COVER CROP IDENTIFICATION TOOL HANDBOOK

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COVER CROP MAPPING PROJECT HANDBOOK

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1. INTRODUCTION AND BACKGROUND

Iowa's water quality has been an issue of concern for many years. Over the past 150 years, Iowa's landscape transformed from prairies, wetlands, and forests towards the production of food and industrialization of agriculture. The current cropping system has trended towards planting and growing food from spring through fall and then resting the soil throughout the winter months. Conventionally in Iowa, this has meant leaving the soil with some plant stubble or bare ground throughout the winter; this can lead to soil and nutrient loss through wind and water erosion.

Over the past decade, planting an additional crop during the winter months, called a cover crop, has been advocated as a way to promote soil health and reduce soil loss. The goal is that the cover crop be planted toward the end of the growing season or soon after the harvest to establish biomass and roots before winter temperatures and snow limit growth. The roots hold the soil providing greater protection from wind and water erosion compared to bare, exposed soil. The planting of cover crops is an important strategy to protect Iowa soils and waterways. According to the Natural Resource Conservation Service (NRCS), "Cover crops have the potential to provide multiple benefits in a cropping system. They prevent erosion, improve soil's physical and biological properties, supply nutrients, suppress weeds, improve the availability of soil water, and break pest cycles along with various other benefits."

The Cover Crop Identification Tool (CC ID Tool) provides for the need of IowaView partners and other entities looking for current information about presence of cover crops in Iowa. The CC ID Tool is an important tool for Iowa because it quickly allows land managers to determine the effectiveness of cover crop efforts over a season

This tool provides a rapid assessment for watershed coordinators to determine the effectiveness of cover crop plantings as the cover crop season ends, usually in late spring. The CC ID Tool addresses an underlying need for conservation managers and practitioners to understand which conservation efforts are effective on the landscape, track and manage those efforts over time, and plan/prioritize future conservation efforts. This dataset provides insights on areas of the state that have adopted cover crops or other similar soil holding practices as well as areas of potential opportunity for further outreach and incentives.

2. COVER CROP IDENTIFICATION TOOL

INTRODUCTION AND GOALS

During the months after harvest, we observed that in many areas of Iowa, fields are bare in areas not specifically planted to cover crop or covered in permanent vegetation, such as forest or grass. The CC ID Tool uses satellite imagery to capture a snapshot of fields in the fall, early spring, and later spring to document areas of growth and change on the landscape.

The Normalized Difference Vegetation Index (NDVI) is a formula that uses the near-infrared satellite imagery band (which vegetation strongly reflects) and the red light band (which vegetation absorbs) to quantify the vegetation on the landscape by calculating a value ranging from -1 to 1. The high values indicate dense canopy and greater vitality and plant health and low or negative values indicate water, bare earth, or urban areas. Using NDVI reveals areas of intentional growth by observing a pattern of greenness in individual images as well as from fall through spring.

The goals of this project are to create a publicly shareable process to determine the presence of cover crops over a season using public imagery and to produce a statewide map showing potential cover crops.

DISCUSSION OF TOOL

The tool operates in three consecutive steps. The first step produces an NDVI image for each of the three Sentinel 2 input images and creates a geodatabase for each scene. The second step examines each pixel of the NDVI images and assigns values indicating low, moderate, and high growth/greenness. The final step of the tool reclassifies the composite image into one of three categories: No Cover Crop, Potential Cover Crop, and Cover Crop. These raster values are then summarized by field boundary to give a generalized indication of cover crop potential in the region.

This section will provide an in-depth description of the three major processes that are occurring within the tool.

TOOL PREPARATION

Before the tool is run, the data and software need to be set up to properly perform the analysis. The tool requires ArcGIS Desktop or ArcGIS Pro licensed with the Spatial Analyst extension. Before the tool can be run, Spatial Analyst must be enabled.

To run properly, the data and scripts need to be in the following folder configuration. This configuration can be in any parent folder.

Folder	Contents
GIS Data	Contains the field and watershed boundary shapefiles or feature classes to be used by the tool
Imagery	Contains the zipped imagery files to be used by the tool
Scripts	Contains the tool python script and toolbox

STEP 1

For the first step of the tool, users input three zipped (please do not unzip them) Sentinel-2 images that they have selected and downloaded from the USGS Earth Explorer website (https://earthexplorer.usgs.gov/), along with a field boundaries layer, and watershed boundaries layer.

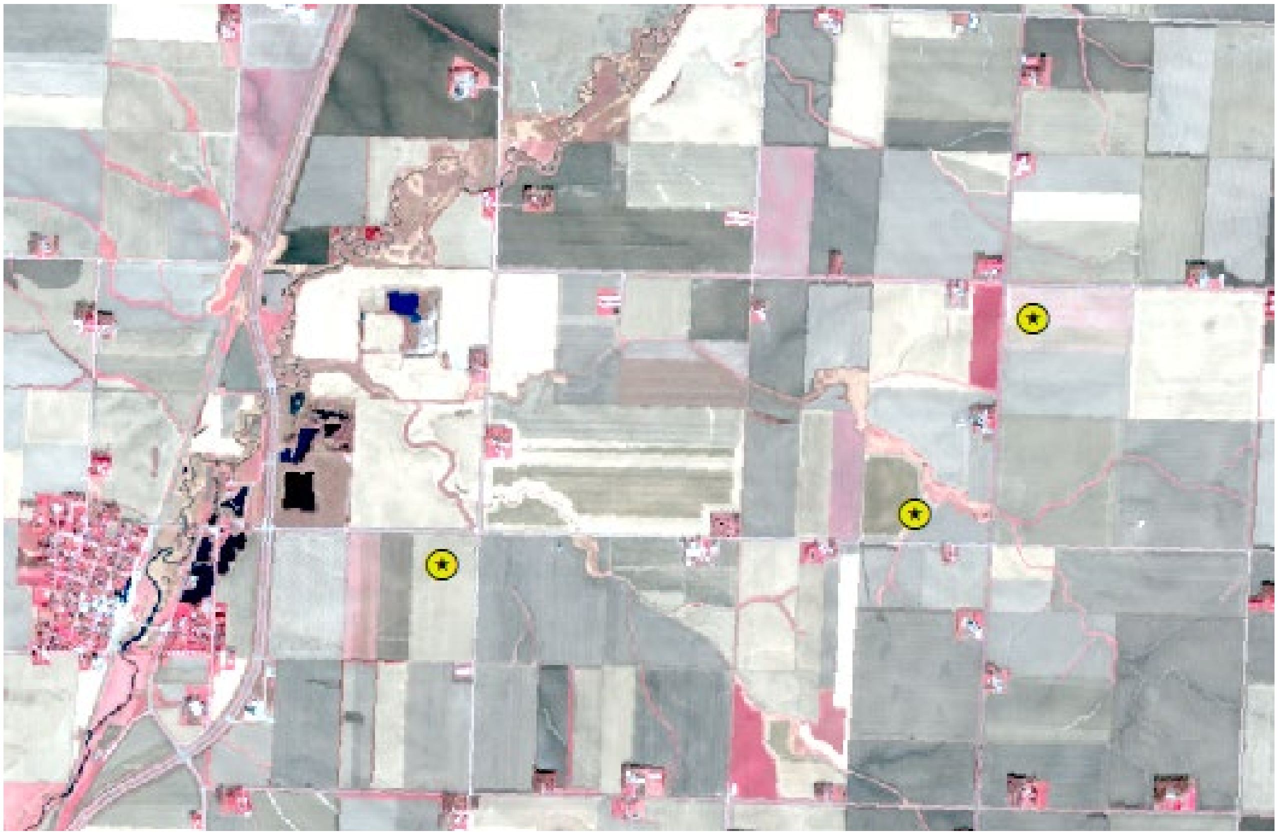
The first step of the tool unzips each of the images (A=fall image, B=early spring image, and C=late spring image) and projects them into UTM Zone 15N which is the projection we used for our project. Users can choose their own projection. Then the tool uses the footprint of the scene to clip the correct field boundaries and watersheds for the project. The tool includes all watersheds that are at least partially within the scene. Then the tool creates a geodatabase for each of the three supplied images. The imagery geodatabases each contain four Sentinel-2 bands, a Normalized Difference Vegetation Index raster for the image, a field boundaries layer that has zonal statistics for each field, and a zonal statistics table.

SENTINEL 2 BANDS

The four Sentinel-2 bands that are included are (band description, central wavelength): Band 2 (blue, 490nm), Band 3 (green, 560nm), Band 4 (red, 665nm), and Band 8 (visible and near infrared, 842nm), which are the high-resolution bands (10 m). These bands can be used to create a composite natural color image (Bands 4,3,2) or color infrared image (Bands 8,4,3) for further analysis.

NATURAL COLOR IMAGE

This is an example of Sentinel-2 natural color imagery created by combining Band 4, Band 3, and Band 2. This is most similar to what we see with our eyes. Areas of vegetation appear green and water is blue or black and bare soil appears brown, tan, and gray. The yellow circles with stars are areas of known cover crop. Notice how subtle these areas are in the natural color image. This image was captured on November 21, 2017, late fall. This time of year most fields will be bare, except those planted to permanent vegetation or cover crop.



COLOR INFRARED IMAGE

This is an example of color infrared imagery. Color infrared imagery is used in remote sensing to help distinguish actively growing vegetation. Growing vegetation shows up in the image as red and pink and bare soil is gray and tan. Color infrared is useful when examining areas of suspected cover crops because of the contrast of vegetation with soil. This is the same image that was displayed above in natural color. Notice how the fields with growing vegetation (red/pink) stand out against bare soil (gray/tan).

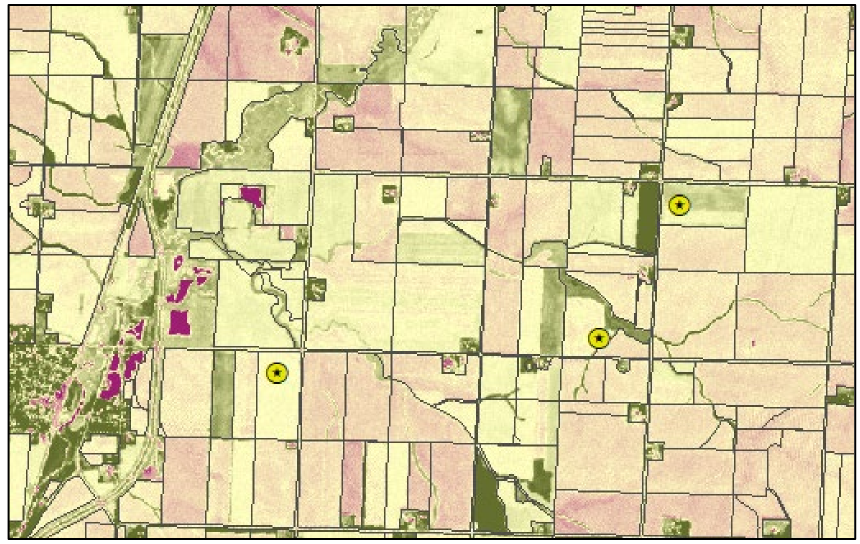
NORMALIZED DIFFERENCE VEGETATION INDEX IMAGES

Band 8 (visible and near infrared) and Band 4 (red) are needed to create the Normalized Difference Vegetation Index (NDVI): (B8-B4)/ (B8+B4). NDVI values show the greenness of vegetation on the landscape by producing a value ranging from -1 to 1, with higher values indicating greater vitality and plant health. https://gisgeography.com/sentinel-2-bands-combinations/

Compare the next three images and notice the changes in NDVI from fall to early spring to later spring. The color range in the images is a gradient of maroon to cream to bright green (-1 is maroon, 0 is cream, and 1 bright green.) The starred areas are the approximate location of documented cover crop fields.

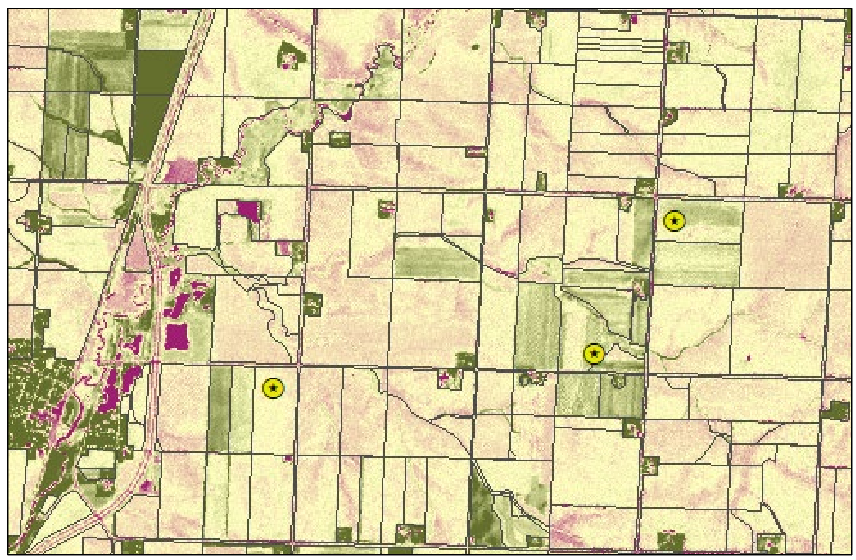
FALL NDVI IMAGE – 11/21/2017

In this late fall image, most fields are light maroon or cream, indicating non-vegetated fields. Areas of intense green indicate permanent vegetation such as a pasture or riparian area. Light green in crop fields are potential cover crop fields.



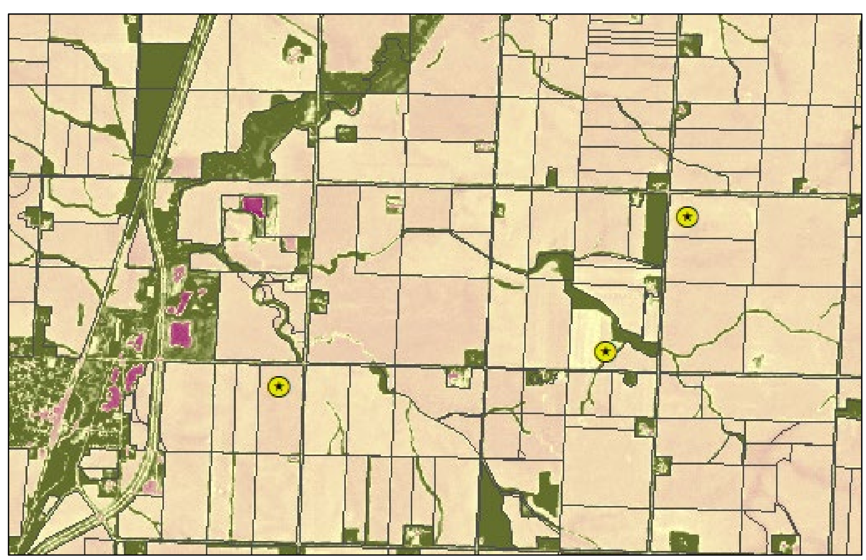
EARLY SPRING NDVI IMAGE – 04/25/2018

In this early spring image, most fields are still light maroon or cream, indicating non-vegetated fields. The areas of intense green indicate permanent vegetation. In this spring image, there are more areas of light green beginning to emerge. Notice the rectangular patterns of these areas. They appear to be planted intentionally, although not always planted in full fields.



LATE SPRING NDVI IMAGE – 05/25/2018

In this late spring image, many of the potential cover crop fields have vanished. The cover crops are culled to ready the fields for a new planting season. In comparing this image to the two previous images, there is much less of the cream and light green and more maroon or intense green. Areas of intense green indicate permanent vegetation such as a pasture, riparian area, permanent field practices such as grassed waterways, and vegetation along roadside ditches, farmsteads, and in town.



ZONAL STATISTICS TABLE AND FIELD BOUNDARIES LAYER

The Zonal statistics table allows the end user to examine the fields at each date to observe phenological changes of the individual fields as well as larger landscape analysis. The Zonal statistics table is joined with the field boundaries layer to allow end users to click on a field and find the statistics for each field.

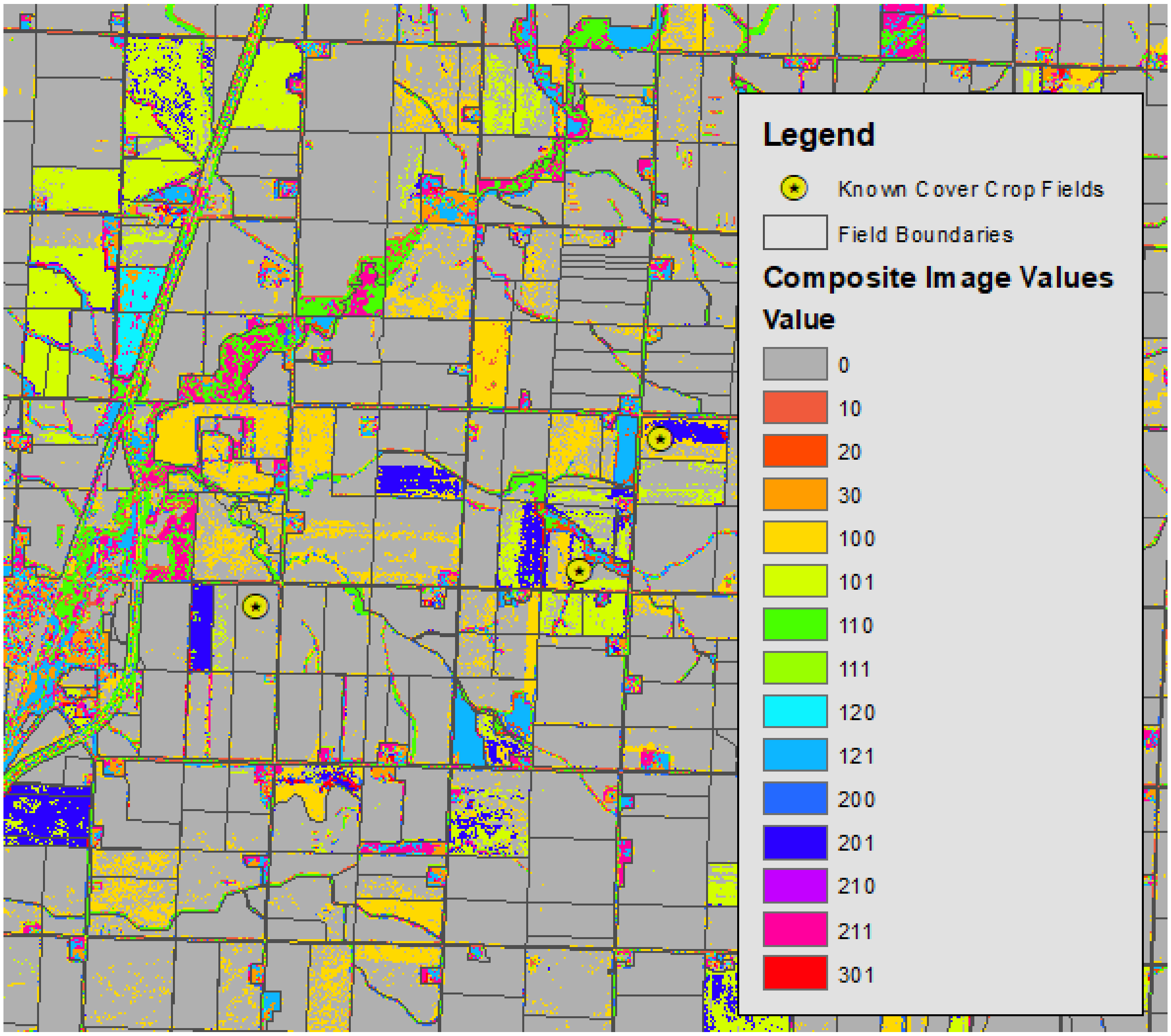
STEP 2

The second step of the tool determines if the scene is in the northern or southern region for determining reclassification values from the NDVI values produced in Step 1. Below are the thresholds for northern and southern reclassification values.

Northern Region Reclassification Values	Southern Region Reclassification Values
-1 - .16 – these values indicate low greenness which indicates a lack of vegetation	-1 - .25 – these values indicate low greenness which indicates a lack of vegetation
.17 - .35 – values in this range indicate moderate greenness which indicates there is likely something growing but not a dense canopy	.26 - .40 – values in this range indicate moderate greenness which indicates there is likely something growing but not a dense canopy
.36 – 1 – values indicate a high level of greenness – this indicates strong growth and a dense canopy. While this could be cover crop, these stronger values are often seen in permanent vegetation such as pasture or forested areas rather than cover crops.	.41 – 1 – values indicate a high level of greenness – this indicates strong growth and a dense canopy. While this could be cover crop, these stronger values are often seen in permanent vegetation such as pasture or forested areas rather than cover crops.

Next, the tool examines each pixel of the three NDVI images (A = fall image, B=early spring image, and C=late spring image) and assigns values indicating low greenness (0), moderate greenness (100 for fall and late spring, 101 for early spring), and high greenness (10). The greenness values were determined by examining several individual field plots around the state over a number of different growing seasons to determine patterns in the growth.

After values are determined for each NDVI image (A, B, and C), the three images are combined using the Raster Calculator tool to create a composite image (pixel values from image A + B + C = composite value). The values from each of the images combine to create a composite image with 15 possible values indicating likelihood of cover crop for each pixel.



RASTER CALCULATOR COMPOSITE IMAGE

Notice how many of the fields have a value of zero for all three images. This indicates that for all three dates the pixel did not meet the minimum threshold to indicate growth. Review the table below for a description of each value of the composite image.

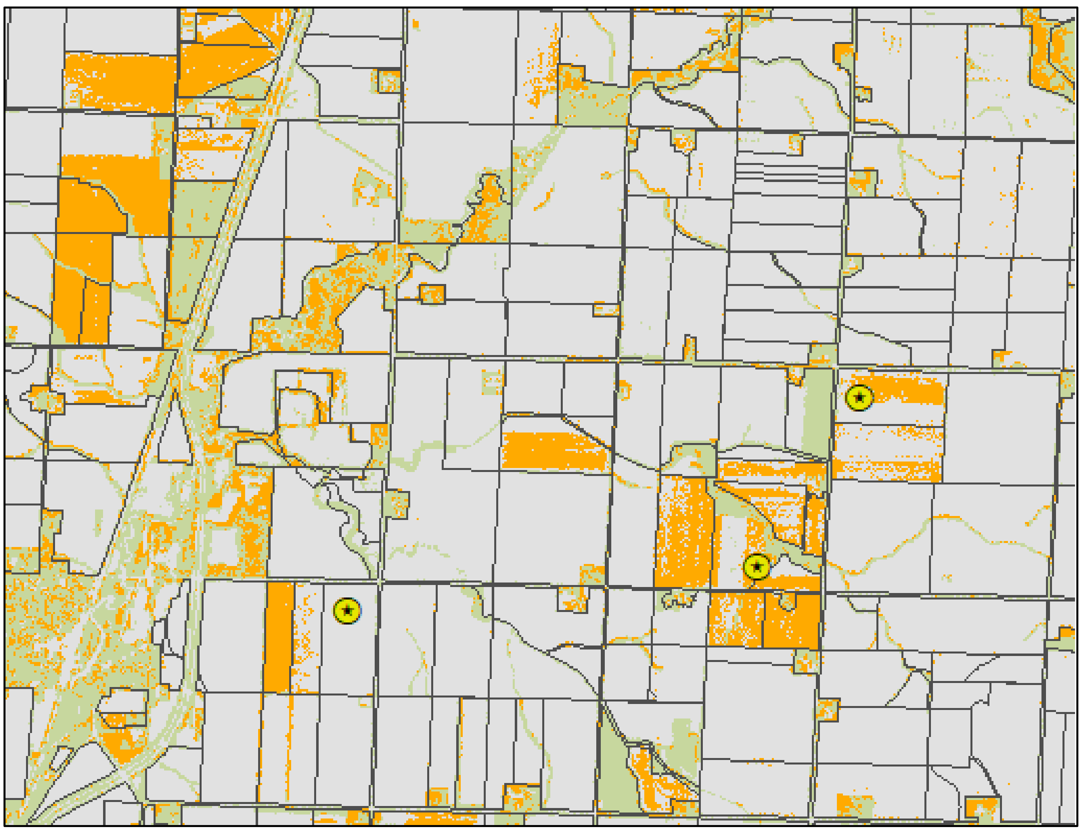
DESCRIPTION OF THE 15 VALUES OF THE COMPOSITE IMAGE

Code Number	Comments	Designation	Reclass Value
0	Nothing significant growing in any images	No Cover Crop	0
10	One image of high greenness	No Cover Crop	0
20	Two images of high greenness	Potential Cover Crop High Veg	3
30	Three images of high greenness	Potential Cover Crop High Veg	3

100	One image of moderate greenness but not early spring image	No Cover Crop	0
101	One image of moderate greenness in early spring	Cover Crop	2
110	One image of moderate greenness and one image of high greenness	Potential Cover Crop High Veg	3
111	One image of moderate greenness in early spring and one image of high greenness	Cover Crop	2
120	One image of moderate greenness and two images of high greenness	Potential Cover Crop High Veg	3
121	One image of moderate greenness in early spring and two images of high greenness	Potential Cover Crop High Veg	3
200	Two images of moderate greenness but not in early spring* *Note – We decided to exclude this one because it was picking up a lot of grass waterways and not adding much other content	Potential Cover Crop High Veg	3
201	Two images of moderate greenness including early spring image	Cover Crop	2
210	Two images of moderate greenness in fall and late spring and an imager of high greenness in early spring	Potential Cover Crop High Veg	3
211	Two images of moderate greenness (including early spring) and one image of high greenness	Cover Crop	2
301	Three images of moderate greenness including early spring image	Cover Crop	2

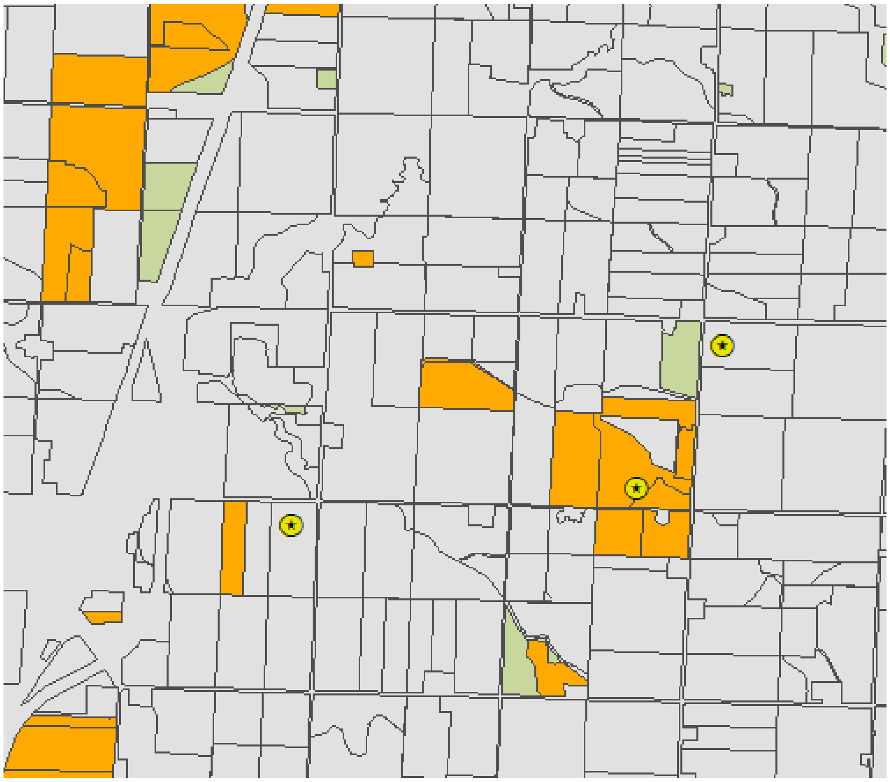
STEP 3

The final step of the tool reclassifies the composite image from 15 potential values to three values. The new categories are: 0 - No Cover Crop, 2 - Cover Crop, and 3 - Potential Cover Crop. The tool creates two products: a reclassified raster image and a polygon layer that shows the majority pixels of each field to give a general indication of cover crop potential by field.



PRODUCT 1: RECLASSIFIED RASTER IMAGE

This raster image takes the 15 different values from Step 2 and narrows them into three categories for generalization. In this image, the gray pixels indicate areas of no cover crop, orange pixels indicate areas of cover crop and green pixels indicate areas that had high vegetation, some of which could be cover crop but also include riparian areas, urban/developed areas, forested areas, and permanent cover (pasture, forest, or best management practices.)



PRODUCT 2: POLYGON LAYER SHOWING GENERAL MAJORITY

This polygon layer uses the raster pixels to calculate a majority category of pixels for each field. This approach generalizes each field into no cover crop, cover crop, and potential cover crop/high vegetation. While this approach works well on fields that are fully cover cropped, there is the potential that the tool will ignore fields partially planted to cover crop or have had field boundary changes.

3. DATA STRUCTURE AND INPUT DATA

GEODATABASE

The Iowa Cover Crop Identification Tool creates an output folder for each scene. Within this folder, there are four geodatabases. The tool creates a geodatabase for each of the three dates used in the input fields. Each of the three date geodatabases contain: an NDVI raster for that date, the 4 (10m) Sentinel 2 rasters used to make the NDVI image, a zonal statistics table that provides NDVI by the field boundaries provided in the tool, and a featureclass of the field boundaries which have been joined with the zonal statistics table.

Please note: XX = the letters of the cover crop scene, MM = number of the month, DD = day of the month, YYYY = year. In this document, we refer to the cover crop year as the fall that the cover crops were planted. For this project, we refer to 2017 as our cover crop year because the cover crops were planted in Fall 2017.

File Name	Data Type	Description
T15TXX_YYYYMMDDT165849_B02 ' '_B03 ' '_B04 ' '_B08	Raster	These four rasters contain the four 10m Sentinel 2 bands for the scene.
NDVI_MM_DD_YYYY	Raster	A raster displaying the Normalized Difference Vegetation Index for the scene.
XX_MM_DD_YYYY	Polygon	This featureclass shows the field boundaries for the scene.
ztab_MM_DD_YYYY	Table	A zonal statistics table created to generalize the NDVI pixels by field boundaries.

The fourth geodatabase is the final product (scene_Final). This geodatabase contains six files: XX_cc_YYYY, XX_fields_YYYY, XX_FinalReclass_YYYY, XX_FinalTab_YYYY, XX_reclass_YYYY, and XX_watersheds_YYYY

File Name	Data Type	Description
XX_cc_YYYY	Polygon	This feature shows the field boundaries for the scene joined with the final zonal statistics table. The attribute table contains zonal statistics data. Symbolize with the majority statistic to see which fields identify as cover crops.
XX_fields_YYYY	Polygon	This featureclass shows the field boundaries for the scene.
XX_FinalReclass_YYYY	Raster	This is the final output raster. Each pixel is reclassified as 0 – no cover crop, 2 – cover crop, or 3 – likely cover crop
XX_FinalTab_YYYY	Table	A zonal statistics table created to generalize the final raster by field boundaries.
XX_reclass_YYYY	Raster	This raster is the product of raster calculations of three different images overlaid on each other. There are 15 resulting pixel combinations.
XX_watersheds_YYYY	Polygon	This featureclass contains all HUC 12 watershed boundaries contained in this Sentinel-2 scene.

DEVELOPMENT OF TOOL

Staff started by downloading and examining dozens of Landsat 8 and Sentinel-2 images spanning a year from August 2017 to July 2018 to begin to narrow the window of image dates to use for developing the process. Over the fall the cash crop (corn or soybeans) begins to mature and dry out and eventually is harvested. During this time most fields are going from a higher NDVI value to a lower NDVI value as the fall progresses. Much of the cash crop is harvested by October or November.

After examining both Landsat 8 and Sentinel-2 imagery staff decided to use the Sentinel 2 imagery for this project. Sentinel-2 imagery provides a clearer image with 4 bands at 10m resolution when compared to Landsat 8 which is 30m resolution. Sentinel-2 also has two sensors which means more images are collected and at a more frequent rate. When choosing an image, staff tried to find images that were free of snow, smoke, and clouds, or at least minimal cloud cover. One challenge staff noticed with using Sentinel images from the USGS Earth Explorer is that sometimes only partial images were available. This was challenging and required staff to choose images that were less optimal for full scene coverage. Towards the end of the project, it was discovered that while Earth Explorer did not have the full image available, it may be available through the European Space Agency website.

During a typical year, imagery from January and February were not especially useful as there is often snow coverage during this time. Staff also ruled out using imagery from July through September because this is during the peak cash crop growing season and not useful for our project.

Eventually staff decided to use a general window of November 1 to December 15 when searching for fall imagery with a preference of mid to late November. General guidelines for cover crop planting is to occur before October 30. However, some years have later planting dates due to delayed crop harvest. Through imagery observations, staff decided that the early spring window would be March 20 through April 30 with a preference for mid-April (April 15-25). The reason is that generally snow has melted by mid-April and the cover crop fields are beginning to green up.

Another pattern that was observed is that often in mid to late May, many fields are treated to cull any remaining cover crops and weed growth before the cash crop has emerged. When this time is captured by the satellite imagery, it is very telling on the landscape. See the three images in Step 2, page 8 for an example of this. Hitting this window of time makes the tool more robust, but it can be challenging as this is also a time of stormy spring weather. In many instances, late spring imagery is less than ideal with spring rains. Many times, staff had to settle for early May imagery in which cover crop is still visible or just beginning to decline. This can result in a potentially less accurate cover crop dataset.

To develop the tool, staff began by working in one watershed in east central Iowa. This watershed was chosen because it had a high number of known cover crop fields. This watershed was also located in the same scene as an Iowa Learning Farm/ Practical Farmers of Iowa (ILF/PFI) trial plot (https://www.iowalearningfarms.org/content/cover-crop-research) with 5+ years of data. Staff used this small field as a way to observe how cover crops behaved through the seasons. The ILF/PFI study was run for a number of years and had important dates recorded such as planting date of cover crop, measurement of peak biomass, kill date of cover crop, planting date of cash crop.

Staff were able to use the data from the ILF/PFI study to help refine our understanding of cereal rye as a cover crop. We selected imagery on or near the dates recorded in the report to understand the range of observed NDVI values over different conditions and years. This allowed staff to get a better understanding of acceptable NDVI values for cover crop fields under different conditions. For example, one year the plot performed extremely well and recorded biomass of over 6,000 lbs/acre where as in a normal year, it performed closer to 800 lbs/acre and in a poor year it may be less than 100 lbs/acre or had crop failure.

As staff began to extrapolate the methodology, a new site was chosen in northwest Iowa. This site was chosen for having a number of known cover crop sites in the HUC 12 watershed. At this stage, more decisions were made about which of the 15 values would be included in the cover crop model. In western Iowa, there are more terraces and so many were showing up consistently in the value 200. Therefore, we determined that we would remove that value from the cover crop category for additional clarity.

This toolbox was developed for use in Iowa with a focus on the 2017 cover crop year with funding from AmericaView Consortium and the ISU GIS Facility With the vagaries in the of weather and image availablitiy (cloud and snow cover), NDVI cutoffs should be evaluated for each set of imagery. Default values may be acceptable but some adjustments should be expected. Application of the toolbox in other states should be evaluated with local planting dates and cover crop species in mind.