



# Field Boundary Extraction

Using ArcGIS Pro with Image Analyst  
In SWAT Modelling

June 26-30, 2023 Aarhus, Denmark



# 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

**SWAT +**

Field Boundaries determine HRUs in SWAT Modelling



# 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

# 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

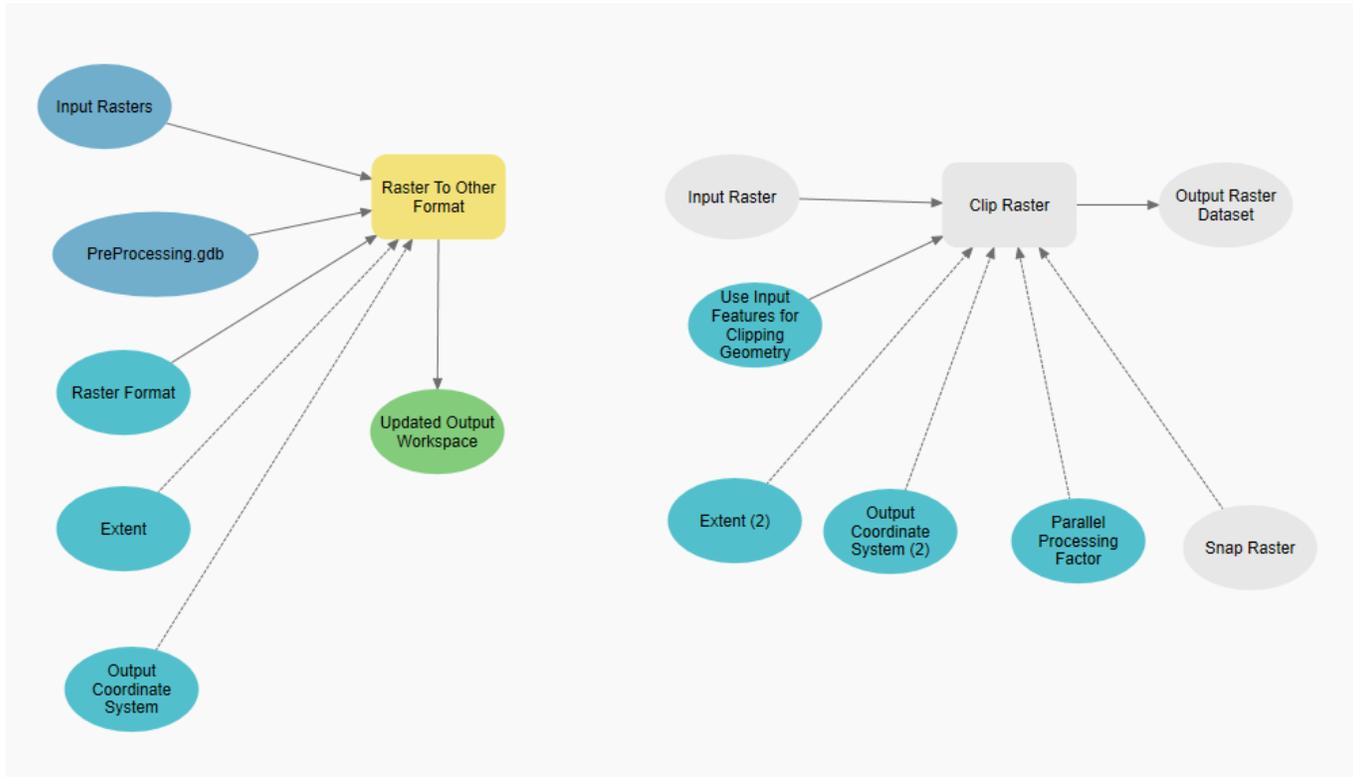
## 2 Training Samples Manager (Image Analyst)

- 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

Geoprocessing

Export Training Data For Deep Learning

Parameters Environments

Input Raster  
Dallam111\_aea

Additional Input Raster

Output Folder  
E:\DLModels\TrainedData\ClassifiedTiles\Field\Dallam\_3k\_HED\_data

Input Feature Class Or Classified Raster Or Table  
DallamTrainingSamples

Class Value Field  
Classvalue

Buffer Radius  
0

Input Mask Polygons

Image Format  
PNG format

Tile Size X  
256

Tile Size Y  
256

Stride X  
256

Stride Y  
256

Rotation Angle  
0

Reference System  
Map space

Output No Feature Tiles

Metadata Format  
Classified Tiles

Minimum Polygon Overlap Ratio  
0

## Environment

Geoprocessing

Export Training Data For Deep Learning

Parameters Environments

Processing Extent  
Extent  
Default

Parallel Processing  
Parallel Processing Factor  
90%

Raster Analysis  
Cell Size  
Dallam111\_aea

## Messages

Export Training Data For Deep Learning (Image Analyst Tools)

Started: Thursday, May 4, 2023 at 9:31:41 AM  
Completed: Thursday, May 4, 2023 at 9:25:51 PM  
Elapsed Time: 11 Hours 54 Minutes 10 Seconds

Parameters Environments Messages (2)

Start Time: Thursday, May 4, 2023 9:31:41 AM  
Distributing operation across 58 parallel instances.  
NumTilesWritten = 160784, NextTileIndex = 192481  
Succeeded at Thursday, May 4, 2023 9:25:51 PM (Elapsed Time: 11 hours 54 minutes 10 seconds)



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

## Parameters

Geoprocessing Train Deep Learning Model

Parameters Environments

Input Training Data  
Dallam\_3k\_HED\_data

Output Model  
Dallam\_3kpng\_300epochsHEDModel

Max Epochs 300

Model Parameters  
Model Type  
HED Edge Detector (Pixel classification)

Batch Size 64

Model Arguments

Name	Value
chip_size	256
monitor	valid_loss

Advanced  
Learning Rate  
Backbone Model  
ResNet-18  
Pre-trained Model  
Validation % 20  
 Stop when model stops improving  
 Freeze Model

## Environment

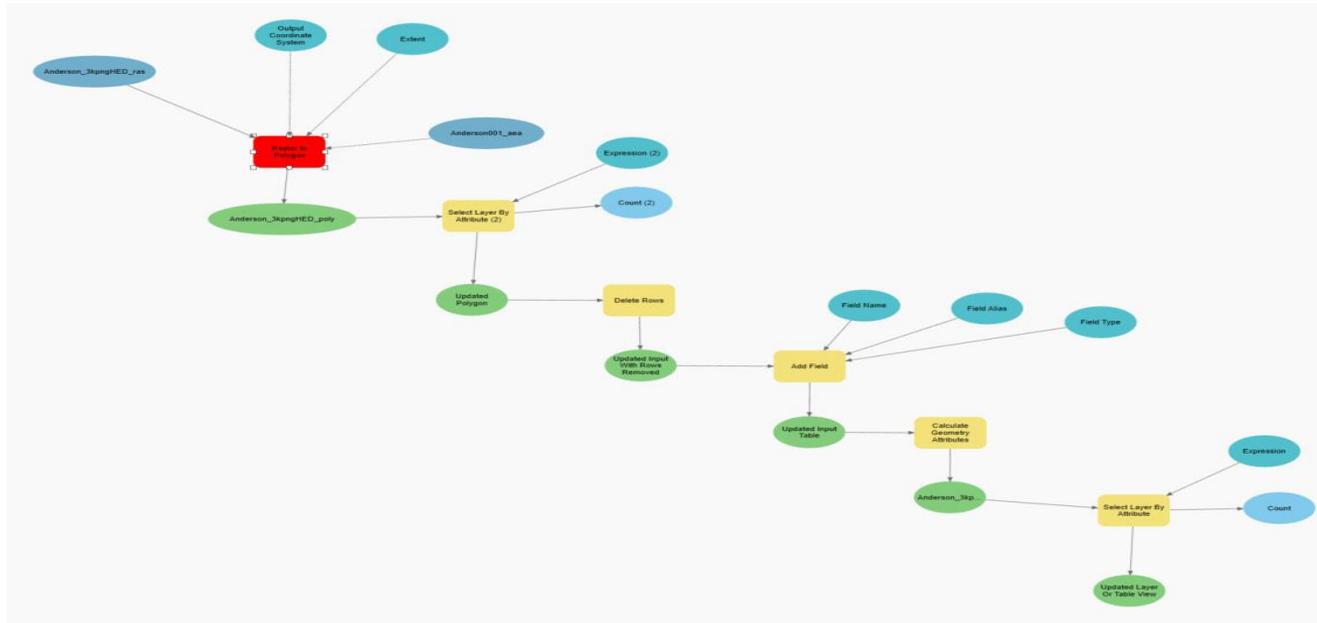
Geoprocessing Train Deep Learning Model

Parameters Environments

Processor Type  
Processor Type  
GPU  
GPU ID 0

- 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

# Post-Processing using ModelBuilder

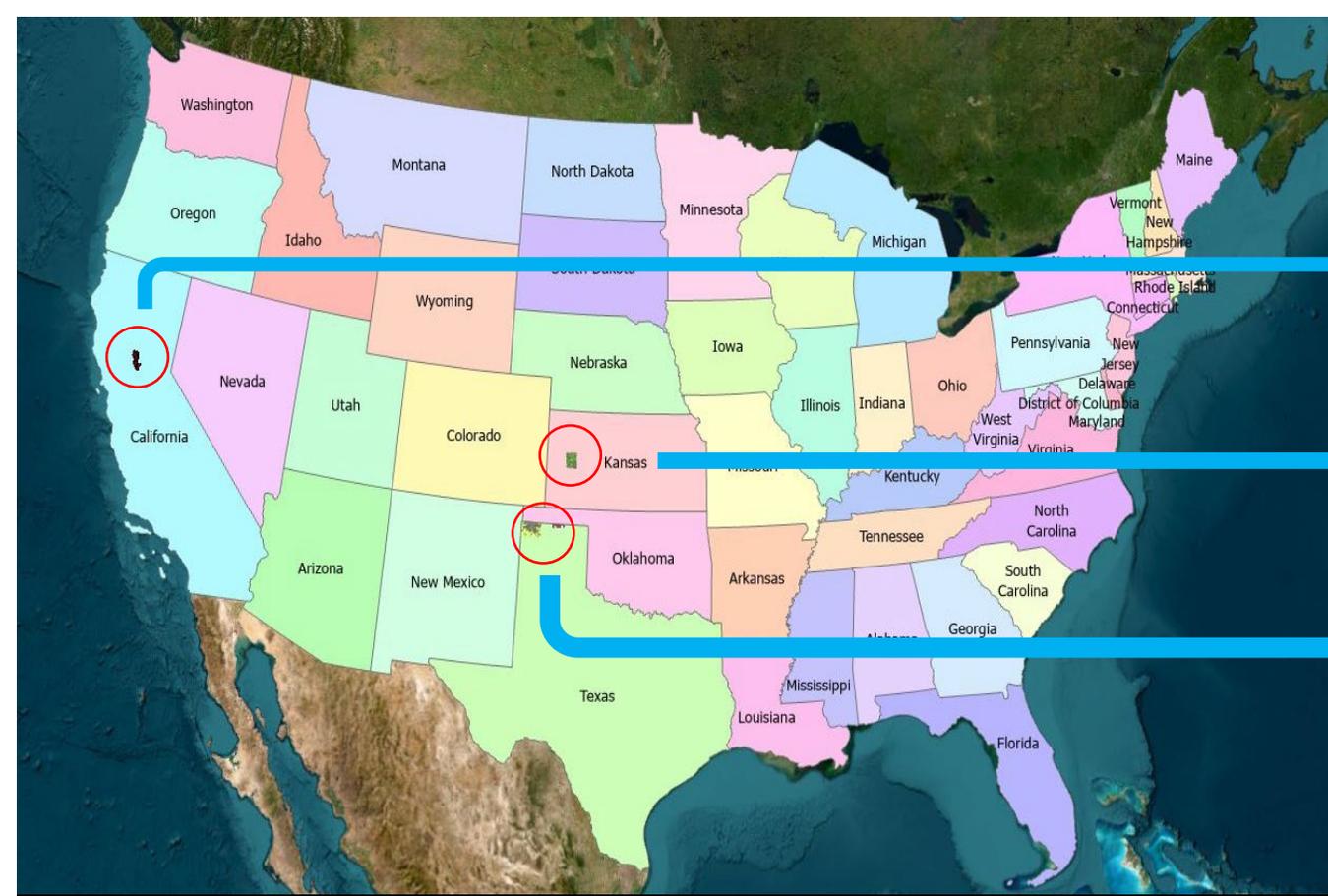


## Convert Raster to Polygon:

- 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.

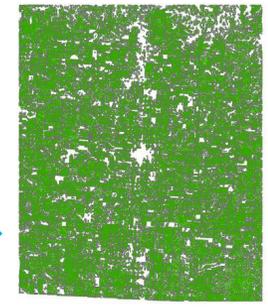




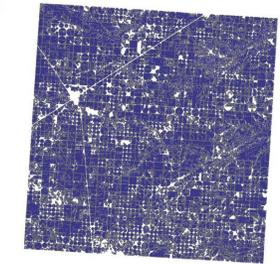
Sutter County, California



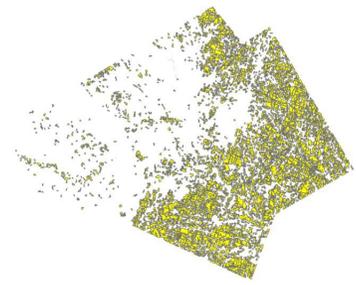
Scott County, Kansas



Dallam County, Texas



Hansford County, Texas



Bell County, Texas

Sherman County, Texas

# Model Output

Post-Processed Polygons



# 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](https://www.sophiesworld.net/wp-content/uploads/2010/06/IMG_9021.jpg)

## How much training data?

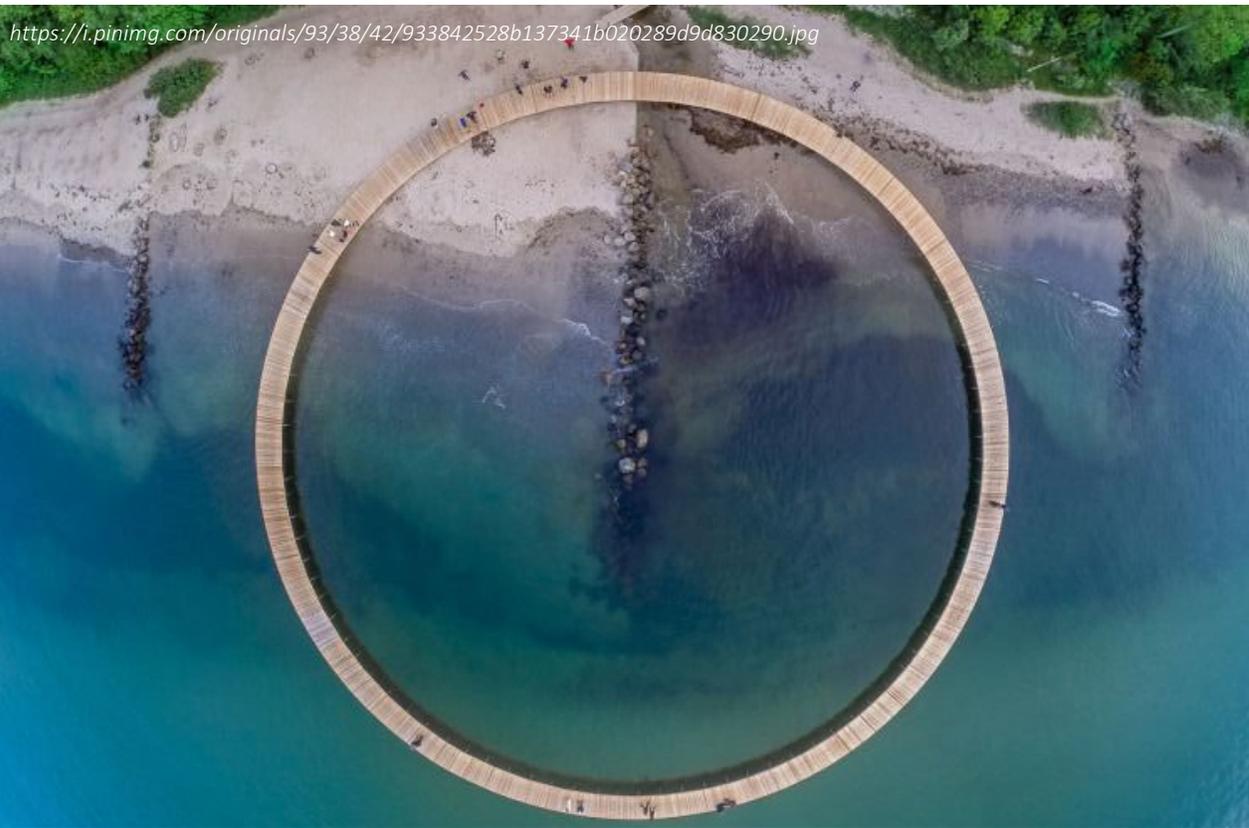
*The more, the better; create samples for entire area of interest if possible (e.g., county)*

## Size of chips

*Size  $\geq 400px$  (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



- 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

# Thank You



Marilyn Gambone 

Temple, Texas 

[marilyn.gambone@usda.gov](mailto:marilyn.gambone@usda.gov) 

[Grassland Soil and Water Research Laboratory : USDA ARS](#) 