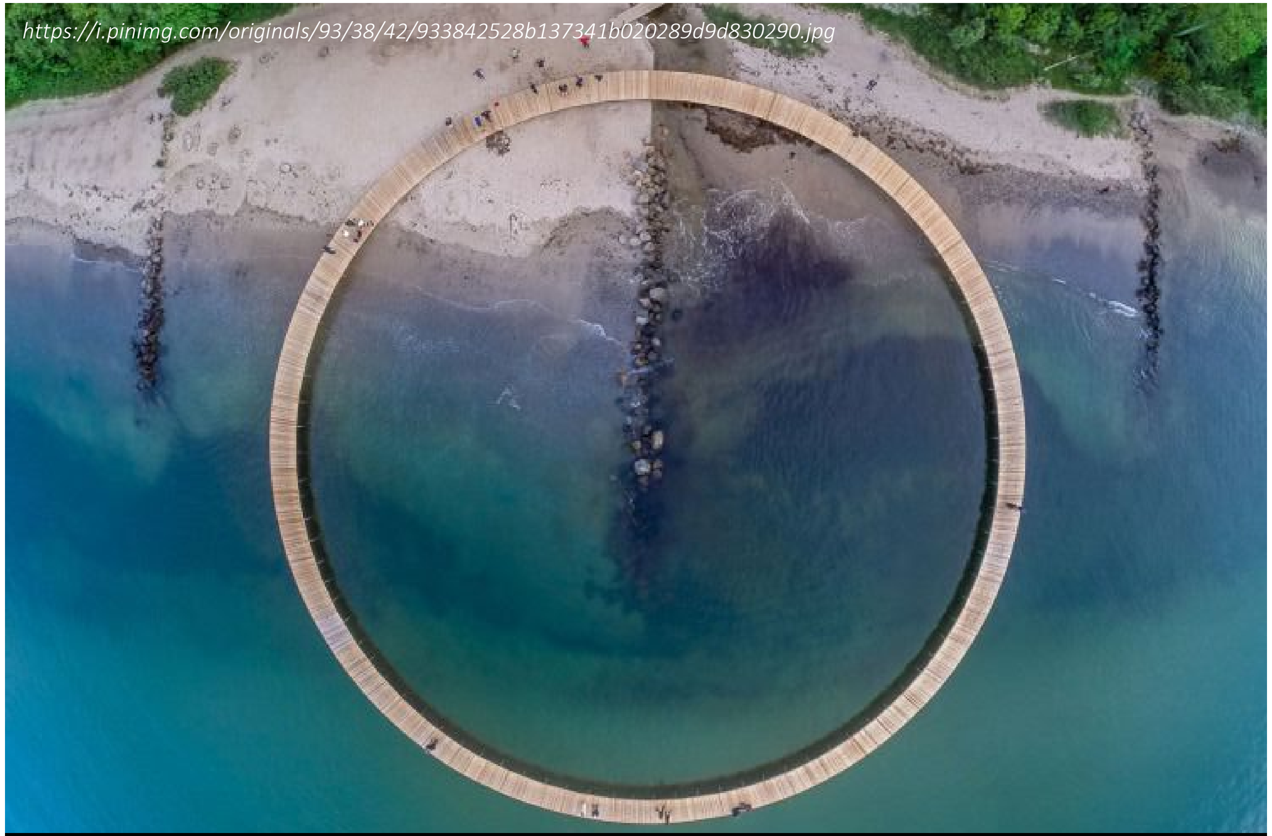
The more, the better; create samples for entire area of interest if possible (e.g., county)

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 Using Deep learning In SWAT Modelling

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- Deep Learning using orthographic satellite imagery and HED model type can extract field boundaries for cropland, pasture, grassland.
- A single model was tested in different counties in the United States with good results (75.84% accuracy)
- Results can be used as input to SWAT modeling for HRU classification

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Thank You

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