Appendix 4-Q

Land Use Classification Manual

RIVERSIDE

global science solutions

COHYST 2010

Land Use Classification Manual

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INTRODUCTION

1. Overview

This manual is intended to describe in detail the process by which land use was determined for the COHYST study area during years 2006-2010. The detailed steps and processes are intended to be described in a way so that the task and corresponding steps could be repeated for additional years of study. Graphics are including within the manual to illustrate certain processes where descriptions alone may be complex. The manual is broken into four main sections, each section being one of the four main tasks performed. These four main tasks include:

(Task I) - Image Processing

Begins with the evaluation and collection of raw Landsat satellite imagery. Select images are processed into a format for classification analysis and stored in a standardized collection framework.

(Task II) - Parcel Editing

Entails developing an agricultural parcel GIS database for the entire COHYST study area. Each year having individual yearly ground-based representations derived from aerial photographic interpretation.

(Task III) - Image Classification

Utilizes processed imagery from the image processing task to develop and assign agricultural crop types for each parcel created in the parcel editing task. Task 3 also utilizes aerial image sources for classifications of supplemental static land cover.

(Task IV) - Irrigated and Non-Irrigated Irrigation Separation

Provides assigned irrigation status to each parcel. Irrigation status was determined by using selected imagery from the image processing task and validated with ancillary reference data sources.

2. Guidelines

In order to obtain the final yearly land use products, several sub-processes and steps are needed for each task. Each process is documented, described and numbered; having its own title within this manual. The main objective of the specific process is described in the title and the table of contents to help navigation of the manual and the specific step.

The manual is intended to be performed in a sequential order starting with Task 1 for each year of analysis. While efficiencies may be found in performing specific processes for multiple year simultaneously, its encouraged for a user to review the entire manual before beginning analysis. Additionally, a user should understand any future implications of the manual should utilize appropriate data sources and processes with technological change.

TASK I. IMAGE PROCESSING

3. Imagery Archive Review

USGS Global Visualization Viewer (GLOVIS) and Earth Explorer Use / Inventory

3.1.1. Register an account on the USGS EarthExplorer website: https://earthexplorer.usgs.gov/register/.

3.1.2. ***Note:*** *Task I Section 2* provides details steps for using GLOVIS for downloading selected scenes. It is suggested to review the entire archive prior to process ding with downloading to insure suitable imagery is available for a given year and period of study.

3.1.3. Once connected to the GLOVIS web application a user can review the Landsat archives for image evaluation of temporal coverage and cloud cover percentages. The following example is used to describe a review of 2013 Landsat 5 imagery for scene Path 32 Row 31 of the COHYST boundary.

3.1.4. Before proceeding with the review of the online archive it is suggested to set up a tracking spreadsheet to record scenes and corresponding cloud cover percentages. Using the template spreadsheet "Imagery_XXXX_QC_TrackingTool_Temp.xlsx" update the dates available for each scene available by each frame. Enter the ID. Columns Year, Julian and DOY will be populated from pre-built formulas. Finally, enter the cloud cover percentage estimate for agriculture lands. Figure 1 shows an example of imagery reviewed for two COHYST frames. Step 1.1.7 provides details on estimating cloud cover percentages from agriculture lands.

COHYST Landsat Download and Process Tracking					Scene Id	Cloud Cover %
EX. 3231		Year	Julian	DOY	SceneID	0%
032031	5/27/06	2006	06147	147	LT50320312006147	0%
	6/12/06	2006	06163	163	LT50320312006163	10%
	6/28/06	2006	06179	179	LT50320312006179	40%
	7/14/06	2006	06195	195	LT50320312006195	0%
	7/30/06	2006	06211	211	LT50320312006211	20%
	8/23/06	2006	06235	235	LE70320312006235	0%
	9/16/06	2006	06259	259	LT50320312006259	20%
	10/2/06	2006	06275	275	LT50320312006275	5%
Total Scene Count						
031031	5/20/06	2006	06140	140	LT50310312006140	5%
	6/5/06	2006	06156	156	LT50310312006156	5%
	6/29/06	2006	06180	180	LE70310312006180	0%
	7/7/06	2006	06188	188	LT50310312006188	15%
	7/31/06	2006	06212	212	LE70310312006212	0%
	9/17/06	2006	06260	260	LE70310312006260	1%
	9/25/06	2006	06268	268	LT50310312006268	5%
	10/27/06	2006	06300	300	LT50310312006300	0%

Figure 1. "Imagery_XXXX_QC_TrackingTool_Temp.xlsx"

3.1.5. Once connected to GLOVIS, select a Landsat Archive to begin review. Figure 2 shows how to turn Landsat 5 on.

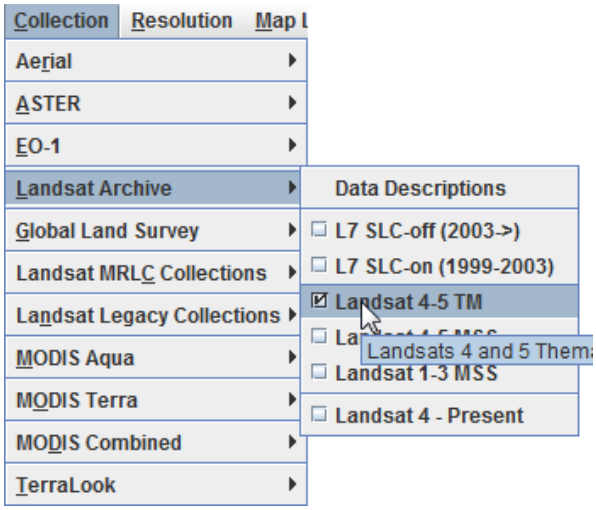


Figure 2. Landsat Sensors selection

3.1.6. It is suggested to load an existing agriculture lands shapefile for estimating cloud cover over these locations. Use the read shapefile tool to load a parcel layer. The parcel must be in a geographic coordinate system or the layer will not show correctly. Another useful layer to load is the COHYST study boundary.

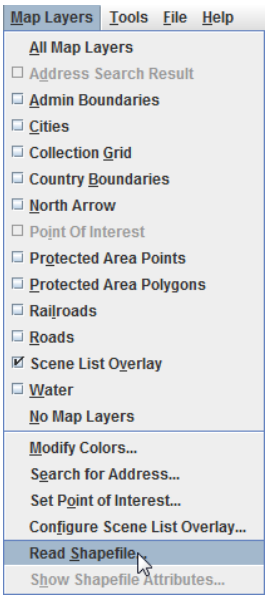


Figure 3. Read Shapefile Dialog

3.1.7. With loaded AOI shapefile, look at the estimated CC cloud cover for the entire scene. Now look at how the clouds appear to cover the specific AOI. Reduce or increase the estimate to better represent the AOI. Figure 4 shows the

area of interest for an example scene on 4/4/2013. Although the estimate CC is 0% clouds can be seen in the Northern portion of the AOI. CC is more likely a better estimate of 5-10%. Record all information in the tracking spreadsheet, and then move to the next available scene for the frame until all scenes are recorded for the period of interest.

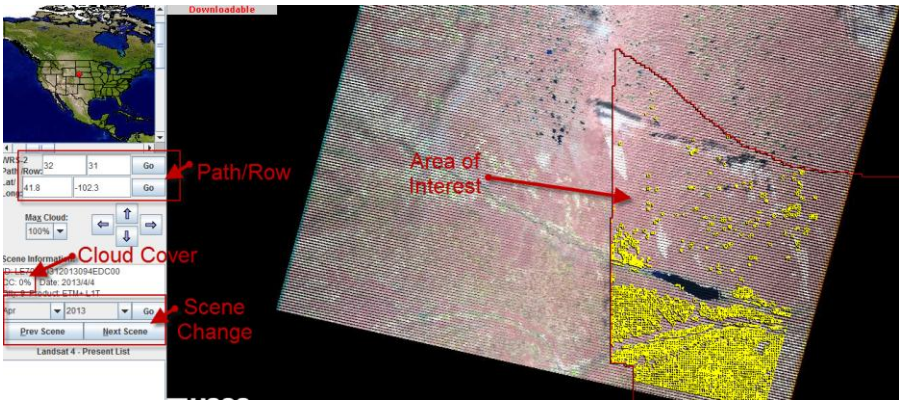


Figure 4. AOI Shapefile

3.1.8. It is suggested to perform step 1.1.7 for all frames and scenes for a given year. Ideally, a minimum of one scene is recommended per month for each frame. Adjacent paths do overlap by approximately by one third on each side should be considered.

3.1.9. With all available scenes reviewed from both Landsat 5 and 7 sensors, evaluate cloud cover percentages that will expectable for download.

4. Imagery Selection

USGS Global Visualization Viewer (GLOVIS) and Earth Explorer Use

4.1.1. Register an account on the USGS EarthExplorer website: https://earthexplorer.usgs.gov/register/.

Figure 5. Register Tab in the Upper Right Corner of the EarthExplorer Homepage

4.1.2. Follow the registration instructions to create a USGS account.

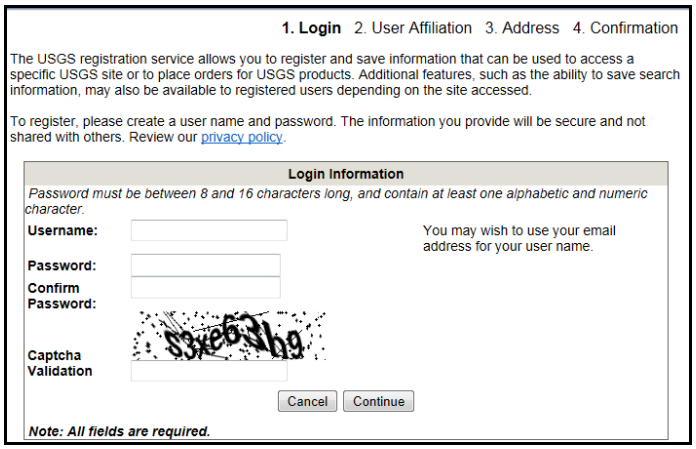


Figure 6. USGS Account Registration Instructions

4.1.3. Once the registration has been completed, access the USGS GLOVIS website: http://glovis.usgs.gov/

4.1.4. If a Java run application prompt appears, click **Run**.

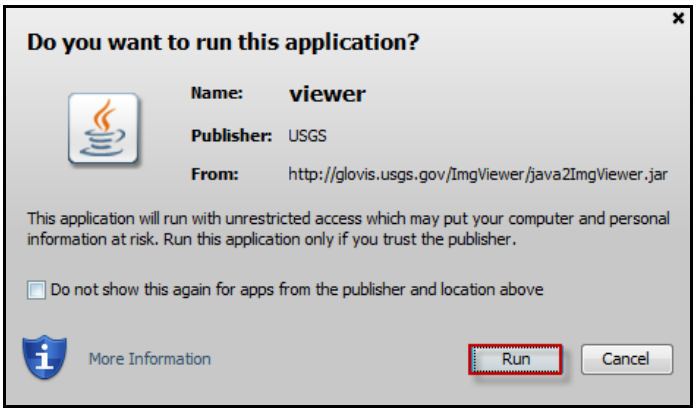


Figure 7. Java Run Application Prompt

4.1.5. Verify browser requirements to ensure the proper functionality of the GLOVIS website.

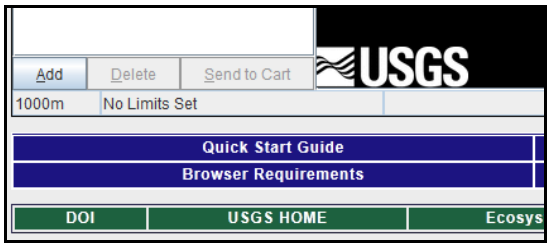


Figure 8. Browser Requirements Tab in the Bottom Left Corner of the GLOVIS Homepage

4.1.6. On the Menu Bar click on the **Collection** tab.

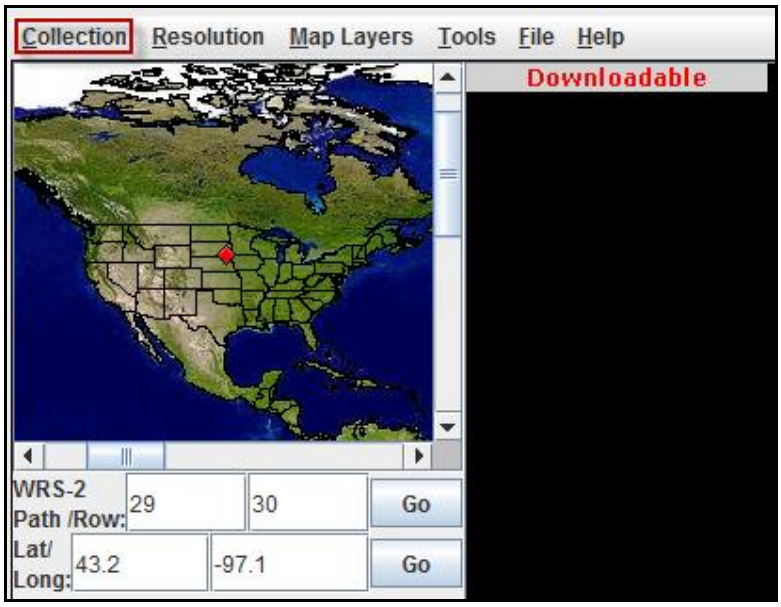


Figure 9. Collection tab on the Menu Bar

4.1.7. Within the Collection menu, select Landsat Archive.

Figure 10. Collection Menu
Displaying Dataset Collection Types

4.1.8. Within Landsat Archive, select **Landsat 4-5 TM**.

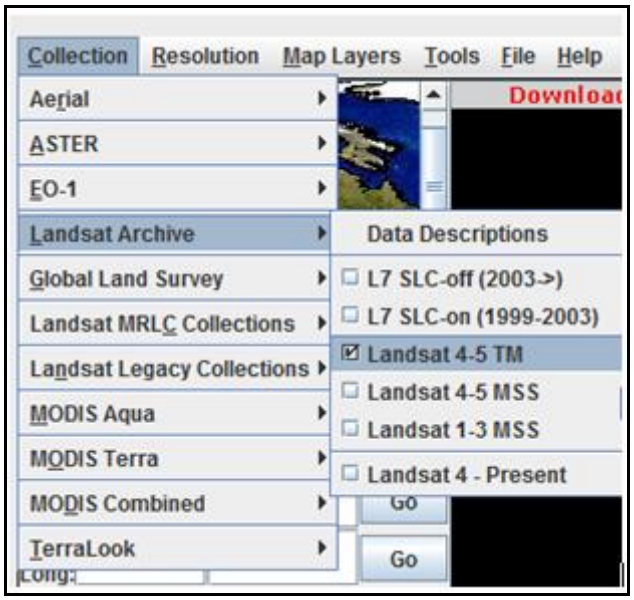


Figure 11. Landsat Archive Data Types

Note: Within this list, there are different Landsat data types to choose from depending on what is needed for a data source such as resolution, number of bands, data coverage, and time period. For the COHYST project, Landsat 4-5 TM and L7 SLC-off (2003->) were the data types used.

4.1.9. On the Menu Bar click on the **Resolution** tab and select **240m**. This changes the resolution displayed in the image display to a larger scale.

Figure 12. Resolution Menu

4.1.10. Enter in the World Reference System (WRS-2) path and row for the image frame to be selected and then click Go.

Note: The maximum allowable cloud cover for the frame can be set by clicking on the Max Cloud drop down menu but this will limit the number of scenes available for that frame depending on the cloud cover percentage chosen.

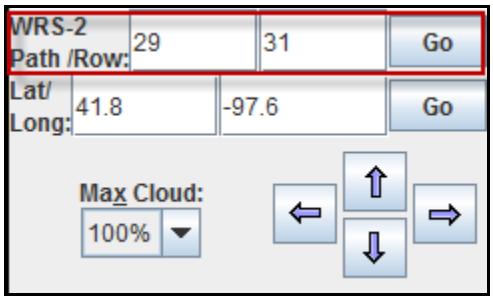


Figure 13. WRS-2 Path and Row Designator Windows

4.1.11. Select the acquisition date of the individual scenes within the imagery frame using the month and year dropdown menus and then click Go. This displays the first scene for that month chronologically. Additional scenes for the selected month, previous month, or next month can be viewed by clicking on the Next Scene and Previous Scene buttons.

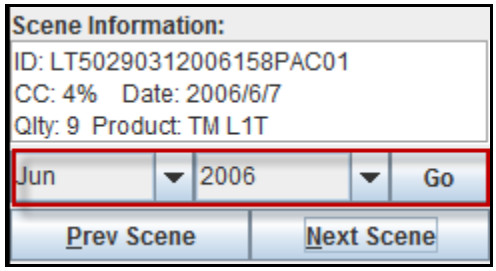


Figure 14. Month and Year Dropdown Menus

4.1.12. Once the scene has been selected, click the Add button. This adds the selected scene into the Scene List window.

Note: Before selecting the image scene, verify the input parameters within the Scene Information window.

- ID: the scene ID
- Cloud Cover (CC): the estimated cloud cover
- Date: the acquisition date
- Quality (Qty): image quality value ranging from 0-9

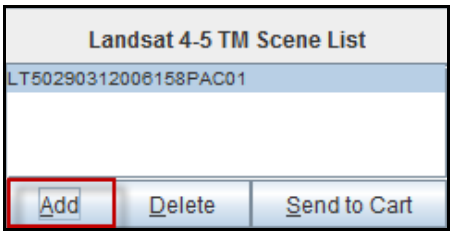


Figure 15. Selected Scene Added in the Scene List Window

4.1.13. Additional scenes can be added to the scene list by changing the path and row of the frame and/or the date of the scene. Once the required scenes have been selected and added to the list, click the Send to Cart button.

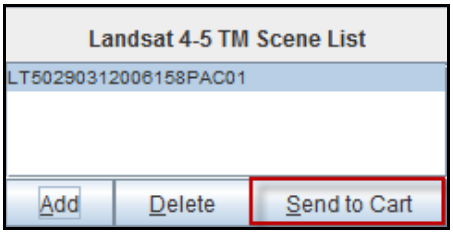


Figure 16. Scene List Send to Cart Button

Note: If not already logged on, a sign in screen will appear, enter in the username and password that was created for the USGS account.

4.1.14. Within the Pending Scenes section, the Level 1 Landsat image can either be ordered or bulk downloaded depending on the product availability. Check the box that applies for the image.

Note: The Level 1 Landsat Geotiff image is the primary product that needs to be downloaded since it has the seven bands that can be used for imagery analysis and processing.

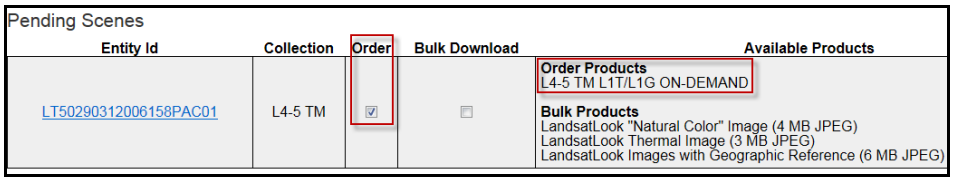


Figure 17. Order Imagery Download Option

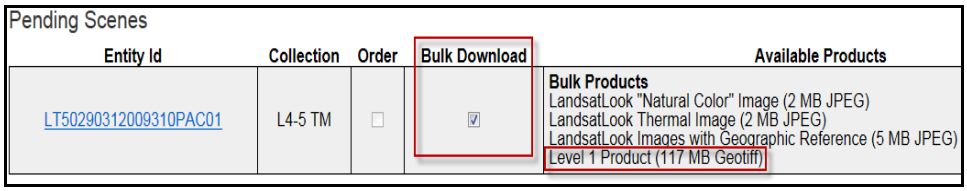


Figure 18. Bulk Download Imagery Download Option

4.1.15. Click the Apply button.

Figure 19. Pending Scenes Section Apply Button

4.1.16. Click the Go to Item Basket button.

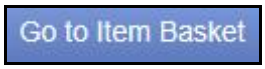


Figure 20. Pending Scenes Section Go to Item Basket Button

4.1.17. Within the Order section, verify the information for the scene being ordered by clicking on the Expand Scene List dropdown.

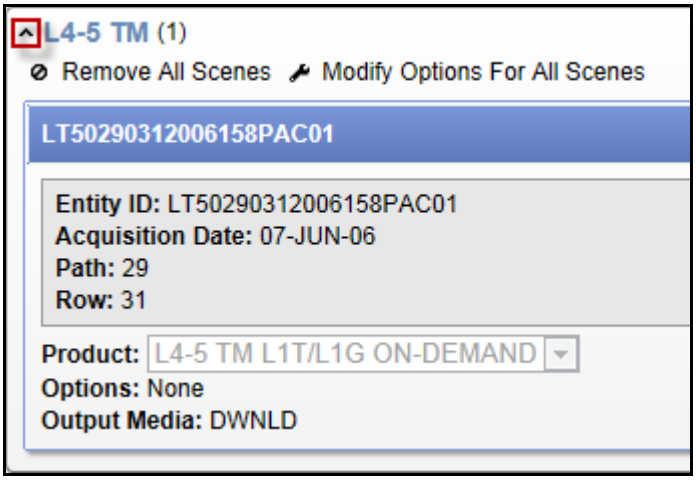


Figure 21. Order Section Scene Information

4.1.18. Click the Proceed To Checkout >> button.

Figure 22. Order Section Proceed To Checkout Button

4.1.19. Click the Submit Order button.

Figure 23. Order Section Submit Order Button

Note: This places an order for the scene that has been selected. An online order confirmation from USGS will be sent to the email address provided in the USGS account registration. A scene that is ordered can take up to two days to process. Once the order has been processed, another email will be sent from USGS notifying that the product is ready to be downloaded from the EarthExplorer website. A scene that is bulk downloaded will be available immediately to download using the Bulk Download Application. This will be explained in the Bulk Download Application tool section.

4.1.20. Within the order confirmation summary section, review the order information and when finished, either logout of the website or click the Return to EarthExplorer button to go to EarthExplorer.

Figure 24. Return To EarthExplorer Button

4.1.21. Access the USGS EarthExplorer website: http://earthexplorer.usgs.gov/.

4.1.22. Login to the user account.

4.1.23. Click the Data Sets tab.

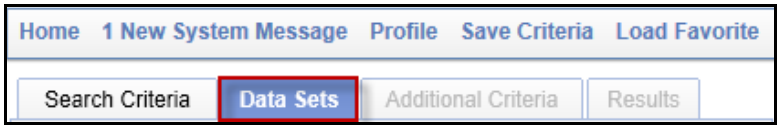
4.1.24. 

Figure 25. Data Sets Tab

4.1.25. Within the Select Your Data Set(s) window, check the box for Landsat Archive – L4-5 TM.

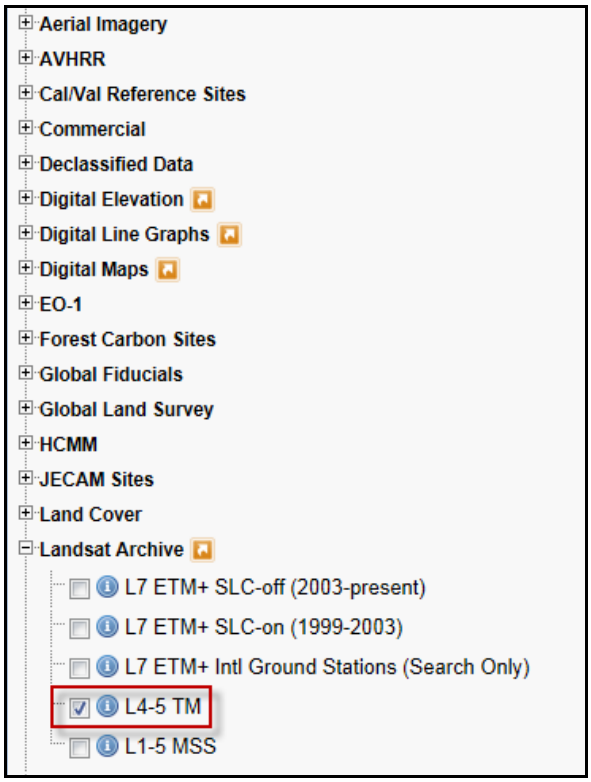


Figure 26. Select Your Data Set(s) Window

4.1.26. Click the Additional Criteria tab.

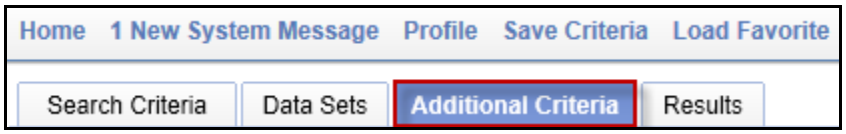


Figure 27. Additional Criteria Tab

4.1.27. Enter the Landsat scene identifier for the image to be downloaded.

Figure 28. Additional Criteria Landsat Scene Identifier Input

4.1.28. Click the Results tab.

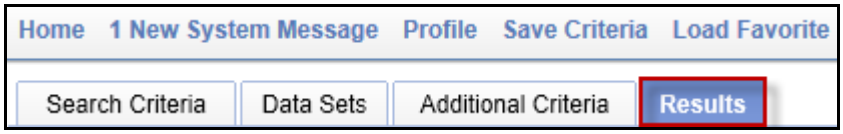


Figure 29. Results Tab

4.1.29. Click the Add To Bulk Download icon for the selected scene.

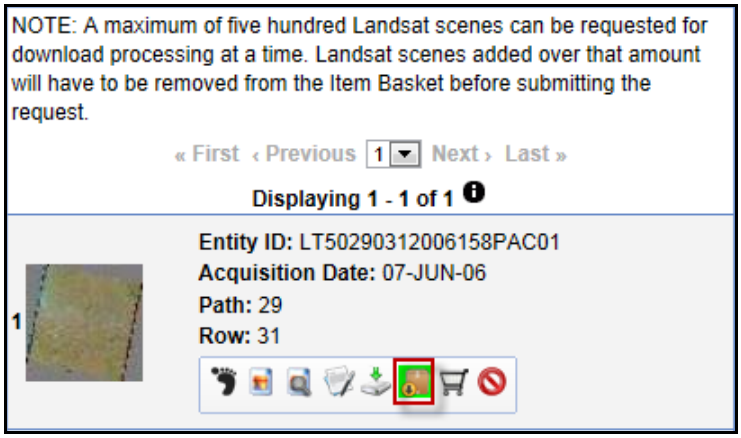


Figure 30. Add To Bulk Download Scene Download Option

4.1.30. Click the View Item Basket >> button at the bottom of the Results window.

Figure 31. View Item Basket Button

4.1.31. Click the Proceed To Checkout >> button.

Figure 32. Proceed To Checkout Button

4.1.32. Click the Submit Order button.

Figure 33. Submit Order Button

4.1.33. Within the bulk download confirmation summary section, review the order information and when finished, either logout of the website or click the Return to EarthExplorer button to go back to EarthExplorer.

Figure 34. Return To EarthExplorer Button

Bulk Download Application (BDA)

4.1.34. Download the BDA from the USGS EarthExplorer website: http://earthexplorer.usgs.gov/bulk/.

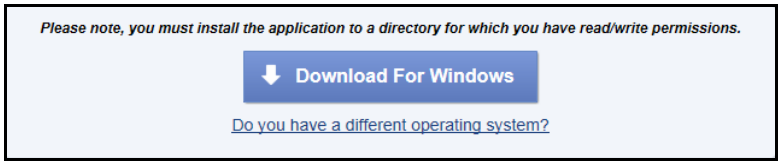


Figure 35. Download Button for the BDA

4.1.35. Sign in to the USGS registered account if needed.

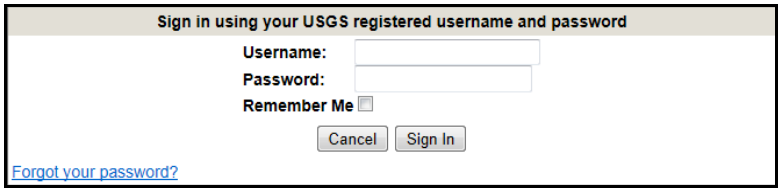


Figure 36. USGS Account SignIin

4.1.36. Download and install the BDA.

4.1.37. Open the BDA.

Figure 37. BDA Icon

4.1.38. Login using the username and password for the registered USGS account.

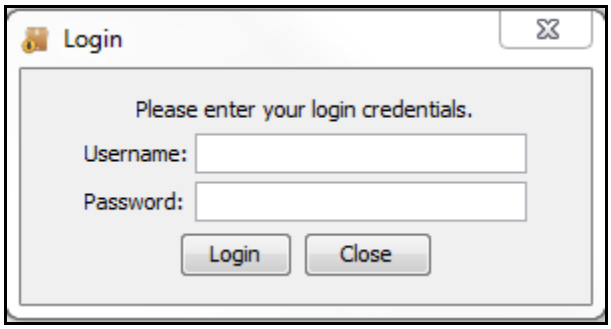


Figure 38. BDA Login

4.1.39. Select the order to be downloaded and click the Select Order button.

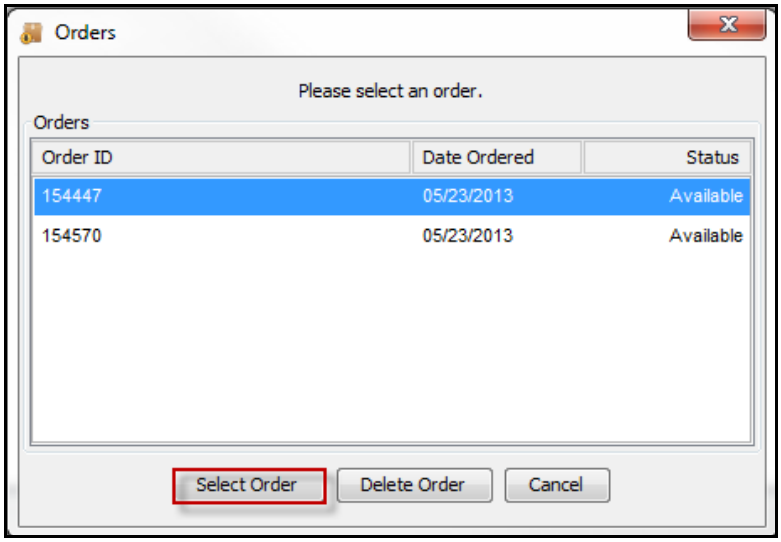


Figure 39. BDA Available Orders

4.1.40. Choose the output location of the download by clicking on the folder browser icon in the upper right hand corner of the BDA.

Figure 40. Browse Folder Location Icon

4.1.41. Click on the Begin Download button.

Figure 41. Begin Download Button

4.1.42. Once the download is complete, click on the Clear Completed Downloads button.

Figure 42. Clear Completed Downloads Button

5. Imagery Storage Structure and Extraction

Server Storage Design

5.1.1. Riverside developed a specific storage framework for all collected Landsat data used in organizing data. It is recommended to mimic the framework if a user wishes to use tools for additional processing. A user could modify all the tools to except other network system paths if a location other than the one used by Riverside is needed. Riverside used the following directory for imagery storage and extraction: *D:COHYST\Landsat.*

5.1.2. Within the processing directory a yearly folder is used to store imagery by individual years. Looking at an example year of 2006, Figure 43 shows the corresponding sub-folders used.

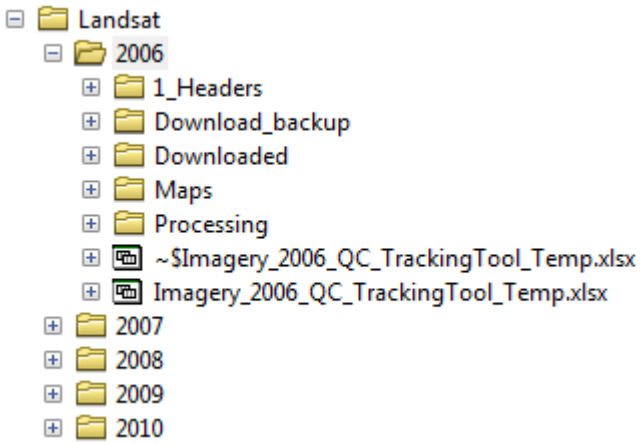


Figure 43. Subfolder Structure

Unzipping

5.1.3. Raw scenes selected for download are placed in the downloaded folder in zip format. Numerous zip utilities are available including 7zip and WinZip. Using a

zip utility, extract a scene to the downloaded folder as a single folder with the same scene ID as the folder name as seen in Figure 44.

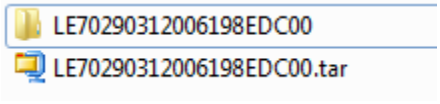


Figure 44. Unzipped Folder Naming

Processing Organization

5.1.4. Move the .tar zip file into the download_backup folder. Move the unzipped scene folder into the Processing folder under the corresponding path/row folder. The path/row directory is seen in Figure 45.

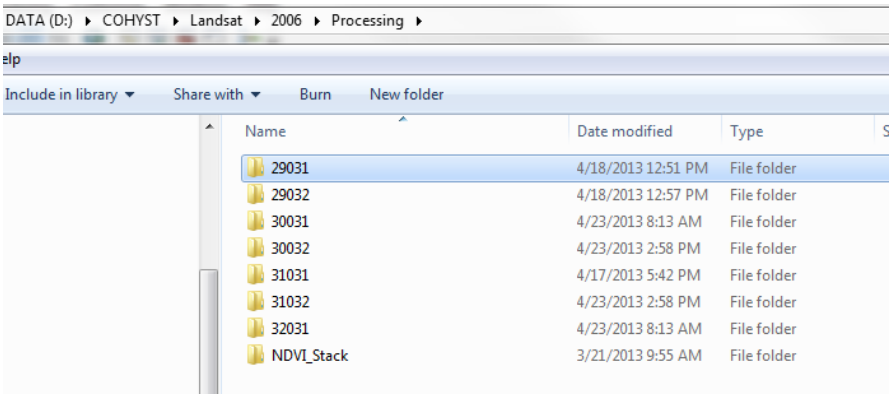


Figure 45. Path/Row Directory

5.1.5. Inside the corresponding path/row folder all unzipped scene folders should be seen as shown in Figure 46.

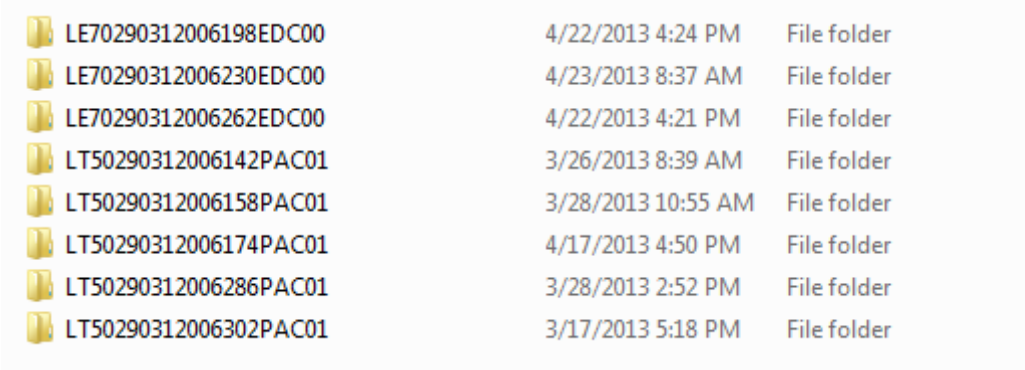


Figure 46. Unzipped Folders in Path/Row Directory

5.1.6. Inside the scene folder, all the raw files corresponding to specific downloaded scene are seen. Depending on the sensor, the number and name of files may vary. For the example L7 scene of 2006 the files seen in Figure 47 are available.

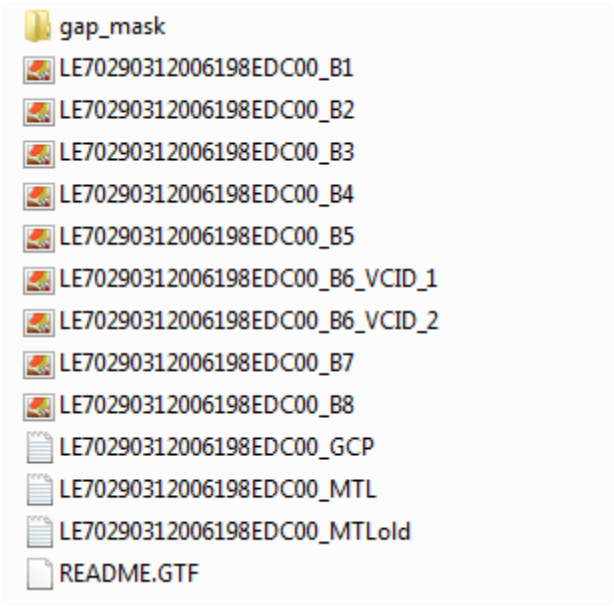


Figure 47. Example L7 Scene Files

5.1.7. Insure the folder name for a given scene matches the base scene ID of the individual files inside. The scene ID should also match the Tracking Tool Temp Spreadsheet that is found in the yearly folder directory. Update the tracking spreadsheet to monitor and track download status by scene.

5.1.8. Once all scenes have been: downloaded, unzipped and organized for a given year of study, a user can move to the first processing step.

6. Imagery Processing

Image Processing

6.1.1. Using the specific image processing (IP) storage framework recommended by Riverside, the toolset developed by Riverside can be used to automate specific IP procedures. The tools are intended to be used once all Landsat 5 and 7 imagery has been collected and extracted as described in section 3.3.2.

6.1.2. A single directory stores toolboxes and scripts used in processing imagery. Tools are organized by software used in executing functionality. Figure 48 shows the structure of tools used within the ESRI ArcGIS environment.

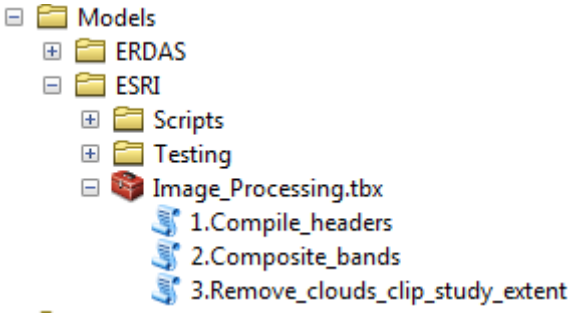


Figure 48. Structure of Tools Used within the ESRI ArcGIS Environment

Compile Headers

6.1.3. The compile headers script is used to remove all the header files provided with Landsat imagery downloads and place them in a single directory for further processing. The tool dialog is seen in Figure 49 and specifies the processing directory containing Landsat imagery for a single year and the output folder to place all headers files.

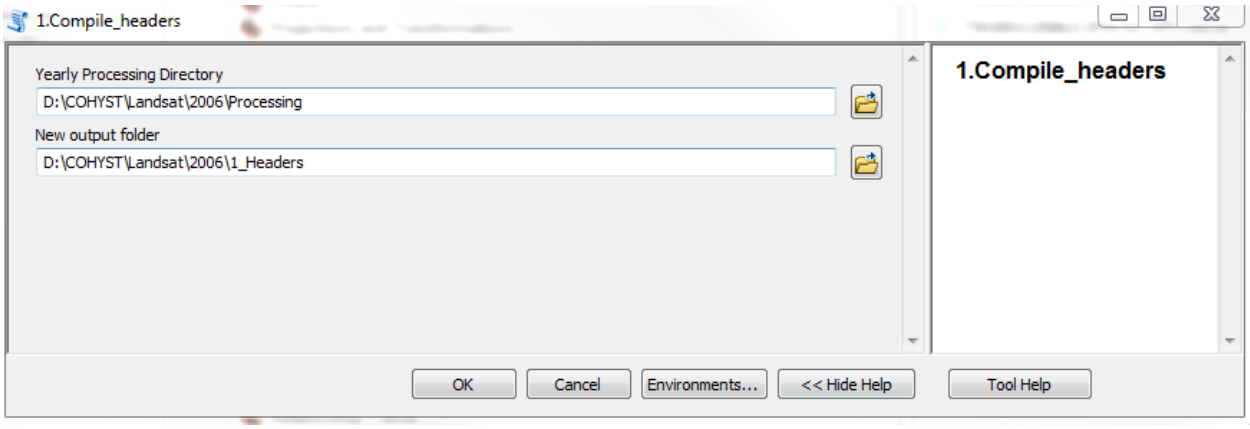


Figure 49.Tool Dialog

Multi-Band Stacking

6.1.4. By default all downloaded Landsat scenes are delivered in "tif" format by each band. The composite band script will go into each scene folder and compile all bands for a specific date into a single IMG file, using the scene ID for raster name. A user will need to change the background script to use the L7 script to correctly reference band 6. Figure 50 shows the tool dialog for entering a directory for band stacking. Run both Composite_bands.py and composite_Bands_L7.py if collections from both sensors was performed.

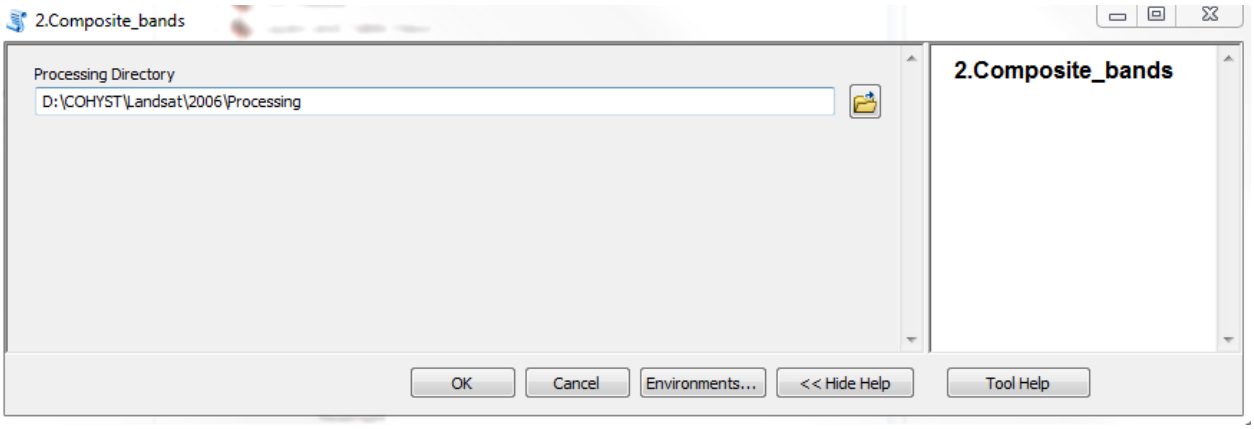


Figure 50. Tool Dialog for Entering a Directory for Band Stacking

6.1.5. The resulting IMG file for each scene can be seen in Figure 51.

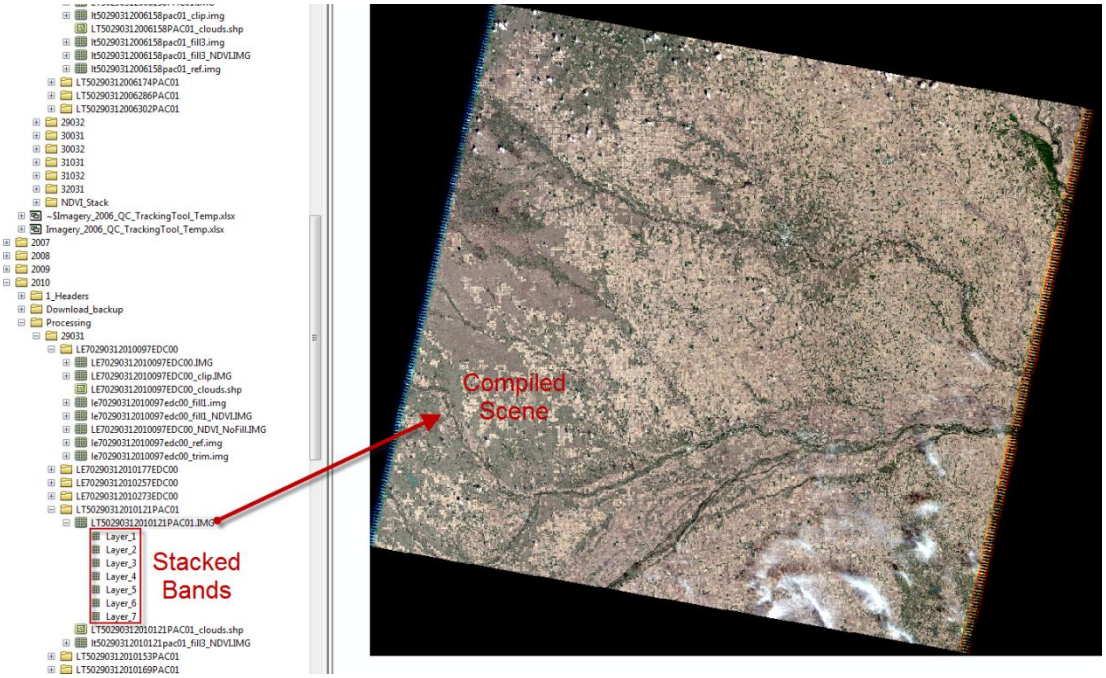


Figure 51. IMG File Output

7. Imagery Correction

TOA Correction for Landsat Data

7.1.1. Open the spreadsheet called "TOA_Correction.xlsm". Make sure to click on the tab called "START HERE" at the bottom of the spreadsheet once the spreadsheet is open.

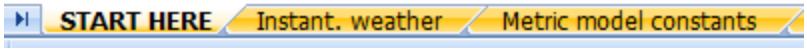


Figure 52. Showing the Location of the START HERE Tab

7.1.2. Change the name of the "pathname" and the name of the "meta file". The pathname is the folder in which the Landsat meta files are located, and the meta file is the exact name of the meta file.

Figure 53. Example showing where to change the pathname and meta file within the TOA Correction spreadsheet.

7.1.3. Click on the gray "Press" button located in the box called "Press button to Read Metafile + for happy results" on the left hand side of the spreadsheet. After being pressed, there should be no warning messages other than messages indicating the pathname and meta file have changed.

Note: All of the other cells that are highlighted in yellow within the spreadsheet will automatically update once "Press" is pushed.

Figure 54. The button to click on once the pathname and meta file has been changed.

7.1.4. At the bottom of the TOA Correction spreadsheet, click on the tab called "Metric model constants".

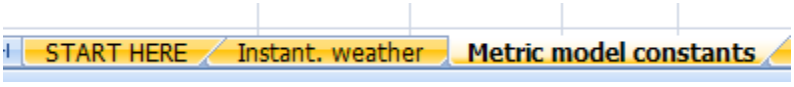
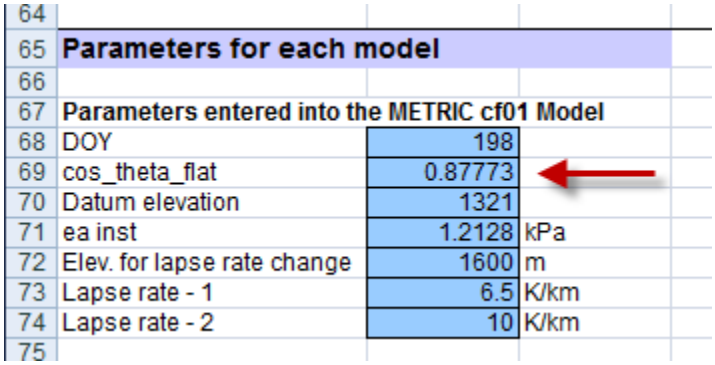


Figure 55. Showing the location of the Metric model constants tab.

7.1.5. About halfway down the page, you will notice blue cells that have values within them. You will want to record specifically the "cos_theta_flat" value.

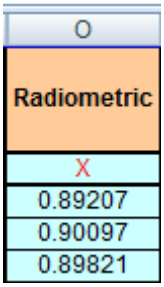


64			
65	**Parameters for each model**		
66			
67	**Parameters entered into the METRIC cf01 Model**		
68	DOY	198	
69	cos_theta_flat	0.87773	
70	Datum elevation	1321	
71	ea inst	1.2128	kPa
72	Elev. for lapse rate change	1600	m
73	Lapse rate - 1	6.5	K/km
74	Lapse rate - 2	10	K/km
75			

Figure 56. The red arrow shows the location of the cos_theta_flat value within the spreadsheet.

7.1.6. Record the "cos_theta_flat" value in a different tracking spreadsheet. This tracking spreadsheet is called "Imagery_2006_QC_TrackingTool_Temp". For following years (2007, 2008, 2009, and 2010), the name of the year was changed in the name of the spreadsheet.

Note: Record the "cos_theta_flat" value from each individual scene into the "Imagery_2006_QC_TrackingTool_Temp" spreadsheet under the column labeled "Radiometric".



O
Radiometric
X
0.89207
0.90097
0.89821

Figure 57. Showing where to record the cos_theta_flat value within the "Imagery_2006_QC_TrackingTool_Temp" spreadsheet.

7.1.7. Repeat steps 5.1.2 through 5.1.6 for all scenes that are being processed.

7.1.8. Within ERDAS Imagine, Click on the tab called "Toolbox" near the top of the screen.

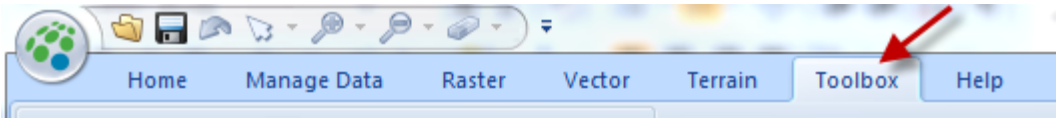


Figure 58. Example showing where the Toolbox tab is located in ERDAS Imagine.

7.1.9. Click on the icon "Model Maker".

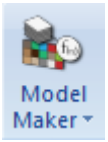


Figure 59. Model Maker Icon

7.1.10. Click on File → Open. Use the drop down button to navigate to the location of the TOA model. Select the model, and hit "OK".

Note: For Landsat 5 scenes, open the model called "ref_toa_metric_l5.gmd." For Landsat 7 scenes, open the model called "ref_toa_metric_l7.gmd"

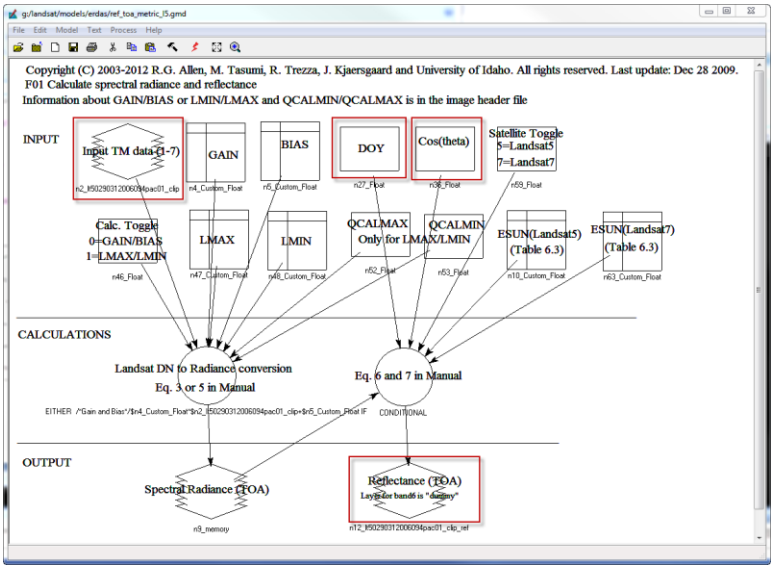


Figure 60. Example of the "ref_toa_metric_l5.gmd" model that is used for TOA correcting Landsat 5 scenes.

7.1.11. Notice the red boxes that show the variables that need to be edited for every Landsat scene (refer to later steps for more detail).

7.1.12. Within the model, double click on the variable "Input TM data (1-7)". Using the drop down menu, navigate to the workspace where the trimmed Landsat scenes are. Once the scene is selected, click "OK".

7.1.13. Double click on the variable "DOY" and in the value field, enter the date of the scene. Make sure you enter the date in Julian days. For example, if the scene date is 06/12/2006, enter the date as 163. The Julian date is also the last 3 numbers of the Landsat scene.

7.1.14. Double click on the variable "Cos(theta)" and in the value field, enter the cos_theta_flat value that was recorded in the Radiometric column of the tracking spreadsheet and click on "OK".

7.1.15. Double click on the variable "Reflectance (TOA)". Set the "File Name" to be the output .img file. Keep the name of the scene the same as the input Landsat scene, but add "_ref.img" to the end of the scene name to show that the scene has been TOA corrected. An example of an output scene name is… LT50290312006302PAC01_ref.img.

7.1.16. Once the variables "Input TM data (1-7)", "DOY", "Cos(theta)", and "Reflectance (TOA)" have been edited, click on "Process" → "Run". This will run the entire model for the Landsat scene. All of the other variables within the model are static, and do no need to be changed.

7.1.17. Repeat steps 5.1.12 through 5.1.16 for each Landsat scene until all of the Landsat scenes have been TOA corrected.

Note: Keep in mind to use the correct model, depending on if the scene that is being TOA corrected is Landsat 5 or Landsat 7". Refer back to step 5.1.10 for instructions on how to change the model.

8. Cloud Identification

Manual Heads-up Cloud Identification

8.1.1. Clouds will need masked for all Landsat scenes used in the COHYST project. To insure the following standards are applied across all scenes, the following steps need applied:

8.1.2. Create cloud shapefile. Shapefile will use the same projection for each scene it references. Use a naming convention of the following scene for each shapefile example "LT50290312006094PAC01_clouds.shp" Place the clouds shapefile in the corresponding scene folder as seen in Figure 74.

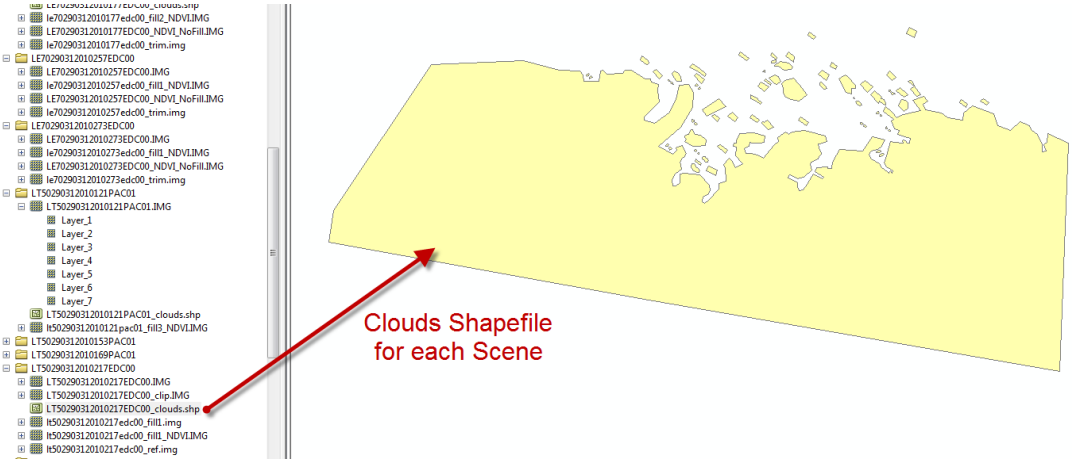


Figure 61. Digitize Clouds

8.1.3. Load the layer stacked image, COHYST boundary and new clouds shapefile into an ArcMap session. Digitize Cloud shadow features at a 1:10,000-25,000 scale. Only identify and mask clouds found within the COHYST boundary.

8.1.4. Use various band combinations to re-identify clouds. 5,3,1 3,2,1 5,2,1 are good RGB indicators used in cloud identification. Flicker various combinations on-off to help identify clouds. Use at least four combinations of the same scene while reviewing for hard to identify cloud shadow occurrences.

8.1.5. Insure all haze, jet contrails, and shadows are digitized into shapefile format. If the haze is almost impossible to recognize, exclude it from digitizing as digital numbers should be minimally altered.

8.1.6. Save edits.

Shapefile Cleanup

8.1.7. Create an attribute field called “Factor”. Make the field type ‘Text’ and character length ‘10’.

8.1.8. Run a dissolve command on the cloud features.

8.1.9. Calculate the ID field equal to “0”.

8.1.10. Record the cloud presence in the yearly tracking sheet with an “X” in the field “Clouds digitized”.

Alternative Cloud Identification by Classification

8.1.11. For some instances of cloud cover, a classification approach can be used to identify cloud cover. Typically, the approach is only used for areas with large occurrences of small cumulus clouds. The approach minimizes the effort required from digitizing. The approach is not often used as it usually makes more sense to not use the scene.

8.1.12. An unsupervised classification using 20-30 classes is used to isolate the clouds and cloud shadows. The cloud-covered scene is input into the classification and the remote sensing analyst must identify classes of clouds and shadows using the ERDAS Imagine signature editor and raster attributes. If there are classes in the unsupervised classification that are mixed (cloud shadow and lakes for example) the classes are further classified into smaller groups, a technique known as cluster busting. When the clouds and shadows have been isolated into unique classes the, final signature file is used to run a supervised classification on the cloud covered scene. The resulting classification is then used to create a mask (clouds and shadows = 0, all other classes = 1). The mask is multiplied with the original cloud covered scene. The result is an image with

the clouds and shadows filled in with zeros. This method is preferred for scenes containing many clouds with unclear boundaries and multiple shadows. For more information on this process and the capabilities of ERDAS Imagine on isolating and manipulating individual cover-type signatures see the ERDAS Imagine Field Guide.

9. Cloud Masking and Study Area Clip

Remove clouds and clip tool

9.1.1. Once clouds have properly digitized for each scene the image processing tool Remove_clouds_clip_study_extent can be used to run through each scene folder to create a new IMG file where clouds have been removed and the scene has been clipped to a buffered COHYST study boundary extent. Figure # shows the dialog for running the tool.

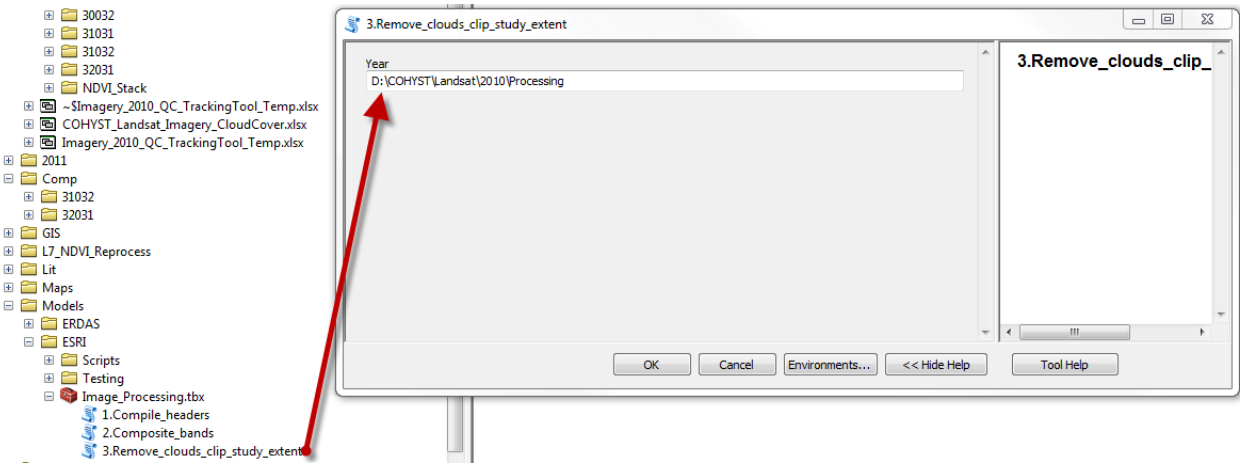


Figure 62. Cloud removal tool dialog

9.1.2. The tool will look in each scene folder and search for a cloud shapefile. If no clouds are present, clipping will only be performed. The clipping operation uses the scene ID to call the corresponding AOI file for clipping. If clouds are found, the tool will remove clouds and then clip to the AOI file. Areas with corresponding clouds presence will have pixel values set to zero. For Landsat 7 scenes, missing scan line areas will also have pixel values set to zero. Figure 76 shows an example Landsat 5 scene where clouds were removed and clipped to the AOI extent.

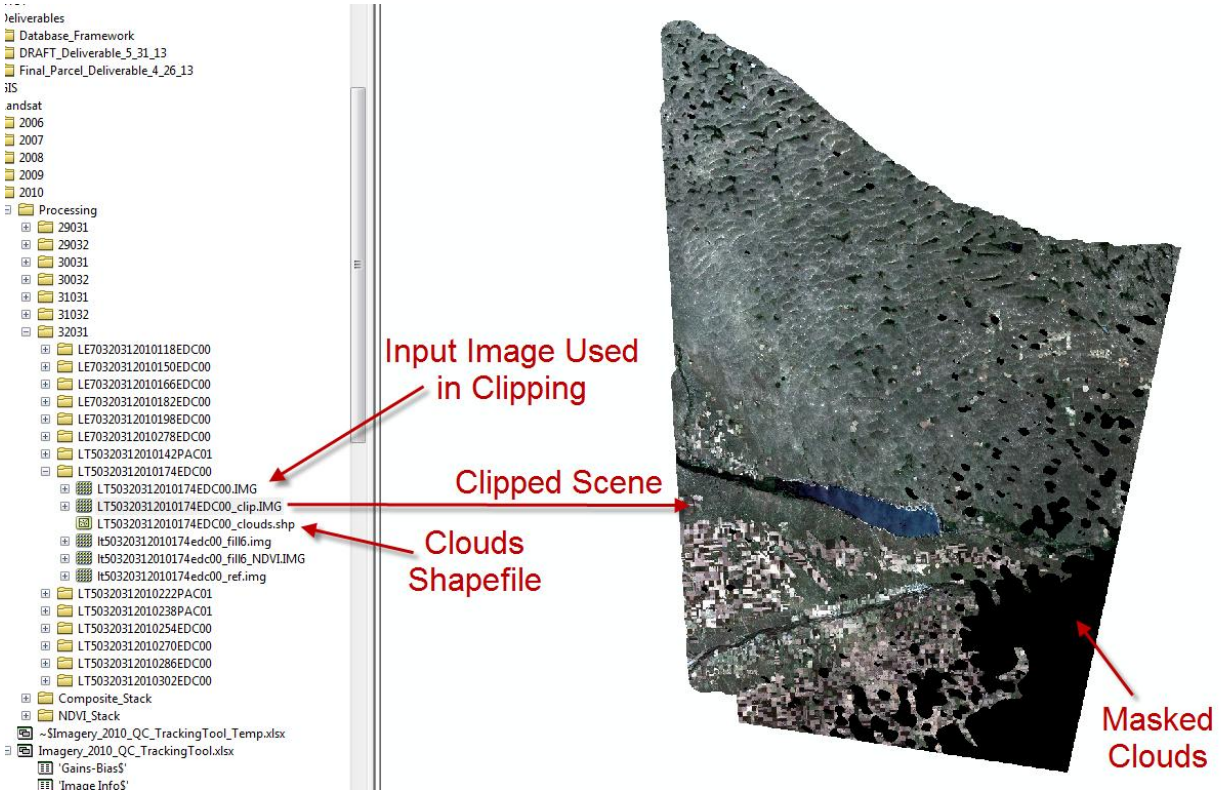


Figure 63. Resulting image with clouds removed

10. Cloud Filling Procedure

10.1.1. The cloud fill procedure that Riverside used requires a two step process. Step 1, in which images are identified and selected to use in the cloud fill procedure and Step 2, in which the masked clouds are filled with the selected cloud free images.

Identifying Landsat Images For Use To Fill Clouds of Masked Scenes

10.1.2. Although the same process is used for both Landsat 5 and Landsat 7 to select imagery to fill masked scenes with, there is a slight difference in the Landsat 7 imagery.

10.1.3. Open ArcMap.

10.1.4. Using the "Add Data" icon, navigate to the location of the scene that has masked clouds. Click on the scene and select Add. The masked scene will be 'black' in areas in which the scene needs to have filled clouds.

Figure 64. The Add Data icon

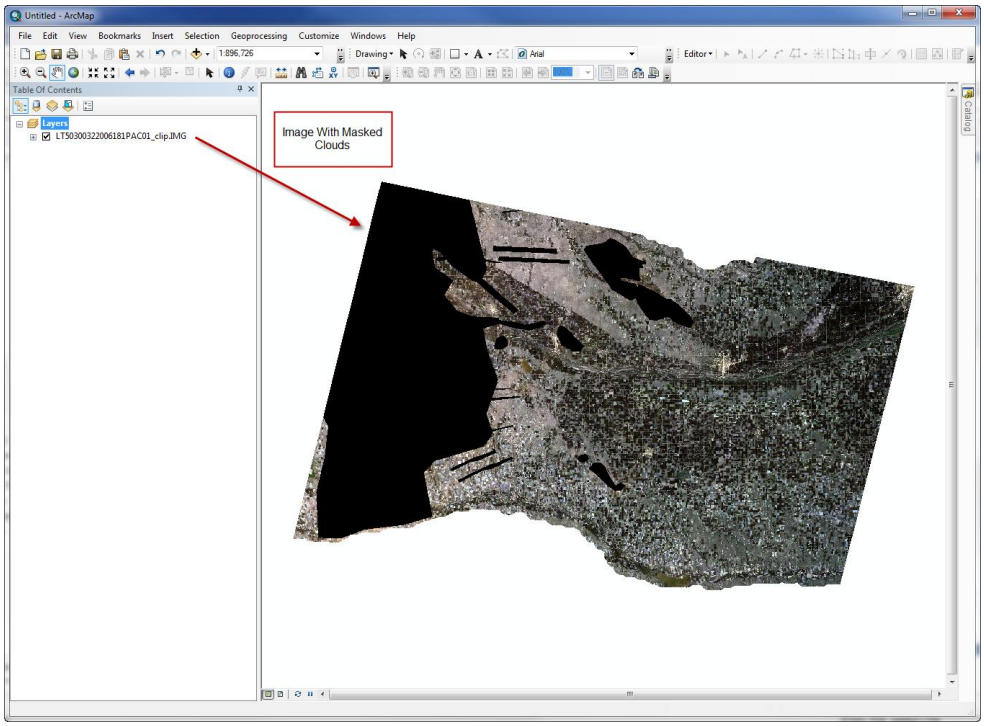


Figure 65. Image with masked clouds in ArcMap. Notice the areas that used to be clouds are now black areas.

10.1.5. Since many of the images taken form Landsat overlap, filling from adjacent frames is possible for certain frames. Refer to the tracking spreadsheet to see if the frame is eligible for filling from scenes of different frames. For example, for the year 2006, in the tracking spreadsheet called "Imagery_2006_QC_TrackingTool_Temp.xlsx" there are columns denoting whether or not the frame has a left fill option, and right fill option from other frames. If no right or left fill options are available, fill scenes will have to be taken from prior or later scenes.

10.1.6. Using the "Add Data" icon, load the next closest date scene into ArcMap. This scene can either be an adjacent scene from a frame to the right (right fill) or left (left fill), or a scene of the same frame as the scene that has been masked and needs filled.

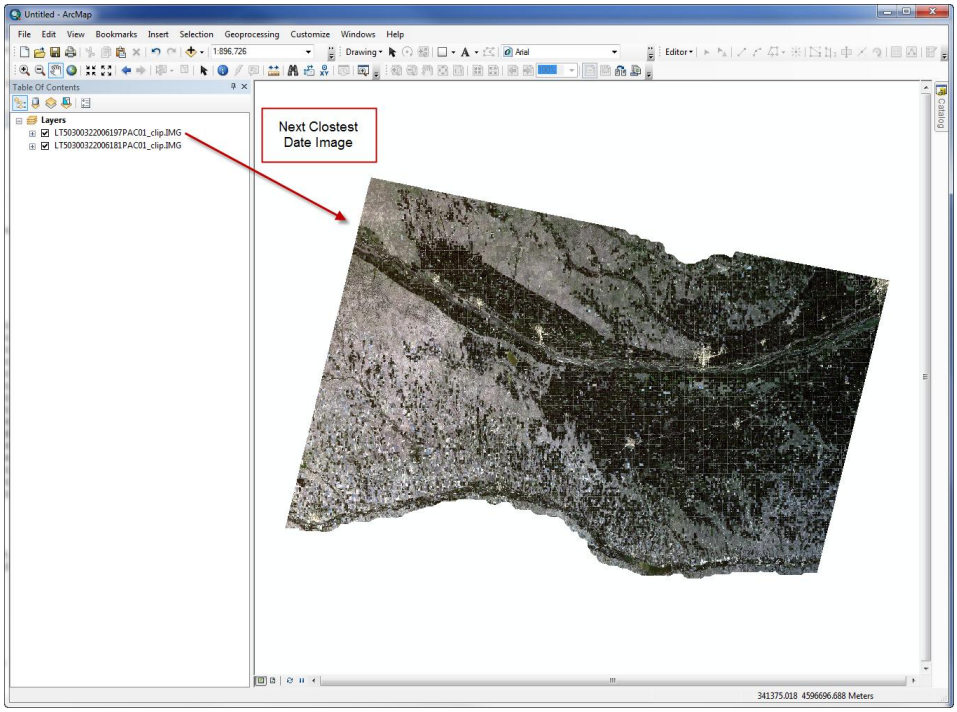


Figure 66. Showing the next closest date image in ArcMap This image was taken 16 days later than the masked scene that needs filled. Notice that this scene is cloud free, and thus will cover up all of the masked areas of the image beneath it that needs filled.

10.1.7. Toggle the cloud free image on and off to see if the cloud free scene 'covers up' all of the masked clouds of the scene that you are trying to fill. If the scene does not fill all of the masked areas, bring in the next closest date scene and so on until all of the masked areas are covered.

> ***Note:*** Only use scenes that are no more than a month apart from the masked scene since ground cover, NDVI values, etc. can start to greatly vary if there is over a month of gap between scenes.

10.1.8. If the scene selected for fill is from a frame to the right or left, record the frame and Julian date of the scene in the tracking spreadsheet.

10.1.9. If the scene selected for fill is from the same frame (either prior or after), record the date in the tracking spreadsheet.

Y	Z	AA	AB	AC	AD	AE
Left fill Option	Clouds Replaced (Left)	Right fill Option	Clouds Replaced (Right)	Cloud Replaced Same Frame (Prior)	Cloud Replaced Same Frame (After)	All of clouds covered?
Yes	5/27 (32031-147)	Yes	5/29 (30031-149)	N/A	6/5 (31031-156)	Yes

Figure 67. Example showing a scene with masked clouds that has had images selected for fill. Notice this scene has fill scenes from both the right and left, as well as a fill scene from a later date.

10.1.10. Repeat steps 8.1.4 through 8.1.9 until all masked Landsat 5 images have had filling options evaluated.

10.1.11. For Landsat 7 images after 2003, a scan line correction error occurred, so there are black gaps of no data in these Landsat 7 scenes. These gaps are linear, and are thicker near the edges of the scene. These gaps can be treated as masked clouds, and need to have imagery selected for filling the same as the Landsat 5 scenes.

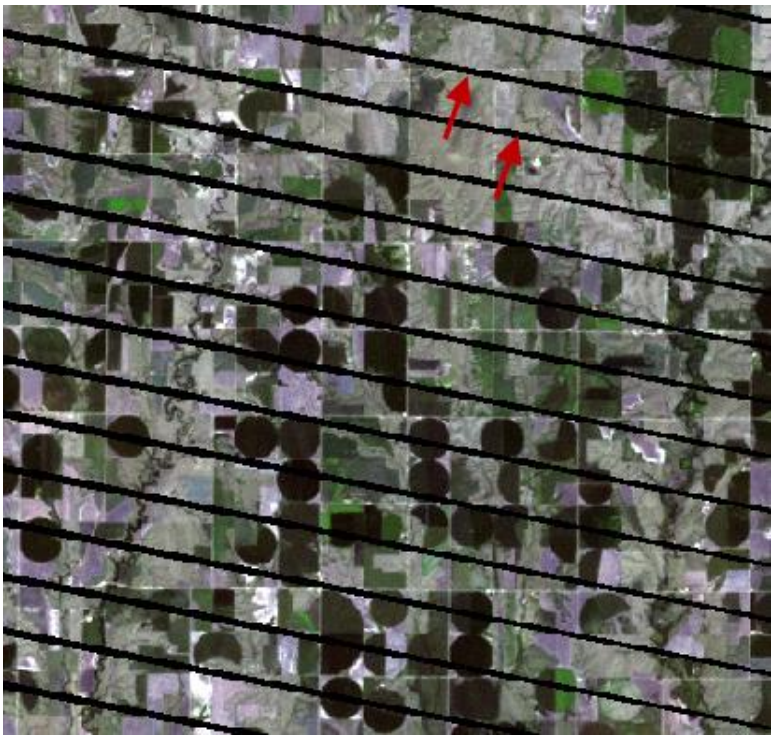


Figure 68. Portion of a cloud free Landsat 7 scene. Notice the red arrows pointing to the scan line gaps that all Landsat scenes following the year 2003 have. These black lines are areas of 'no data' so they can be treated the same as masked clouds and can be filled the same way as Landsat 5 scenes.

10.1.12. Repeat steps 8.1.4 through 8.1.9for all Landsat 7 scenes.

10.1.13. All Landsat 5 and Landsat 7 images that have had clouds masked and/or scan line errors (Landsat 7) should now have fill imagery selected. These masked scenes are now ready to be filled by the selected cloud free images.

Filling Masked Clouds

10.1.14. The process of filling the scenes that have masked clouds should only be started once **all** of the masked Landsat 5 scenes and **all** Landsat 7 scenes have had scenes selected for fill.

10.1.15. Open the tracking spreadsheet for the year with the scenes that need filling.

10.1.16. Open ERDAS Imagine

10.1.17. Within ERDAS Imagine, Click on the tab called “Toolbox” near the top of the screen.

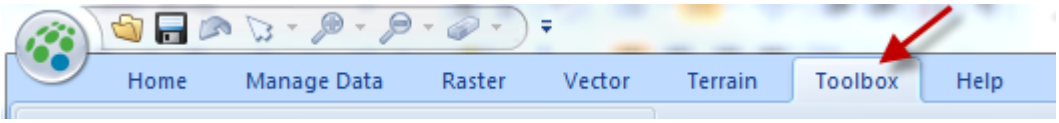


Figure 69. Example showing where the Toolbox tab is located in ERDAS Imagine.

10.1.18. Click on the icon “Model Maker”.

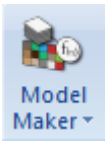


Figure #. Model Maker icon.

10.1.19. Click on File → Open. Use the drop down button to navigate to the location of the fill model. The name of the model used for filling masked clouds is “clouds_fill_new.gmd” Select the model, and hit “OK”.

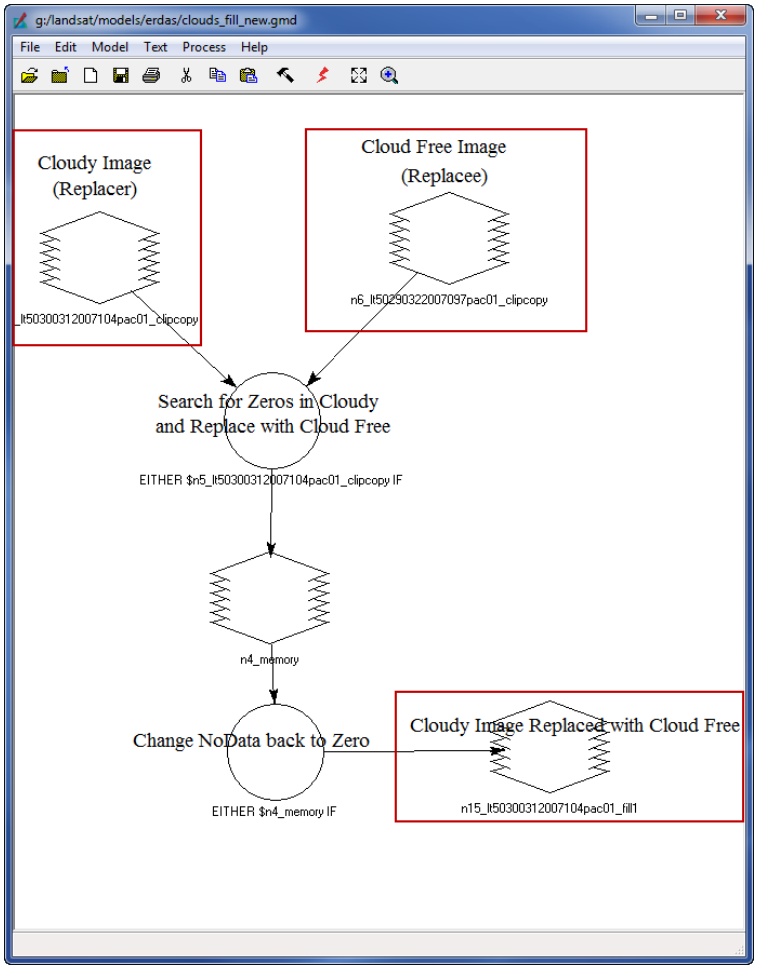


Figure 70. Showing the "clouds_fill_new.gmd" model that is used to fill the masked clouds. Notice the 3 variables in the red boxes that are going to need to be changed for every scene.

10.1.20. Double click on the variable "Cloudy Image (Replacer)". This variable is the scene that has had clouds masked. Under the "File Name (*.img)" box, click on the yellow folder icon and navigate to the workspace that has the first scene that needs to be filled. Click "OK".

10.1.21. Double click on the variable "Cloud Free Image (replace)". This variable represents the next closest fill date that was determined in step 1. The fill scenes should already have been recorded in the tracking spreadsheet. Click on the yellow folder icon and navigate to the workspace that has the fill scene. Once the scene is selected, click on "OK".

Y	Z	AA	AB	AC	AD
Left fill Option	Clouds Replaced (Left)	Right fill Option	Clouds Replaced (Right)	Cloud Replaced Same Frame (Prior)	Cloud Replaced Same Frame (After)
Yes	NO	Yes	NO	9/25 (31031-268)	N/A

Figure 71. Showing the selected fill scenes for a given masked scene. Notice this masked scene only needs one other cloud free date to fully fill all of the masked clouds. Other masked scenes may need more that one fill scenes depending on the amount of masked clouds and if a right/left fill is used.

10.1.22. Double click on the variable "Cloudy Image Replaced with Cloud Free". This variable represents the output scene (.img) that will be the original masked scene with the new fill. Use the yellow folder icon to navigate to the output workspace where you want the new filled scene to go. Keep the same naming convention as the masked scene, except add "_fill1" to the end of the scene to show that the scene has been filled with 1 scene. An example name of a filled scene would be…' lt50300322006181pac01_fill1.img'.

10.1.23. Make sure the model has the correct 'Area of Interest' set. Each frame has a different area of interest (frame boundary), so this will need to be set for each frame. To set the area of interest, click on "Model"→ "Area of Interest…". Press the "AOI File" radio button. Use the yellow folder icon to navigate to the location of the AOI files and click on the respective AOI file for the corresponding scene. For example, if you are filling frame 31032, the correct AOI file will be '31032.aoi'. Click "OK".

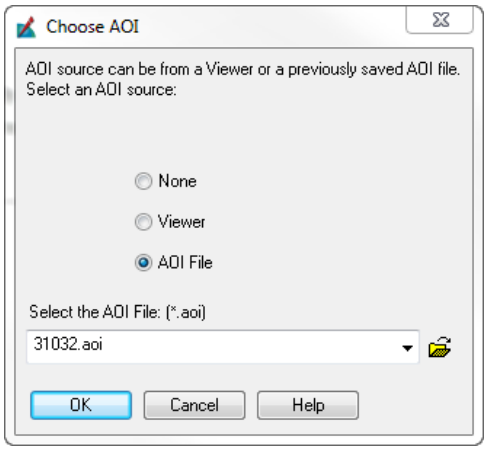


Figure 72. Changing the AOI for a frame.

10.1.24. If the masked scene needs more than one fill scene to fill all of the masked clouds, use the last *_fill* scene as the "Cloudy Image (Replacer)" variable. For example, if the masked scene needs 3 fill scenes, the final fill scene should have the name '_fill3' at the end of the final output fill scene.

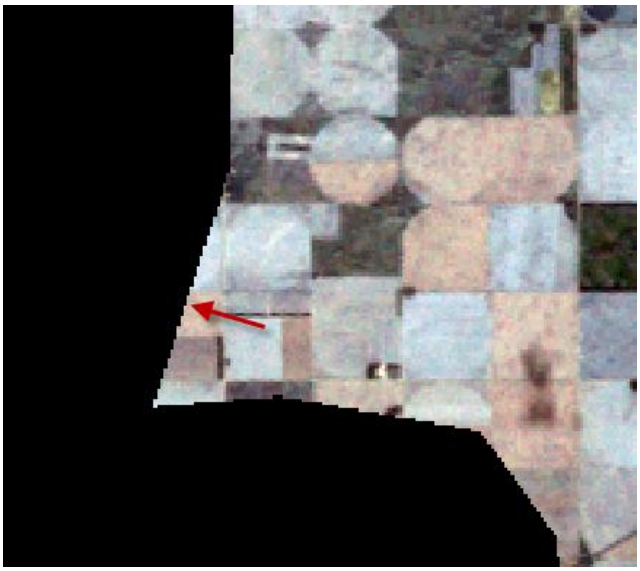


Figure 73. Showing the 'un-filled' masked scene. Notice the black areas being the masked areas that need filled.

Figure 74. Showing the same masked scene that has now been filled by another scene. Notice the red arrow pointing out the boundary of where the fill scene filled the masked scene.

10.1.25. Use the "clouds_fill_new.gmd" model to fill all of the masked scenes, as well as all of the Landsat 7 scenes. Refer to the figures below for figures of Landsat 7 scenes before and after filling. After the scene has been filled, record in the tracking spreadsheet under the column "All of clouds covered?" whether or not all of the masked clouds have been filled.

AE
All of clouds covered?
Yes
Yes
Yes
Yes
No

Figure 75. Showing the column where to note whether all of the masked clouds have been covered by the fill process. Some reasons for marking 'NO' may be that there wasn't adequate cloud free fill scenes to fill with, or that the fill scenes are more than a month away from the masked scene and thus cannot be used for fill.

Figure 76. Showing a typical Landsat 7 scene. As mentioned before, treat the scan line gaps as masked clouds that need to be filled.

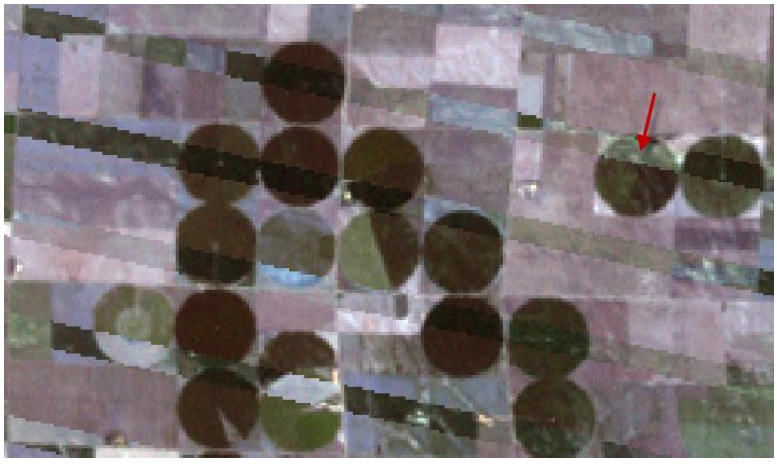


Figure 77. Showing the Landsat 7 scene, after the scan line gaps have been filled by another scene. Notice the red arrow pointing out the newly filled scan line gap.

11. NDVI Generation

Generate NDVI For the Individual Image

11.1.1. Once all clouds have been filled and instances of scenes with remaining clouds have been recorded within the tracking spreadsheet The Normalized Difference Vegetation Index (NDVI) can be calculated for each filled scene.

11.1.2. Use the developed "NDVI" tool to automate the processing of NDVI results for each scene. Values are left at floating point scaled from -1 to 1. Disk space for floating point precision is not much greater than integer.

NDVI Composite Generation

11.1.3. The NDVI Composite is produced by compiling each available coverage using the Composite Bands tool. Begin by right-clicking on your Toolbox menu and adding the following toolbox:
COHYST\Landsat\Models\ESRI\Image_Processing.tbx

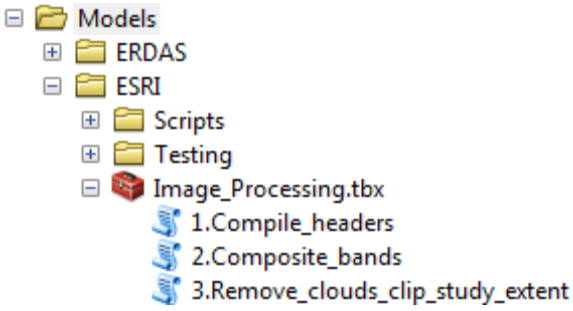
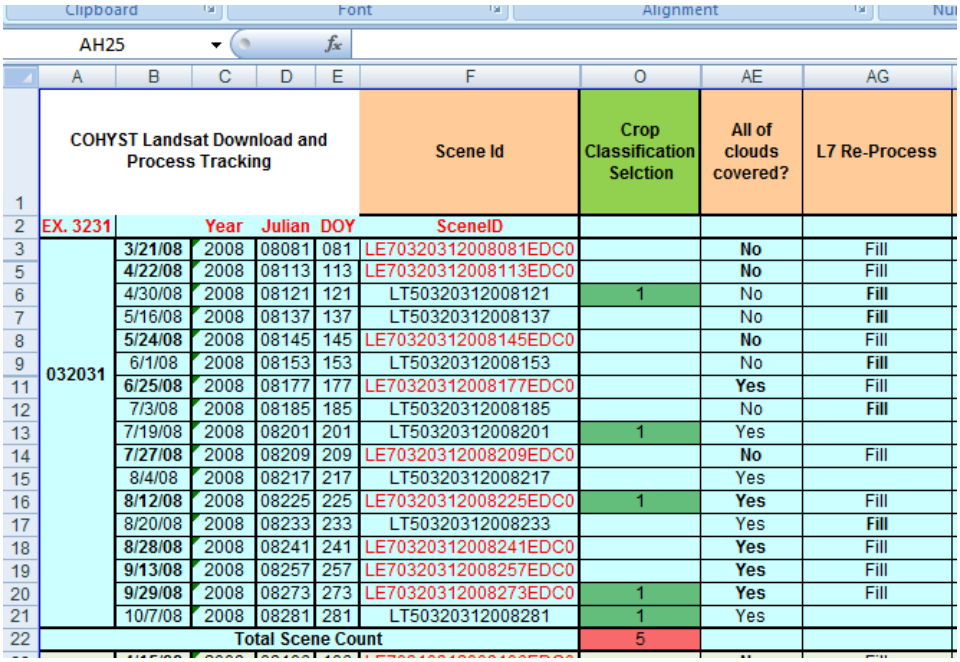


Figure 78. Adding Composite Bands to Tool Box Menu

11.1.4. In order to properly stack the imagery in the order of date taken it is necessary to use the following tracker as well:

X:\Projects\COHYST\Landsat\2010\Imagery_2010_QC_TrackingTool_Crops.xlsx

11.1.5. Column E in the spreadsheet corresponds to the Julian day of the year, which is also shown in the highlighted area of the coverage file name.



	A	B	C	D	E	F	O	AE	AG
1	COHYST Landsat Download and Process Tracking					Scene Id	Crop Classification Selction	All of clouds covered?	L7 Re-Process
2	EX. 3231		Year	Julian	DOY	SceneID			
3	032031	3/21/08	2008	08081	081	LE70320312008081EDC0		No	Fill
5		4/22/08	2008	08113	113	LE70320312008113EDC0		No	Fill
6		4/30/08	2008	08121	121	LT50320312008121	1	No	Fill
7		5/16/08	2008	08137	137	LT50320312008137		No	Fill
8		5/24/08	2008	08145	145	LE70320312008145EDC0		No	Fill
9		6/1/08	2008	08153	153	LT50320312008153		No	Fill
11		6/25/08	2008	08177	177	LE70320312008177EDC0		Yes	Fill
12		7/3/08	2008	08185	185	LT50320312008185		No	Fill
13		7/19/08	2008	08201	201	LT50320312008201	1	Yes	
14		7/27/08	2008	08209	209	LE70320312008209EDC0		No	Fill
15		8/4/08	2008	08217	217	LT50320312008217		Yes	
16		8/12/08	2008	08225	225	LE70320312008225EDC0	1	Yes	Fill
17		8/20/08	2008	08233	233	LT50320312008233		Yes	Fill
18		8/28/08	2008	08241	241	LE70320312008241EDC0		Yes	Fill
19		9/13/08	2008	08257	257	LE70320312008257EDC0		Yes	Fill
20		9/29/08	2008	08273	273	LE70320312008273EDC0	1	Yes	Fill
21		10/7/08	2008	08281	281	LT50320312008281	1	Yes	
22	Total Scene Count						5		

Figure 79. Spreadsheet tracking

11.1.6. Add each clipped image from earliest to latest, in the order it appears in the spreadsheet. Only use the selected images that have the least amount of fill. In this case, only the images that are green under column O will be used for NDVI stack., The naming convention for the above NDVI composite is as follows: 30032_NDVI_Stack_mMjjjJJAASS. This naming convention uses a lower-case letter for the first month beginning with the same letter, and then a capitalizes the letter of the next month of the same letter. In this case the name of this image shows that the bands were taken in this order: March, May, June, June, June, July, July, August, August, September, September

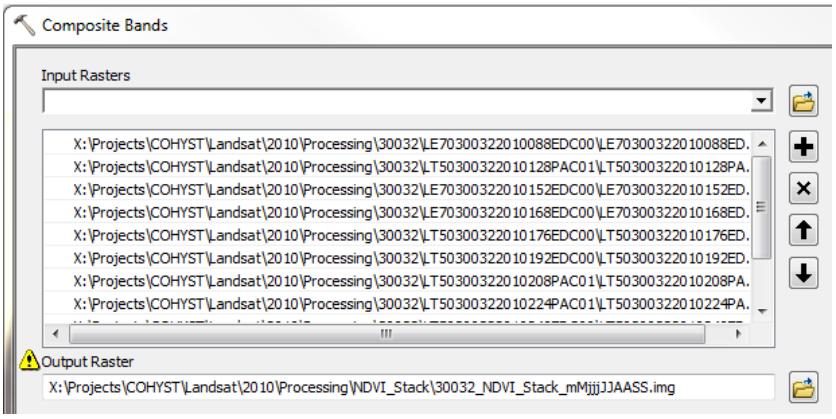


Figure 80. Composite bands dialog

11.1.7. Create a folder for your NDVI composites, and output your files there. Your NDVI coverage will initially show the first three available images for each band.

There will more than likely be gaps in coverage and bands of distortion; in addition to this, using only the first three bands will not give the three season view of the study area that is needed. Toggle the bands by clicking on the symbols for each band.

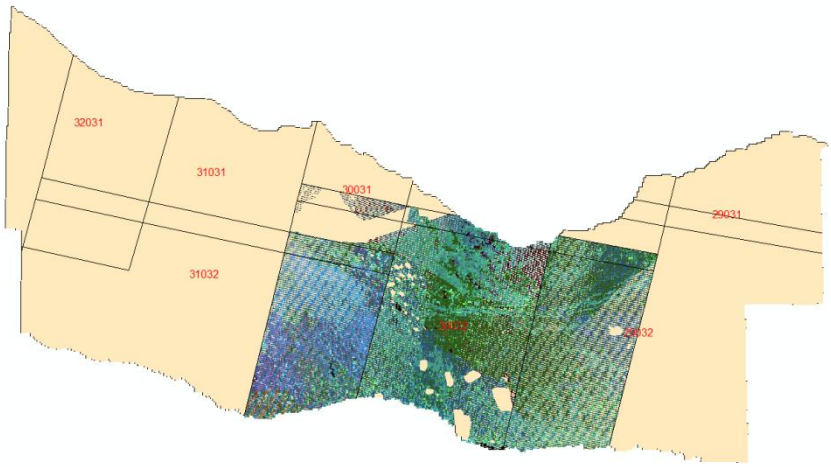


Figure 81. NDVI results for frame 30032

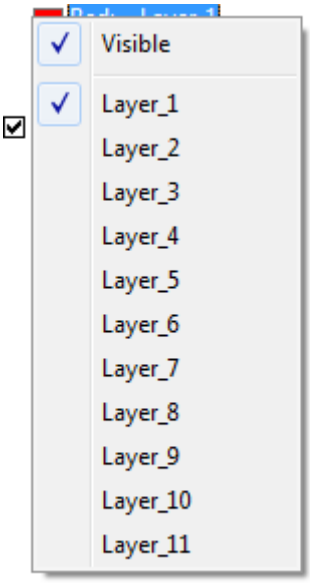


Figure 82. Band adjustment dialog

11.1.8. The following image was achieved using a 1,5,11 band combination – or March, June, September.

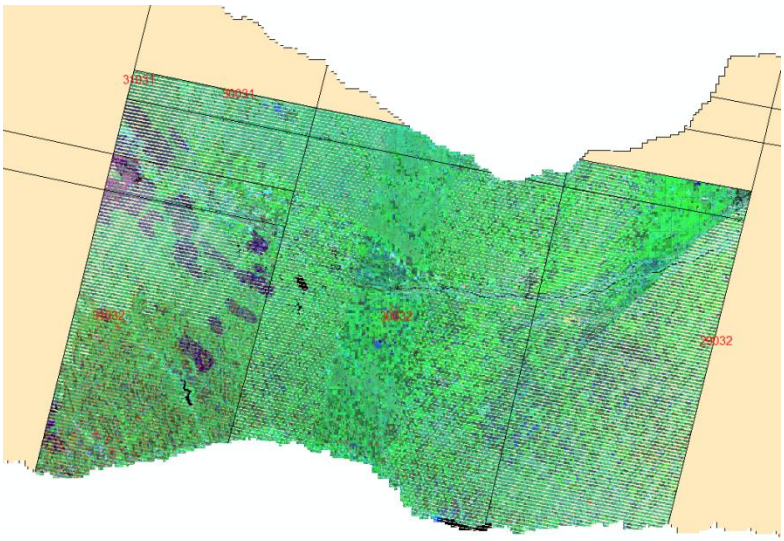


Figure 83. Altered band adjustment for specific day combination

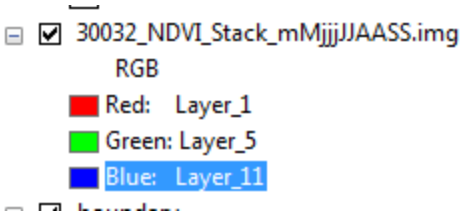


Figure 84. Band adjustment set for May, Late--June, Early-September

11.1.9. Each coverage will require some amount of adjustment; at times it is necessary to adjust the bands while working within the same coverage area in order to view changes in land use and to remove distortion in isolated areas.

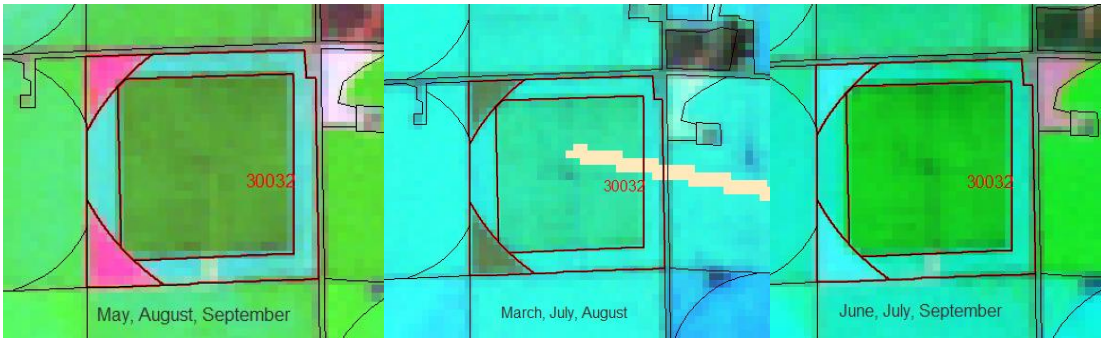


Figure 85. Example parcel review under three different band combination settings

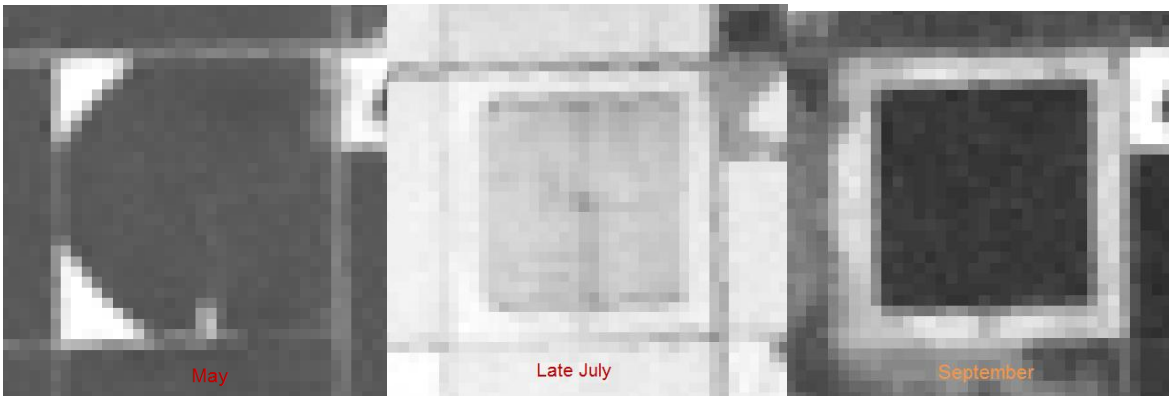


Figure 86.

11.1.10. The top row shows three different band combinations, while the second row shows three individual months. Using a variety of band arrangements as well as single month views can show planting and harvesting patterns, in addition to parcel and crop boundaries. It can be determined using the above collection of images that the crops in the left hand corners of this parcel may have been harvested sometime in late June to early July.

TASK II. PARCEL EDITING

12. Overview

Objective

12.1.1. The objective of this task is developing an accurate GIS dataset which contains individual yearly datasets representing all agricultural parcel boundaries within the COHYST study area.

Definitions

12.1.2. Agricultural Parcel – An area defined by a clear boundary where the soil has been altered for purposes of crop production or where feedlot operations are active. Parcels can be irrigated or non-irrigated. In addition, parcels which appear to be temporarily fallow should fall within this definition.

12.1.3. Parcel Boundary – The parcel boundary should represent the true edge of the agricultural activities. County or City roads, farm buildings and homesteads, gravel or paved lots, on-farm ponds or lakes, or other non-agricultural use areas should fall outside of the parcel boundary. Small on-farm roads may be included within the parcel boundary.

Figure 87.Parcel boundary adjustment to reflect area of agriculture

12.1.4. The images above depicts a parcel that required a change in geometry in order to remove the homestead. Changes in geometry to remove non-agricultural parcels may be performed using the Reshape feature tool in the editor toolbar.

13. Editing Guidelines

Maintain Topology

13.1.1. Maintaining the topology rules can most easily be achieved by always using auto complete polygon when making parcel adjustments and enabling snapping.

When editing parcels it is not always possible to see where there are small gaps and overlaps – these errors in topology will become evident when performing topology validation at the very end.

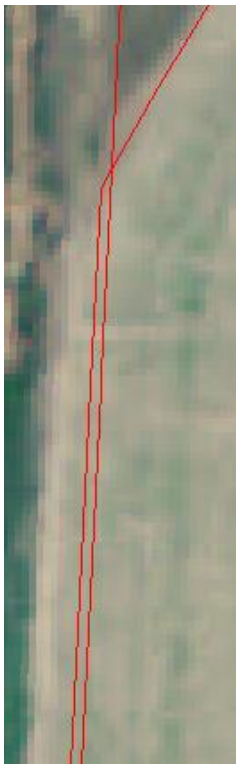


Figure 88.Topology error requiring adjustment

13.1.2. Areas of parcel overlap such as this may be adjusted using the Reshape Feature editing tool.

Provide Attribution for Feedlots

Figure 89. Example feedlot

13.1.3. The majority of feed lots will appear similar to the above image on NAIP; individual stalls will be visible and at times livestock can be seen grouped

together within these stalls. Feed lots will also appear very dark in color on Landsat NDVI imagery.

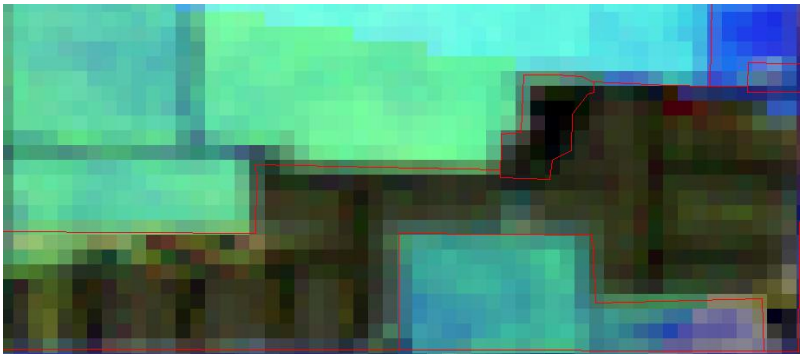


Figure 90. Feedlot as seen by the Multi-Temporal NDVI

13.1.4. Feed lots may be attributed quickly utilizing the following method. First, open the attribute table of the preceding year and select from the LANDUSE_TYPE field all features that are feed lots.

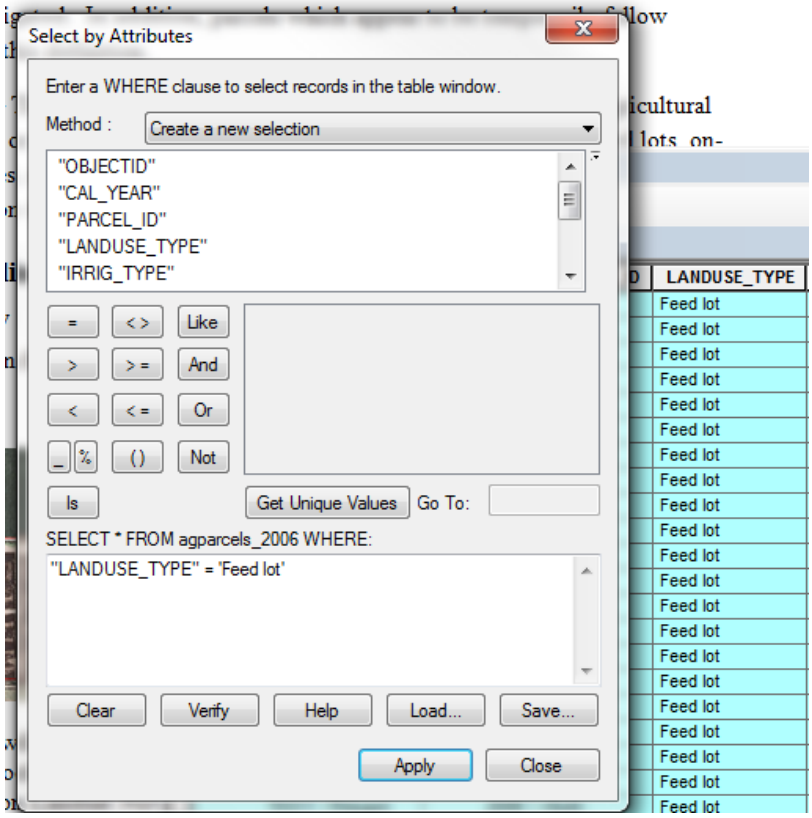


Figure 91. Land use attribution dialog

13.1.5. Once all feed lots have been selected, right click on the parcel shapefile for that year in the table of contents, go to Data, and then Export Data. This will

export the selected parcels to a new shapefile showing feed lot parcels only. From here you will use the Feature to Point tool in order to create points that will be generated at the center of each parcel.

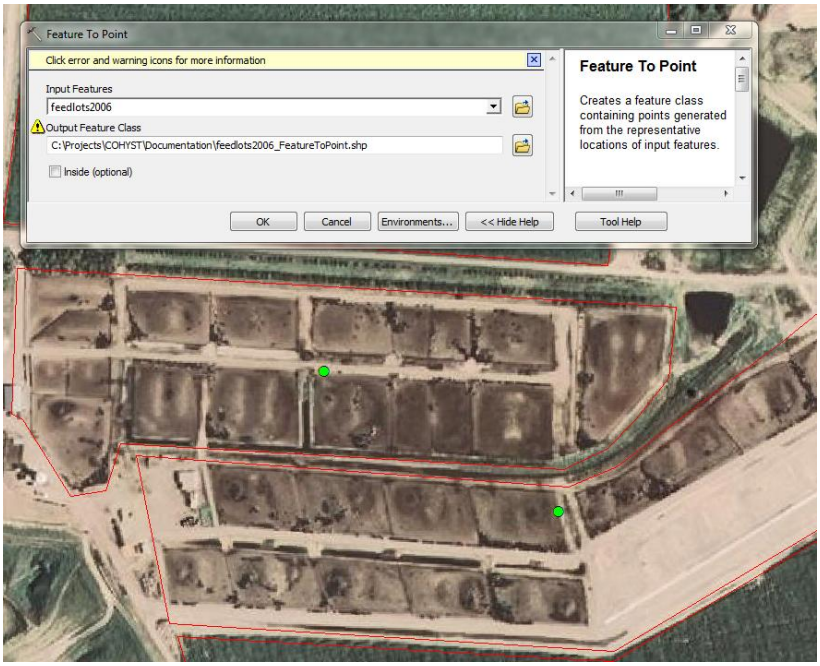


Figure 92. Feedlot point based layer used in reviewing addition years

13.1.6. From there a Selection by Location can be performed in order to calculate the location of feed lots into the new year. Begin by clicking on 'Selection' on the top menu and then Select by Location. Choose the shapefile of the year the values will be calculated into as the target year, and the feed lot point file as the Source Layer. Use 'contain the source layer feature' as the spatial selection method, and apply a search distance for 100 feet. The application of a search distance will be more important for attributing center pivots when using this method, in order to account for crop splits and yearly perimeter variability.

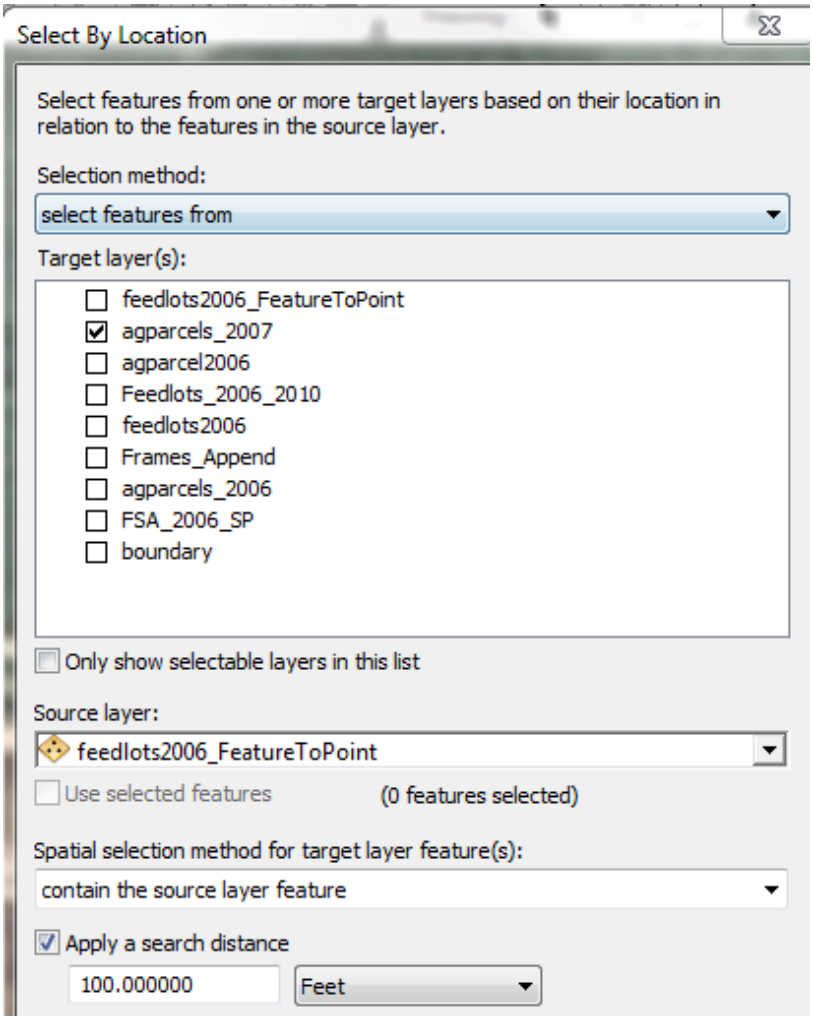


Figure 93. Feedlot selection dialog

13.1.7. Once your selection is created begin an Editor session by clicking on the Editor toolbar and 'Start Editing'. Open the attribute table of the target parcel year, click on 'show selected records' at the bottom of the table, and the right click at the top of the LANDUSE_TYPE field and select the field calculator. Enter "Feed lot" into the field calculator and this will enter this value into each selected record.

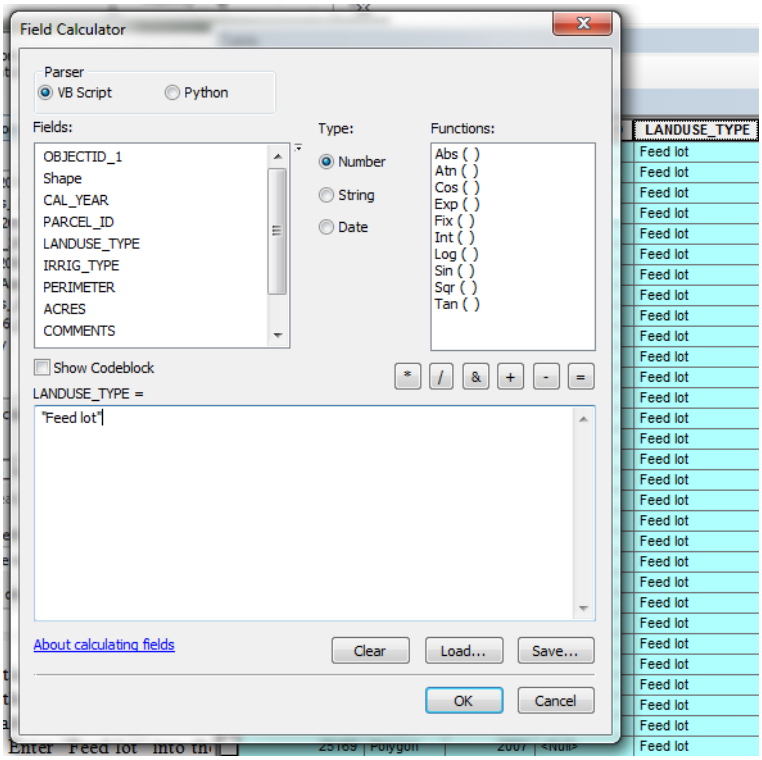


Figure 94. Feedlot attribution dialog

13.1.8. This method may be used to attribute any feature, such as center pivots or golf courses; however, the study area must be reviewed for accuracy as the locations of features vary with each year. Feed lots may appear or be repurposed year to year, or the shape of the feed lot parcel may change and be missed by the Selection by location.

Utilize Circle Construction Tool for Center Pivots

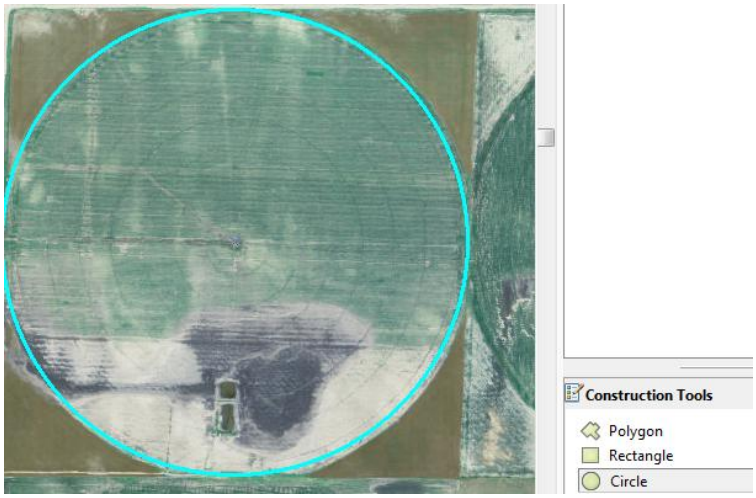


Figure 95. Pivot construction tool

13.1.9. The circle construction tool should be utilized when adding new center pivot parcels; however, center pivots are best adjusted using the End Point Arc Segment tool in the editor toolbar. This tool will reshape uneven or improperly delineated pivot segments.

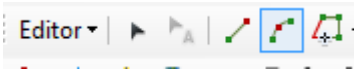
13.1.10. 

Figure 96.

Use Auto Complete Functionality for Parcel Adjustments

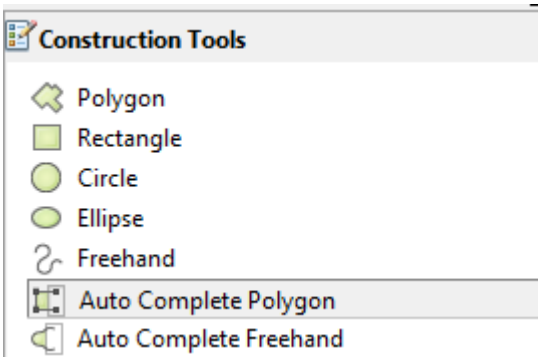


Figure 97.

13.1.11. Unless adding a new parcel that will not be connected to a pre-existing parcel, it is necessary to use Auto Complete Polygon to maintain proper topology and geometry. The following shows as example of adding a center pivot using the End Point Arc Segment tool with Auto complete Polygon selected.

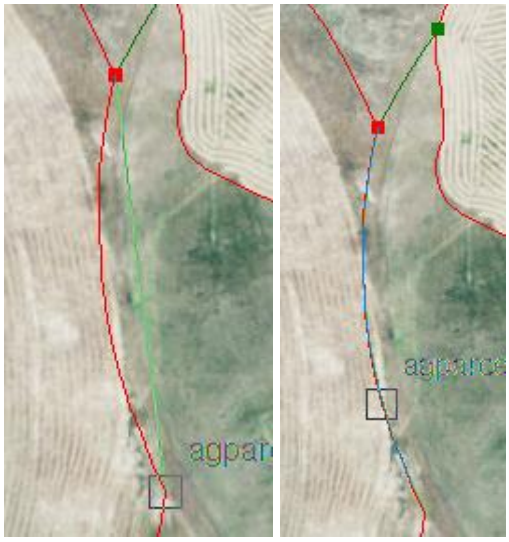


Figure 98. Parcel boundary adjustment

13.1.12. Using these tools ensures that your edits will conform to the existing geometry.

Maintain Project Projection: NAD 1983 State Plane Nebraska FIPS 2600 Feet

13.1.13. The proper projection may be maintained for all items in your MXD by setting your coordinate system in the data frame properties.

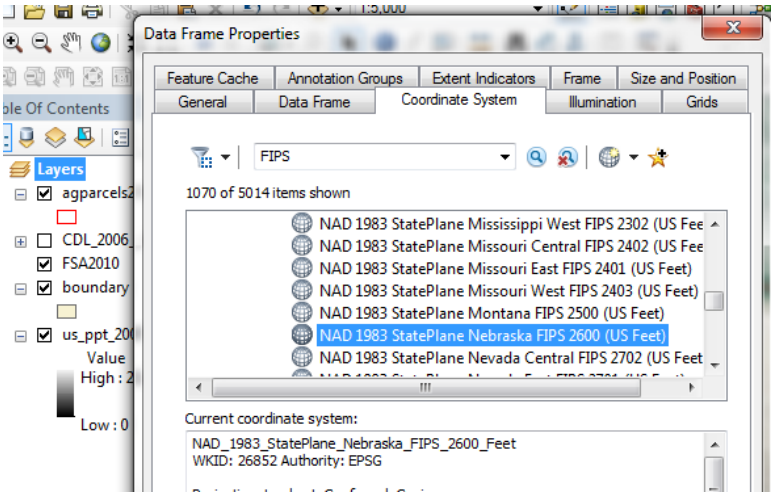


Figure 99. Projection verification dialog

13.1.14. Right click on the data frame in your Table of Contents and select properties, and then Coordinate System. This projection can be found under Projected Coordinate Systems >> State Plane >> NAD 1983 (US Feet). You can also maintain the proper projection for any geoprocessing outputs by setting the coordinate system in your environment settings, which can be found under the Geoprocessing tab in your top menu.

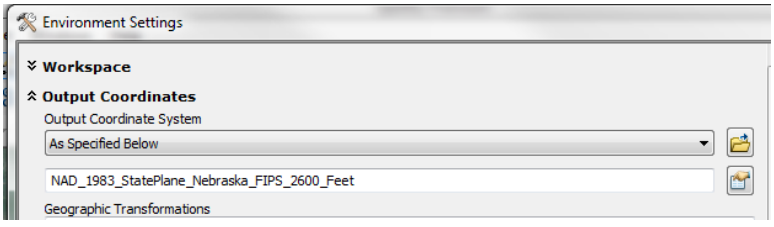


Figure 100. Map projection assignment dialog

13.1.15. Review and Perform Editing at a 1:5,000 – 1:6,500 Scale

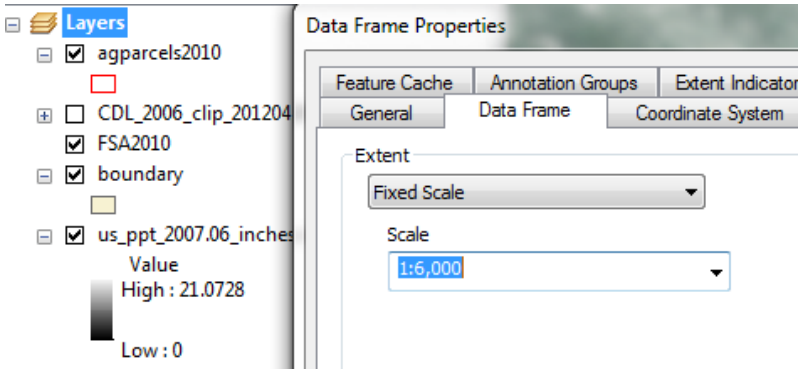


Figure 101. Map scale set

13.1.16. Parcel review and editing is more accurately done between a 1:5,000 – 1:6,500 scale. Maintaining a constant scale can be done by setting a Fixed Scale extent under the Data Frame tab in your Data frame properties, in the same way as maintaining a uniform projection.

Attribute Center Pivots

13.1.17. Use the method described for Feed lot attribution in step 11.2.2 to begin Center Pivot attribution. Center Pivot irrigation is highly variable year to year, and so the attribution of this feature requires a greater review process than the attribution of other features. The NAIP must be reviewed to check for center pivot parcels that may have been added, repurposed, or parcels requiring a geometry change. Landsat NDVI imagery may be used in order to delineate center pivot boundaries that are hard to differentiate with NAIP imagery.

NASS CDL

13.1.18. The National Agricultural Statistics Service's Cropland Data Layer will be used in combination with the NAIP imagery in order to detect the presence of crops. The CDL will also be used to differentiate between different crop types that may not have distinguishing features in aerial imagery. While the CDL will show the presence of a wide range of crops, the resolution is too poor to use this product alone when delineating parcels. When used with the NAIP, the CDL is an accurate guide to parcel boundary placement.

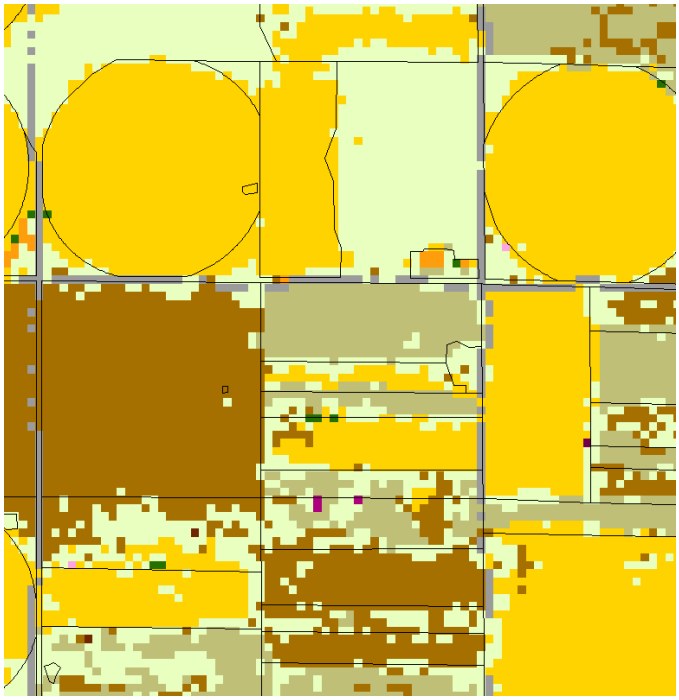


Figure 102.CDL raster overlaid with agriculture parcel boundary

Figure 103. Agriculture parcel boundary overlaid with NAIP imagery

13.1.19. The use of the CDL is necessary to create the initial general parcel delineations for the study area, and to provide a base for finer revisions using the Landsat NDVI imagery.

Landsat NDVI Archive

13.1.20. Once a foundation showing parcel area and general land use is created the Landsat NDVI may be used in order to account for temporal variability in crop type. The NDVI will also show greater distinction between crop types, as well as aid in attributing center pivots. To begin using the Landsat NDVI bring in the file Frames_Append.shp in order to show available Landsat coverage areas. Along with seasonal band, these coverage's will be toggled through while moving through the study area.

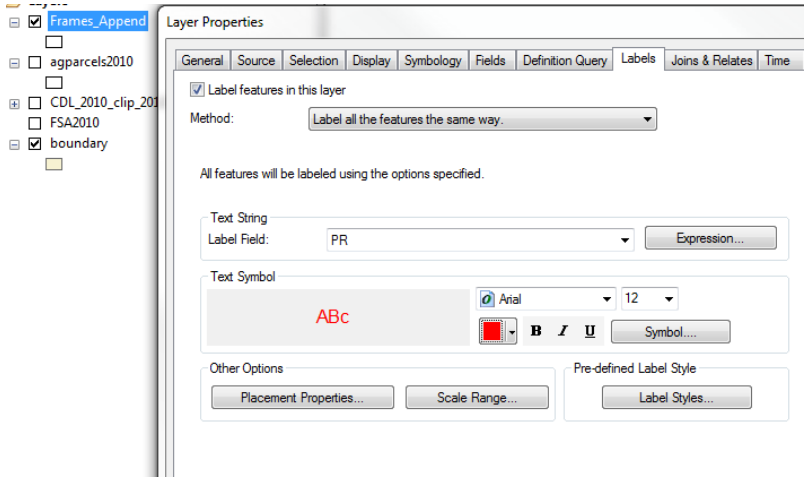


Figure 104.Labeling Dialog

13.1.21. Right-click on Frames_Append to open the layer properties, and go to layer properties. Check the label features box, set the label field to PR, and then use a text symbol setting that will be easily visible to you.

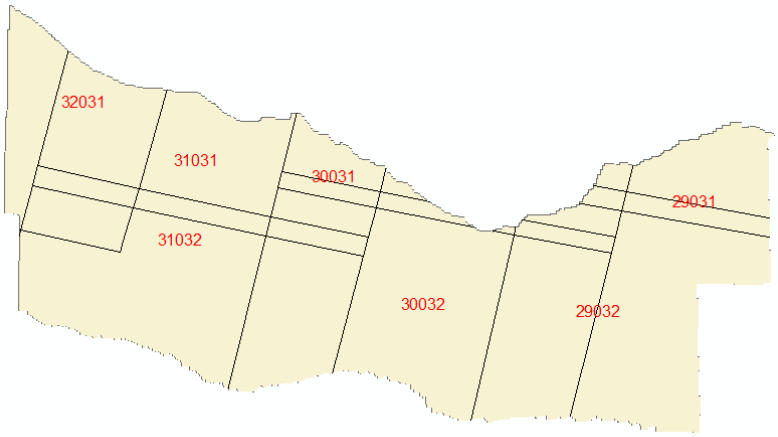


Figure 105.Study area Landsat frames

13.1.22. There will be overlapping areas of coverage in some areas, which can prove to be helpful if you find that it is hard to get a cloud and distortion-free three season coverage in these places.

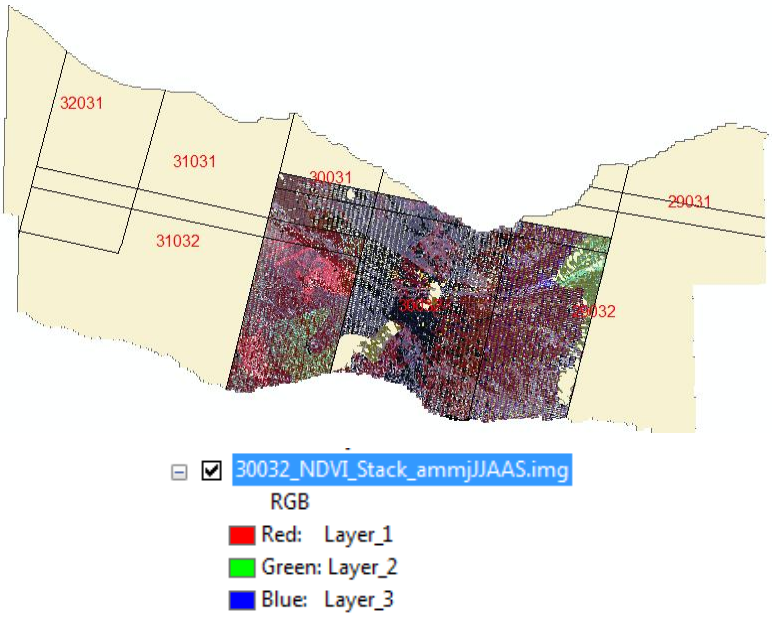


Figure 106. Studay area review with Landsat frames

13.1.23. The above coverage example is comprised of nine bands representing the following months: April, May, May, June, July, July, August, August, and September. When bringing your imagery the default setting will show the first three bands, which will more than likely have gaps in coverage, distortion, and cloud cover – in addition to not showing the three season picture needed for the temporal crop cover analysis. Toggle between bands until the desired image clarity and coverage is reached.

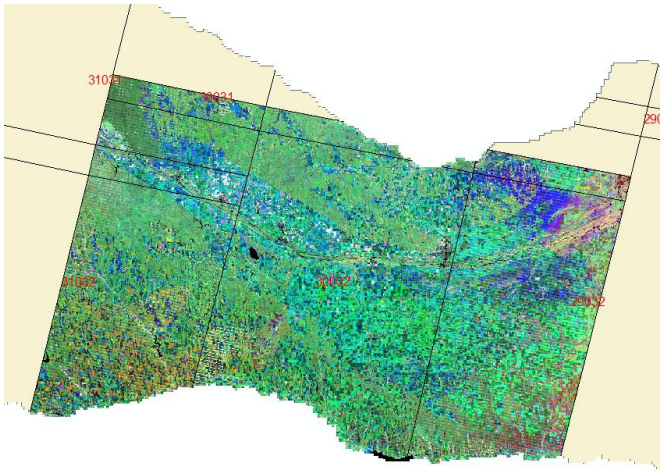


Figure 107.Frame 30032 Multi-Temporal NDVI

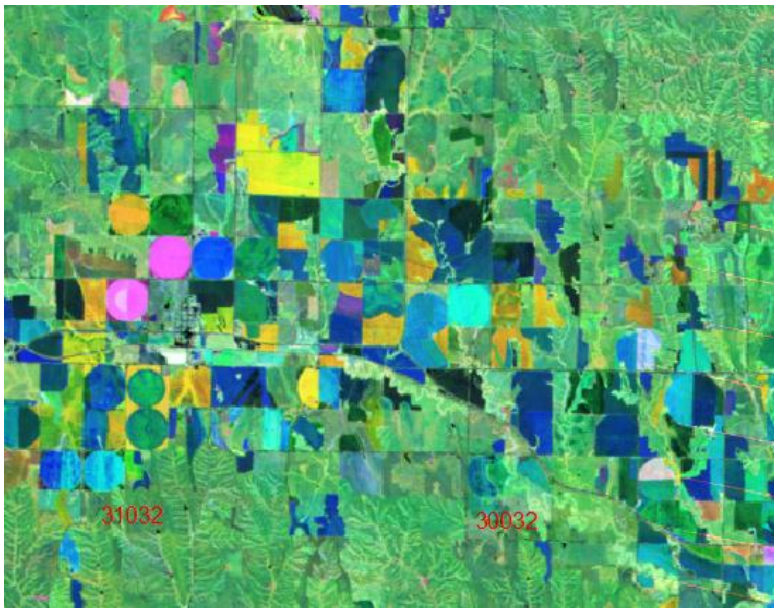


Figure 108.

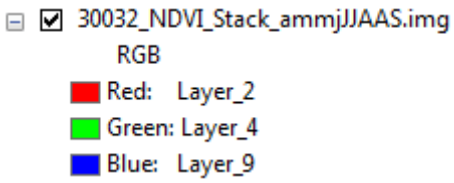


Figure 109.Multi-Temporal NDVI with set band adjustment

13.1.24. The above imagery was created using a May, June, September combination. The optimal combination will vary between each coverage that you use.

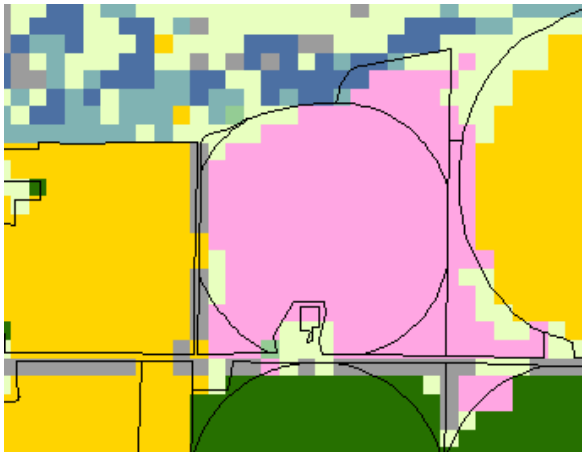


Figure 110. CDL raster overlaid with agriculture parcel boundary

Figure 111 Agriculture parcel boundary overlaid with NAIP imagery

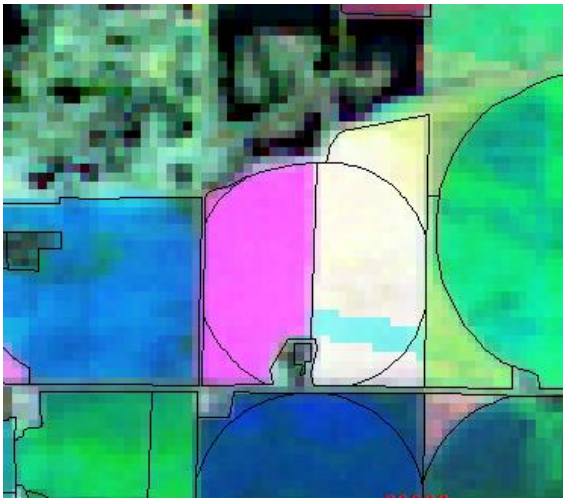


Figure 112. Multi-Temporal NDVI with Agriculture parcel boundary

13.1.25. The above is an example of the NDVI imagery identifying a crop split that is undetectable both in the CDL and NAIP. The NDVI is not always the best detector of crop splits and other features that must be captured – all available forms of information should be consulted for the greatest accuracy. The following shows an example where the CDL provides the greatest crop split detection.

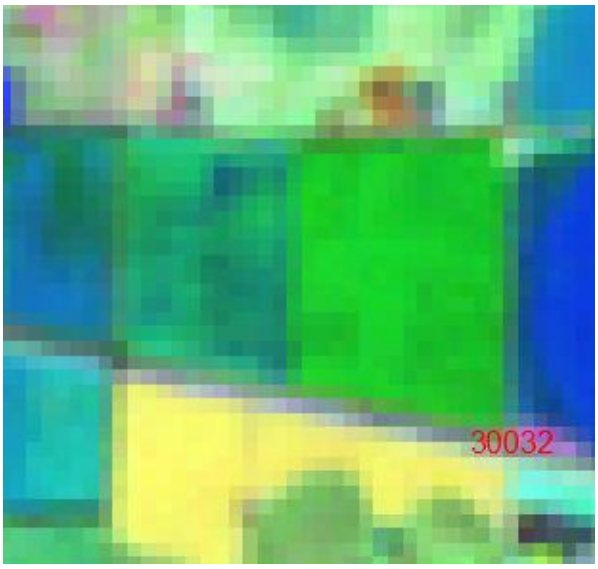


Figure 113.

Figure 114.

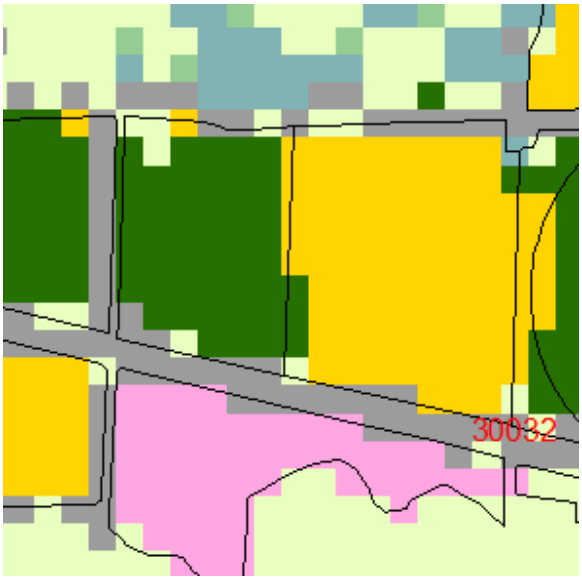


Figure 115. CDL shown split

13.1.26. The CDL can also show where it is required to merge split parcels.

Figure 116. CDL shown merge

13.1.27. These parcels can be merged by selecting both of the target parcels and then choosing the 'merge' function in the editor drop-down menu.

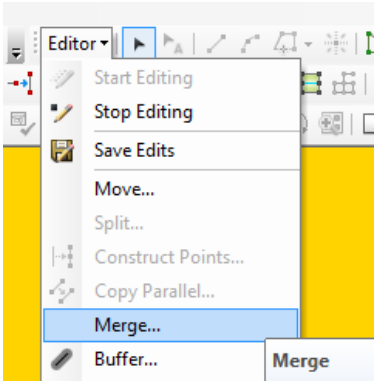


Figure 117. Editing save dialog

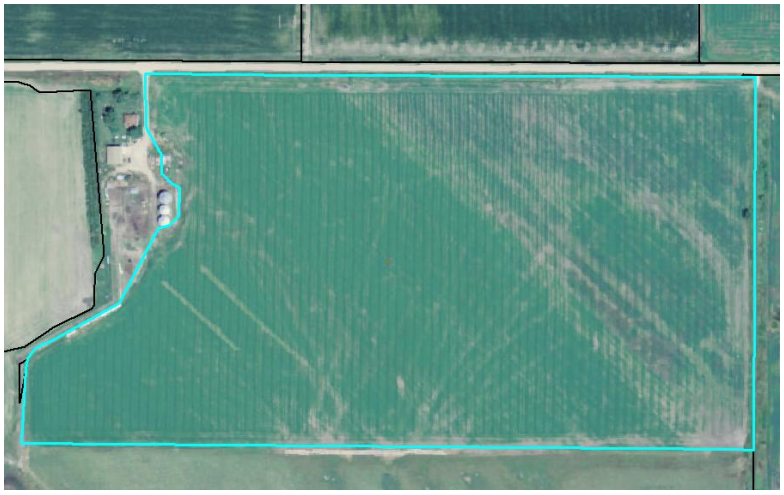


Figure 118. Auto-complete parcel addition

13.1.28. There may also be instances where a parcel is visible with the NAIP and CDL, but does not register on the NDVI imagery. These parcels must be added using the auto complete polygon tool, or the polygon tool if isolated.

Figure 119. Auto-complete parcel addition

Figure 120. Auto-complete parcel addition

Pivot Attribute Adjustment

13.1.29. Once the Selection by Location method has been performed on the center pivots, a second revision must be performed to capture areas missed by the selection operation. The following example shows areas missed by using the previous year's data depicted in red.

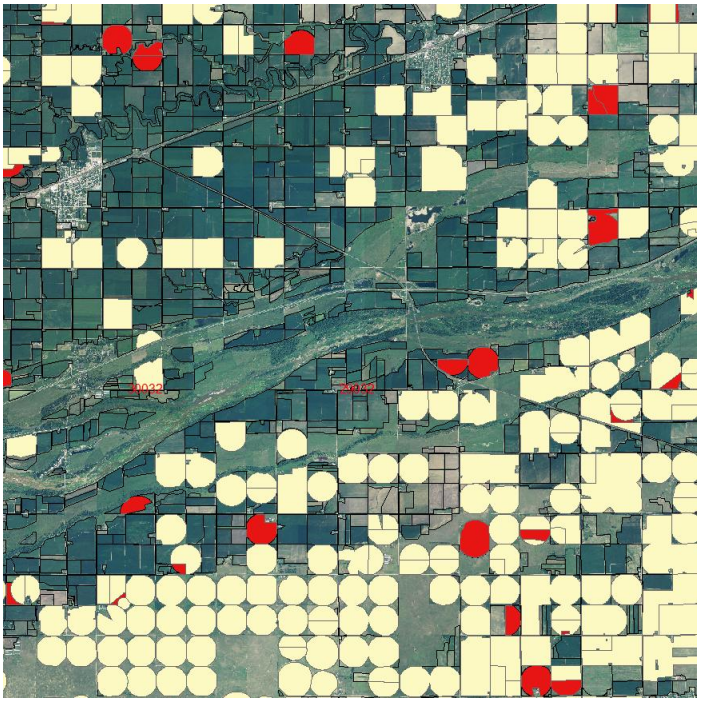


Figure 121.Pivot review

13.1.30. In addition to this there may also be parcels attributed as center pivots which are no longer using center pivot irrigation. In this example we can see a parcel that was a center pivot in the year before, but has been left fallow in the current year.

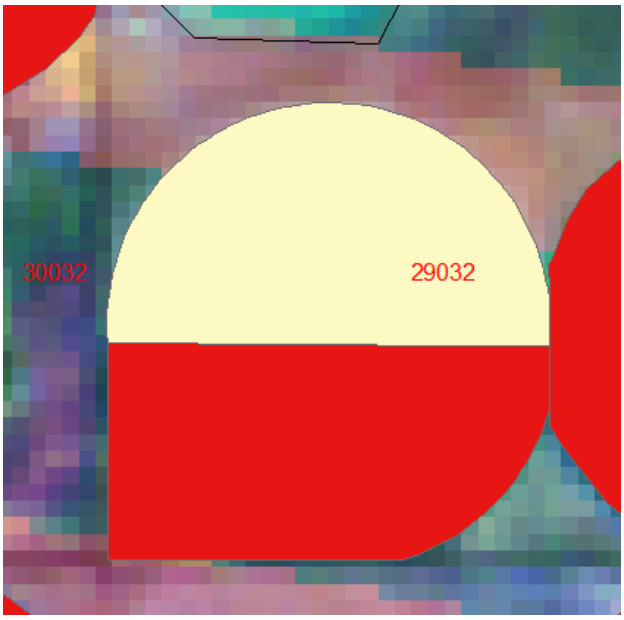


Figure 122.Pivot review

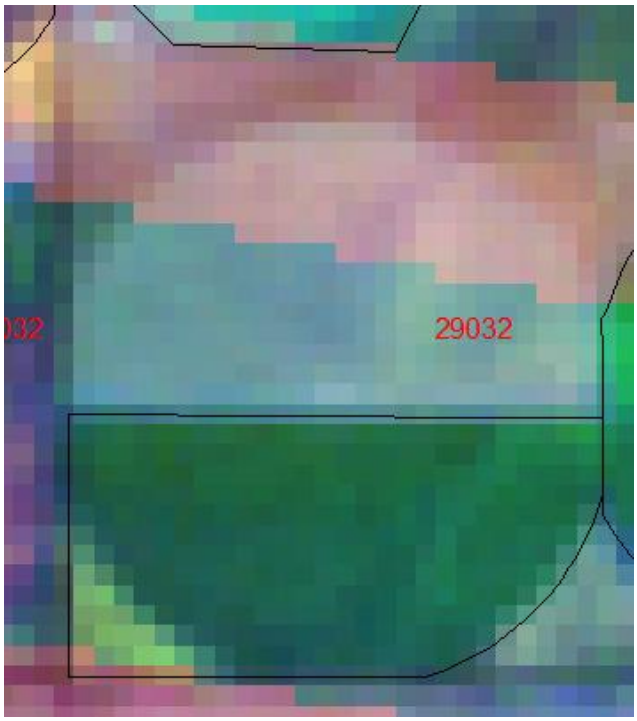


Figure 123.Pivot review

Figure 124.Pivot review

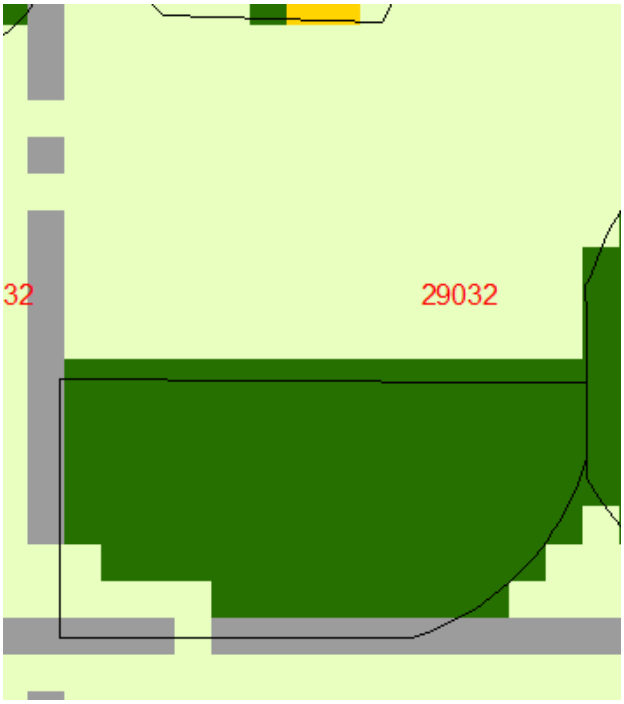


Figure 125. Pivot review

13.1.31. All three of these data sources will help show where center pivot boundaries require cutting as well.

Figure 126. Pivot review

NAIP Used in Actual Parcel Delineation

13.1.32. When one imagery dataset is unavailable for one year, the datasets from the years before and after may be used to analyze the information that is available for that year. The following example uses NAIP imagery and parcels from 2007 and 2009 to interpret parcel locations for 2008; there is no NAIP imagery for this year, but CDL and NDVI are available. This step can be performed in a number of ways – the goal is to identify changes that take place between the years before and after, which can also be confirmed with the data you have.

Figure 127. Pivot review

Figure 128. Pivot review

13.1.33. The above depicts parcels from 2007 in red and 2009 in black, using 2007 NAIP imagery in the first image and 2009 in the second. The top of this parcel is

split between two crops in 2007, but is merged in 2009. The data you have available can be used to determine which of these parcel features appeared in 2008. The following shows NDVI, CDL, and parcel data from 2008.

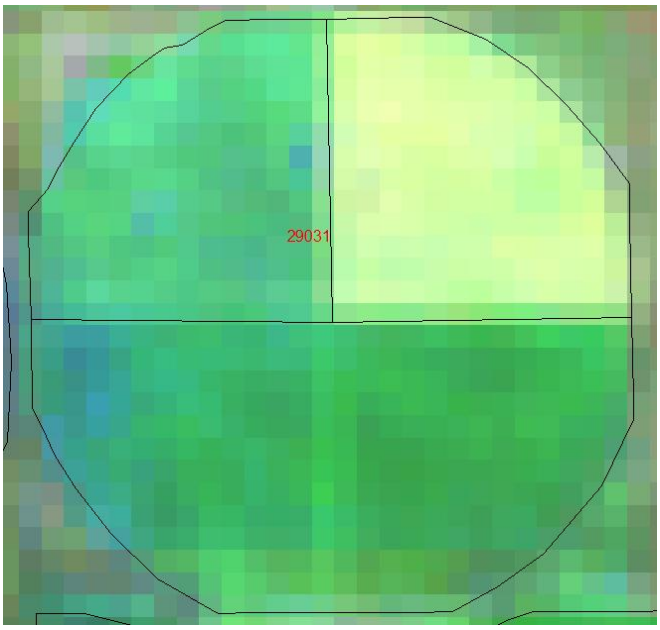


Figure 129. Pivot review

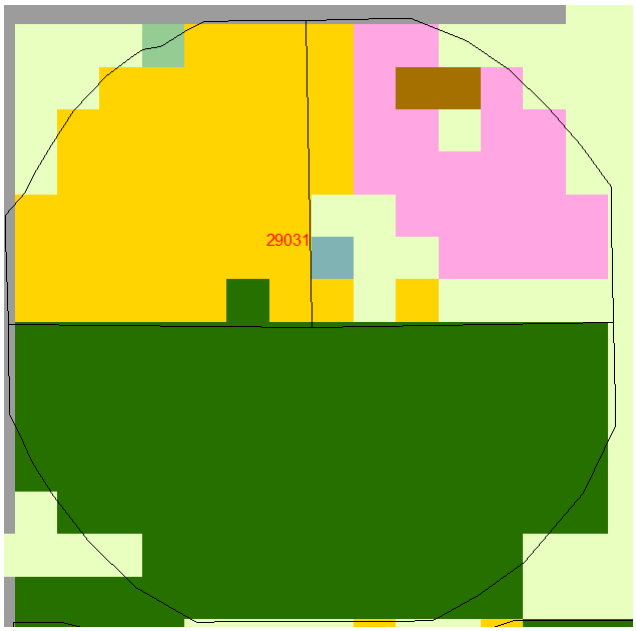


Figure 130. Pivot review

13.1.34. Based on this it can be determined that the crop split remained in 2008.

14. Parcel Standardization

Attribute Schema Standardization

14.1.1. Attribute schema may be easily standardized through the utilization of domains. The use of domains will create a drop down list of commonly used parcel edits, which will mitigate the need to check for spelling errors and typos. The Domains toolset can be found within the Data Management toolset in Arc.

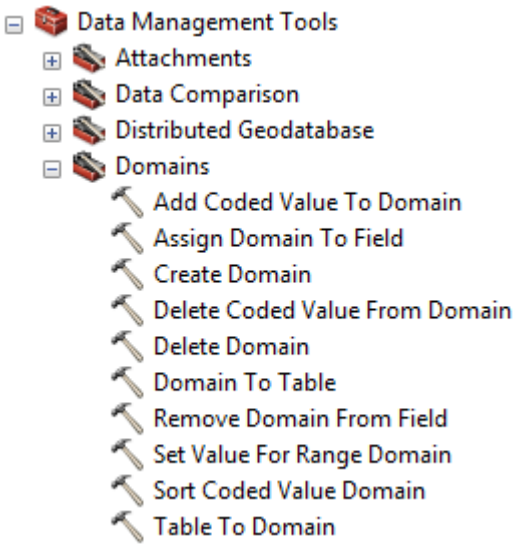


Figure 131.Add Domain

14.1.2. Begin by creating your domain.

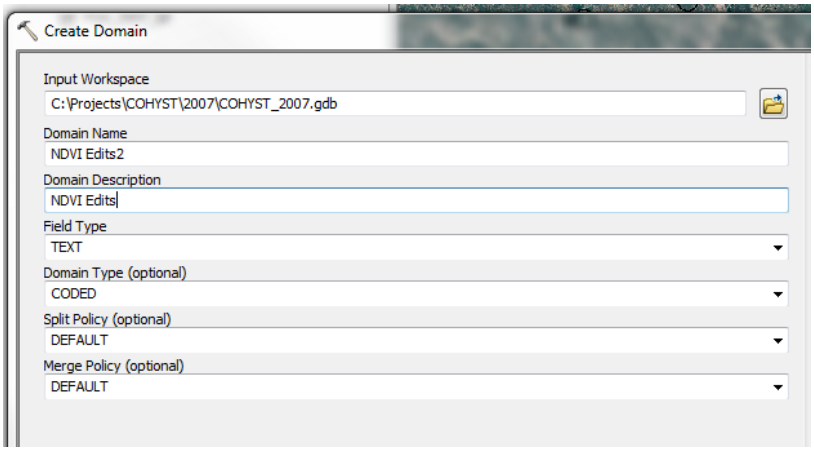


Figure 132. Add Domain

14.1.3. Next, enter the values you would like to use in your attribute field with Add Coded Value to Domain.

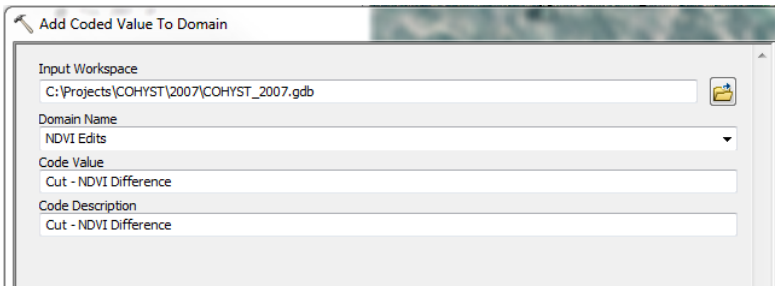


Figure 133. Add Domain

14.1.4. Once you have entered the desired values into your list, assign the domain to the table and field you wish to use your domain with.

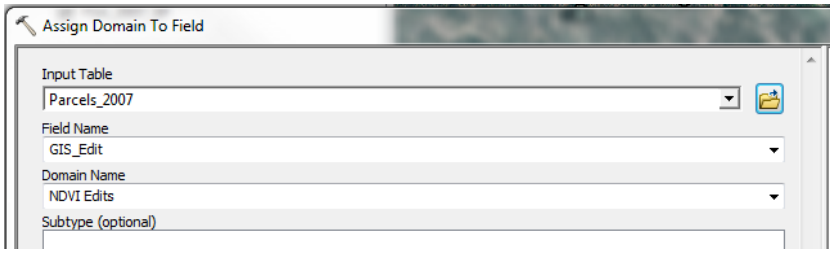


Figure 134. Add Domain

14.1.5. Your domain will appear as follows when editing your parcels, based on which values you choose to use.

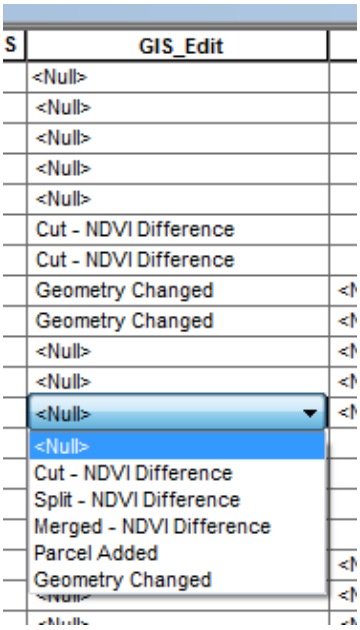


Figure 135. Add Domain

Feature Attribution QC

14.1.6. Attribution maybe checked for errors via querying individual values in the attribute table.

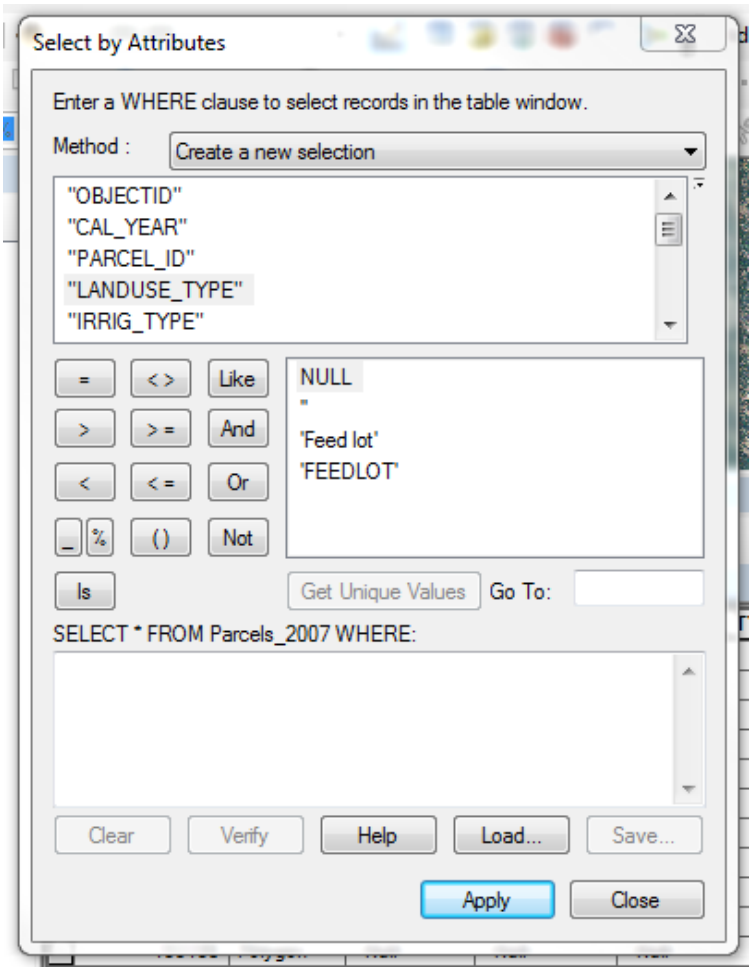


Figure 136. Add Domain

14.1.7. Once errors are identified, they may be selected out and then adjusted by the field calculator in order to create uniform naming conventions.

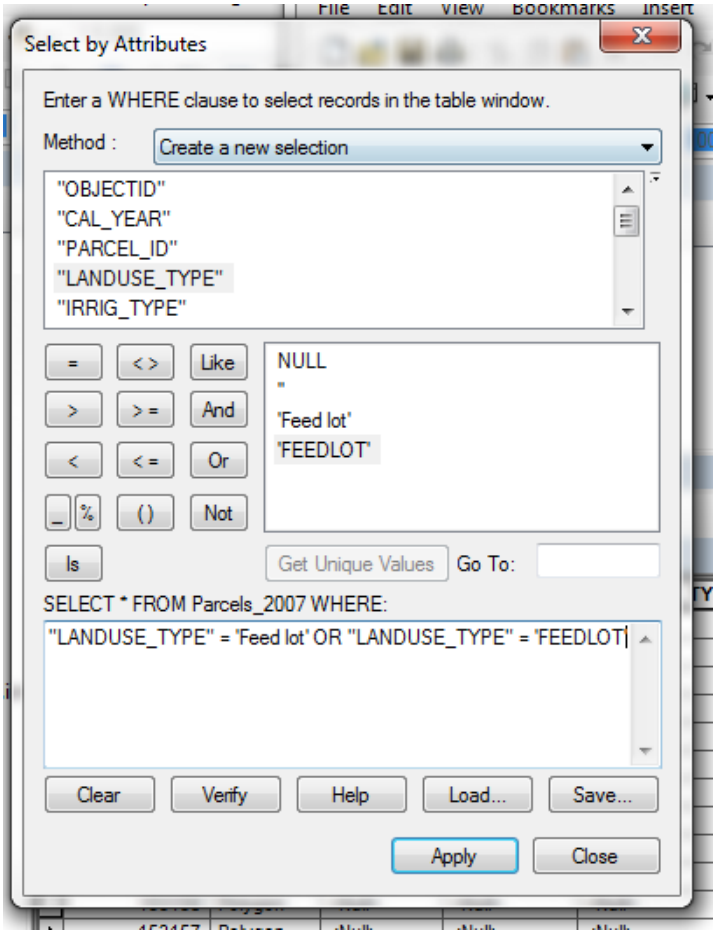


Figure 137. Attribute QC

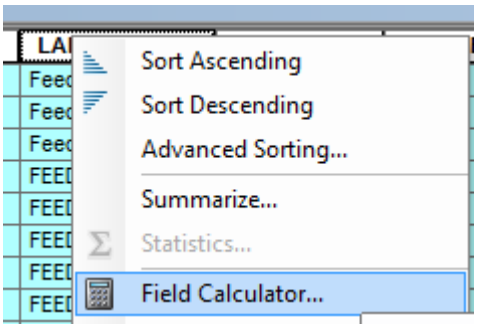


Figure 138. Attribute QC

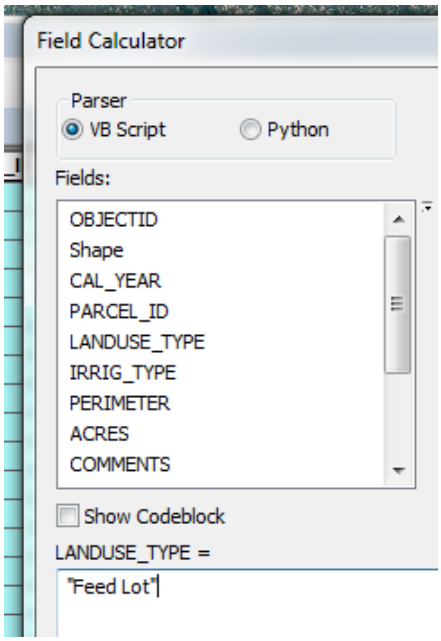


Figure 139. Attribute QC

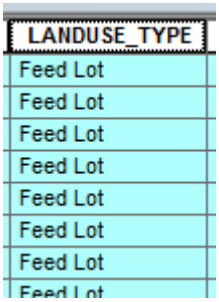


Figure 140.Attribute QC

Field Comments

14.1.8. It is advisable to create a field for comments separate from your standardized edit field in order to identify parcels that may require review or have notable features. If there are multiple personnel working on parcel delineation for one year having a field for comments becomes especially helpful in communicating which parcels need further review.

Topology Validation

14.1.9. This step is to be performed once parcel edits and attribution QC is complete for each year. The first step is creating a new feature dataset within your geodatabase.

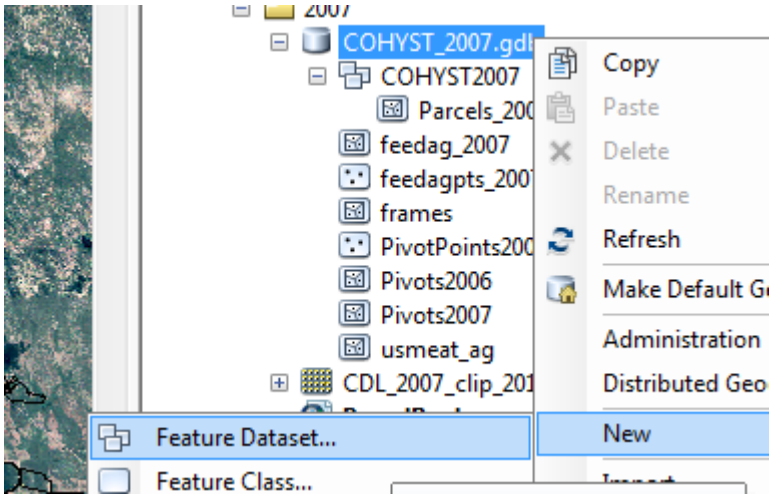


Figure 141.Topology validation

14.1.10. Export your parcel shapefile into the feature dataset, then right-click the feature dataset icon and select New >> Topology.

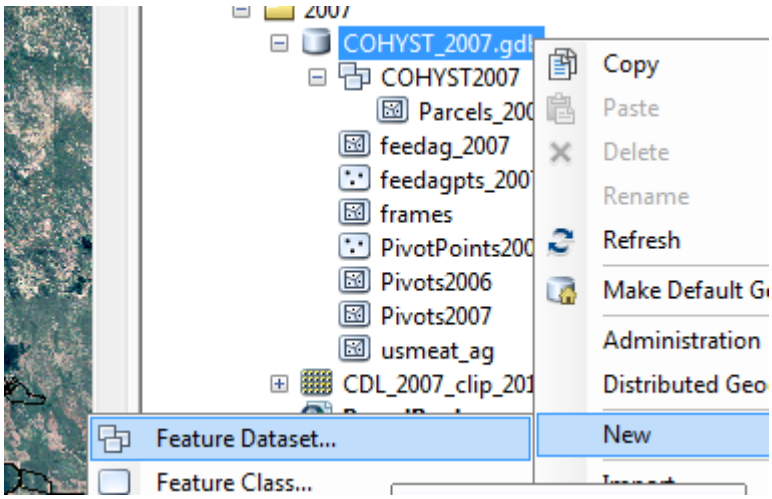


Figure 142.Topology validation

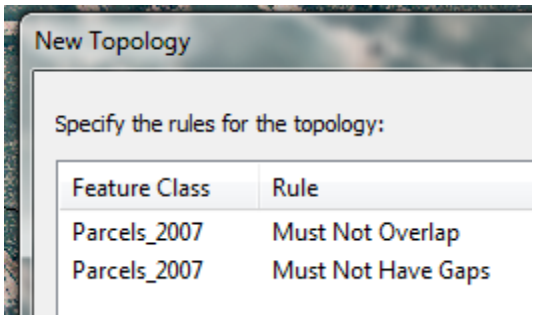


Figure 143. Topology validation

14.1.11. Once your topology is created, validate your topology. Start an editing session, and drag your new topology into your table of contents – this will allow you to view your errors and make corrections. Begin by right-clicking on your topology and selecting properties. From the Errors tab you can generate a summary to view how many errors exist and which rules they fall under.

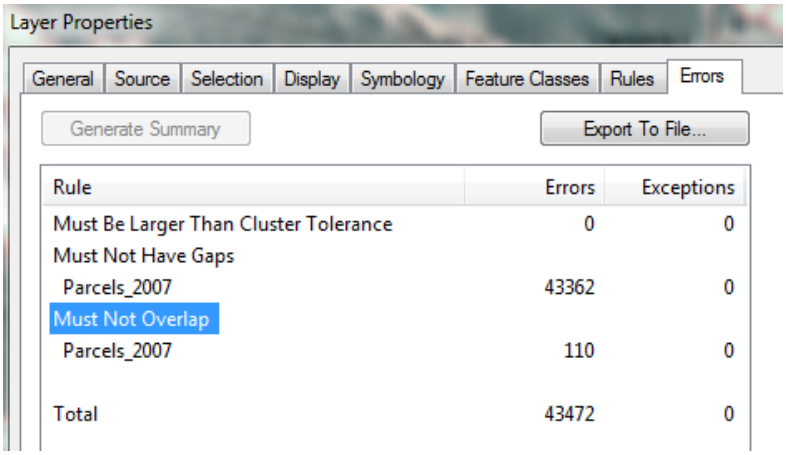


Figure 144. Topology validation

14.1.12. In order to correct these errors in topology, begin by opening the error inspector from the editor toolbar.

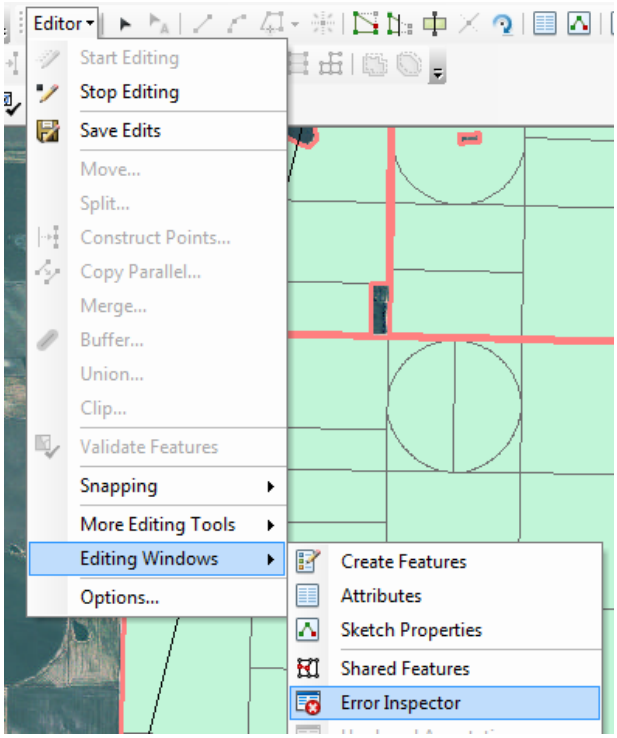


Figure 145. Topology validation

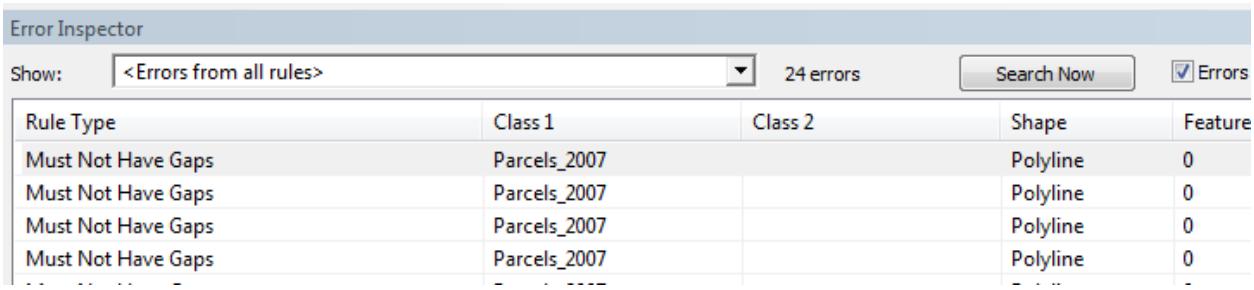


Figure 146. Topology validation

14.1.13. Using the error inspector you may view and correct individual errors, or select many errors that require the same correction.

QA/QC Checking

14.1.14. Once you have completed review for all years, use the following geodatabase format and naming conventions for your data.

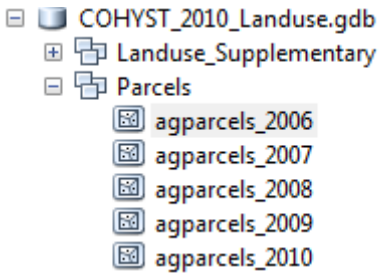


Figure 147. Parcel feature class organization

14.1.15. X:\Projects\COHYST\Deliverables\Final_Parcel_Deliverable_4_26_13\COHYST_2010_Landuse.gdb\Parcels\agparcels_2010

TASK III. IMAGE CLASSIFICATION

15. Instructions to Perform Crop Type Maximum Likelihood Supervised Classification

Classification Introduction

15.1.1. The classification process involves multiple steps and utilizes two different software programs (ERDAS 2013, ArcMap10.1). Figure 147 shows the different trapezoid notation used with all procedures numbered corresponding to various procedures.

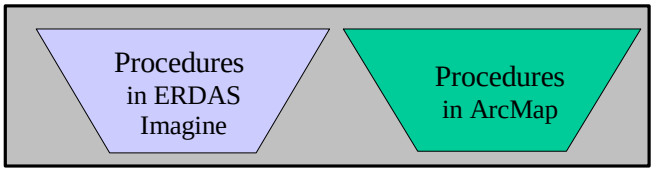


Figure 148. Notation to Identify Model Used for a Procedure

15.1.2. Process Step.1 (Imagery Input)

The classification process involves using prepared satellite imagery data from a multi-temporal composite of Landsat bands (not including the thermal band) and a multi-temporal composite of Landsat based NDVI index. Landsat composite and NDVI composite cloud filled images are then stacked on a seasonal interval for each frame, based on cloud suitability and the number of image dates present for each frame. Both composites contain input images from the cloud masking and study area clip procedure where frames were processed clipped to a buffered study area boundary.

15.1.3. Process Step.2 (Ground Truth Input)

The second part of the classification process involves separating reference data into subsets of training and test datasets for input and validation of the classification procedure.

The reserved training ground truth data are available for classification procedures input once they have been checked using the multi-temporal NDVI evaluation. With any possible outliers removed, the shapefile can be negatively buffered by a distance of 30m for classification signature extraction.

15.1.4. Process Step.3 (Classification)

The third part if the classification involves performing the ERDAS MLC classification.

15.1.5. Process Step.4 (Accuracy Assessment)

The forth part involves performing and evaluating accuracy assessment.

15.1.6. Process Step.5 (Parcel Crop Assignment)

The final component of the procedure involves crop type assignments to individual parcel layers.

15.1.7. The following diagram shows the classification process in greater detail and in order of operation using corresponding software packages.

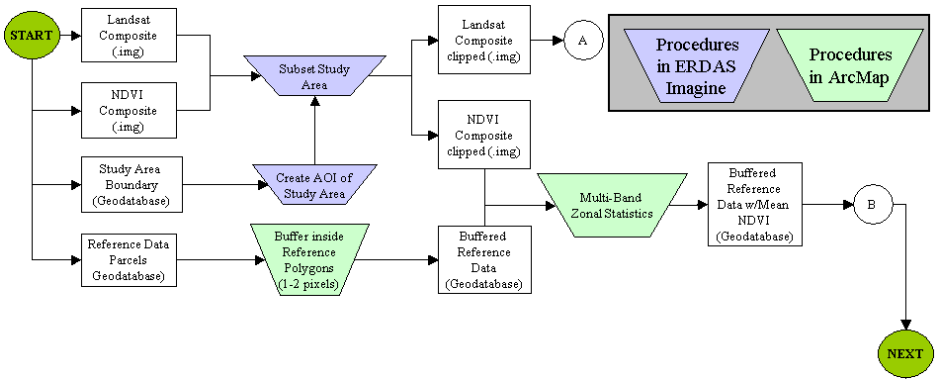


Figure 149. Classification Processes Flowchart, page 1

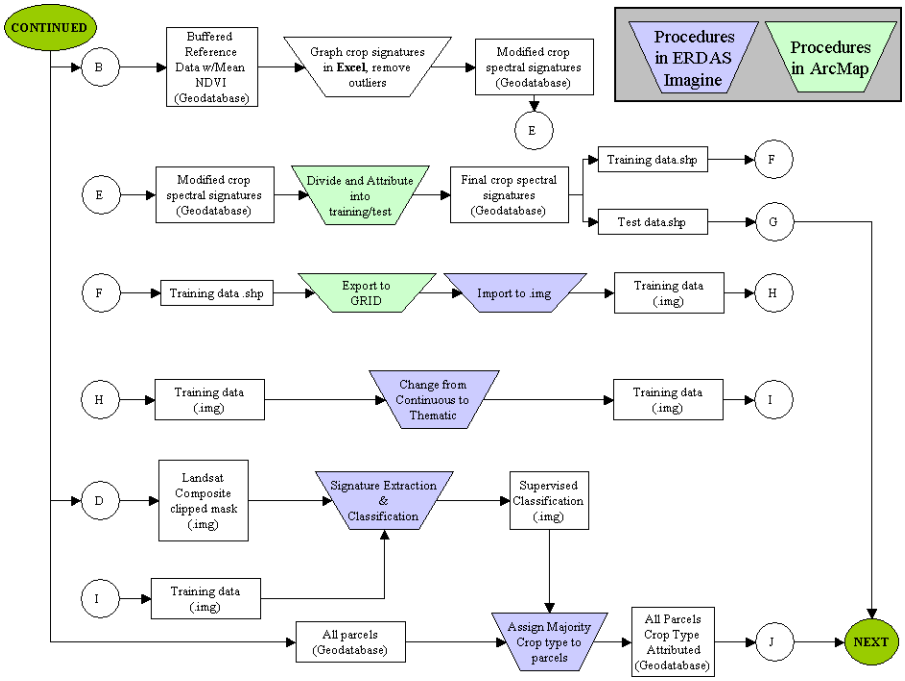


Figure 150. Classification Processes Flowchart, page 2

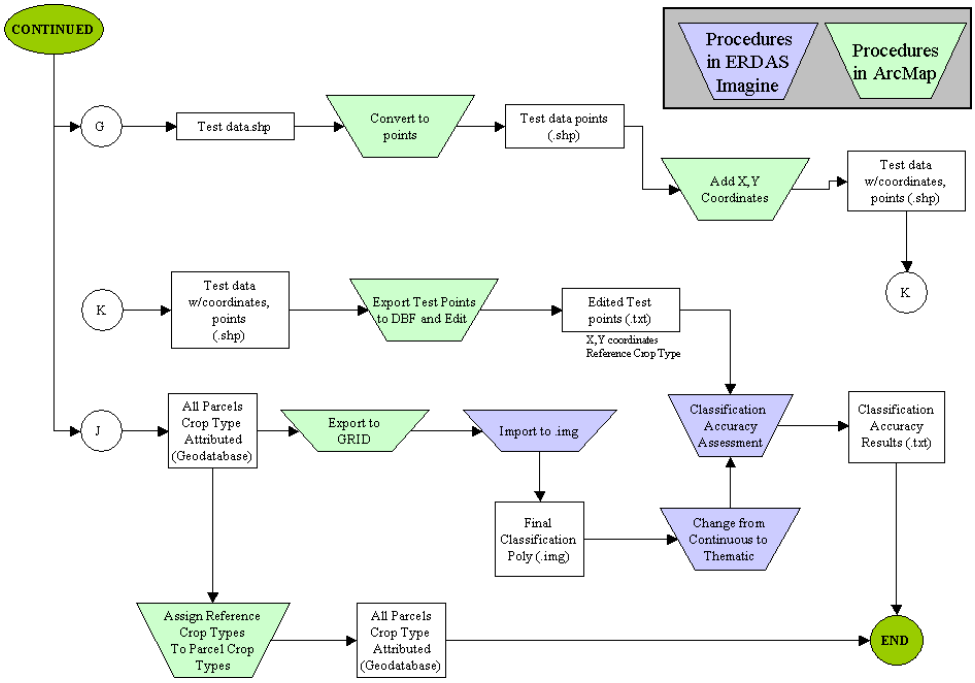


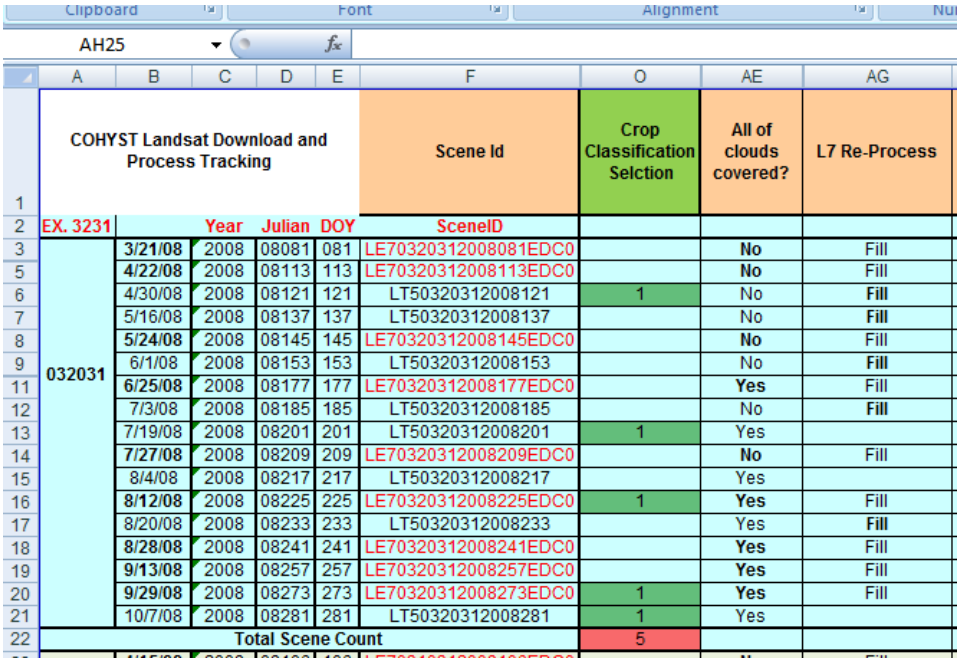
Figure 151. Classification Processes Flowchart, page 3

Process Step.1 (Imagery Input)

15.1.8. The NDVI composite generation process and results are used again in the classification procedure for validating ground truth locations. The composite procedure is performed in addition for each frame using all bands, minus the thermal band. The resulting multi-band stack is used within the ERDAS classification process.

15.1.9. Just as the NDVI images are stacked into a multi-temporal composite, the same can be done for the filled and masked Landsat images. Composite images are made on a frame-by-frame basis.

15.1.10. Open up the spreadsheet '…TrackingTool_Crops' for the respective year. You will see a column titled 'Crop Classification Selection'. This column shows a number '1' next to frames that have been selected to use for classification. These frames have been selected based on quality & amount of fill as well as the date of the scene to try to give good coverage throughout the year with minimally filled scenes. Both Landsat 5 and Landsat 7 scenes are used for Landsat Composites.



	A	B	C	D	E	F	O	AE	AG
1	COHYST Landsat Download and Process Tracking					Scene Id	Crop Classification Selction	All of clouds covered?	L7 Re-Process
2	EX. 3231		Year	Julian	DOY	SceneID			
3	032031	3/21/08	2008	08081	081	LE70320312008081EDC0		No	Fill
5		4/22/08	2008	08113	113	LE70320312008113EDC0		No	Fill
6		4/30/08	2008	08121	121	LT50320312008121	1	No	Fill
7		5/16/08	2008	08137	137	LT50320312008137		No	Fill
8		5/24/08	2008	08145	145	LE70320312008145EDC0		No	Fill
9		6/1/08	2008	08153	153	LT50320312008153		No	Fill
11		6/25/08	2008	08177	177	LE70320312008177EDC0		Yes	Fill
12		7/3/08	2008	08185	185	LT50320312008185		No	Fill
13		7/19/08	2008	08201	201	LT50320312008201	1	Yes	
14		7/27/08	2008	08209	209	LE70320312008209EDC0		No	Fill
15		8/4/08	2008	08217	217	LT50320312008217		Yes	
16		8/12/08	2008	08225	225	LE70320312008225EDC0	1	Yes	Fill
17		8/20/08	2008	08233	233	LT50320312008233		Yes	Fill
18		8/28/08	2008	08241	241	LE70320312008241EDC0		Yes	Fill
19		9/13/08	2008	08257	257	LE70320312008257EDC0		Yes	Fill
20		9/29/08	2008	08273	273	LE70320312008273EDC0	1	Yes	Fill
21		10/7/08	2008	08281	281	LT50320312008281	1	Yes	
22	Total Scene Count						5		

Figure 152. Showing the scenes that will be used for a Landsat composite image

15.1.11. Open Arc Catalog. Search for the 'Raster.tbx'. Within this toolbox you will see a tool called 'Composite Bands'. Double click on it to open the tool.

15.1.12. Navigate to where the clipped and filled images are that you want to composite. Click on the '+' sign next to the image you want to drag in. This will show the bands of the image. Drag into the tool only bands 1, 2, 3, 4, 5, and 7 from the selected images found in the spreadsheet into the 'Input Rasters' line of the tool. Leave out band 6 since this band is a thermal band which wasn't used for this analysis. (Refer to the figure below). Make sure the images are in the correct order, starting with the bands from the earliest date in the spreadsheet first. Set the output workspace to a directory where each frame's composite image will be stored. Give the output image a naming convention denoting which frame the image is a composite of.

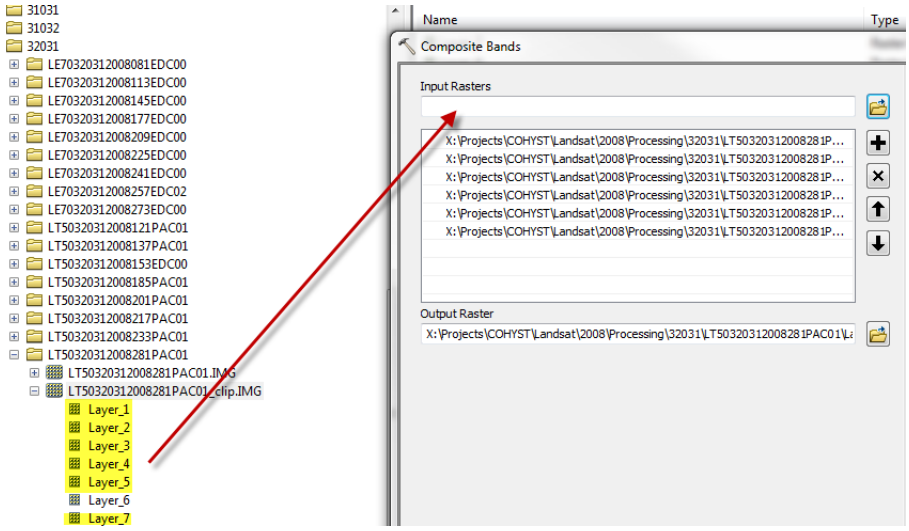


Figure 153. The Composite Bands Tool used to make Landsat multi-temporal composites

15.1.13. Repeat the previous step for all of the frames in order to get mulit-temporal composites for each frame.

15.1.14. Each frame should now have its own composite image. Each band represents each band of the original image that was used to make the composite in order from earliest to latest. Since multiple layers from each image were used in the composite, there will be many bands within the composite depending on how many scenes were used. For example, if 5 scenes were used in the composite, the final frame composite should have 30 bands (since 6 bands were used from each scene). Band 1 of the composite should be band 1 of the earliest image used for the composite, and band 7 should be the first band of the second image used in the composite (second earliest image) and so on.

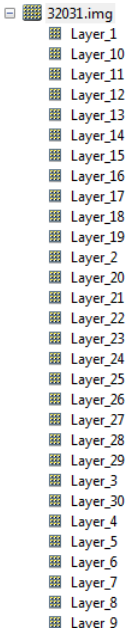


Figure 16.#. Showing the layers of a final stacked composite image. This frame was stacked using 5 scenes, so there are 30 total layers.

154. The Composite Bands Tool results in a single img file for all selected bands

Process Step.2 (Ground Truth Input)

15.1.15. Ground truth data sets are an important input to the classification process and require careful review before integrating. Various source can be used to collect ground truth data, the following sources were available for the historic 2006-2010 period:

15.1.16. Using Google Earth street view, a road index was created showing county and state roads where photo-imagery was captured. Each road was then traversed in street view if crop cover was separable based on growth cycle and visual confirmation the location and crop type was recorded within a GIS layer.

15.1.17. The NRD well program collects crop types for registered well. A given location is referenced to the PLSS section reference system. These locations were intersected with the corresponding year digitized parcel layer. Both locations are cross-referenced by area to insure a correct match.

15.1.18. A layer titled “CALMIT 2010” was provided by COHYST for the year on 2010. The layer is presumable the result of field based ground truth collections. The collector traversed the study are collecting reference data as available. Field data from actual in person field observation was only provided for 2010.

15.1.19. Future work would benefit from a field collection program on a yearly interval for the corresponding year of study. It should be noted the Farm Service Agency (FSA) collects field data throughout the US under the common land unit program. As sited by the FSA website on 11/11/2013:

Please be advised that with the enactment of The Food, Conservation, and Energy Act of 2008, Title I - Commodity Programs, Subtitle F - Administration, Section 1619 on May 22, 2008, the Farm Service Agency (FSA) is no longer allowed to make the geospatial data, including access to the Common Land Unit records, available to the public, even through the Freedom of Information Act (FOIA). Section 1619 is an Exemption 3 statute that prohibits FSA from sharing this data with the public.

If regulation changes in relation to farm bill, the CLU dataset is a incredibly useful dataset for future integration.

15.1.20. Ground truth data can be extracted via Google Earth for use in determining actual crop types. Google Earth uses various dates for imagery, and as a result certain years within Google Earth's 'Street View' can be used for corresponding years that fall within the COHYST years of study. Only 3 years are available for Google Earth Street View use. These years are 2007, 2008, and 2009. Using Street View imagery, locations and crop types can be editing using ArcMap to record the locations and crop types of locations referenced in Google Earth. The following steps outline the process used to capture locations and crop types of certain parcels for years 2007, 2008, and 2009. By looking at the Google Earth Imagery, certain crop types can be visually noticed based on certain traits of the crops. Common crops recorded from Google Earth are Corn, Soybeans, Alfalfa, Sorghum, Fallow, and Winter Wheat. If visible irrigation was seen in Google Earth such as center pivots, hoses, pipes, etc. this was also recorded.

15.1.21. Launch Google Earth

15.1.22. Drag and hover the orange street view icon over the imagery. This will show in blue the locations for which Google Street View is available.

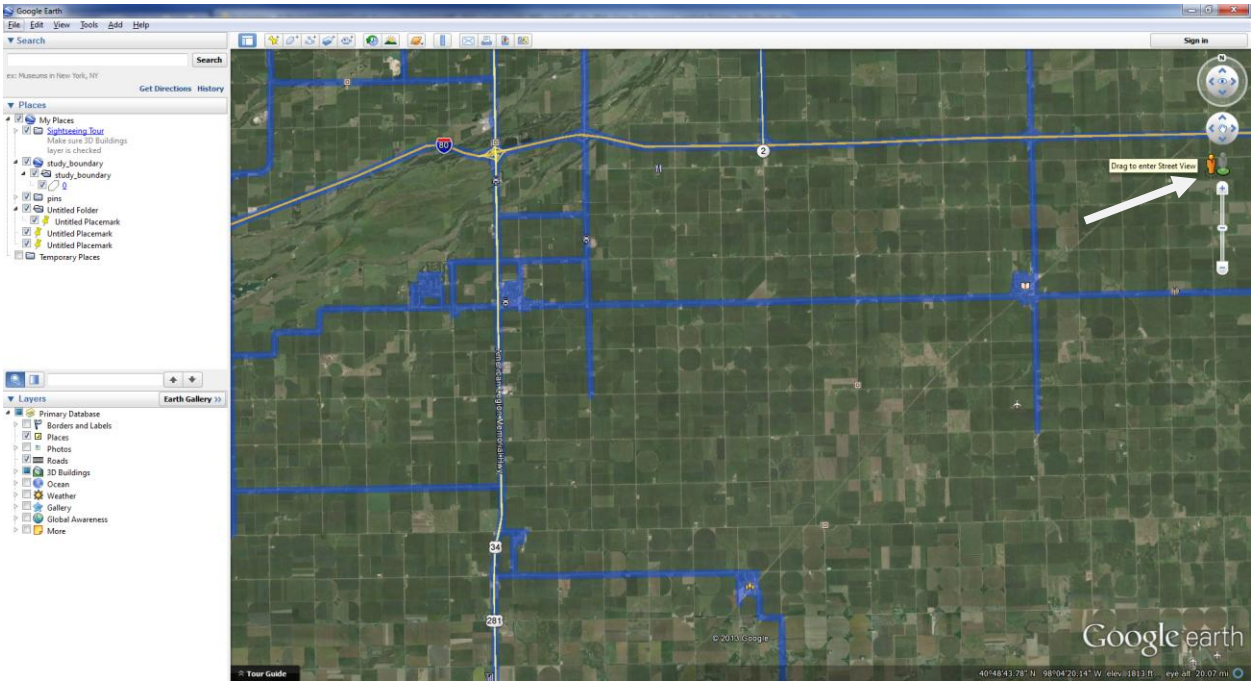


Figure 155.showing the Street View icon (white arrow) and the available roads that can be used in Street View.

15.1.23. Zoom in to a road within the study area that you would like to start looking at. Insure you are looking at the right year of imagery in Street View.

15.1.24. Open ArcMap, load the parcel shapefile for the respective year and zoom to the location that you chose to start looking at imagery and recording crop types and/or irrigation. You will have to visually compare common roads and intersections in order to align the locations of ArcMap and Google Earth.

15.1.25. Within Street View, pan to the left and right of the street to look at the crop type and if irrigation is visible. Also note the date that the Google Imagery was taken.

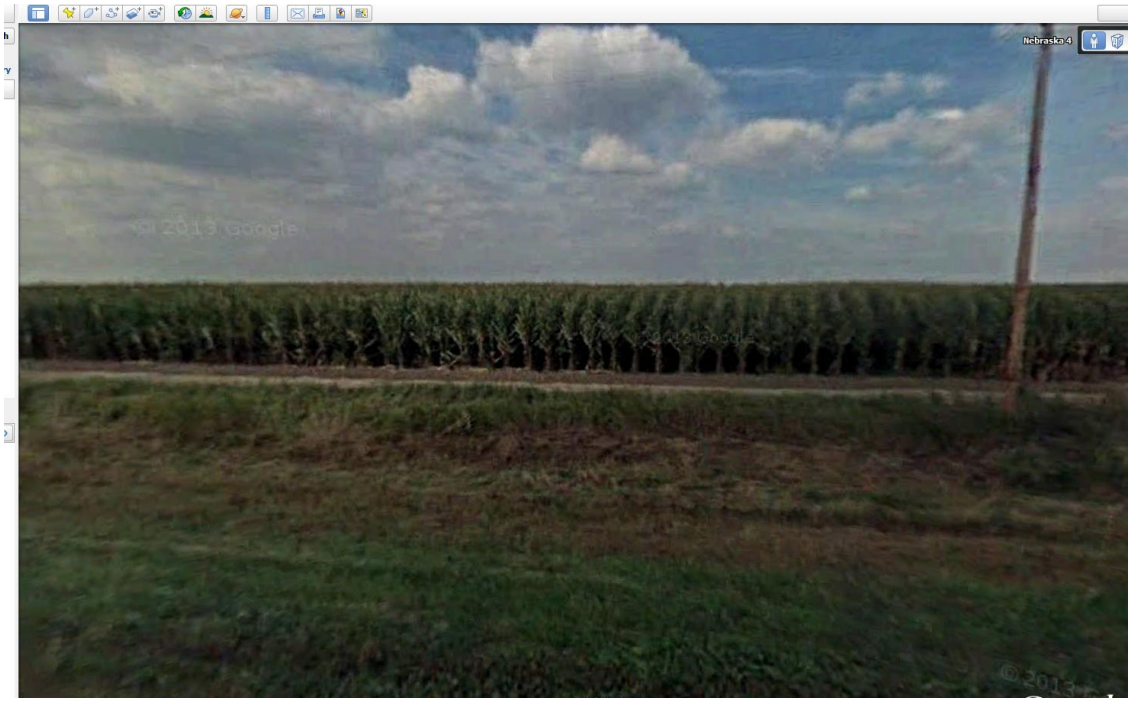


Figure 156.Showing a crop (corn) location in Street View.

15.1.26. Within ArcMap start an edit session and zoom to the parcel that is displayed in Street View. Use streets and imagery to zoom to the parcel location in ArcMap.

15.1.27. Digitize a point within the center of the crop that is shown in both ArcMap and Google Earth Street View. Record the crop type and if irrigation is visible. After this is completed, you are now ready to keep moving down the street in Street View and record crop types and irrigation for other crops in the region.

15.1.28. Record crop type locations as you feel necessary to get a good amount of crop data and a good spatial distribution of the crop locations.

15.1.29. All available ground truth data that was collected and compiled into one shapefile and attributed by source. Use zonal statistics to extract the mean NDVI value for each parcel ground truth parcel. The results will be exported to excel and used to analyze NDVI trends for each parcel. This is used to identify ground truth parcels that may not have crop type correct. The NDVI trends throughout the year can be plotted on an Excel graph to help identify outliers that need to be removed from the ground truth parcels.

15.1.30. Open up the main excel spreadsheet that has all of the ground truth data that has been gathered. The one used for this study is called '2010_Neg_Mean_Signatures.xlsx' with the year changing.

15.1.31. Filter by crop type. For example, for corn you may want to filter using 'alfalfa' and 'dry alfalfa' to select all of the ground truth data for alfalfa.

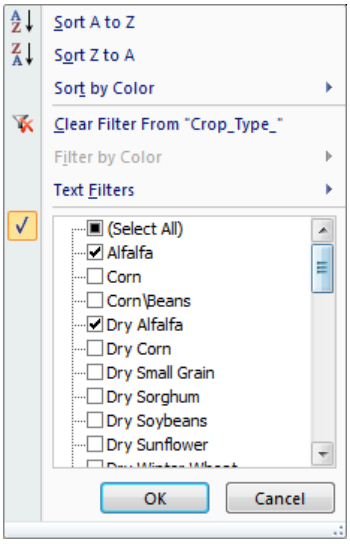


Figure 157.A filter selecting Alfalfa and Dry Alfalfa.

15.1.32. Copy each of the selected crop types into a different excel spreadsheet with each crop type being its own 'sheet' within the spreadsheet. It may be a good idea to use conditional formatting within excel to highlight high, middle. And low NDVI values.

15.1.33. Insert additional sheets next to each crop type's sheet that will be used to display the graphs of the NDVI trends for each crop type. A good naming convention may be something like 'Sugar_beets_graph'.

15.1.34. Insert a graph for each crop type in the '_graph' sheet for each crop type. Select the parcel IDs and the mean NDVI values for each parcel ID as the Y-axis data, and the NDVI date for each parcel as the X-axis data. Create a graph for each crop type.

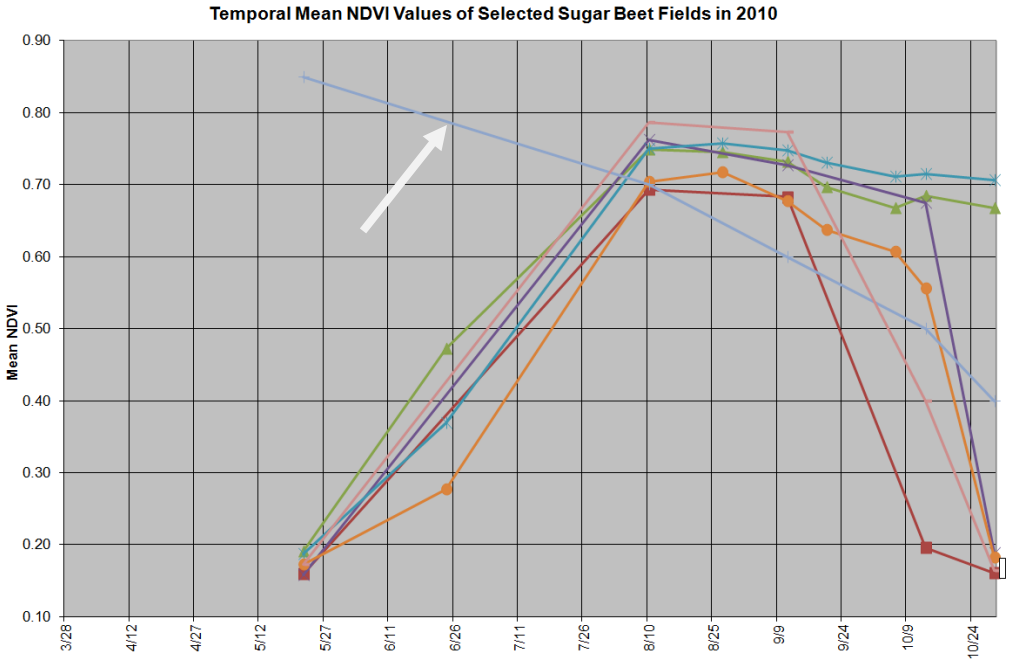


Figure 158.Example of mean NDVI trend for sugar beets

15.1.35. As visible in the previous graphic, a common NDVI trend can be visible for the sugar beet ground truth parcels. Outliers are also visible on the NDVI trend graph. Notice the parcel that the white arrow is pointing too… this parcel is likely not a sugar beet parcel based on its NDVI trend compared to the other sugar beet parcels.

15.1.36. Remove outliers from the spreadsheet for each crop type. This will ensure that only valid ground truth locations will be used.

15.1.37. Record which parcels got removed from the spreadsheet. This is important because the removed outliers also need to be removed from the shapefile that has all of the compiled ground truth data.

15.1.38. Remove any parcels from the spreadsheet and shapefile that have been 'flagged' from the original ground truth QC. Also, remove parcels that do not have any NDVI values for neither of the frames.

15.1.39. You should now have NDVI trend graphs for every crop type with the outliers removed. The NDVI trends for each crop type are different based on crop type, but a common NDVI trend should be seen for each crop type. With the outliers removed, you should now truly have quality ground truth data for the study area.

15.1.40. Setting Aside Ground Truth Data For Accuracy Assement

Now that the ground truth has been finalized, it is now time to set aside half of the ground truth data to be used later for accuracy assessment. Only scenes that have at least 20 ground truth points per crop type need to be extracted. For example, if there are only four ground truth locations for potatoes, there is no need extracting two of the parcels for accuracy assessment. All four potato parcels will be used for classification.

15.1.41. Within ArcMap, load the shapefile that has all of the compiled ground truth data minus the parcels that were removed from the NDVI trend verification process.

15.1.42. Open the attribute table for the ground truth shapefile.

15.1.43. Add two fields to the shapefile. One field called ‘Random’ and another field called ‘Accuracy’.

15.1.44. Within the attribute table, use the ‘table options’ drop down menu and click on ‘select by attributes’.

Figure 159.Table Options

15.1.45. Select the crop type that you want to extract half of the parcels from. For example, if you want to select half of the corn parcels for accuracy assessment, within the ‘select by attributes’ dialogue enter “Crop_Type” = ‘Corn’. This will select all of the corn ground truth parcels.

15.1.46. Right click on the shapefile layer within ArcMap and under the ‘Selection’ tab, click on’ Create Layer From Selected Features’. This will add a layer to the map that is all of the corn ground truth parcels.

15.1.47. Open up the attribute table for this newly created layer. In order to get a good spatial distribution of the ground truth parcels, half of the parcels will need to be extracted from each frame. For example, if frame 32031 has 40 parcels of corn and frame 30031 has 30 parcels of corn, 20 parcels of corn need to be extracted from frame 32031 and 15 parcels of corn need to be extracted from frame 30031.

15.1.48. Select by attributes all of the crop type that fall within the first frame. For example, to select all of the corn that falls within frame 29031you want to type "Crop_Type" = 'Corn' and "29031_1" < > 0. This will return all of the corn that falls within frame 29031.

15.1.49. Right click on the shapefile layer within ArcMap and under the 'Selection' tab, click on 'Create Layer From Selected Features'. This will add a layer to the map that is all of the corn ground truth parcels within frame 29031.

15.1.50. Start an edit session.

15.1.51. Open the attribute table for the newly created layer.

15.1.52. Right click on the field 'Random' and select 'Field Calculator'.

15.1.53. Now assign random numbers to the selected parcels to ensure that half of the parcels will be pulled out with random order. Within the 'Field Calculator' dialogue, make sure the Parser is set to VB Script and that the 'Show Code block' radio button is checked. Within the 'Pre-Logic Script Code' copy and paste the following:

15.1.54. dim max, min

max=20

min=5

x=(Int((max-min+1)*Rnd+min))

Set the max to be the upper limit of the random numbers and the min to be the lower limit of the random numbers. So if for example you want the random numbers to go from 1-20, set the max=20 and min=1.

Within the 'Ran =' codeblock, enter 'x'

Select 'OK'

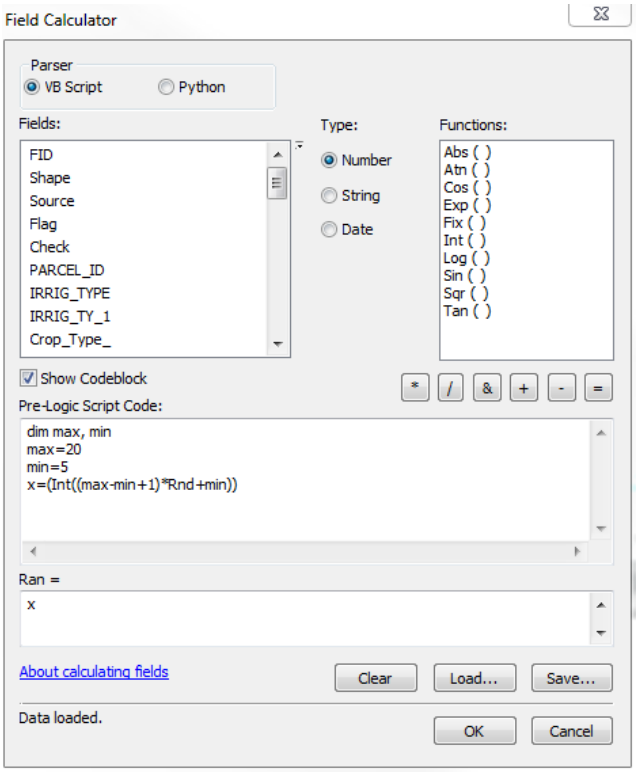


Figure 160. Field Calculator dialogue for calculating random values.

15.1.55. The field ‘Random’ will now be assigned random values.

15.1.56. Right click on the field ‘Random’ and click on ‘Sort Ascending’. This will list the random values from largest to smallest.

15.1.57. Select either the top half or the bottom half of the random values. For example, if you have random values ranging from 1-20, select values 1-10 or 11-20.

15.1.58. Within the ‘Accuracy’ field enter a ‘1’ for the selected values. The unselected values should all have ‘0’ in the ‘Accuracy’ field. The parcels that now have ‘1’ for ‘Accuracy’ will be used for accuracy, and those that have 0 of ‘Accuracy’ will be used for classification.

2031_1	Random	Accuracy
.385224	1	0
0.17199	2	0
.173181	3	0
.177576	4	0
.241982	5	0
.495915	6	1
.815381	7	1
.210476	8	1
.183524	9	1
.711522	10	1

Figure 161. Showing how parcels that will be used for accuracy are determined.

15.1.59. Repeat these steps for every frame in which the crop has ground truth parcels. For example, if you just did this step for 29031 corn, next you want to move on to 29032 corn.

15.1.60. Also repeat the steps for all of the crop types that have at least 20 ground truth parcel locations.

15.1.61. After all of the crops and frames for each crop type have been assigned random numbers and either '0' or '1' for 'Accuracy', the parcels that have been assigned a '1' for 'Accuracy' are now ready to be removed for accuracy.

15.1.62. Within the main ground truth shapefile, open the attribute table.

15.1.63. From the 'table options' drop down menu click on 'Select by Attributes' and enter 'Accuracy" = 1

15.1.64. All of the crops that have been assigned a '1' in the 'Accuracy' field are now selected and ready to be exported.

15.1.65. Right click on the ground truth shapefile and click Data → Export Data…

Chose your workspace to export the data to and give the data a name to know that the data is to be reserved for accuracy.

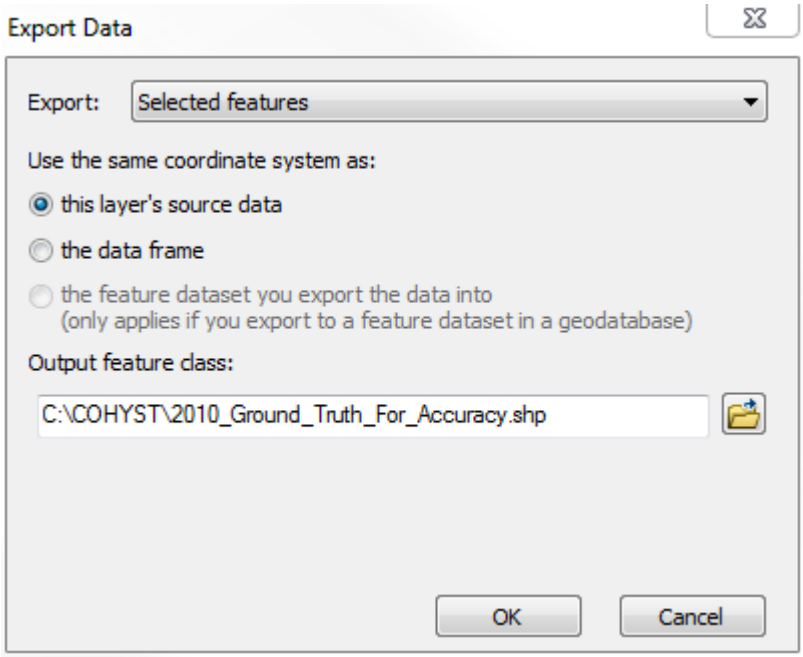


Figure 162. The 'Export Data' dialogue

15.1.66. Now that the parcels that are to be used for accuracy have been exported, parcels that will be used for classification need to be exported on a frame-by-frame basin.

15.1.67. Within ArcMap, open the attribute table of the ground truth parcel shapefile. Just like the previous step, click on 'Select by Attributes'. Since you want to export all of the parcels that have been assigned '0' in the 'Accuracy' field and also parcels based on frame, enter "Accuracy" = 0 AND FRAME< > 0 with FRAME being the field that you want to pull the parcels from. For example, if you want to select all of the parcels that will be used for classification in frame 29031 enter… "Accuracy" = 0 AND "R29031_1" < >0.

15.1.68. Now the parcels that will be used for classification are now selected for one frame. Next you need to export this data to its own shapefile.

15.1.69. Right click on the ground truth shapefile and select Data→Export Data… When writing to your output location, be sure to specify the frame that is being exported.

15.1.70. Repeat these steps until all of the frames with '0' in the 'Accuracy' field are exported.

15.1.71. You should now have

15.1.72. - One main ground truth shapefile

15.1.73. - Ground truth shapefile for accuracy assessment (all of the 1's).

15.1.74. - Individual ground truth shapefile for each frame (0's)

15.1.75. Manual Addition of Additional Ground Truth Locations

Although most of the ground truth data adequately covered each frame for each year, some additional ground truth data needed to be added for frames that were lacking certain crop types or didn't have enough ground truth locations for certain crops. For example, if a frame had less than 5 locations of corn, soybeans, alfalfa, winter wheat, fallow, and sorghum then more ground truth locations needed to ba added. This was accomplished by looking at the NAIP imagery, NDVI stacks, and the CDL classification.

15.1.76. Launch Arc Catalog. Create a new shapefile that will be used to record additional ground truth locations. This shapefile needs to have polygon geometry. Create a new ground truth shapefile for every frame.

15.1.77. Bring the newly created ground truth shapefile into ArcMap. Also bring in the NAIP imagery from the year, the specific CDL for the year, as well as the frames NDVI stack for the year.

15.1.78. Zoom in to a scale that is reasonable for accurately identifying crop types. A scale of 1:5000 seems to work well.

15.1.79. Pan around using the CDL as a reference to locate crops that need more ground truth points (i.e. common crops that have less than about 5 current valid ground truth locations.

15.1.80. Start an edit session.

15.1.81. Digitize a polygon that defines the crop type that needs added.

The example graphics below show an example of how a parcel of fallow is added as a new ground truth location using the CDL. The CDL shows the parcel as being fallow, and the imagery shows the parcel as being brown in color, barren, and is indicative of a parcel that has no 'active' crops and is thus fallow.

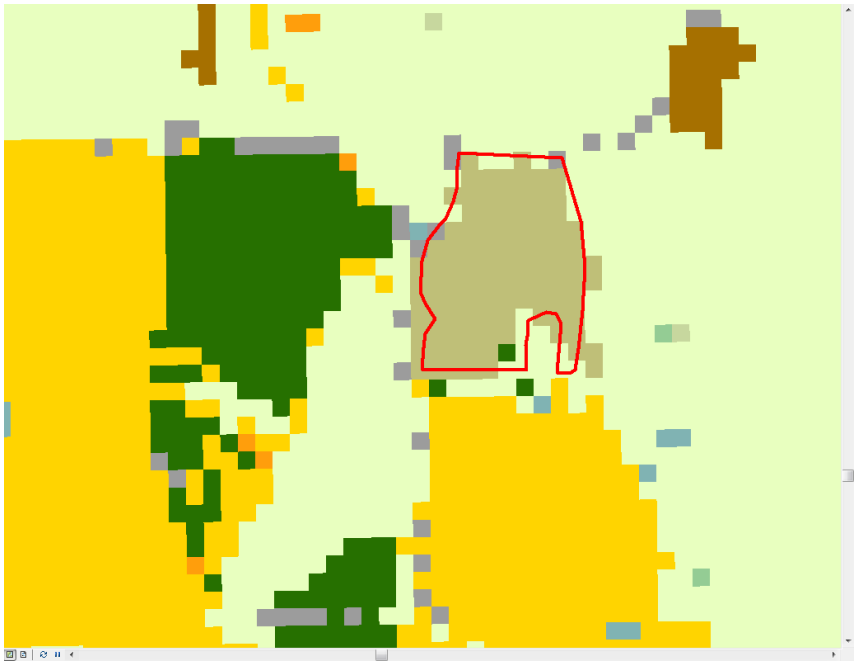


Figure 163.Showing the parcel in red classified according to the CDL classification.

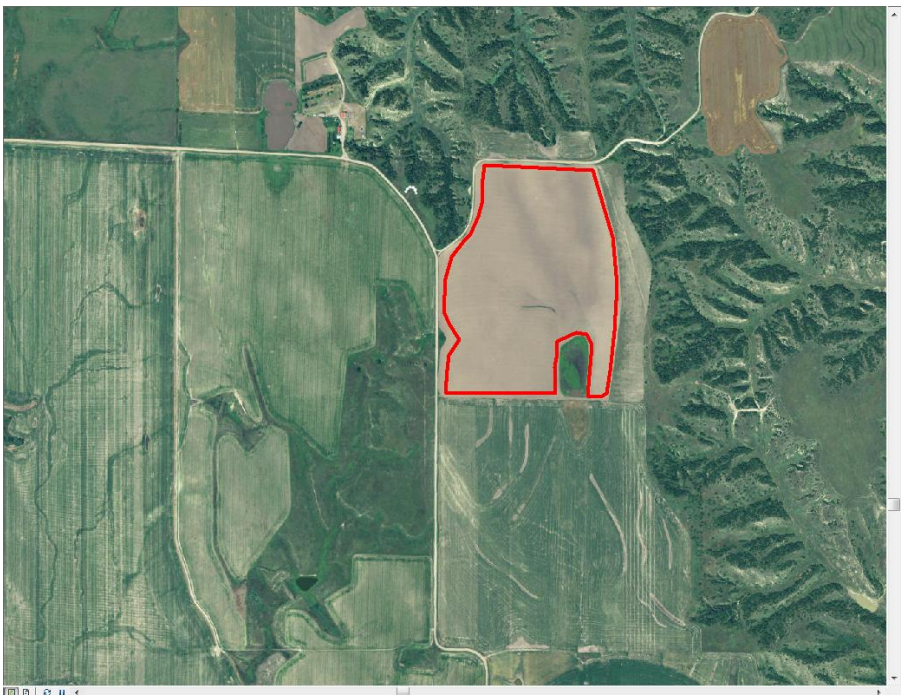


Figure 164.Showing the parcel in red with the NAIP imagery in the background. Notice how barren the parcel look compared to the adjacent crops. Since the CDL has the parcel classified as fallow, and since the parcel appears fallow in the NAIP imagery, it would be safe to call this parcel in fact fallow.

15.1.82. After the parcel has been digitized, record in the attribute table the value that is associated with the certain crop type. For example, fallow is classified with a value of '19', so '19' would be added to the 'Value' field of the attribute table of the newly digitized fallow parcel.

15.1.83. Continue to digitize and attribute additional ground truth parcels until between 5-10 ground truth locations exist for the main crop types within the frame. For example, don't worry about having 5-10 sunflower ground truth locations if the frame only has a few/no locations of sunflower according to the CDL.

15.1.84. After additional ground truth locations have been added for the frame, save your edits and open up the 'GT_Format_For_Classification' model. This model will merge the newly created ground truth shapefile with the already existing ground truth data, clip to the respective frame boundary, and create a raster of the two combined ground truth shapefile which will then be used for classification.

15.1.85. Set the 'Output Train Raster' to your workspace.

15.1.86. Set the 'L Stack for snap' to be the NDVI stack that was previously created for the frame.

15.1.87. Set the 'GT with Value added' to be the recently created ground truth shapefile that has your newly digizitized ground truth parcels.

15.1.88. Set the 'Frame Shapefile' to be the frame boundary or area of interest (a.k.a. 'AOI')

15.1.89. Set the 'GT with Value added 2' to be the existing ground truth shapefile that existed before any new ground truth locations were digitized.

15.1.90. Select 'OK' and the model will run giving an output raster that will be used for training the classification.

15.1.91. Repeat these steps for all of the frames of interest.

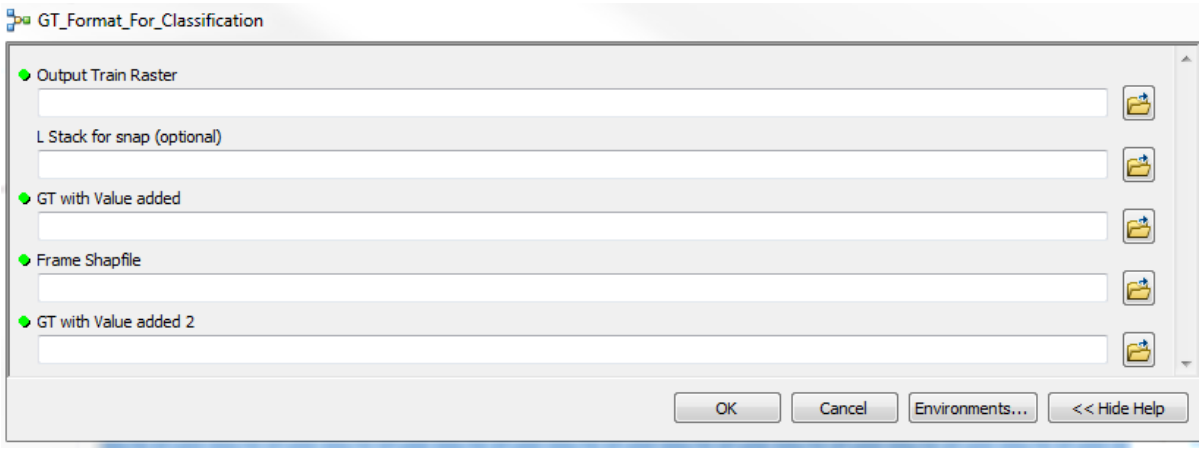


Figure 165. The 'GT_Format_For_Classification' model

15.1.92. 1Ground Truth Verification using NDVI Composite Stacks

Additional ground truth data can also be verified by using NDVI composite stacks that were created. All groups show different NDVI signatures, and thus common NDVI trends can be seen within alike crops.

15.1.93. Launch ArcMap.

15.1.94. Bring in the CDL from the year you want to add ground truth data to. Also bring in the NAIP imagery from the year.

15.1.95. Depending on the frame that you want to add ground truth data to, bring in the NDVI stack that corresponds to the correct frame.

15.1.96. Pan around the CDL and NAIP imagery to try to find crops that you need to add additional ground truth data to. For example, if you need to add additional sorghum, pan around the CDL for sorghum.

Figure 166. Showing potential CDL sorghum sites that can be added to ground truth.

15.1.97. Toggle different layer combinations for the RGB values for the NDVI stack in the image for a combination that makes the crops stand out. Since every layer is a different NDVI date, certain combinations work better for different crops. In this example, additional sorghum is being added to frame 31032 thus I would use the NDVI stack '31032_NDVI_Stack_ammjjJJJAASO'. I found that a good combination that works for sorghum is setting Red to layer 10, Green to layer 9 and blue to Layer 6. This means that the image combination is August (layer 10) August (layer 9) and July (Layer 6).

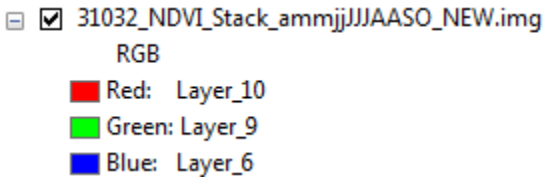


Figure 167.Showing band combination adjustment

15.1.98. Turn off the CDL so that just the NDVI composite is visible, with the bands that you have selected. I should become apparent that certain alike crops stand out based on the composite dates that you have chosen. The CDL's classification isn't always right, so using NDVI verification for adding ground truth data is a good additional process to get accurate additional ground truth locations. The figure below shows the 10-9-6 NDVI combination that was used to help identify sorghum. Notice that the sorghum appears yellow, while all of

the other surrounding crops do not appear this color. This is a good indication that the crops are in fact sorghum and that the CDL is correct in calling these crops sorghum.

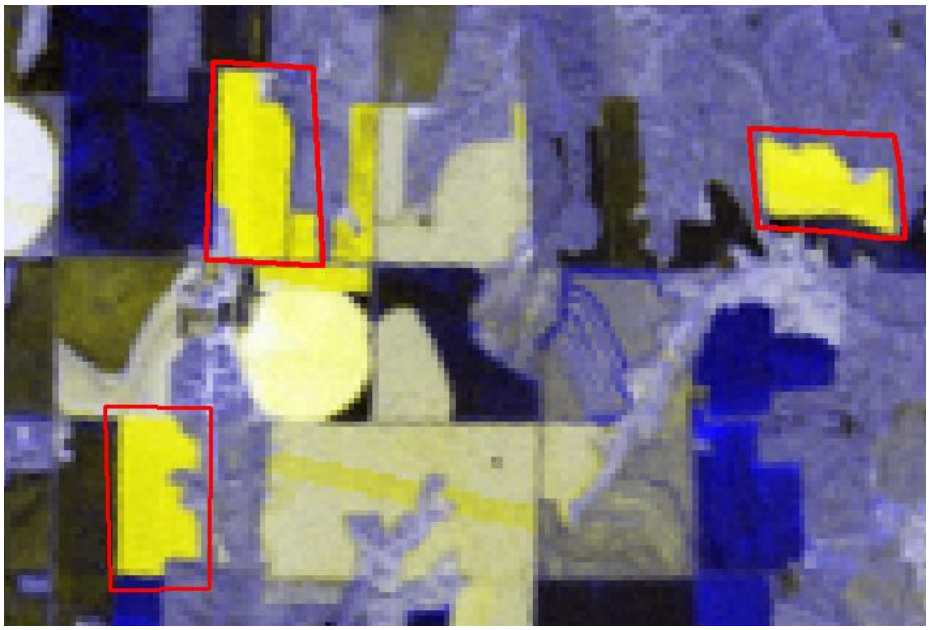


Figure 168. Showing the same extent as the previous CDL graphic, only this is the NDVI composite. Notice that the sorghum stands out in yellow, while all of the other different crops appear dull.

15.1.99. Since theses sorghum crops have been verified by the NDVI composite, it is now safe do digitize the crops and attribute them as sorghum. Refer to the previous section on instructions on adding additional ground truth locations.

Process Step.3 (Classification)

15.1.100. The third part of the classification involves performing the MLC classification.

15.1.101. Landsat composite and NDVI composite cloud filled images are then stacked on a seasonal interval for each frame. Based on cloud suitability and the number of image dates present for each frame. Both composites contain input images where frames were processed clipped to a buffered study area boundary.

15.1.102. The reserved training ground truth data sets are available for classification procedures input once they have been checked using the multi-temporal NDVI evaluation. With any possible outliers removed, the shapefile can be negatively buffered by a distance of 30m for classification signature extraction.

15.1.103. ERDAS requires the training dataset is converted to raster format. The process can be performed in ERDAS or ArcGIS using a vector to raster conversion tool. Cell size should match the image to be classified and pixel snapping implemented. This insures signatures are extracted from the correct corresponding multi-band pixel values.

15.1.104. The classification procedure is performed in ERDAS and is first started with the import and formatting of the training data. To start, the training data must be changed from continuous to thematic data type. Open a viewer in ERDAS

15.1.105. Right click on the image in the contents panel and scroll to the metadata option.

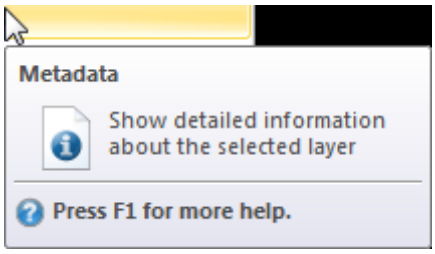


Figure 169. Showing the ERDAS metadata interface prompt

15.1.106. On the Image Info window click Edit>Compute Statistics.

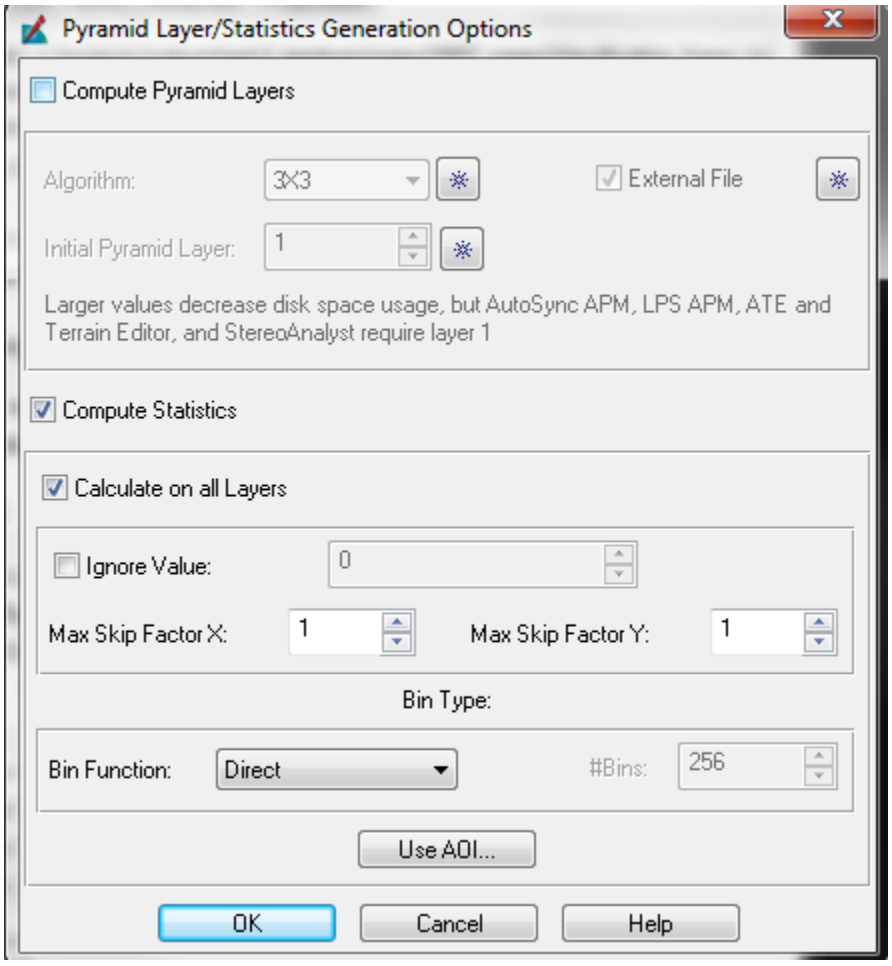


Figure 170. Showing Computing statistics for a continuous image in the metadata interface

15.1.107. On the statistics Generation Options window that comes up, change the Skip Factor for x and y to equal 1, and change the Bin Type to be “Direct”. Click OK.

15.1.108. On the Image Info window, click Edit>Change Layer Type.

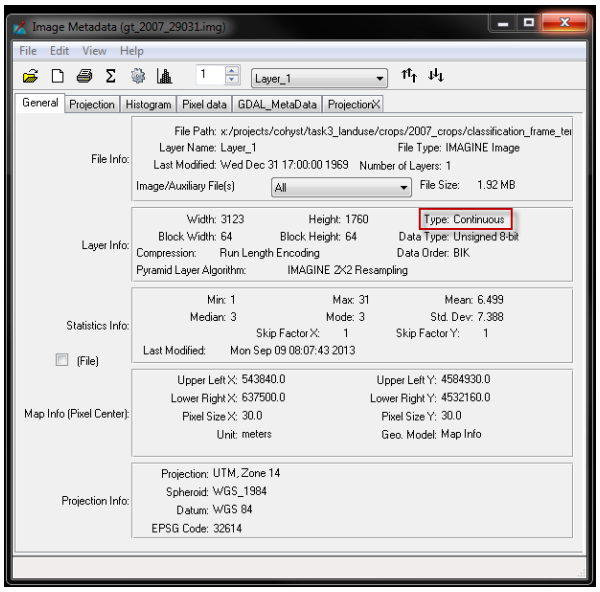


Figure 171.. Image Info Window for thematic layer

15.1.109. The displayed type of image will then change from Continuous to Thematic.

15.1.110. Close the Image Info window. On the Viewer window, click Raster>Attributes.

15.1.111. On the raster attribute editor, click Edit>Add Class Names.

15.1.112. Now go through each record in the raster attribute editor and label each class name and allocate a unique color to each crop type and click save.

15.1.113. Signature Extraction and Classification

15.1.114. Now extract the spectral signatures from the input Landsat composite masked imagery within the training parcels using the signature editor. In ERDAS Imagine click the Raster>Supervised>Signature Editor.

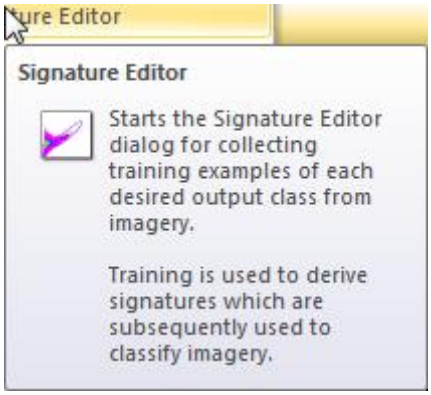


Figure 172.Showing the ERDAS signature editor dialog

15.1.115. Select Edit>Image Association.

15.1.116. Select Landsat_composite_mask.img.

15.1.117. Select Edit>Extract from Thematic Layer on the signature editor.

15.1.118. Choose the Training Data for the Input Thematic File, and call the Output Signature File Landsat_composite_mask.sig, click OK.

15.1.119. Once completed, load the Landsat_composite_mask.sig file into the signature editor.

15.1.120. Name the class names and give them unique colors. Save the Landsat_composite_mask.sig. Evaluate each signature by band.# for histogram display and pixel count.

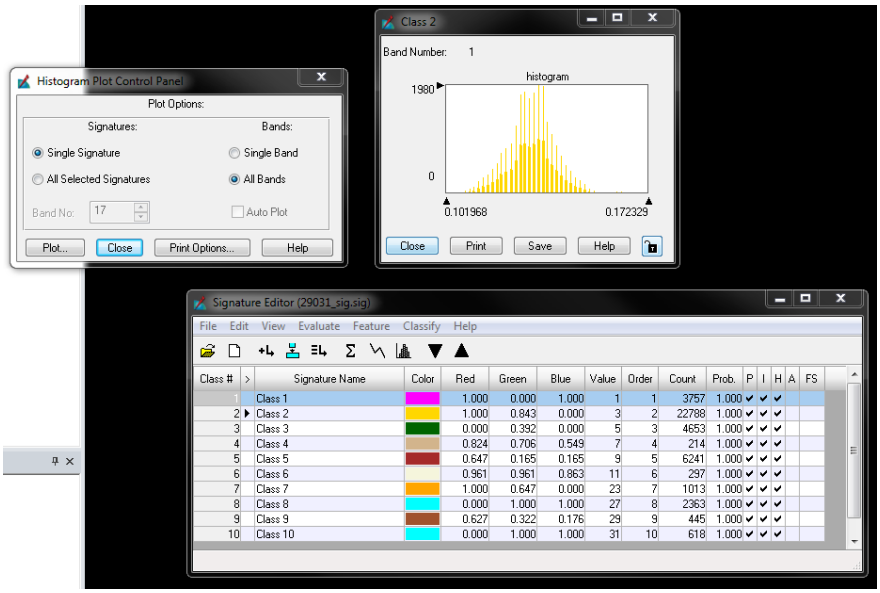


Figure 173. Showing the ERDAS signature review interface

15.1.121. Next, you will create a supervised classification of the Landsat_composit.img based upon the newly created Landsat_composite_mask.sig signatures. On the signature editor, click Classify > Supervised. Populate the dialog with the following inputs:

Input Raster – Multi-temporal Landsat stack

Input Signature File – Signature file corresponding to the input raster

Classification File – Output classified raster

Distance File – Output QC review file

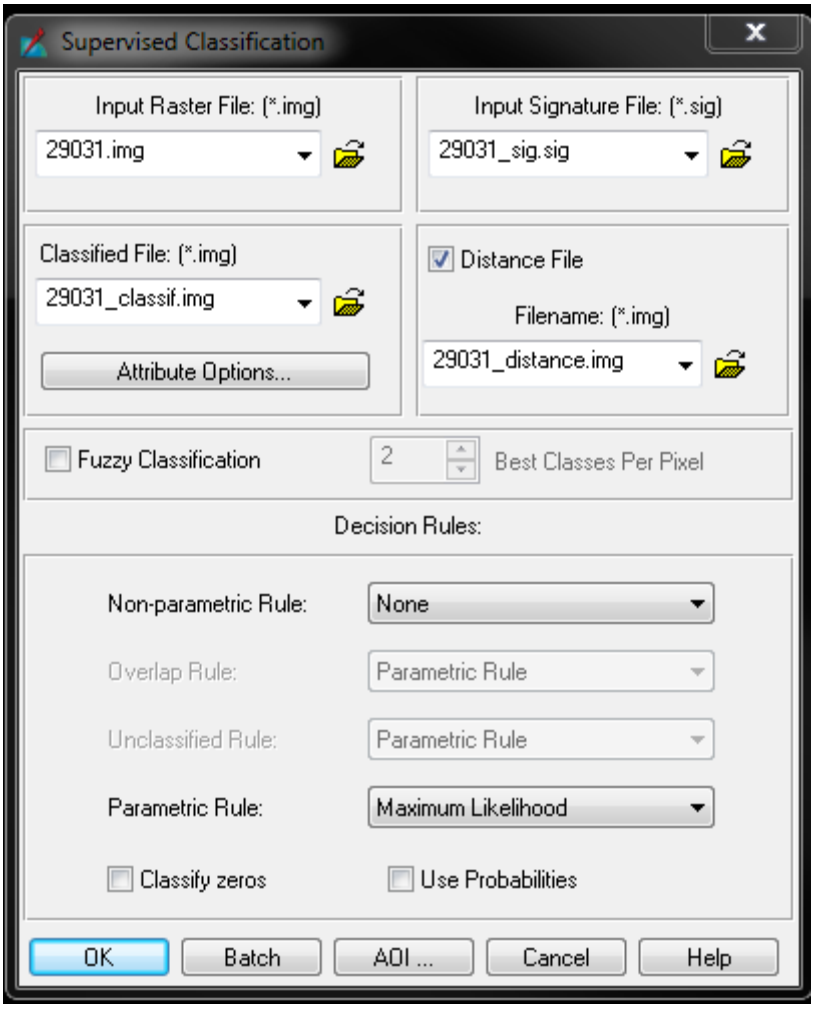


Figure 174. Showing the supervised classification interface

15.1.122. Open the classified image in ArcMap and inspect the results. Review the distance file for any locations with higher values. As described in the ERDAS 2013 help documentation:

15.1.123. The brighter pixels (with the higher distance file values) are spectrally farther from the signature means for the classes to which they are assigned.

15.1.124. These locations are more likely to be misclassified. If during the review the classification seems incorrect for a given reason, the following solutions should be reviewed:

- Removal of neighboring ground truth locations by re-evaluating NDVI based training signatures.
- Additional of training data for classes with minimal location input. Will require NDVI validation.
- Thresholding distance results for further analysis.
    - Process requires evaluating pixel results that are most likely incorrect. Results can be re-classed into a binary grid and used in masking composite img file. Additional training data can be used to re-classify the masked portion. Re-classify and re-evaluate the distance file until the classification appears correct.

Process Step.4 (Accuracy Assessment)

15.1.125. The forth part involves performing and evaluating accuracy assessment.

15.1.126. Accuracy assessment is performed on the results of the parcel-level classification. The accuracy assessment is the final review step to insure the classification procedure was performed correctly. Using ArcGIS Zonal Statistics, the majority classified crop type will be extracted for each reserved accuracy assessment parcel. The results table indicates the majority crop type value for each accuracy-assessed parcel. A third column can be calculated to indicate the match and finally summary statistics can be ran to tabulate the counts.

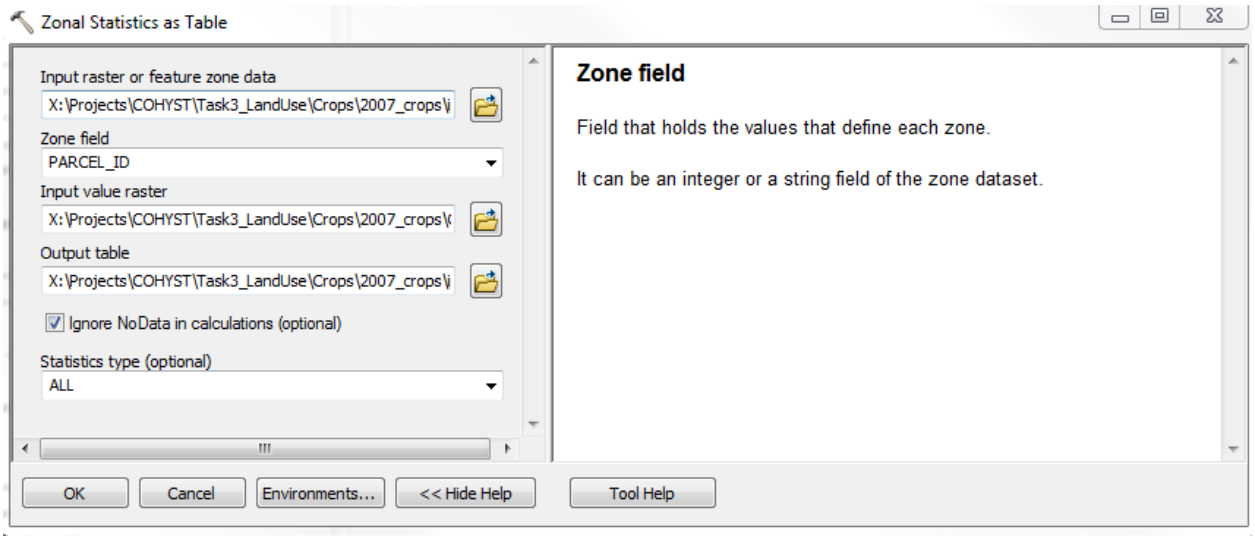


Figure 175. Showing the ArcGIS zonal statistics tool interface for extracting accuracy values

15.1.127. Populate the zonal statistics tool to create and output summary of the classification results.

15.1.128.

15.1.129. Using the table output from the summary statistics, populate an excel based template Error Matrix with the classification results.

15.1.130.

Traditional Error Matrix

Classification Data	Categories		Reference Data: Alfalfa 1	Corn 3	Soybeans 5	Small Grains 7	Winter Wheat 9	Hay/Pasture 11	SugarBeats 13	Dry Beans 15	Potatoes 17	Fallow 19	Sunflowers 21	Sorghum 23	Spring Wheat 32	Total	Error of Commission	User's Accuracy
	Alfalfa	1	50	5	2	2	1	3								63	20.6%	79.4%
	Corn	3	0	855	9	1	0	4								869	1.6%	98.4%
	Soybeans	5	0	11	314	0	0	1								326	3.7%	96.3%
	Small Grains	7	3	0	1	5	0	1								10	50.0%	50.0%
	Winter Wheat	9	2	2	1	0	4	1								10	60.0%	40.0%
	Hay/Pasture	11	0	0	0	0	1	6								7	14.3%	85.7%
	SugarBeats	13	0	0	0	0	0	0								0	#DIV/0!	#DIV/0!
	Dry Beans	15	0	0	0	0	0	0								0	#DIV/0!	#DIV/0!
	Potatoes	17	0	0	0	0	0	0								0	#DIV/0!	#DIV/0!
	Fallow	19	0	1	0	0	0	0								1	100.0%	0.0%
	Sunflowers	21	0	0	0	0	0	0								0	#DIV/0!	#DIV/0!
	Sorghum	23	0	0	2	0	0	0								2	100.0%	0.0%
	Spring Wheat	32	0	0	0	0	0	0								0	#DIV/0!	#DIV/0!
	Total		55	874	329	8	6	16	0	0	0	0	0	0	0	1288		
	Error of Omission		9.1%	2.2%	4.6%	37.5%	33.3%	62.5%	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!			
	Producer's Accuracy		**90.9%**	**97.8%**	**95.4%**	**62.5%**	**66.7%**	**37.5%**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**	**#DIV/0!**		**Overall Accuracy**	**96%**
	Kappa per Class		**0.96**	**0.62**	**0.81**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**	**1.00**			

Calculations 2010 Results

Proportional Error Matrix

Classification Data	Categories	Reference Data: Alfalfa	Corn	Soybeans	Small Grains	Winter Wheat	Hay/Pasture	SugarBeats	Dry Beans	Potatoes	Fallow	Sunflowers	Sorghum	Spring Wheat	Total
	Alfalfa	0.039	0.004	0.002	0.002	0.001	0.002								0.05
	Corn	0.000	0.664	0.007	0.001	0.000	0.003								0.67
	Soybeans	0.000	0.009	0.244	0.000	0.000	0.001								0.25
	Small Grains	0.002	0.000	0.001	0.004	0.000	0.001								0.01
	Winter Wheat	0.002	0.002	0.001	0.000	0.003	0.001								0.01
	Hay/Pasture	0.000	0.000	0.000	0.000	0.001	0.005								0.01
	SugarBeats	0.000	0.000	0.000	0.000	0.000	0.000								0.00
	Dry Beans	0.000	0.000	0.000	0.000	0.000	0.000								0.00
	Potatoes	0.000	0.000	0.000	0.000	0.000	0.000								0.00
	Fallow	0.000	0.001	0.000	0.000	0.000	0.000								0.00
	Sunflowers	0.000	0.000	0.000	0.000	0.000	0.000								0.00
	Sorghum	0.000	0.000	0.002	0.000	0.000	0.000								0.00
	Spring Wheat	0.000	0.000	0.000	0.000	0.000	0.000								0.00
	Total	0.04	0.68	0.26	0.01	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**1.00**
	Actual Agreement (Po)	0.96													
	Chance Agreeemnt (Pc)	0.52													
	2010 Results KHAT* **	**0.91**	*KHAT Values range from -1 to +1 representing measure of agreement or accuracy												

Figure 176. Showing the excel accuracy assessment matrix

15.1.131. If accuracy percentages at the crop level are below anticipated standards, further analysis and refinement will be required.

Process Step.5 (Parcel Crop Assignment)

15.1.132. The final component of the procedure involves crop type assignments to individual parcel layers.

15.1.133. With a Landsat frame classified, reviewed and corresponding accuracy assessment indicating suitable percentages, parcel crop types can be assigned to the parcel layer. The process is performed in ArcGIS using the zonal statistic majority function. The tool will extract the corresponding crop type for each parcel. Due to noise occurrences on parcel boundaries, it is suggested to negative buffer parcels by 30m in extraction crop types. For parcels smaller than 30m that result in a geometry loss result back to the default parcel size and review results. Insure the extracted table is joined to the full parcel feature class.

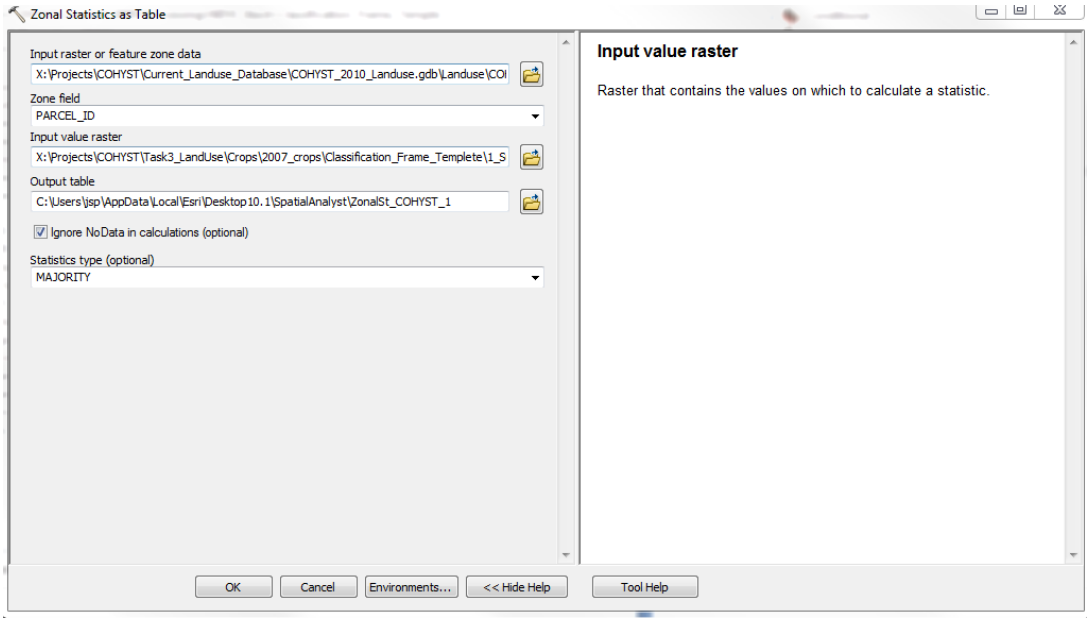


Figure 177. Shows the ArcGIS zonal statistics tool for extracting crop types

15.1.134. The resulting zonal table can then be joined back to the parcel feature class on PARCEL_ID. As a QC measure, it is recommended to append the crop type from each classified frame as the overlap portion from adjacent frames provides cross-scene validation. If differences are seen, further review will be required.

Trees, Riparian, Water, and Bare Ground Classification

15.1.135. Extract an aerial image from the 2010 NAIP file geodatabase using the **Copy Raster** tool in **Arc Toolbox**. The tool is located at: Data Management Tools -> Raster -> Raster Dataset.

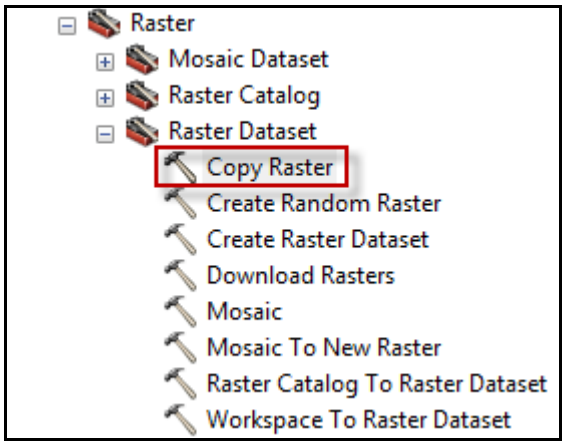


Figure 178. Copy raster tool in Arc Toolbox

15.1.136. Choose the appropriate output location for the copied raster file, ensure the No Data Value is **256**, and choose the Pixel Type **8_BIT_UNSIGNED**.

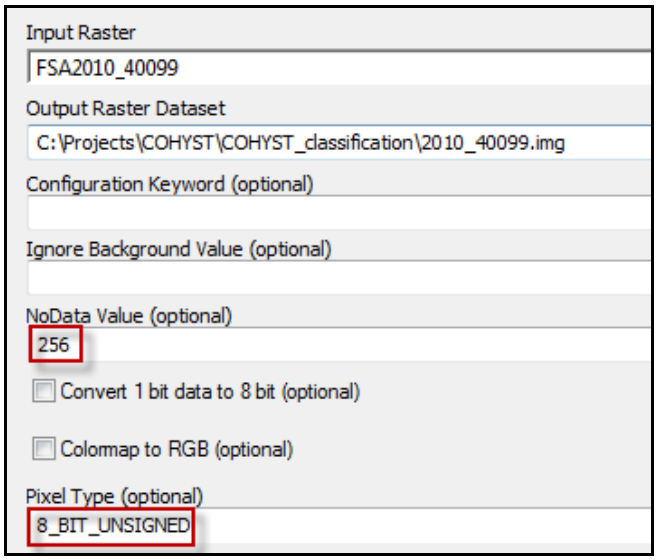


Figure 179. Copy Raster tool input values

Note: The extension .img creates an ERDAS IMAGINE file which reduces the file size and more characters can be used in the name of the output file. The Pixel Type, 8 Bit Unsigned integer, also reduces the file size of the

copied raster file and the value 256 ensures there is a numerical No Data Value assigned to the image that does not fall between 0 to 255.

15.1.137. Clip the copied aerial image to the COHYST boundary using the Raster Clip tool in Arc Toolbox and a shapefile or feature class of the COHYST boundary. The tool is located at: Data Management Tools -> Raster -> Raster Processing.

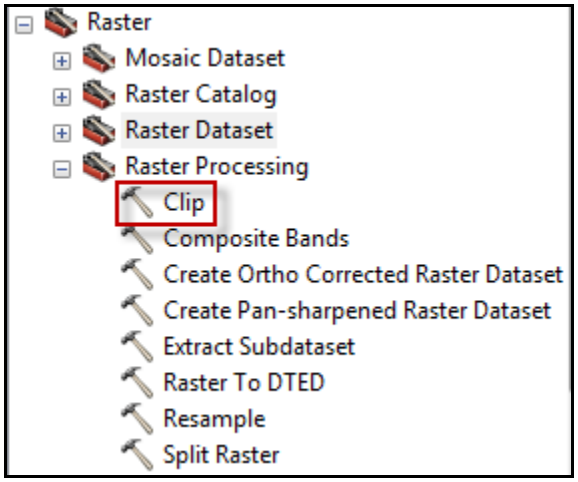


Figure 180. Raster Clip tool in Arc Toolbox

15.1.138. Choose the appropriate output location for the clipped raster file, select the Output Extent which is the COHYST boundary, check the box for Use Input Features for Clipping Geometry, and enter 256 for the No Data Value.

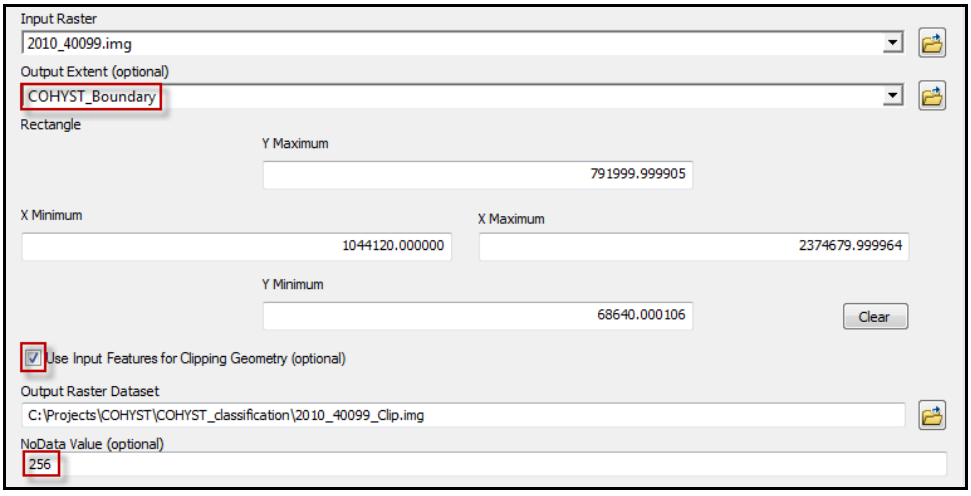


Figure 181. Raster Clip tool input values

15.1.139. Change the grid cell size of the aerial image from 3.32 ft (1 meter) to 10ft (3 meters) using the Resample tool in Arc Toolbox. The tool is located at: Data Management Tools -> Raster -> Raster Processing.

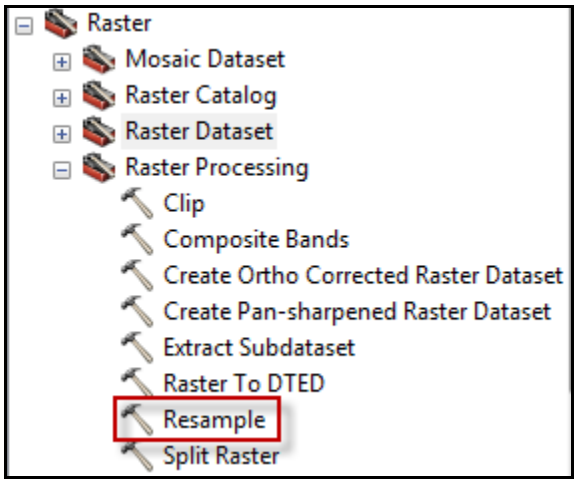


Figure 182. Resample tool in Arc Toolbox

15.1.140. Choose the appropriate output location for the resampled raster file, enter the value 10 for the new X and Y cell size for, and select NEAREST for the Resampling Technique.

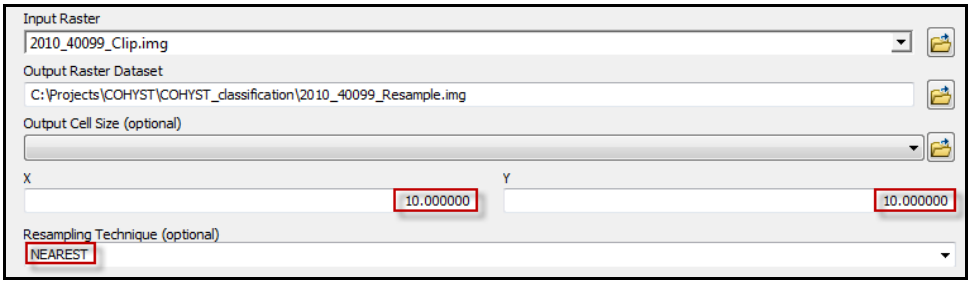


Figure 183. Resample tool input values

15.1.141. Create a NDVI file of the resampled raster file using the Image Analysis window in ArcMap which is located on the Menu toolbar under the Windows tab at the top of ArcMap.

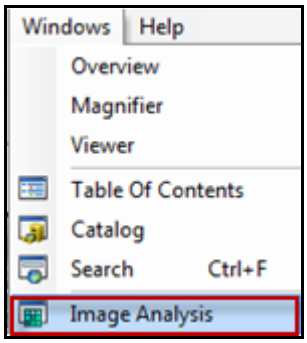


Figure 184. Image Analysis window in ArcMap

15.1.142. Within the Image Analysis window click on the raster file that the NDVI file will be created for and then click on the NDVI processing button to create a temporary NDVI layer in ArcMap.

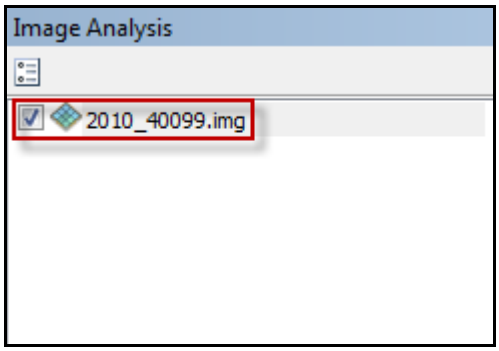


Figure 185. Selected raster file in the Image Analysis window

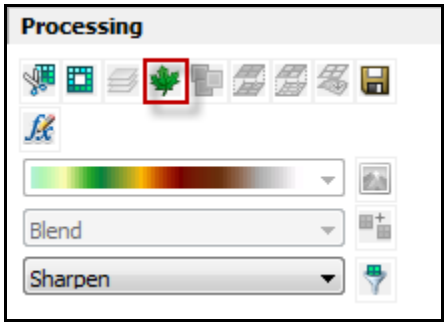


Figure 186. NDVI function in the Image Analysis window

15.1.143. Create a raster file from the temporary NDVI layer using the Copy Raster tool in ArcToolbox using the appropriate input values.

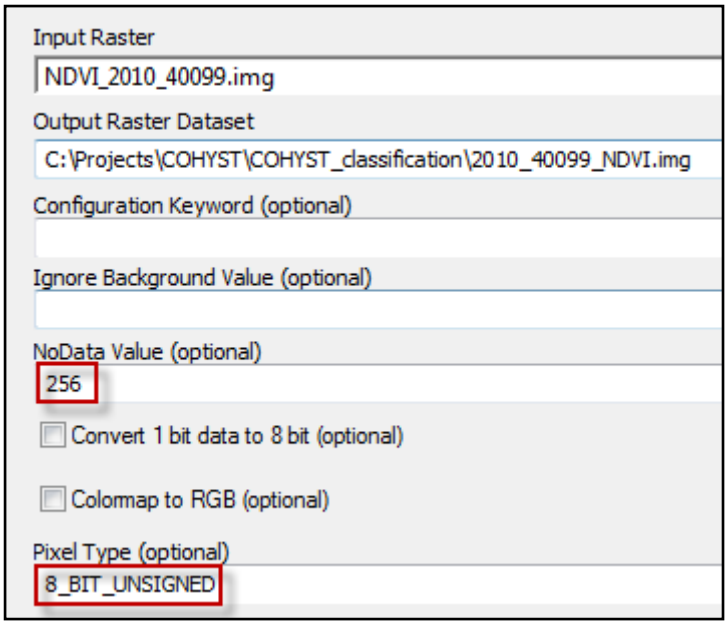


Figure 187. Copy Raster tool input values

15.1.144. Create a composite raster file of the NDVI raster file and Bands 1 and 2 from the resampled raster image using the Composite Bands tool in ArcToolbox. The tool is located at: Data Management Tools -> Raster -> Raster Processing.

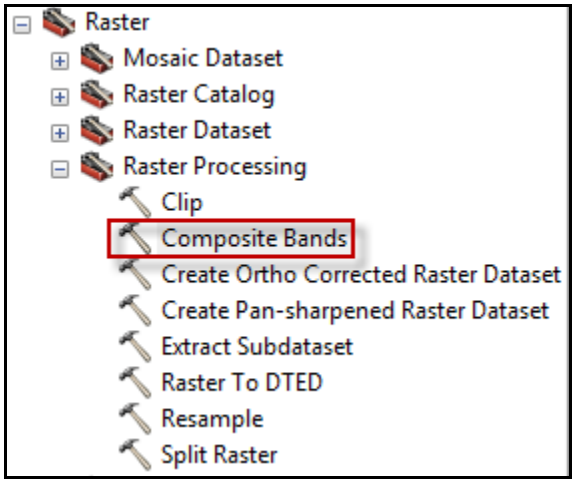


Figure 188. Composite Bands tool in ArcToolbox

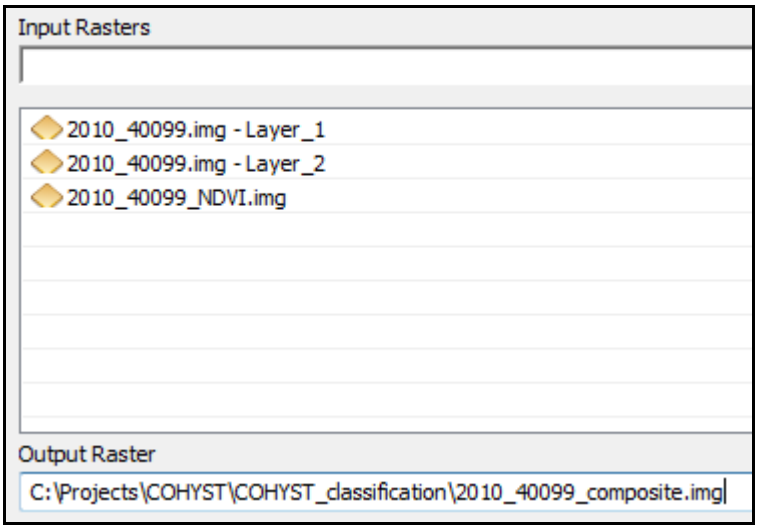


Figure 189. Composite Bands tool input values

15.1.145. Use the extent shapefile of the aerial image to clip the shapefile or feature class of the 2010 crop parcels within COHYST using the Vector Clip tool within ArcToolbox to create a new parcels shapefile. The tool is located at: Analysis Tools -> Extract.

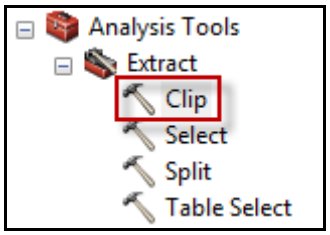


Figure 190. Vector Clip tool in ArcToolbox

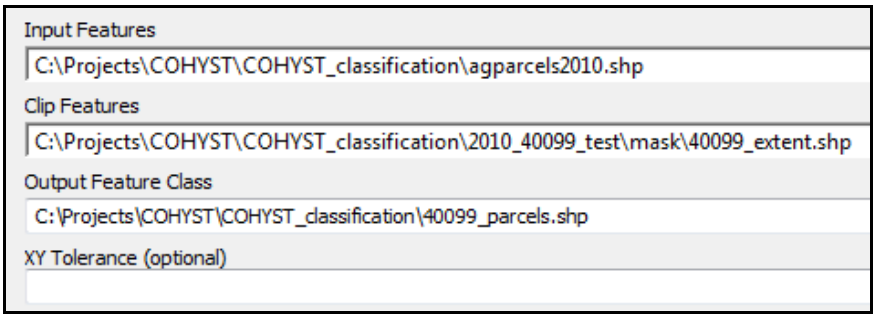


Figure 191. Vector Clip tool input values

15.1.146. Populate the PARCEL_ID or any other designated field in the clipped parcels shapefile with the value 1 using the Field Calculator within the attribute table in an edit session.

15.1.147. Dissolve the clipped parcels shapefile based on the field calculated with the value 1 using the Dissolve tool in ArcToolbox. The tool is located at: Data Management Tools -> Generalization.

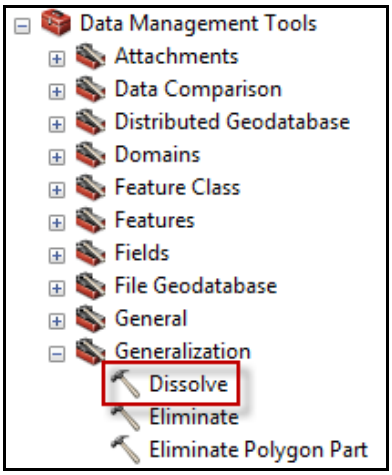


Figure 192. Dissolve tool in ArcToolbox

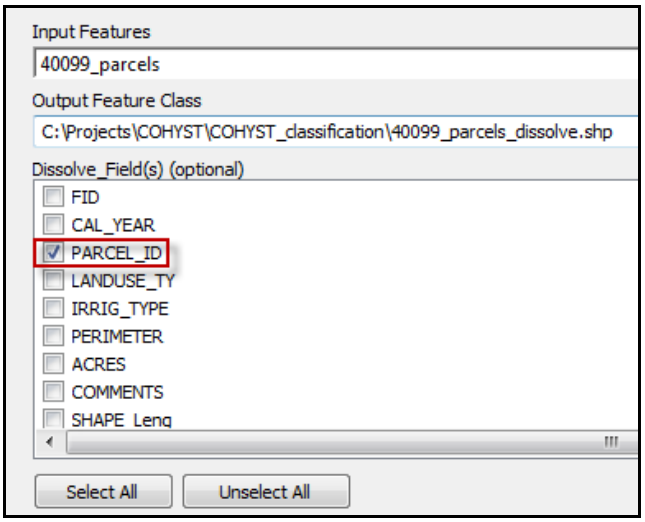


Figure 193. Dissolve tool input values

15.1.148. Create a raster file from the dissolved parcels shapefile using the Feature to Raster tool in ArcToolbox. The tool is located at: Conversion Tools -> To Raster.

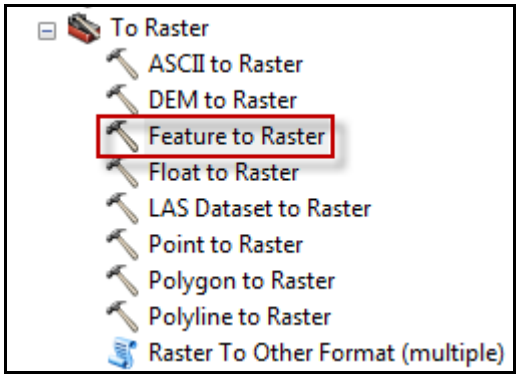


Figure 194. Feature to Raster tool in ArcToolbox

15.1.149. Choose the field that the shapefile dissolve was based on, the appropriate output location for the raster file, and select the resampled raster file to ensure the output cell size is 10ft.

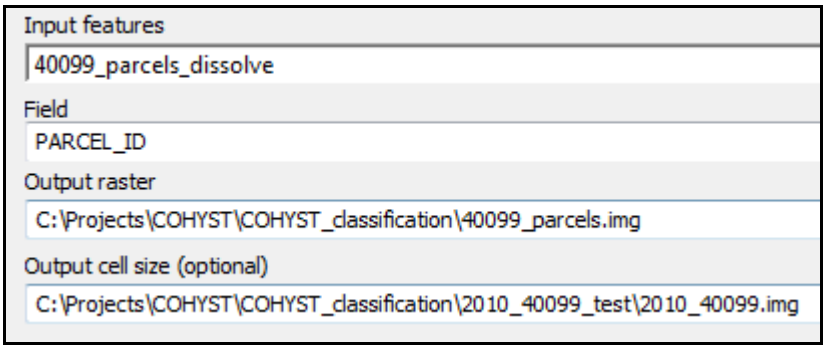


Figure 195. Feature to Raster tool input values

Note: The output raster will contain two values, the value 1 for all of the parcels and the value No Data for everything else. That is why the original shapefile was dissolved on a field with the value 1 which is used as an input. Additionally, the output cell size of the parcel raster file needs to be the same as the resampled aerial image.

15.1.150. Reclassify the values in the parcel raster file using the Reclassify tool in ArcToolbox. The tool is located at: Spatial Analyst Tools -> Reclass.

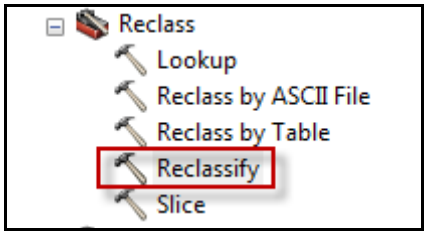


Figure 196. Reclassify tool in ArcToolbox

15.1.151. Choose the Value field for the Reclass field and change the value 1 to No Data and the value No Data to 1.

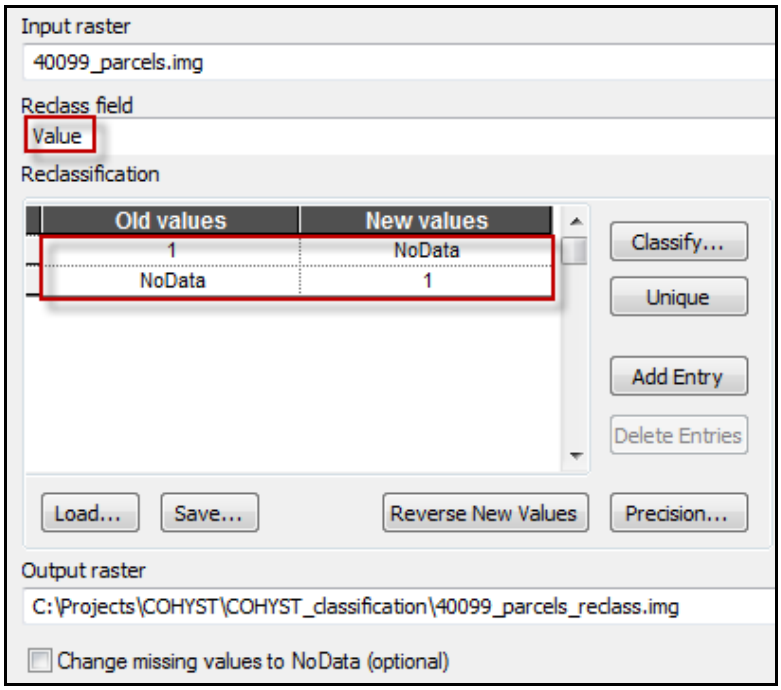


Figure 197. Reclassify tool input values

15.1.152. Clip the reclassified raster file to the COHYST boundary using the Raster Clip tool in ArcToolbox. This creates a raster mask of the crop parcels within the extent of the composite aerial raster file.

15.1.153. Create a mask raster file for the roads within the extent of the composite aerial raster file using the same steps that were used for the crop parcels.

15.1.154. Mask the composite raster file with the parcel raster mask using the Extract by Mask tool in ArcToolbox.

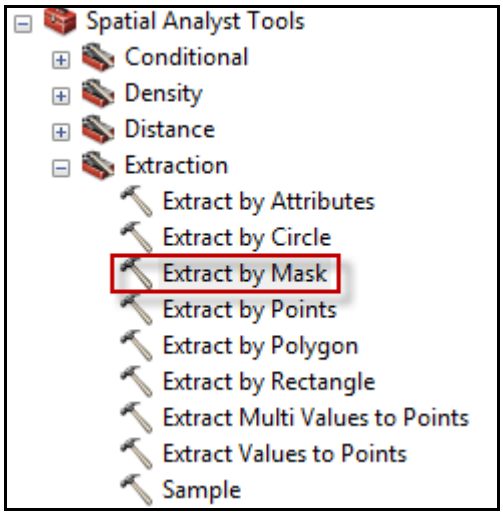


Figure 198. Extract by Mask tool in ArcToolbox

15.1.155. Mask the new raster file with the road raster mask using the Extract by Mask tool in ArcToolbox.

> ***Note:*** At this point the composite raster file should have had the masking function performed on it twice for the parcels and roads. This removes the parcels and roads from the original composite raster file which will increase the accuracy of the classification.

15.1.156. Copy the final masked raster file using the Copy Raster tool in order to set the final parameters of the raster file for classification. Set the NoData Value to 65536 and the Pixel Type to 16_BIT_UNSIGNED.

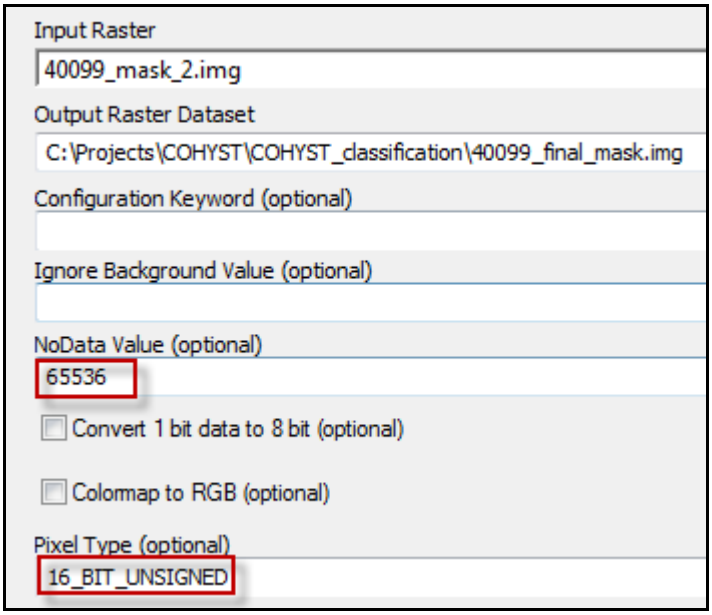


Figure 199. Copy Raster input values

15.1.157. Open ERDAS IMAGINE and click the Raster tab on the Menu Bar.

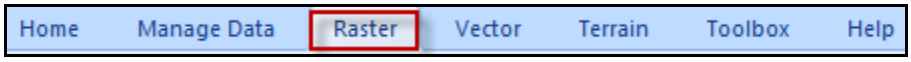


Figure 200. ERDAS IMAGINE Menu Bar

15.1.158. Click on the Unsupervised tab and select Unsupervised Classification.

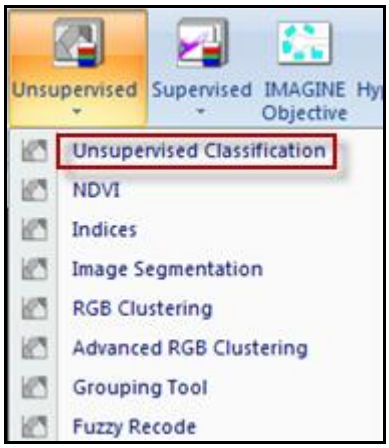


Figure 201. Unsupervised drop down menu

15.1.159. Select the final raster mask file for the input raster file, choose the appropriate output locations for the output classification layer and signature file, set the number of classes to 50, and set the maximum iteration number to 10. Click OK.

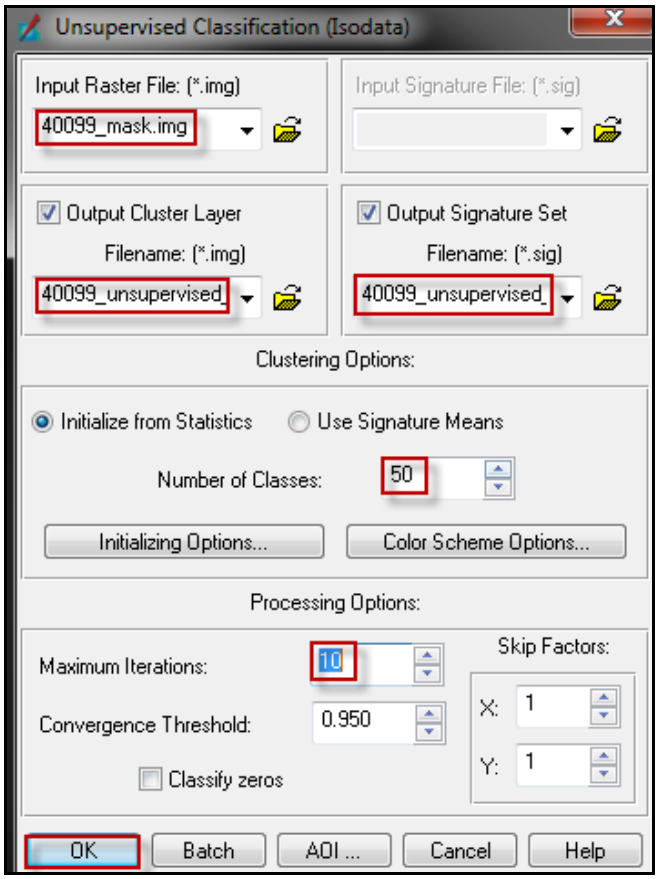


Figure 202. Unsupervised Classification dialog box

Note: The number of classes and maximum iterations shown above is just a recommendation and depends on user preference such as allowable processing time and accuracy of the classification.

15.1.160. Once the classified raster file is created, add it to ArcMap along with the 2010 clipped, resampled aerial image. The 2010 aerial image will be used to assign values to the 50 classes that were created in the classification such as trees, water, bare earth, and non agricultural areas.

15.1.161. Right click on the classified raster layer in ArcMap, select Properties, and then click on the Symbology tab.

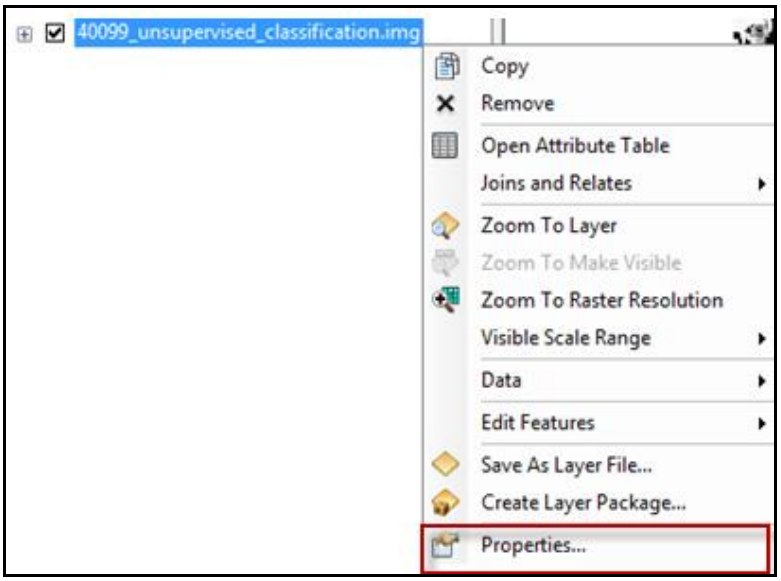
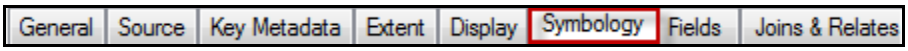


Figure 203. Properties menu for the classified layer



Properties tabs for the classified layer

15.1.162. Click on Unique Values in the Show window.

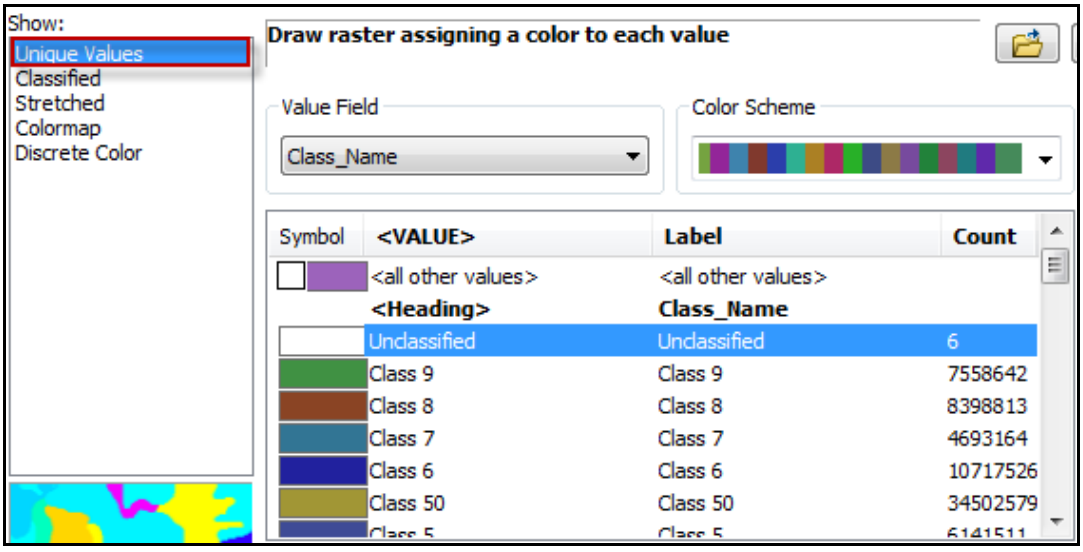


Figure 204. Symbology tab property options

Note: From here the symbol for each class can be changed to a preferred color or made hollow so it will not show depending on user preference. Using the aerial imagery, values (color) can be designated for each class that designates the land type. Colors can be changed by left clicking on the symbol to left of each class.

15.1.163. The classification results from each NAIP tile can then be reclassed into the corresponding classes and mosaiced into a seamless supplemental classification for static land cover classes. The 2010 supplemental classification is seen below and compared with the 2005 Landsat based classification method to the right and the 2010 NAIP input to the left.

15.1.164. Classes include: Water, Riparian/Forest/Woodland and Barren areas.

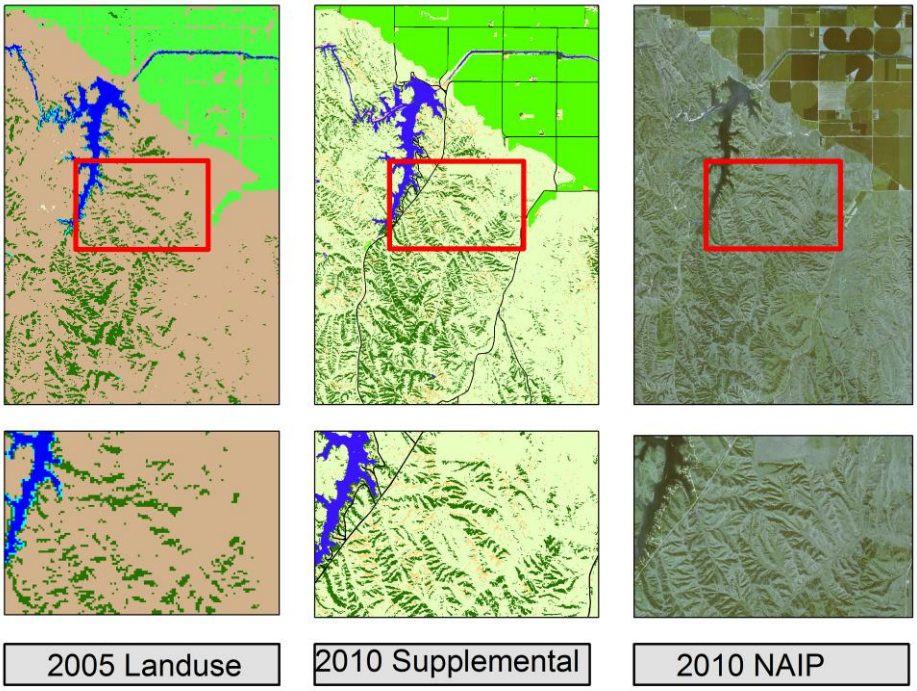


Figure 205. NAIP classification results

TASK IV. IRRIGATED AND NON-IRRIGATED IRRIGATION SEPARATION

16. Instructions to Classify Irrigated and Non-Irrigated Parcels

The irrigation assignment procedure is performed using the crop classification and NDVI thresholding procedures to determine potential irrigation status. The results are then verified using ancelary GIS datasets including: pivots, wells and certified acres. The method is outlined in the following graphic.

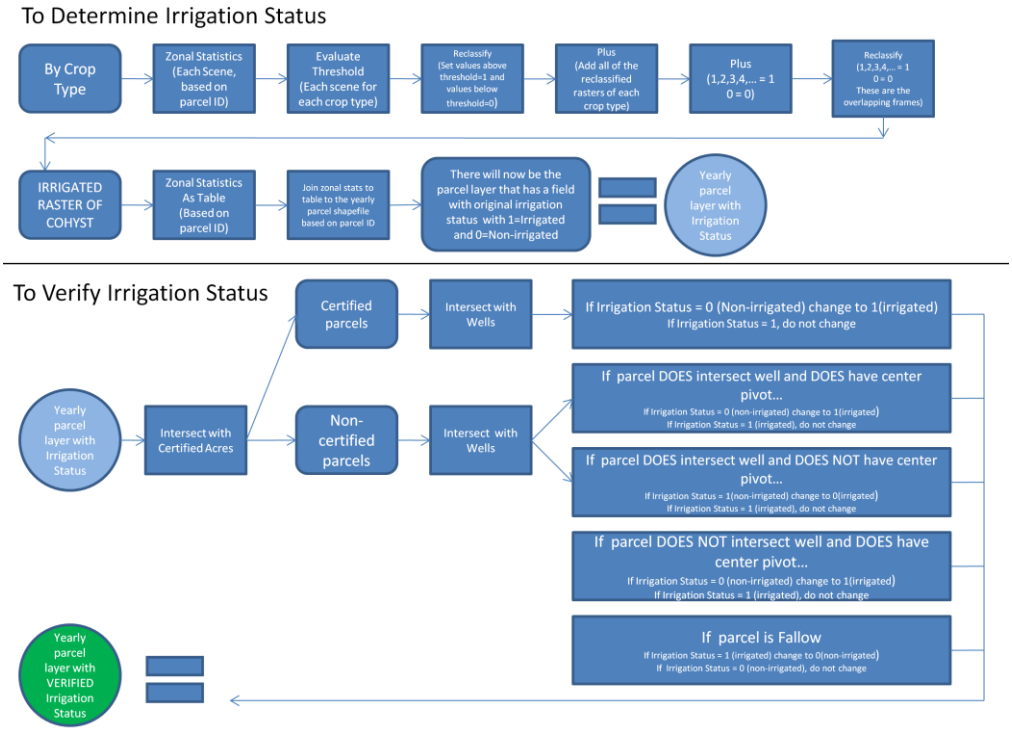


Figure 206. Showing the irrigation assignment procedure as performed

16.1.1. Find NDVI Landsat scenes that are minimally filled with clouds. Dates between July and August are typically best for crops such as corn and soybeans, as many crops typically show full cover between these dates.

16.1.2. Once individual scenes have been selected, open up ArcMap.

16.1.3. Load selected NDVI scene into ArcMap using the "Add Data" icon and navigate to the workspace of the selected scenes.

Figure 207. Add Data Icon

16.1.4. Along with adding the selected NDVI scene(s) into ArcMap, also add known irrigation, ground truth, certified acres, center pivots, etc. shapefiles into ArcMap using the "Add Data" icon.

16.1.5. In ArcMap, click on the "Search" icon located near the top of the screen.

Figure 208. Search Icon

16.1.6. Search for and click on "Zonal Statistics".

16.1.7. Use the crop type shapefile for the frame (e.g., corn, soybeans, alfalfa, etc.) as the "Input", the crop type parcel feature ID (FID) as the "Zone Field", the selected Landsat NDVI scene as the "Input value raster". Specify the "Output raster" to save to your local workspace, and make sure to add the date of the scene and crop type of the zonal statistics in the output name. Specify the "Statistics Type (optional)" as "Mean" from the dropdown menu.

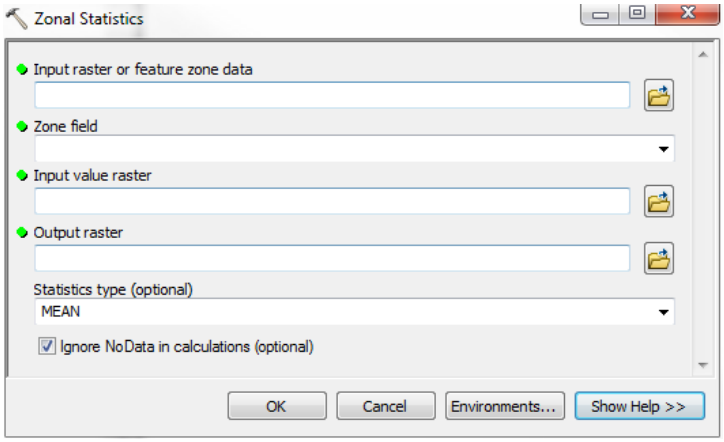


Figure 209. Zonal Statistics Icon

16.1.8. The Zonal Statistics raster that is created shows the average NDVI value for each crop parcel within the selected frame. Based on this mean NDVI value for each parcel, irrigated and non-irrigated crops become apparent.

16.1.9. Add the Zonal Statistics raster into the ArcMap document using the "Add Data" icon and make sure the Zonal Statistics raster is checked on.

16.1.10. Compare the mean NDVI values from the zonal statistics to the shapefiles of known/potential irrigation shapefiles (certified acres, center pivots, etc.). The irrigated crops will have higher NDVI values than the non-irrigated crops. The mean NDVI value of the parcel can be determined using the "Identify" tool in ArcMap and clicking on the parcel.

Figure 210. Identify Icon

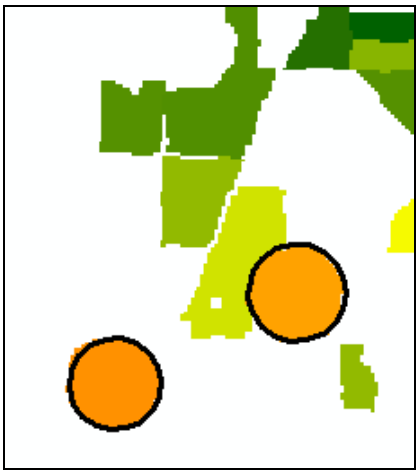


Figure 211. Example of zonal statistics of corn parcels for an NDVI scene.

16.1.11. In Figure 174, orange represents higher mean NDVI values, while green and yellows represent lower mean NDVI values. Notice the 'orange' corn parcels exhibit higher NDVI values than the surrounding 'green' corn crops. The black circles represent known center pivots (irrigation).

16.1.12. Based on the difference of the NDVI values, a threshold value can be determined in order to separate the irrigated crops from the non-irrigated crops. Record the determined threshold value in a tracking spreadsheet in order to keep track of thresholds for each selected Landsat scene and crop type. For example, it may be determined that all apparent irrigated corn crops of the scene show a mean NDVI value of greater than .75, while apparent non-irrigated corn crops show NDVI values below .75. Based on this example, a good threshold for irrigated corn for the scene may be .75.

- While using the Identify tool to compare different NDVI values of the scene, certain trends will become apparent. For example, you may notice that most crops that have center pivots have NDVI values above certain values, and that crops that do not have center pivots have values below certain values.
- Within ArcMap, you can right-click the scene and click on "Properties" → "Symbology". From here you can classify the raster to reflect different colors for different values that you notice. Refer to the figure below for an example.

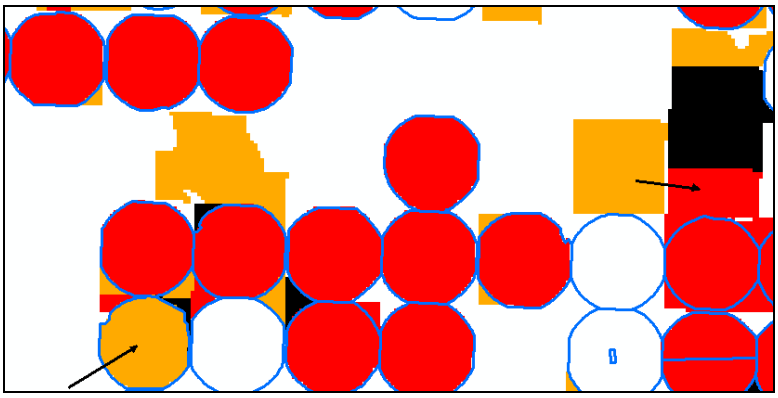


Figure 212. Example of a zonal statistics raster of corn parcels, with center pivots repressing the blue circles.

16.1.13. In Figure 175, the symbology has been changed to show parcels that have mean NDVI values greater than .7 to be red, parcels that have mean NDVI values between .6 and .7 to be orange, and parcels that have mean NDVI values less than .6 to be black. Since center pivots are a good indicator of irrigation, the corn parcels that are not associated with the center pivots are likely non-irrigated. This particular symbology was chosen since it became apparent that the majority of corn parcels that had center pivots had NDVI values greater than .7 and that corn parcels that are not associated with center pivots had NDVI values less than .7 and thus a threshold value of .7 was determined for this example.

- Notice that this method is not perfect. For example, if you look at the parcel that the black arrow in the bottom left of the figure is pointing to, this parcel has a value less than .7 and is thus orange. Although this parcel is likely irrigated since it has a center pivot, the parcel's NDVI is less than the threshold and will be classified as non-irrigated. Conversely, if you notice the parcel that the arrow on the right hand of the figure is pointing to, this parcel has a value of higher than .7 and thus is red in color. Although this parcel is not associated with a center pivot, and is likely not irrigated, the NDVI value of the parcel is above the threshold, and will be classified as irrigated. Like mentioned previously, this method is not perfect, but overall, the threshold of .7 correctly identified the likely irrigated and non-irrigated corn parcels.

Note: Even the slightest adjustment in the threshold value can start to under/over-estimate the irrigated and non-irrigated crops. Refer to the figures below for examples.

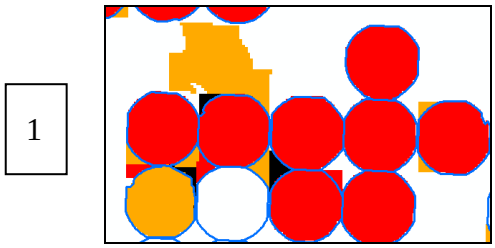


Figure 213. Example showing corn parcels with the best determined threshold of .7.

16.1.14. In Figure 176, notice this threshold correctly identifies corn parcels with center pivots as irrigated (red) while identifying corn parcels that do not have center pivots as non-irrigated (orange and black).

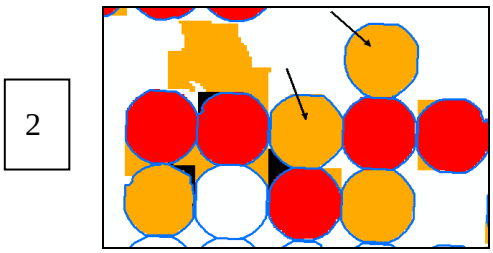


Figure 214. Example where the threshold was raised from .7 to .72.

16.1.15. In Figure 177, notice the arrows pointing out parcels that would now be classified as non-irrigated since they are below the new threshold, even though the parcels are likely irrigated and appear irrigated with the .7 threshold. This example shows how by just raising the threshold slightly, UNDER-ESTIMATION of crops occurs.

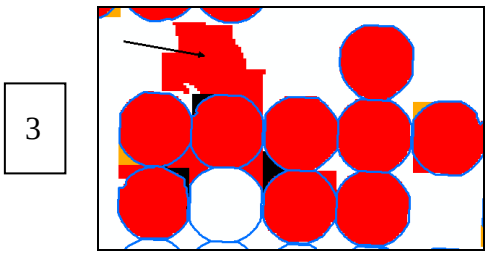


Figure 215. Example showing what would happen if the threshold was lowered from .7 to .68.

16.1.16. In Figure 178, notice the black arrow pointing out a corn parcel that would now be classified as irrigated with the lowered threshold even though the parcel is not associated with a center pivot and likely not irrigated. This example shows how by just lowering the threshold slightly, OVER-ESTIMATION of irrigation crops occurs.

16.1.17. Evaluate and record thresholds for each individual crop type and every selected NDVI scene.

Note: The example in the previous step used a center pivots shapefile to evaluate thresholds, but other shapefiles should also be used such as certified irrigation acres, flood irrigation, etc. to evaluate threshold values.

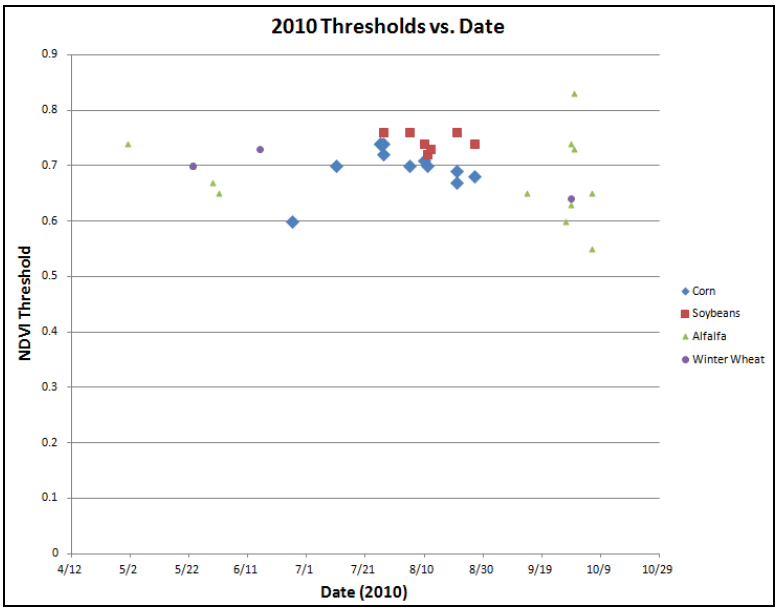


Figure 216. Graph showing NDVI thresholds vs. date for each crop type.

16.1.18. In Figure 179, notice the corn thresholds are highest around late July and soybean thresholds are highest between July and August. Alfalfa is harvested multiple times throughout the summer, so NDVI thresholds vary greatly.

16.1.19. After all thresholds are evaluated, the next step is to "Reclassify" each Zonal Statistics raster so that all pixel values beneath the threshold can be classified as 0 (non-irrigated), and that all pixel values above the threshold are classified as 1 (irrigated).

16.1.20. In the ArcMap document, click on the "Search" icon.

Figure 217. Search Icon

16.1.21. Search for and click on "Reclassify".

16.1.22. Use the Zonal Statistics raster as the "Input Raster", use "Value" as the "Reclass Field", set all "Old values" that are lower than the recorded threshold to a "New value" of 0, and all "Old values" that are higher than the threshold to

a "New value" of 1. Make sure to also set 'NoData' values to 0 as well. Set the "Output raster" to the local workspace with a naming convention such as '97_soy_reclass' showing that 97 is the Julian day of the year, that the crop is soy, and that the scene has been reclassified.

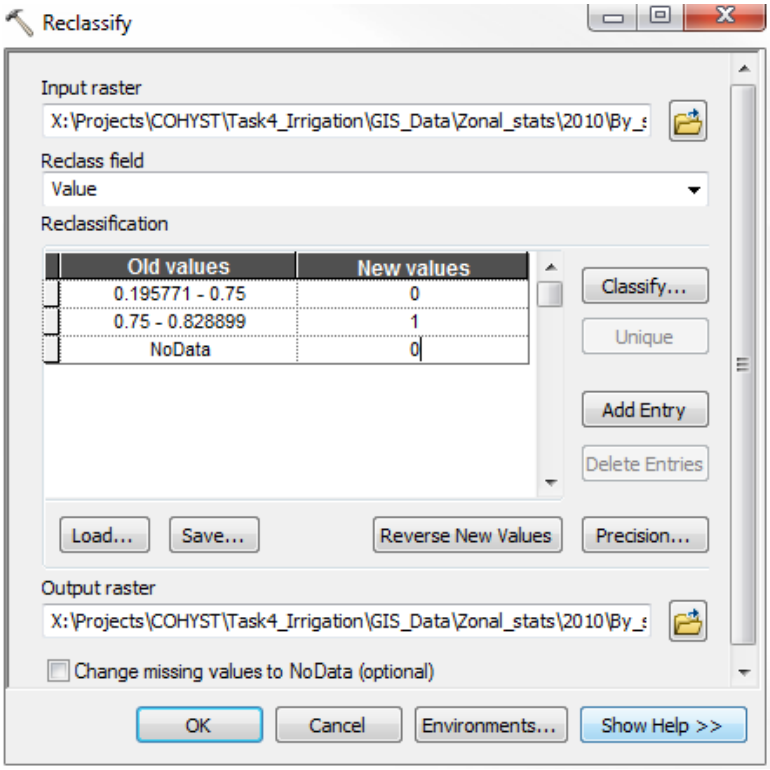


Figure 218. Reclassify tool. (Note that the example threshold is .75)

16.1.23. Reclassify all of the scenes that have had zonal statistics ran on them and thresholds determined. By reclassifying all of the rasters, there will now be individual rasters that are binary with non-irrigated pixels having values of 1 and non-irrigated pixels having values of 0.

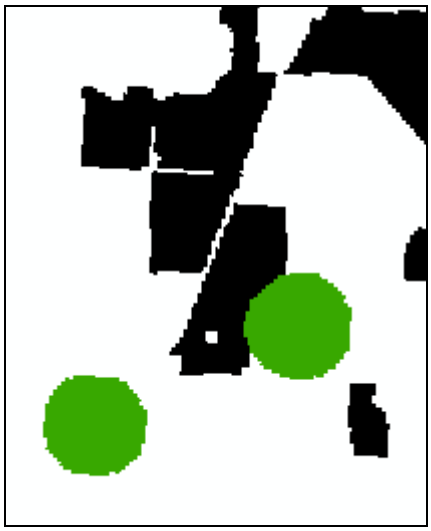


Figure 219. An example reclassified corn scene.

16.1.24. The 'green' represents corn pixels that have values above the threshold and have been reclassified to a value of 1 (irrigated) and the 'black' represents corn pixels that have values below the threshold and have been reclassified to a value of 0 (non-irrigated).

16.1.25. The next step is to add all of the reclassified scenes of each individual crop type together by means of the "Plus" tool. In the ArcMap document, click on the "Search" icon.

Figure 220. Search Icon

16.1.26. Search for and click on "Plus".

> ***Note:*** The "Plus" tool only allows for the addition of two rasters at a time, so this process may have to be repeated, depending on how many reclassified rasters of each crop type there are. Refer to section 2.0 for instructions on how to use ArcGIS Model Builder to more easily add multiple rasters.

16.1.27. For the "Input raster or constant value 1" use one of the reclassified rasters (e.g., '29031_195_soy_reclass.img), and for the "Input raster or constant value 2" use a different reclassified raster (e.g., '29031_212_soy_reclass.img'). Set the output raster to your local workspace with a naming convention such as '29031_195_plus_212_soy.img'.

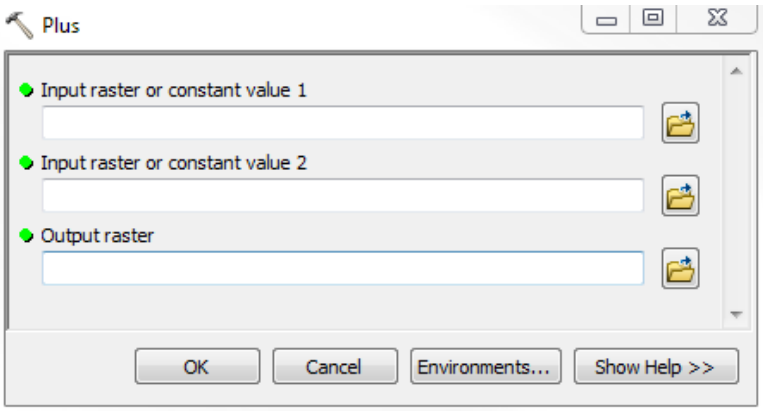


Figure 221. Plus Icon

16.1.28. Repeat the previous step (1.19) until all of the reclassified rasters of each crop type have been added together for the frame. Once all of the reclassified rasters have been added together, there will be a raster of all of the corn, a separate raster for all of the soybeans, etc. for all of the crop types within the frame.

Note: If there are many scenes that need to be added together, ArcGIS Model Builder can be used to make the process more efficient. An example of a sample model for adding reclassified rasters can be found in section 2.

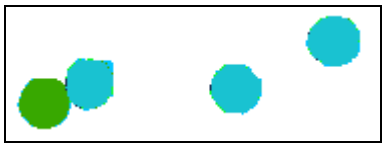


Figure 222. Example of a portion the result raster of the Plus operation on 4 reclassified corn rasters.

16.1.29. The 'green' represents corn pixels that have been classified as irrigated in 3 of the 4 reclassified rasters and the 'blue' represents corn pixels that have been classified as irrigated in all 4 reclassified rasters.

16.1.30. After all of the rasters for the frame have been added together using the plus tool, the next step is to reclassify the final added raster for the specific crop type (e.g., soybeans). This reclassification is needed since the final plus raster will have values of 0,1,2,3,4,5…. depending on how many rasters were added. In the ArcMap document, click on the "Search" icon.

Search for and click on "Reclassify".

16.1.31. Use the final Plus raster as the "Input Raster", use "Value" as the "Reclass Field", leave the "Old values" just as they are, and set the "New values" that are greater than '0' to a value of '1'. Set the "Output raster" to your local workspace with a naming convention such as '29031_soybeans_reclass.img'. Old values of '1' mean that the crop was classified as irrigated in 1 scene, old values of 2

mean that the crop was classified as irrigated in 2 scenes, and so on. Doing this reclassification will create a binary raster of all irrigated crop types having values of 1 and all non-irrigated crops having a value of 0.

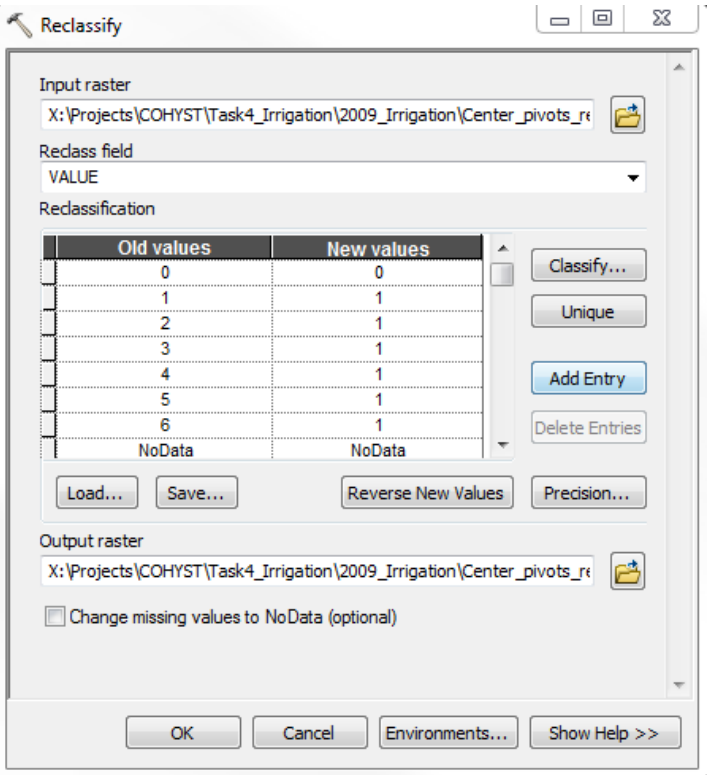


Figure 223. Reclassify Icon. Note that all "New Values" greater than 0 are given a value of 1.

16.1.32. Repeat the previous step (14.1.31) for all crops that need irrigation classification (corn, alfalfa, soybeans, etc.) for the frame.

16.1.33. There will now be rasters for each crop type with each raster showing irrigated crops as a value of 1 and non-irrigated crops as a value of 0 for each frame.

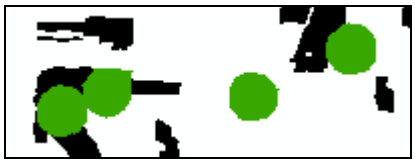


Figure 224. An example of a section of a final reclassified raster of all of the added corn rasters.

16.1.34. The 'green' represents corn pixels that have been reclassified to a value of 1 (irrigated) and the 'black' represents corn pixels that have been reclassified to a value of 0 (non-irrigated).

16.1.35. The next step will be to add all of the reclassified crop rasters of the frame together to get a raster for each scene that has all of the corn, soybeans, alfalfa, etc. added together into one composite raster. Use the 'Plus' tool to add the crop types of the frame together. For example, use the final 29031 corn raster as the input raster 1 and final 29031 soybeans raster as the input value 2. Do this for all crops of 29031 until all of the crops have been added together for the frame. You should now have a final irrigation raster for all of the irrigated crops for the frame. Do this for all of the frames in the study area.

16.1.36. The next step is to add all of the irrigated rasters from each frame together to get one main irrigation raster for the entire study area. Using the 'Plus' tool, add two of the frames together. This is necessary since only two rasters can be added at once. Keep adding frame rasters two at a time until all of the frame rasters have been added together.

16.1.37. There should now be a raster that is the irrigated raster for all of the scenes. This needs to be reclassified since there is overlap between scenes that have been added together. All of the values greater than '0' can all be reclassified back to '1' to get a final reclassified raster of all irrigated crops having values of '1' and all non-irrigated crops having a value of ' 0'. Use the 'Reclassify' tool and use the irrigated raster created in the previous step as the 'Input raster' and use the 'Value' field as the 'Reclass field. Set all of the 'Old values' that are greater than 0 to have 'New values' of 1. Set the output raster to your workspace, with a naming convention such as '2010_irrigation.img'.

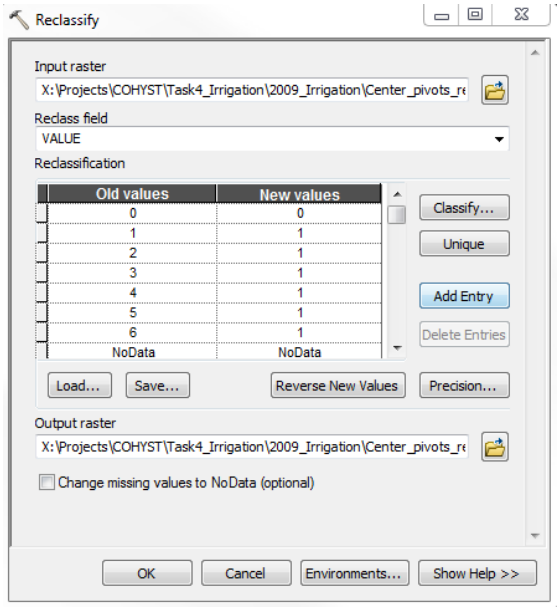


Figure 225. Reclassify Icon. Note that all "New Values" greater than 0 are given a value of 1.

16.1.38. The next step will be to Join the values of the reclassified raster back to the ag-parcel shapefile. In ArcMap, click on the "***Search***" icon located near the top of the screen.

Figure 226. Search Icon

16.1.39. Search for and click on "Zonal Statistics as Table".

16.1.40. Use the ag-parcel shapefile as the "Input raster or feature zone data", the parcel ID as the "Zone Field", the final irrigated crop raster as the "Input value raster". Specify the "Output table" to your local workspace..

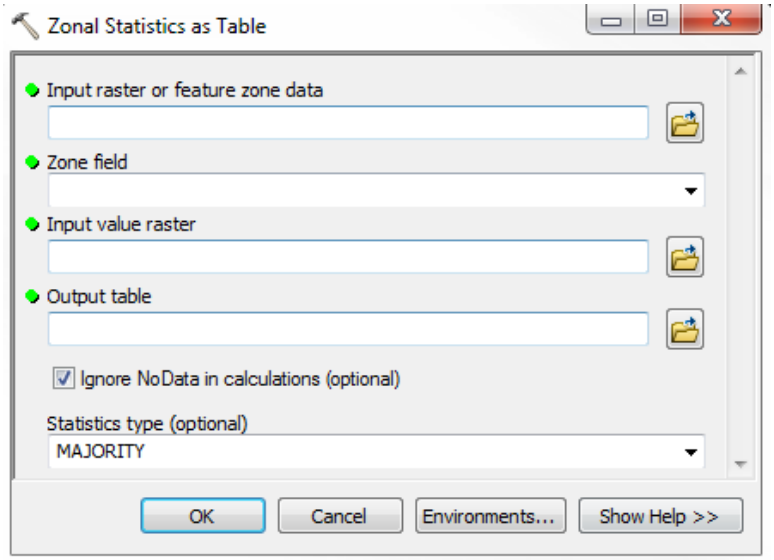


Figure 227. Zonal Statistics as Table Icon

16.1.41. Add the newly created zonal statistics table and the ag-parcel shapefile to the ArcMap document using the "Add data" icon to navigate to the location of the table and the crop type shapefile.

Figure 228. Add Data Icon

16.1.42. Under the Table of Contents in the ArcMap document. Right-click on the ag-parcel shapefile, select "Joins and Relates" → "Join".

16.1.43. Under "1." select the parcel ID (e.g., FID) as the field that the join will be based on.

16.1.44. Under "2." select the newly created zonal statistics table from the drop down menu.

16.1.45. Under "3." Select the feature ID (FID) as the field in the table to base the join on.

16.1.46. Select "Keep only matching records" and select "OK".

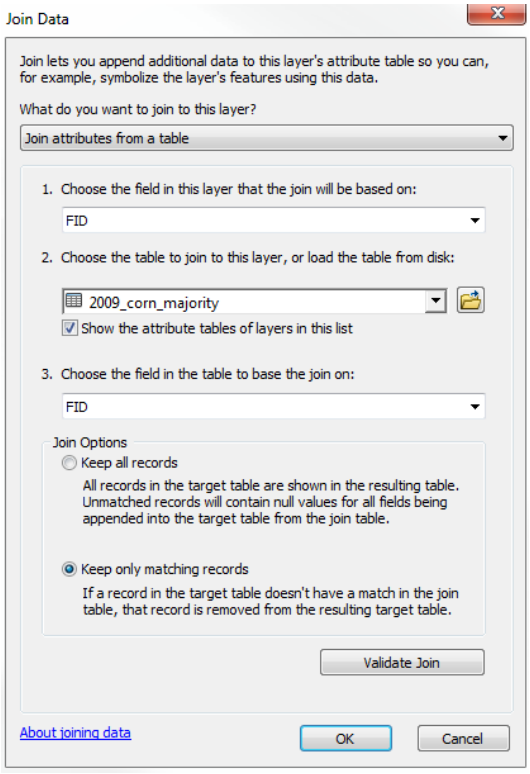


Figure 229. Join data dialog

16.1.47. There will now be an attribute within the ag-parcel shapefile with a field named 'Majority' that has values of '1' for irrigated crops and '0' for non-irrigated crops.

Note: This Join does not make the new Majority field permanent. To permanently keep the Majority field within the crop type shapefile:

- Right click the crop type shapefile that has the Join.
- Select "Data"→ "Export Data"
- Under "Export:" select "All features" from the drop down menu.
- Under "Use the same coordinate system as:" select the radio button "this layer's source data".
- Set the "Output feature class" to your local workspace with a name showing that the irrigation Majority attribute has been added. An

example of a name of the output feature class would be '2010_irrigation_majoirty'. Repeat these steps for all other crop types that need irrigation status determined.

16.1.48. The ag-parcel shapefile now has a field showing whether or not that certain crop parcel is irrigated or not. If the parcel is irrigated, there will be a value of 1 under the Majority field. Alternatively, if the parcel is non-irrigated, there will be a value of 0 under the Majority field.

Rowid	FID	COUNT	AREA	MAJORITY
1	0	550	495000	1
2	1	478	430200	1
3	2	629	566100	1
4	3	1264	113760	1
5	4	1121	100890	1
6	5	1892	170280	1
7	6	234	210600	1
8	7	137	123300	0
9	8	145	130500	1

Figure 230. Example attribute table of irrigated and non-irrigated parcels.

16.1.49. Notice the 'FID' is the individual parcel, and the field 'MAJORITY' is the irrigation status with the number '1' representing irrigated parcels and the number '0' representing non-irrigated parcels.

15. Verifying irrigation status using certified acres, wells, and center pivots.

Using just the NDVI method to evaluate thresholds tends to both over-estimate and under-estimate actual irrigation status. After the original irrigation status has been evaluated, verification steps are needed to help eliminate some of the over and under-estimation. This can be done by using known certified acres, well data, and center pivot data.

15.1 Within ArcMap, bring in the yearly parcel layer that has the irrigation status assigned. Also bring the shapefiles for certified acres, wells and yearly pivots.

15.2 Open the attribute table of the original parcel layer. Add a new field to the shapefile and name the new field 'Irrig_Ver'. Right click on this new field and select 'Field Calculator…' Calculate the field to be whatever the original irrigation field is that has the values of the original irrigation status (this field should have 1's and 0's to represent irrigated and non-irrigated parcels based on NDVI thresholds). The new 'Irrig_Ver' field will be where the editing will be done to verify/change irrigation status.

15.3 Use the selection tool on the top of the screen and click on 'Select By Location'. Use the parcel layer as the 'Target layer' and the Certified Acres shapefile as the 'Source layer'. For the 'Spatial selection method' click on 'have their centroid in the source layer feature'. Click on OK. This will select all of the parcels that have their center within the certified acres.

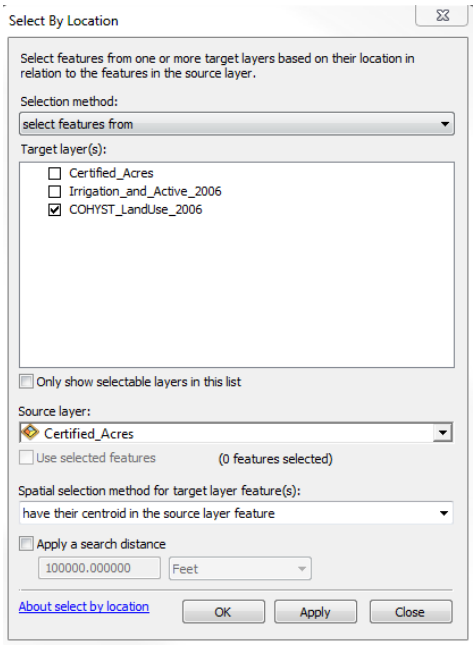


Figure 231. Showing how to select parcels that intersect certified acres.

15.4 In ArcMap, right click on the parcel layer, click on 'Selection' and then click on 'Create Layer From Selected ***Features'***. This will create a new layer within ArcMap that is all of the parcels that intersect certified acres. Rename this layer to have a naming convention that shows that the layer is certified parcels. An example name would be 'COHYST_Landuse_2006_Certified'.

15.5 Now that there is a layer of all of the parcels that are certified for irrigation, you need to create a layer of the parcels that are not certified for irrigation (do not intersect center pivots). To do this, right click on the original parcel layer, and select 'Open attribute Table'. Within the attribute table, select the 'Switch Selection' icon from the toolbar at the top of the attribute table. This will now switch the selection from parcels that intersect certified acres to parcels that do not intersect certified acres.

Figure 232. Switch Selection Icon

15.6 In ArcMap, right click on the parcel layer, click on 'Selection' and then click on 'Create Layer From Selected Features'. This will create a new layer within ArcMap that is all of the parcels that do not intersect certified acres. Rename this layer to have a naming convention that shows that the layer is not certified parcels. An example name would be 'COHYST_Landuse_2006_NonCertified'.

15.7 Next, do a 'Select By Location' between the CERTIFIED parcel layer, and the well layer for the year. Use 'intersect' as the spatial selection method. This will select all of the certified parcels that intersect wells.

15.8 Start an edit session and chose this certified parcel layer to be the shapefile to be edited.

15.9 Select all of the parcels that intersect wells and have been classified as non-irrigated (0) based on NDVI thresholds. Since these parcels were originally classified as non-irrigated, have a well on them, and are certified, the irrigation status needs to be changed from non-irrigated (0) to irrigated (1). Use the 'Irrig_Ver' field to make these changes.

15.10 Next, do a 'Select By Location' between the NON-CERTIFIED parcel layer, and the well layer for the year. Use 'intersect' as the spatial selection method. This will select all of the certified parcels that DO intersect wells. Create a new layer from the selected features. This will create a new layer within ArcMap that is all of the non-certified parcels that intersect wells.

15.11 Within the NON-CERTIFIED parcel layer attribute table, switch the selection. This selection will now be all of the non-certified parcels that DO NOT intersect wells.

15.12 Open the attribute table of the non-certified parcels that intersect wells. Click on 'Select By Attributes' and select all of the parcels that have center pivots. With this selection, if the original irrigation status was classified as non-irrigated (0), change these parcels to irrigated (1) within the 'Irrig_Verif' field. Even though these parcels aren't certified, they do have center pivots and to intersect wells, and are therefore likely irrigated.

15.13 Open the attribute table of the non-certified parcels that DO NOT intersect wells. Click on 'Select By Attributes' and select all of the parcels that DO NOT have center pivots. With this selection, if the original irrigation status was classified as irrigated (1), change these parcels to non-irrigated (0) within the 'Irrig_Verif' field. These parcels are not certified, do not have center pivots, and do not have a well on them. Because of this, these parcels are likely not irrigated.

15.14 Create a selction on parcels that do not interest wells. Create a new layer from the selected features. Select parcels from this layer that interstect the pivots layer. Change the irrigation status from non-irirgated (0) to irrigated (1).

15.15 If the parcel is classified as fallow, change the irrigation status to non-irrigated.

15.16 The 'Irrig_Verif' field will now have the verified irrigation status of the parcels based on verifying the parcels with certified acres, wells, and center pivots.

Instructions to use ArcGIS Model Builder to process multiple rasters

16.1.50. ArcGIS Model builder can be used to process multiple rasters in one 'area'. Model Builder can be used to perform zonal statistics on more than one raster, reclassify multiple rasters, and to add (Plus) multiple rasters. *Below is an example of how to use Model Builder to add (Plus) 2 different reclassified corn rasters.*

ArcCatalog Model Builder

16.1.51. Open ArcCatalog. Select the "Model Builder" icon from the top of the ArcCatalog toolbar.

Figure 233. Model Builder icon

16.1.52. From the 'Catalog Tree' in ArcCatalog, drag all of the reclassified crop rasters from the 'Catalog Tree' into the model. Only bring in rasters from crop types of a single frame at a time. For example, use different models for each of the different frames.

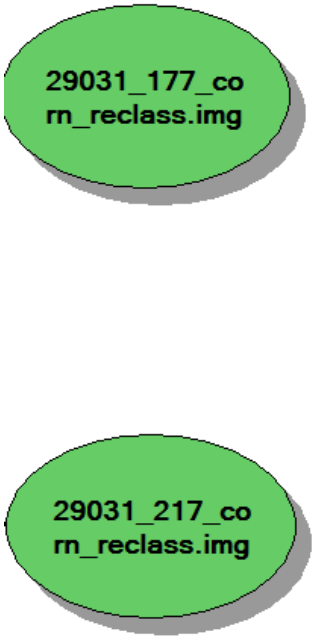


Figure 234. 2 reclassified corn rasters after being dragged into Model Builder

In ArcCatalog, click on the "Search" icon near the top of the screen.

Figure 235. Search Icon

16.1.53. Search for "Plus". Drag the "Plus" into the model. Since the Plus tool can only add two rasters at a time, you may need to drag in a Plus tool for every two rasters that are in the model if you are need to add more than two rasters. For this specific example, there are 2 reclassified corn rasters, thus only one Plus tool is required in order to add the two corn rasters.

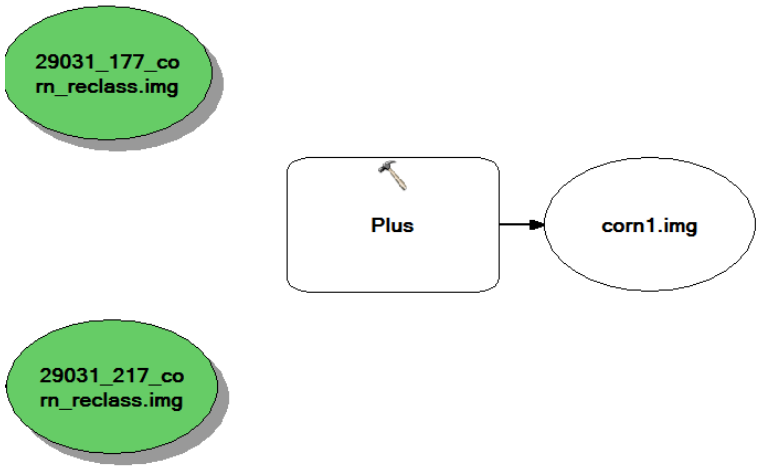


Figure 236. Model after dragging in the Plus tool.

Click on the "Connect" icon within the model.

Figure 237. Connect icon

16.1.54. After clicking on the "Connect" icon, a wand will appear that will allow you to connect the rasters to the Plus tool.

16.1.55. Use the wand to connect the rasters to the Plus tool. Once you connect one of the rasters to the Plus tool, a prompt will come up asking whether you want the raster to be "input raster or constant value 1" or "input raster or constant value 2". It doesn't matter which raster is input 1 or 2 just as one raster is input 1 and the other raster input 2.

16.1.56. Connect all of the input rasters into the Plus tools.

16.1.57. Double-click on the "Plus" tool to set the "Output raster" to the local workspace with a naming convention such as '29031_corn' showing that the tool is adding together the two corn rasters from frame 29031.

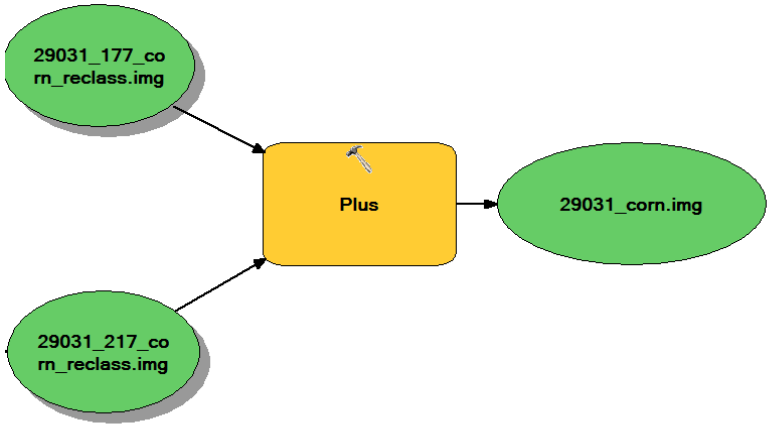


Figure 238. Example model after connecting the input rasters to the Plus tools.

16.1.58. Repeat these steps for each crop type within the frame to get rasters of all added crop types within the frame.

16.1.59. You will now have a raster for each crop type that shows irrigated crops for the scene. The raster will have values such as 0,1,2,3,… with 0 being non irrigated, 1 being irrigated in one scene, 2 being irrigated in two scenes, and so on. You now need to reclassify each crop type raster to set all values greater than 0 as irrigated (va1ues of 1). Drag in the 'Reclassify' tool into model builder and connect the added crop type raster into the tool (i.e. 32031_corn.img).

16.1.60. Double click on the tool to bring up the 'Reclassify' dialogue. Set the 'Reclass field' to be 'value' and make sure to change all of the old values that are greater than 0 to have new values of 1. Set the output to be your workspace and give the raster a name convention to show that the raster has been reclassified.

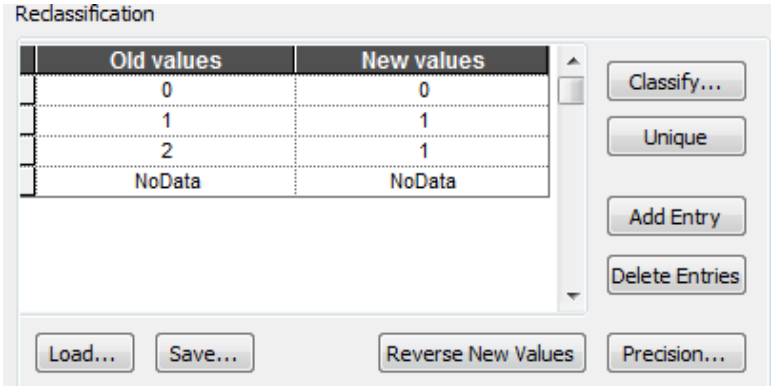


Figure 239. showing reclassification of a corn raster

16.1.61. Now, use the 'Plus' tool again to add all of the reclassified crop rasters together. For example, use the 'Plus' tool to add the reclassified corn, soybeans, Winter Wheat, alfalfa, etc. to get one main irrigation raster of all of the irrigated crops in the scene. Since you can only add two crops at a time, multiple 'Plus' tools may be needed depending on how many crops you are trying to add. The final output should be all of the reclassified crops added together for the scene. Give the final 'Plus' and output that shows that the output raster is all of the frame's crops added together (i.e. 32031_ALL_CROPS.img)

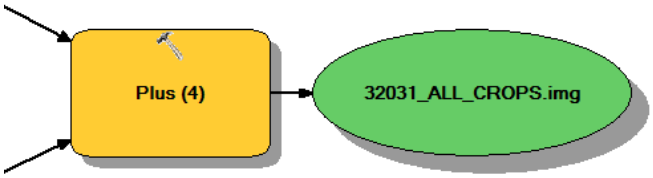


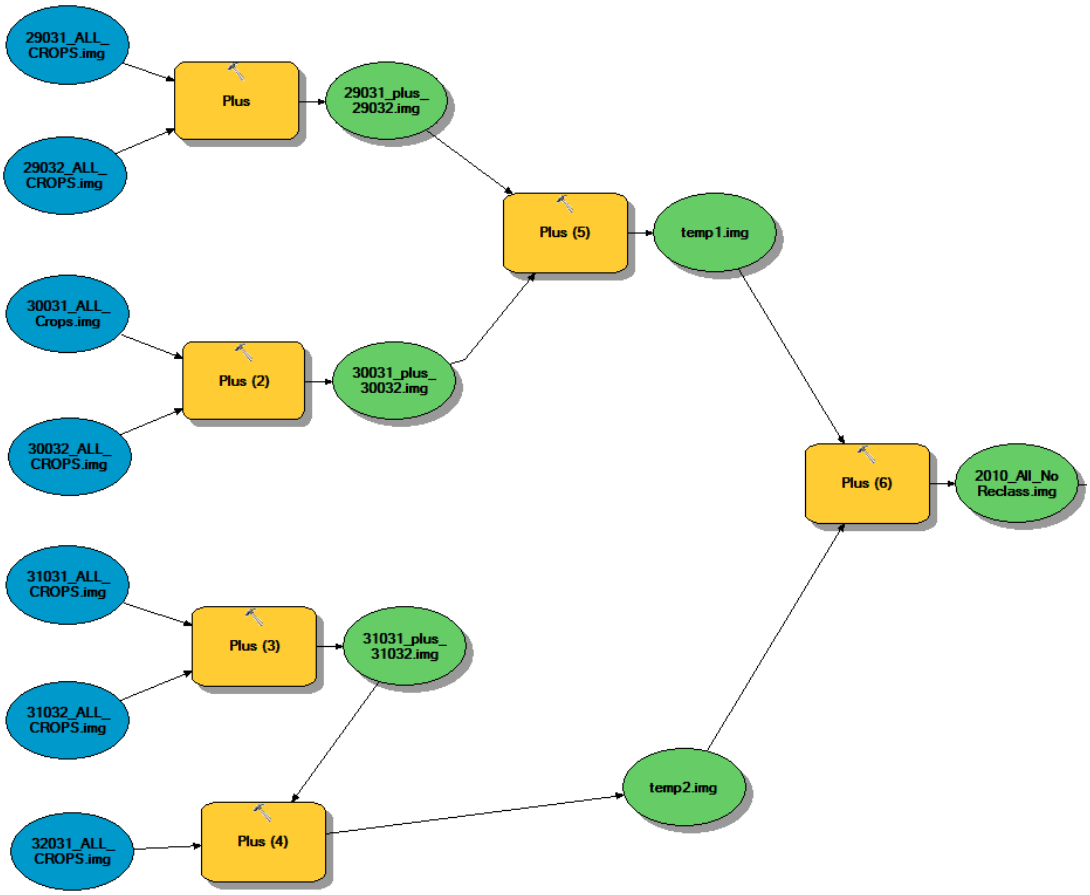
Figure 240. showing the final 'Plus' raster for the frame 32031

16.1.62. Repeat for all of the frames in the study area to get a final raster for EACH frame that has all of the irrigated crop types added together.

16.1.63. The next step is to add all of the frame's irrigated crops together. Drag into the model the final crop rasters that were created in step 14.6.8 for every frame (29031_ALL_CROPS.img, 29032_ALL_CROPS.img, etc.)

16.1.64. Drag into the model the 'Plus' tool which will be needed to add together the individual frame rasters into one final master irrigation raster. Multiple 'Plus' tools will be needed depending on how many scenes you are adding together.

For example, you may need to add '29031+29032' to '30031+30032' to '31031+31032' to '32031'; In this case, six 'Plus' tools will be needed to add all of the frames together to get a master unclassified raster of all of the irrigation. Because of overlap between frames, this raster will need to be reclassified to show all values greater than 0 to be irrigated (values of 1). Give this output raster a naming convention that shows that the raster still needs to be reclassified.



16.1.65.

Figure 241. showing a model that adds irrigation rasters from each frame (blue) to get a final, unclassified irrigation raster

16.1.66. In ArcCatalog, click on the "Search" icon.

Figure 242. Search Icon

16.1.67. Search for "Reclassify".

16.1.68. Drag the "Reclassify" tool into the model.

16.1.69. Connect the final added raster from the final Plus operation created in step 14.6.11 into the "Reclassify" tool.

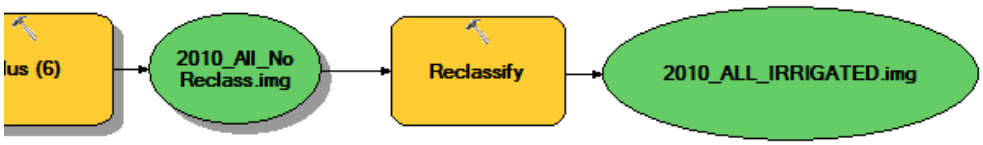


Figure 243. Example model showing the addition of the Reclassify tool

16.1.70. Double-click on "Reclassify".

16.1.71. Use the final Plus raster as the "Input Raster", use "Value" as the "Reclass Field", leave the "Old values" just as they are, and set the "New values" that are greater than '0' to a value of '1'. Set the "Output raster" to your local workspace with a naming convention such as '2010_ALL_IRRIGATED.img'. Old values of '1' mean that the crop was classified as irrigated in 1 frame, old values of 2 mean that the crop was classified as irrigated in 2 frames, and so on. Doing this reclassification will create a binary raster of all irrigated crop types having values of 1 and all non-irrigated crops having a value of 0.

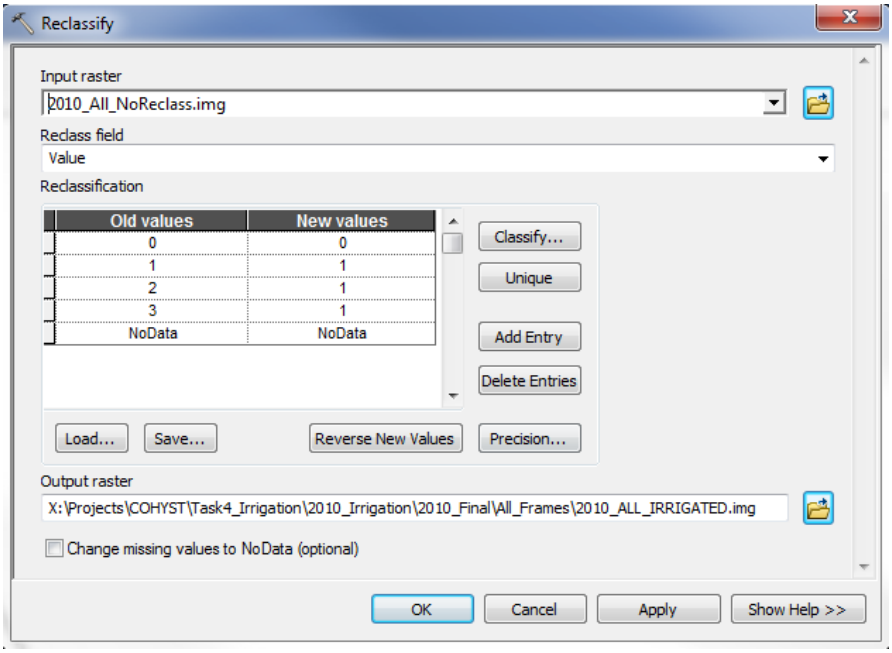


Figure 244. Reclassify tool within model to get the final irrigated raster

16.1.72. Click on the "Validate Entire Model" icon located on the toolbar at the top of the model.

Figure 245. Validate Entire Model icon

16.1.73. Click on "Model" → "Run Entire Model". This will run all of the process within the model, including all of the Plus processes and the Reclassify process.

16.1.74. The final raster created from the Reclassify process will be a binary raster containing irrigated crops with values of 1 and non-irrigated crops with values of 0 for the entire study area.

REFERENCES AND APPENDICES

MANUAL REFERENCES

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APPENDIX. A

Tools and scripts described within the ***COHSYT 2010 Land Use Classification Manual*** are provided to project sponsors by special request. Please send inquires to the following:

RIVERSIDE
global science solutions

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