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USDA LTAR Common Experiment measurement: Post-processing of spatial grain yield data

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Abstract

This protocol provides general recommendations for in-field data collection and detailed methods for post-processing grain yield data. Grain yield is an important measurement for evaluating and comparing the overall economic productivity of cropping systems. Collecting yield data using manual methods of point samples or obtaining average yields over an experimental area (e.g., with a weigh wagon) provides basic information regarding the cropping system. However, additional information about productivity with respect to soil and landscape variability can be obtained if spatial yield data are collected. This process is facilitated by equipping the combine with a grain yield monitor that allows for the collection of continuous yield data. Maps are then produced from yield monitor data; however, errors will arise from combine operation, yield monitor performance, and/or crop conditions. The raw data must be edited or “cleaned” to provide more accurate yield values. Clean yield data provide researchers and farmers with information that reveals spatial patterns due to soil type, water availability, and field traffic patterns while enabling the alignment of grain yields with in-season point measurements.

The process for obtaining high-quality yield monitor data consists of two steps: (1) in-field data collection and (2) post-processing for cleaning, formatting, and assessing yield data. Monitors in the combine collect a wide range of data such as location coordinates, machine speed, grain flow rate, and grain moisture. Ag Leader Integra and John Deere Greenstar are two common brands of yield monitors used within the LTAR network. For post-processing, data are either transferred wirelessly or exported via a USB drive and then imported into a program such as Ag Leader SMS or USDA ARS Yield Editor (Sudduth and Drummond 2007; Sudduth et al. 2012). Using the software, data are reviewed, removed, or edited as a part of the cleaning process to provide accurate data. A survey of the LTAR sites in 2022 showed four sites using Ag Leader SMS software for post-processing, three using John Deere software, and three using USDA ARS Yield Editor software.

This protocol applies to combine yield data for grain crops, including corn, soybean, wheat, and oat. Procedures for non-grain crops such as cotton, peanut, and forages are expected to vary slightly.

Attachments

USDA ARS_Yield_Edito...

799KB

Guidelines

This protocol was developed using the following, recommended software:

- Ag Leader SMS (Ag Leader Technology, Ames IA) was used to read the flash drive from the yield monitor and export a .txt file in Ag Leader Advanced format. This format is required to move the data from the yield monitor into the cleaning software.
- USDA ARS Yield Editor version 2.0.7; this software is recommended for cleaning with optimal, reproducible results.
- Microsoft Excel was used to format the clean yield data in table form after its export from USDA ARS Yield Editor.
- ArcGIS Pro by Esri was used in the spatial evaluation of the clean yield data.

Before start

Two items to note:

1. The ‘<>’ notation found throughout the protocol denotes text in tabs, boxes, options, and filters used in the USDA ARS Yield Editor software and the associated User's manual.

2. We recommend users also have manuals for equipment and software on hand. Links to electronic resources are provided in the References section. The USDA ARS Yield Editor 2.0.7 manual is also attached as a PDF to this protocol.

Harvester setup and calibration

1 Review *USDA LTAR Common Experiment measurement: Collection of grain yield data using a yield monitor* protocol prior to carrying out this protocol. Below are a few important points to consider when collecting data in-field.

2 To ensure the most accurate sensor readings and data collection, follow the calibration guidelines in the combine and yield monitor manuals.

> **Note**
>
> - Properly functioning harvesters are crucial to an effective and efficient harvest.
> - A well-calibrated data collection monitor provides results that accurately reflect what occurs in the field during harvest.

Machine operation

3 Before operating any machinery, understand the basic safety and use protocols.

4 Take time to recognize unique field features, such as low spots, wet spots, terraces, and other features that may alter the harvest pattern.

> **Note**
>
> Information on altered harvest patterns may be important for the highest quality post-processed data.

5 The operator should make sure the appropriate field metadata are chosen or entered in the monitor before starting the field of interest. These metadata can include enterprise, farm and field names, crop type and variety/hybrid, and other identifying information.

6 Follow instructions from the yield monitor manual regarding the initial calibration and the need for additional calibration checks during the season. Calibration checks will likely be suggested for yield and grain moisture.

7 While harvesting the grain, the operator may have to perform tasks such as altering the swath width to account for clean-up rows. This alteration can be accomplished by adjusting the swath indicator on the yield monitor.

7.1 However, the operator has many other things that require attention while harvesting and thus should not be relied on to make constant adjustments.

7.2 Some harvesters automate this adjustment through overlap control that can be toggled on and off.

7.3 An incorrect swath width is a common problem that may need to be corrected in post-processing.

8 To validate the post-processed data, the best practice is to obtain an actual scale weight of grain harvested from the entire field or plot.

9 Collection of at least one grain sample per research area is also recommended, with subsequent moisture determination by a benchtop tester or oven drying.

> **Note**
>
> Because the moisture reading is for grain from a single location, note the monitor moisture reading at the time of sample collection.

Data export from a yield monitor and import to a desktop computer

10 ***John Deere.*** Use SD card/USB drive. Wireless transfer through the mobile app My Transfer.

11 ***Ag Leader.*** Use SD card/USB drive. Wireless transfer through AgFiniti.

> **Note**
>
> Follow the instructions in the Ag Leader Integra manual under the section ‘External Drive’ on pages 73-76 to perform operations related to data management and pages 97-102 for details on AgFiniti transfers.

Data editing capabilities across platforms

12 Across the LTAR network, Ag Leader SMS, USDA ARS Yield Editor, and John Deere are currently used to clean yield data. Ag Leader SMS possesses editing capabilities such as swath

trimming and setting delay times. It also allows multiple field maps to be brought into the same window and analyzed together. Yield Editor has in-depth editing capabilities, including swath trimming and setting delay times. It also provides users with an Automated Yield Cleaning Expert (AYCE) and various manual editing tools to remove specific points. Within the field analyzer window of John Deere operations manager, users can view their maps in the same window, side-by-side and layered. However, the editing capabilities provided by this software are somewhat limited. Given the nonproprietary, open-source nature, we recommend using Yield Editor to process LTAR data. The following steps describe its use.

Data modification before USDA ARS Yield Editor 2.0.7 import

13 To import data, Yield Editor requires specific formatting.

Note

The manual is accessible within Yield Editor in the <Load/Import File> tab: go to <Help and Links> and select <Open.pdf Manual> on the <Load/Import File> tab.

13.1 Data should be formatted in a table following the Ag Leader advanced export format. If other crops or data formats are used, they can be imported into Yield Editor with proper formatting modifications.

Note

Use Tables 1 and 2 on page 10 of the Yield Editor manual to guide the proper formatting of data.

13.2 Remember to save the data as a comma-separated variable file (.csv).

Data import to USDA ARS Yield Editor 2.0.7

14 Data import and configuration setup in the <Load/Import File> tab.

15 Before loading configurations and importing data, check the <Automated Options> box. Within this box, <interactive auto/manual filtering> should be selected. These selections direct the automated filtering in AYCE to run and allow manual edits as necessary. Following automated

cleaning with manual edits ensures that known issues, such as grassed waterways or field edges, are properly accounted for.

16 Load the configuration file which contains the .set extension. Downloading Yield Editor provides users with a file <default.set> however, we recommend creating unique configuration files for fields.

> **Note**
>
> See the *Data export from the cleaning software* section below for instructions on creating configuration files.

17 The configuration file will automatically apply data settings that correspond to the crop type in that file. For example, if your configuration file is created for corn, corn values will be displayed in the <Selected Grain Type and Properties> table.

18 Once the values are correct (check the values in the table to see if they match the crop type data to be imported), import the yield data (see Figure 1).

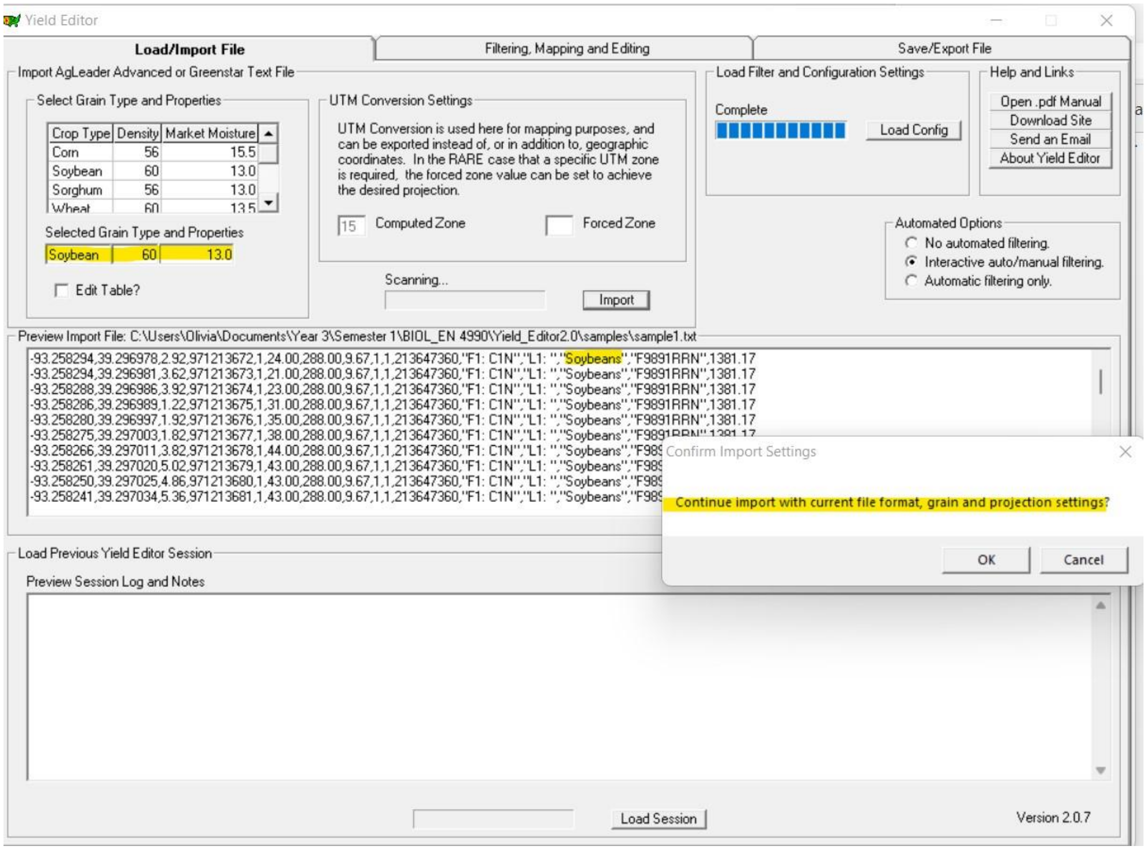

Figure 1. The <Selected Grain Type and Properties> match those of the crop in the <Preview Import File> window where “Soybeans” is highlighted. Since these attributes match, we can select OK from the popup window.

19 When the <Import> button is selected, Yield Editor will look for a .txt file of the Ag Leader Advanced or Greenstar format. The Yield Editor 2.0 manual also mentions FOViewer; however, this app is no longer available.

20 Select the data to import, and Yield Editor will prompt you to confirm the file format, grain, and projection settings are correct.

21 Once again, check the parameter values match those from the chosen configuration in the table. Improper values will alter the yield map and reduce the ability to produce an accurate, clean yield map. An example of improper values would be to use corn values in the table when looking at soybean harvest data.

21.1 If you notice the crop type in the <Preview Imported File> pane does not match the values in the <Selected Grain Type and Properties> table, you can select a different grain type.

21.2 To change the grain type, go to the <Select Grain Type and Properties> table and double-click on the crop you want. This action will change the grain type and properties in the <Selected Grain Type and Properties> table.

21.3 By default, Yield Editor calculates yield in pounds per acre (lb/ac). You can alter the grain type density to obtain the desired units. For example, corn density is 56 pounds per bushel (lb/bu), which is converted to bushels per acre (bu/ac). Reporting in SI units is recommended and further described in the *Data export from the cleaning software* section.

22 Review the Computed Zone within the <UTM Conversion Settings> box. The value is calculated using the longitude and latitude data found in the first line of the imported data file.

22.1 In unusual cases, you may use the <Forced Zone> checkbox to assign the zone. This may be needed if a field is near a zone boundary and needs to be mapped with fields in the adjacent zone.

22.2 As a general warning, use caution when forcing fields into zones because errors can be created in field and data alignments. Major issues occur when exporting data from Yield Editor and importing it to a program such as ArcGIS Pro. This process will be addressed in the *Data export from the cleaning software* section below. See page 8 of the Yield Editor manual for further information on this topic.

Data cleaning using software

23 Once data are imported, operational or sensor-based errors are visible in the map and will be the areas of focus during cleaning. Errors can appear as data points outside field boundaries, intersecting transects, sharp pixel color transitions, and sawtooth patterns.

Note

Operational errors include a poor harvest pattern (e.g., multiple point rows, excessive number of cleanup swaths, and narrow swaths), improper system calibration, or plugging of the combine. Other operational errors are caused by rapid velocity changes, ramping, and swath width.

24 Sensor errors result from poor accuracy or internal component failure. Time lag is an issue with sensors, as there is a delay between when the grain enters the head and when it reaches the sensor.

25 Begin cleaning data in Yield Editor using the <Filtering, Mapping, and Editing> tab.

25.1 Opening this tab reveals the map, <Filter Selection> pane, <Zoom Tools>, <Manual Editing Tools>, the AYCE window, and the legend window.

25.2 If the legend is not visible, select the <Display Legend?> box at the bottom right corner of the window.

25.3 Before cleaning the data, change the class selection within the legend from <eq intervals> to <eq obs>. This action makes the data more visually clear.

25.4 Begin cleaning the data using the preferred method, the AYCE. This tool streamlines and standardizes the initial stages of the cleaning process.

25.5 The AYCE tool is designed to improve the cleaning process, but it has limitations. Specifically, the AYCE will sometimes have problems calculating flow and moisture delays, and manual edits will be required.

25.6 The AYCE window has multiple checkboxes. Please select all checkboxes to be calculated by the AYCE. Eight boxes will be selected.

These boxes correspond with variables of interest which are calculated by the AYCE: flow delay, moisture delay, max and min velocities, max and min yields, local standard deviation, and position.

Note

CAUTION: If large areas of data lie outside the field boundaries, remove these areas before running the AYCE because they will have an unwanted effect on the calculated values (Figures 2a and 2b).

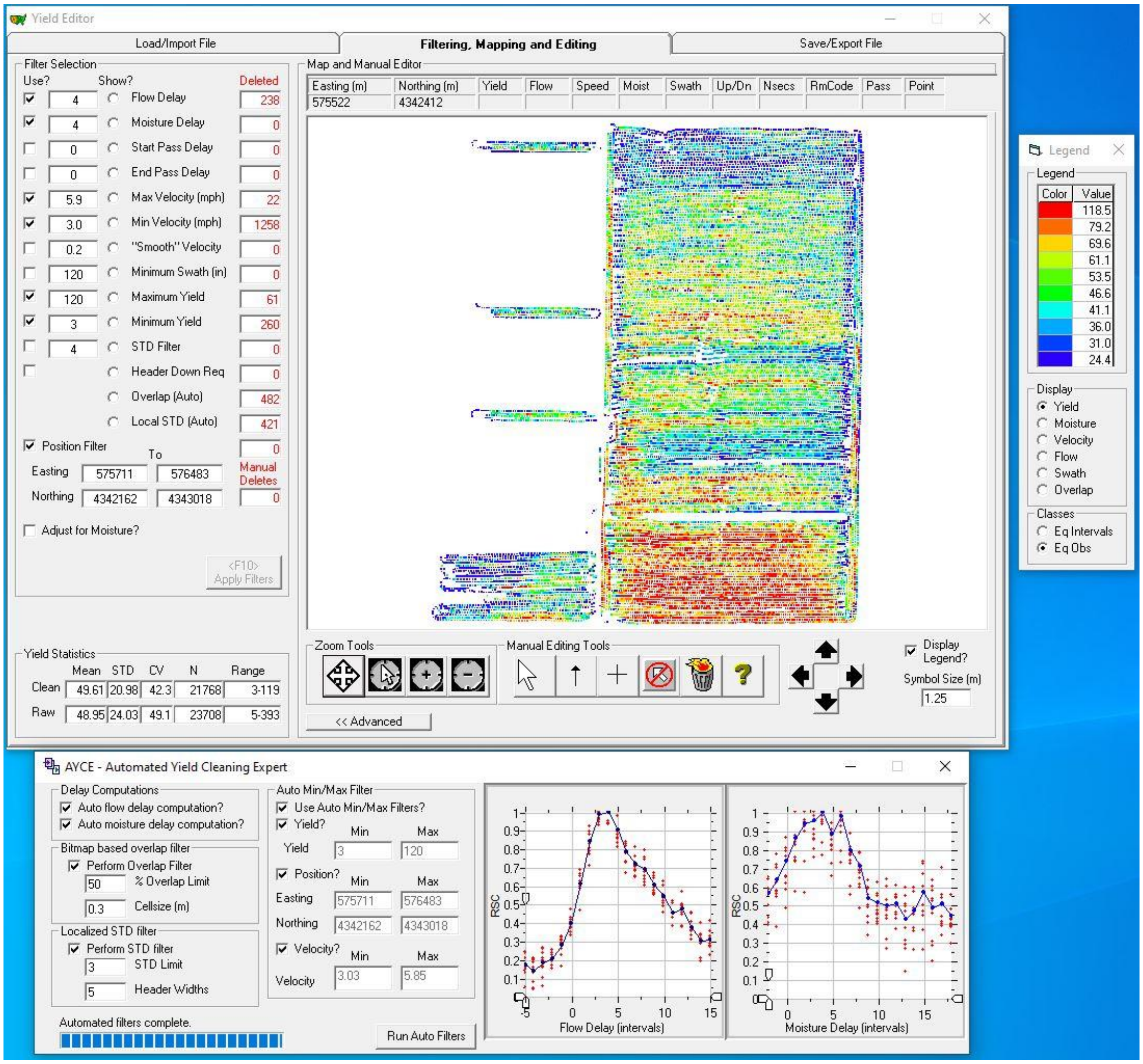

Figure 2a. Field cleaned by the Automated Yield Cleaning Expert (AYCE) *before* removing positional flyers (points that lie outside the field boundary).

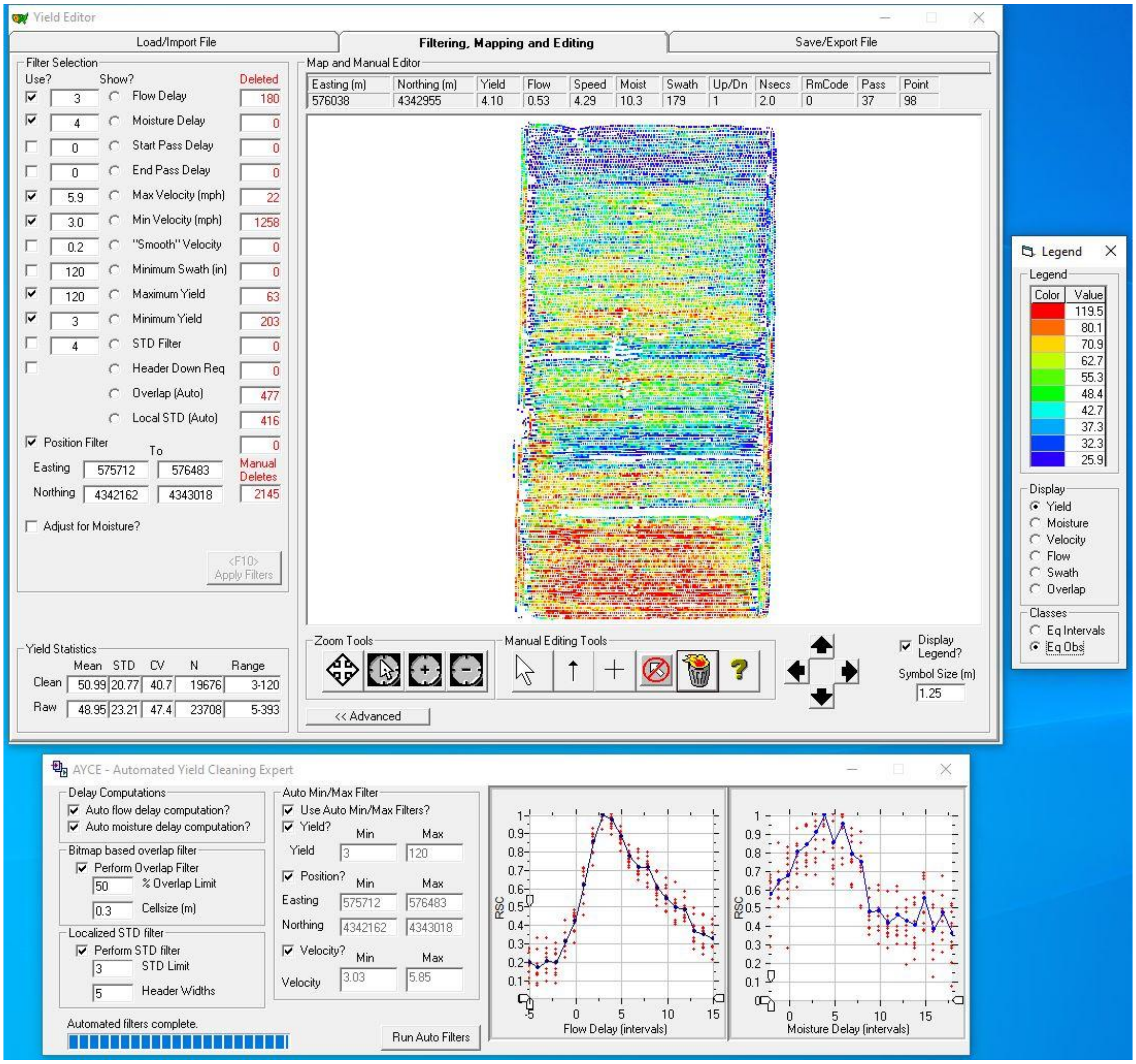

Figure 2b. Field cleaned by the Automated Yield Cleaning Expert (AYCE) *after* positional flyers were removed. Note the difference in yield statistics.

25.7 In the AYCE window, line plots are created for flow delay and moisture delay. These plots provide a visual of how the AYCE selects flow delay values. Depending on variability of the data, one or both plots may have a yellow or red outline.

25.8 Yellow indicates the value selected by the AYCE is a poor fit for the data. This fit is the poorest acceptable fit, and a value will be provided in the <Filter Selection> pane.

25.9 Red indicates the selected value is an extremely poor fit. A value will not be provided.

26 Use the <Filter Selection> pane within the <Filtering, Mapping, and Editing> tab to refine AYCE results and select values not provided by the AYCE.

26.1 In certain situations, the harvest pattern, in combination with how yield fluctuates in the field, prevents the AYCE from determining accurate filter values. In addition, it can be aggressive when removing points.

26.2 Check computed filter values and adjust them in the <Filter Selection> pane according to your knowledge of the field and harvest conditions. For example, if you know the crop did not perform well due to growing season stressors, you may want to lower the value of the minimum yield because the AYCE may have removed yield points that are realistic in this instance.

26.3 You can also visually assess the spatial variability of the map and experiment with different values to see if it is possible to obtain a cleaner map than the AYCE-produced map.

26.4 Previously, line plots for the two delays were discussed. The results provided by these plots should be edited when the software produces a yellow or red outline around one or both plots.

26.5 To determine modified delay values for red and yellow outlined plots, two options are available. Using values from another field with the same combine, crop, and year can provide an estimated value. Alternatively, you can manually alter flow delay values until the spatial variability is well defined (Figures 3a and 3b). Often, delay values are between 11 and 16 seconds.

Note

In some cases, the data export software (such as SMS) applies a delay on export. Then the flow delay adjustment in Yield Editor can be much smaller or even negative.

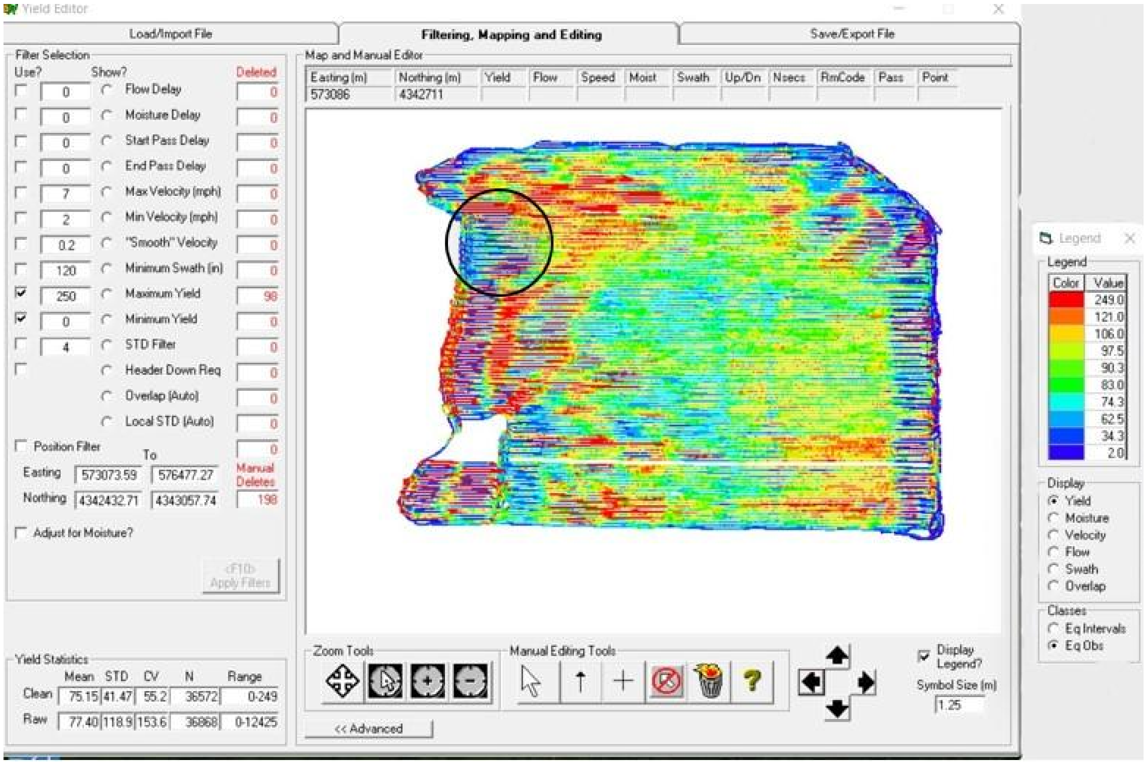

Figure 3a. This map is not clean. You can see sawtooth marks and abrupt transitions.
Alter <Flow Delay> to improve this map.

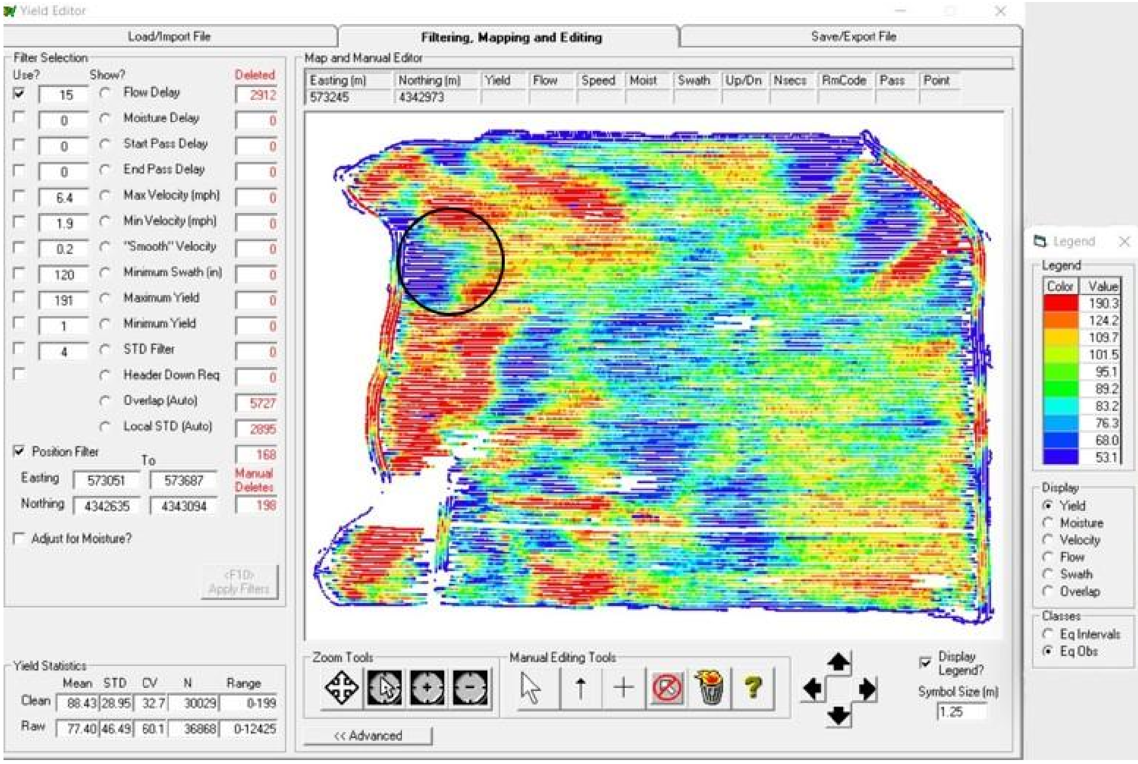

Figure 3b. This map has been cleaned by the Automated Yield Cleaning Expert (AYCE), but only the <Flow Delay> and <Position Filter> boxes were used. This map clearly differs from 3a.

26.6 Next, check the other AYCE-calculated values in the <Filter Selection> pane on the main Yield Editor window. These values can be edited. Values include maximum and minimum yields, maximum and minimum positions for Easting and Northing, and maximum and minimum velocities.

26.7 The maximum velocity and minimum yield are often higher when computed by the AYCE than from manual cleaning.

- The maximum velocity varies based on field conditions, crop type, and the operator. Use your knowledge about the harvest and talk with the operator if there are potential issues with this value. The operator can provide a max velocity in normal harvest conditions, which can be used as a reference. Set the <Max Velocity> slightly above the normal max velocity to only remove necessary points, such as partial swaths, where the operator travels faster than the normal max velocity.
- Typically, the <Minimum Yield> should be set near zero, particularly if the crop endured major stresses. Assigning this filter a low value is unlikely to have a large impact on mean yield because many of the other filters remove low yield points.

Note

The removal of a point by multiple filters is common in Yield Editor. If an edit to a value in the <Filter Selection> pane has little or no effect on the map, another filter could have already removed many of the same types of points.

26.8 <Flow Delay> and <Maximum Yield> values calculated by the AYCE are often similar to values entered manually.

- To check the flow delay, look at transitions from low to high and high to low yield areas. Visually, you should see the pixels gradually change from one end of the spectrum to the other. A transition that is not smooth, such as red pixels next to blue pixels, probably indicates data that should be removed (Figures 4a and 4b).
- Maximum yield values should also be checked. Simbahan et al. (2004) suggested choosing a maximum yield through comparison with a nearby high-yield experiment or output from a crop simulation model. Whatever method is chosen, the estimated maximum yield should be high enough to avoid the removal of valid data. Generally, the maximum yield filter should only remove isolated data points. An area of contiguous high-yield points, particularly if it spans multiple transects, is probably valid and should only be removed based on strong evidence.

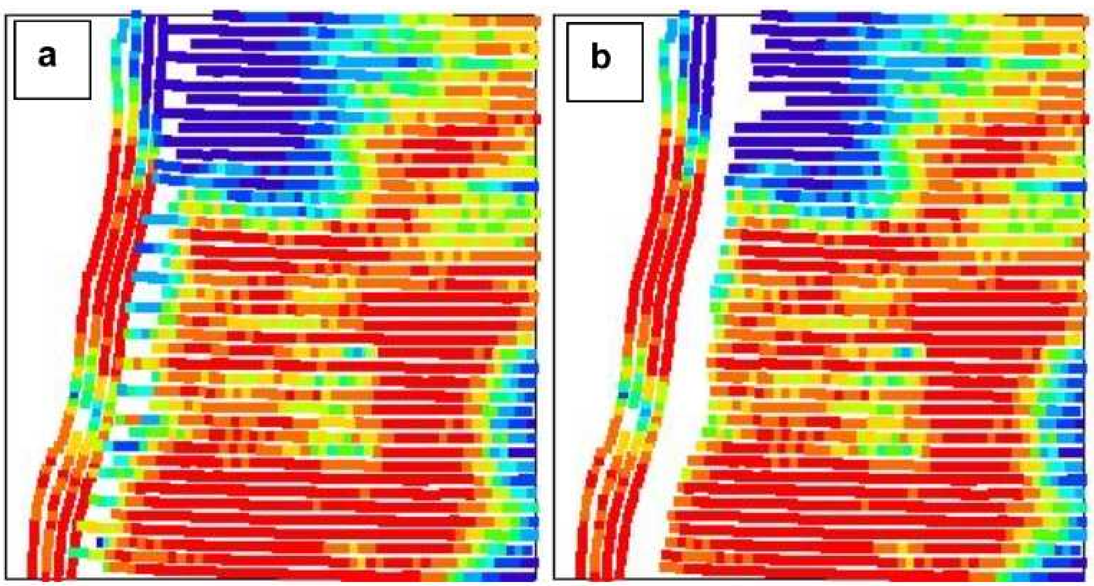

Figure 4a. A yield map without the use of <Start or End Pass Delay>.
Figure 4b. The yield map again with the use of delays.
Notice how the left map appears to have ‘fingers’ going into the end rows, while the right map has rows truncated a similar distance away from the end rows.

26.9 When looking at values for the <Min Velocity>, apply similar concepts as with maximum velocity.

Set the value low enough to only eliminate points that clearly require removal. A point within the field where the operator has greatly reduced speed may need to be eliminated. This is due to the large amount of grain coming through the header, up to the mass plate while the combine travels at a reduced speed. This point would probably be incorrectly recorded by the in-field monitor as having an unrealistically high yield due to the flow delay issues with a large velocity decrease (Figure 5).

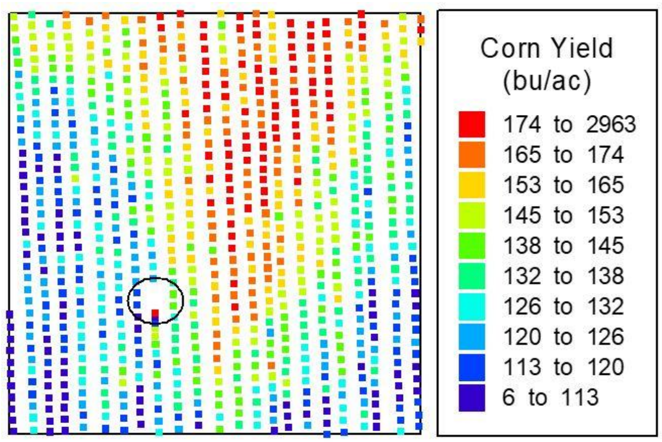

Figure 5. The circled red pixel exemplifies a high yield point due to rapid deceleration. Note that it has altered the legend value to 2963 bushels per acre. This point should be manually removed if it is not removed by the <Smooth Velocity> filter.

26.10 <Moisture Delay> applies the same general principles as flow delay.

- The time for the grain to travel to the moisture sensor may differ from the time taken for grain to travel to the flow delay sensor. This difference is the reason for the additional delay parameter.
- Use visual cues within the data to determine moisture delay values. As with flow delay, the field should transition smoothly when an appropriate value has been chosen.

26.11 Because grain moisture data are inherently less reliable than grain yield data, another editing option is through <Adjust for Moisture>.

- Adjust for Moisture has many settings with multiple options. Look at the value box within the <‘ilter Selection> pane. This value is calculated by the AYCE, but it does not remove data from the yield map. It only allows users to modify yield values based on moisture.
- To use the moisture delay, select the <Adjust for Moisture> checkbox. Upon selecting this box, the user is presented with two more checkboxes, <Expand Dry> and <Sensor Based>,

and one box where a numeric value can be specified.

- When deciding which options to select and what values to use, each situation should be considered individually. Pages 13 and 14 of the Yield Editor manual provide an explanation of considerations for deciding how to use the editing capabilities for grain moisture.

26.12 The <Position Check> box removes points outside the field boundary (i.e., "positional flyers"), but manual editing will be needed. Points outside the boundary may remain or points within the field and along the edge may need removal. This can be seen in a map as a row of red pixels abruptly changing to blue. The blue pixels are probably unreliable because the entire row was red, and the change was abrupt (Figure 6).

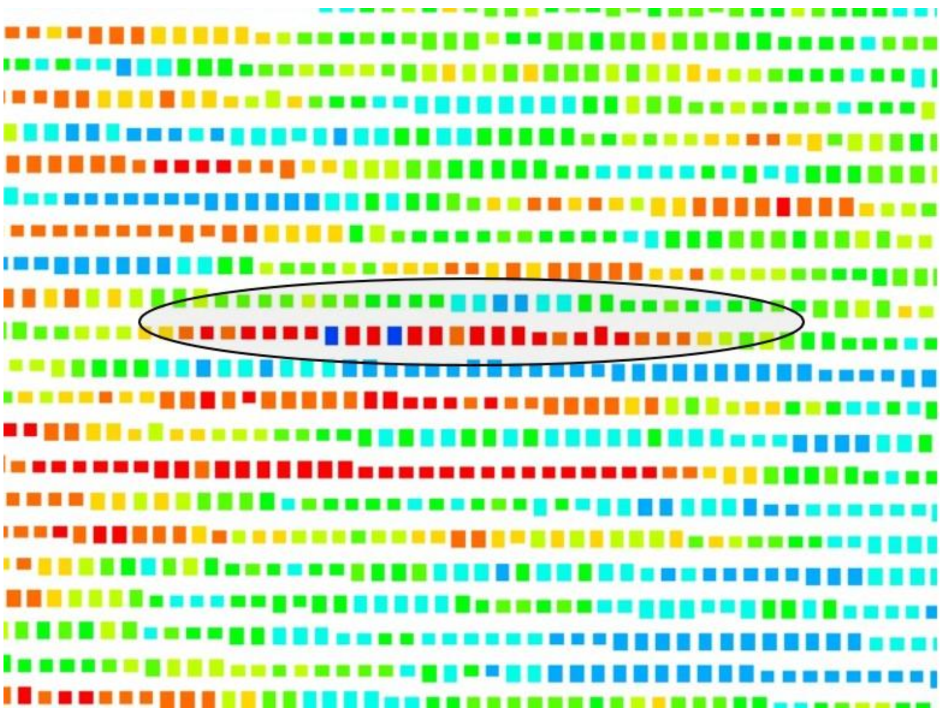

Figure 6. The circled region shows a high-yield area of a transect. Within this area are two dark blue dots representing low yield. There is no sign of a transition from high yield to low yield, and the two blue dots almost appear to be random. It is likely these points should be removed.

26.13 Two values (<Localized STD filter> and <Bitmap-based overlap filter>) calculated by the AYCE are not editable through the <Filter Selection> pane.

- <Localized STD filter> calculates the standard deviation (STD) and mean within grid cells on the map. It removes points that fall outside the user-defined number of STDs. The default STD of three (3), may be too aggressive and require adjustment. If many points are deleted after running the AYCE, the Local STD may be the cause. Select the circle with the label <Local STD (Auto)> in the main map frame under the <Filter Selection> pane. By selecting this circle, you can see what points this filter has removed. If adjustments are needed, change the parameter values in the AYCE window and rerun the AYCE.

- <Bitmap-based overlap filter> removes data where the overlap area exceeds the maximum allowable percent overlap. The purpose is to remove points where the combine traveled over a previously harvested area. This maximum percent overlap can be altered within the AYCE window before running the program; however, the default values were set to achieve accuracy and efficiency when cleaning yield data.

27 After checking the values calculated by the AYCE, determine values for filters the AYCE does not set. These filters include <Start and End Pass Delay>, <Smooth Velocity>, <Minimum Swath>, and <STD Filter>. Use the <Filter Selection> pane to manually select values for these filters.

27.1 When determining <Start and End Pass Delay> values, examine field edges, where the combine enters and exits the field. If the rows in the middle of the field intersect the field boundaries, check the start and end pass delays. Removing these areas is important because yields are often low and inaccurate due to the machine filling (start) and emptying (end) (Figure 4).

27.2 <Smooth Velocity> is not commonly used. However, it is helpful and important when the combine suddenly stops. Stops can be due to an in-field feature (encountering an unexpected ditch), mechanical issue, or operator error. Sudden stops can be identified by an unreasonably high yield value which is the result of a velocity of near zero as yield is a function of mass flow rate and distance traveled (Figure 5).

27.3 The AYCE does not determine a value for <Minimum Swath>; however, it does contain the <Bitmap-based overlap filter>, a feature that removes points where data have been collected twice because of overlap. If harvesting wheat or soybean, the value within the filter selection box can be altered to improve the accuracy of data. In addition, look for short swaths in the field that may have been used to ‘clean up’ the field. These swaths will not span the entire field and may be recognized by their lower yield value than surrounding swaths. Removing these values may require manual editing techniques (Figure 7).

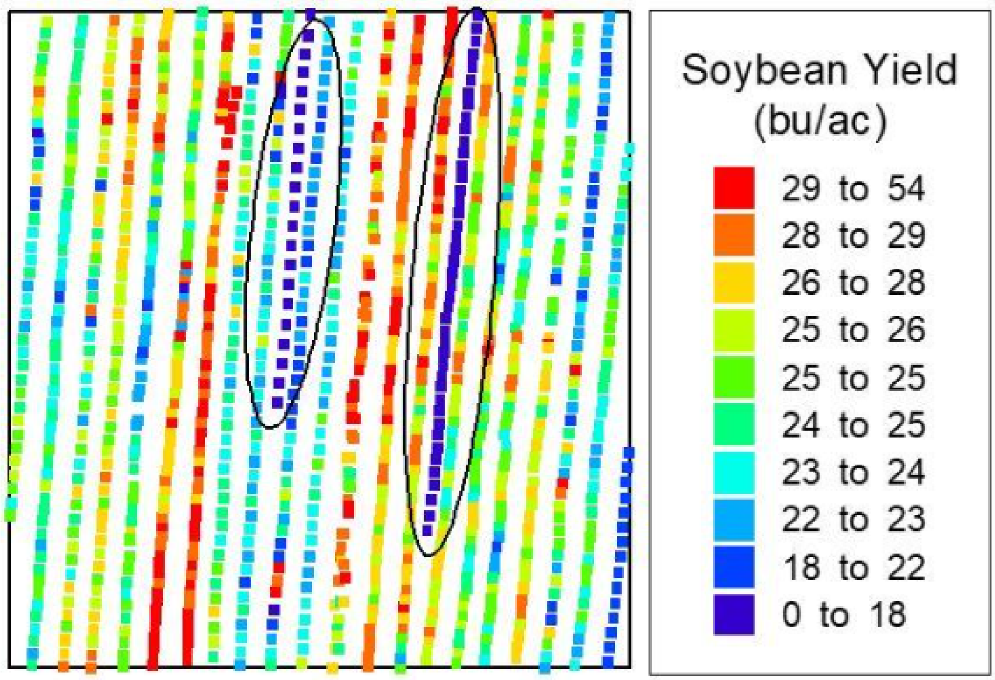

Figure 7. The circled areas indicate low yield due to short and narrow swaths that should be removed. They may be removed through the <Minimum Swath> filter; however, manually selecting and deleting the transects may be required.

27.4 <STD Filter> is based on the mean of the entire field and removes points that are outside of the user-specified number of STDs.

27.5 <Header Down Req (HDR)> is a checkbox option. When this option is selected, yield values originating from when the header was not down will be removed. This filter is typically not used because points are often already filtered out when the harvest data are exported from the combine monitor.

28 Once the tools in the <Filter Selection> pane have been utilized, begin using the <Manual Editing Tools>.

28.1 Begin by looking for points that are obvious outliers. Even if the AYCE and filtering tools have been used effectively, some areas will need extra cleaning. The beginning and end of combine passes are one such area.

During these periods, the combine is filling (start) or emptying (end), which results in yield estimates that are low and probably inaccurate. Figure 8 shows that yields are uniform throughout the transects, but the pixels suddenly turn blue (black circle) at the end of a transect.

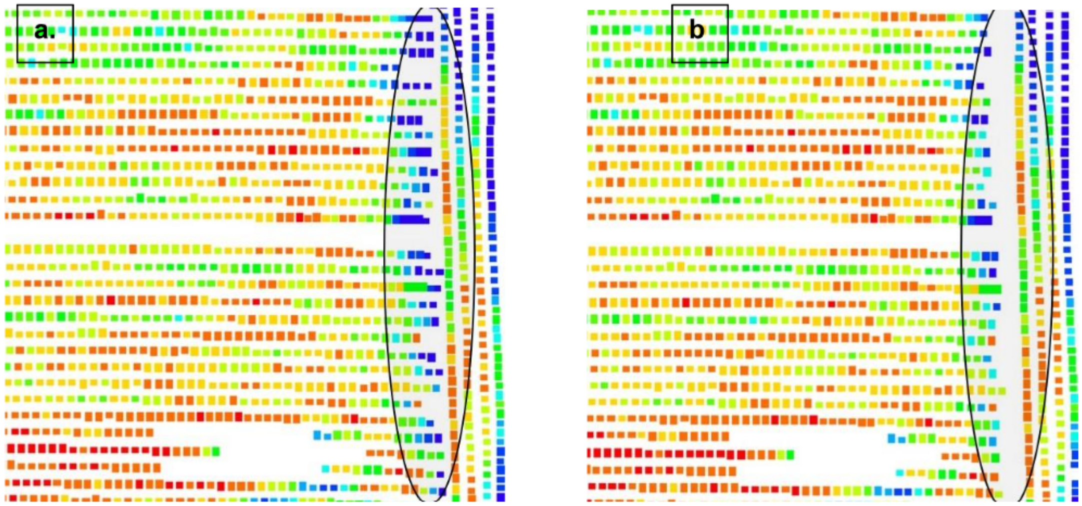

Figure 8a. In this map, additional editing is required at the transect ends.
Figure 8b. In this map, the transect ends have been manually edited through point and bounding box selections.

28.2 Some rows may also be longer than others, another indication that manual editing of these points is needed through point or bounding box selection.

- <Point select> is helpful when only a few points need to be removed.
- <Transect select> can be helpful not only in removing narrow rows (i.e., the width of the row is noticeably smaller than that of surrounding rows) but also in differentiating between points that belong and those that do not. At the edge of the field, points in outer transects (end rows) versus inner transects can be difficult to differentiate. By using this tool, outer transects are clearly defined, and the points that should be removed are easier to determine.
- <Bounding box select> is helpful when removing many points, such as those at the end of transects.
- The <Query tool> allows users to select points in the field and then view a corresponding histogram. This tool can be used to validate cleaning, as discussed in the *Quality Assessment and Quality Control* section below.
- At the bottom of the Yield Editor map window is an option where you can mask a filter for any reason. See the Yield Editor manual for more information.

Data export from the cleaning software

29 The last step is to export the clean data using the <Save/Export File> tab.

29.1 In the <Export Data> pane are multiple data selections. We recommend selecting UTM easting and northing, latitude and longitude, yield, and moisture. Additional metrics may need to be exported to answer specific research questions.

If fields are in different UTM zones, the latitude and longitude coordinates will provide global coordinates that will not be affected by the UTM zone chosen in Yield Editor. This will ensure valid coordinates are used when performing further analyses in other programs, such as ArcGIS Pro.

29.2 Next, there are two boxes: <Formatting> and <Point Types to Export>. When exporting the data for use in Excel, Comma Delimited ASCII is recommended.

Typically, only clean points are exported. Depending on the type of analysis, you may wish to select various point types. For example, to analyze the yield in a particular transect that corresponds to a certain fertilization rate, you can select that transect and export selected points.

29.3 You can create your own configuration, as mentioned in the section *Data import to USDA ARS Yield Editor 2.0.7,* under the <Save Filter and Configuration Settings> pane. A file should be developed for each combine/crop combination. This measure will save time during future harvests and provide values tailored to specific harvest situations.

29.4 The <Session Log and Notes> pane is a great tool for providing information about the cleaned map and its data. Recommended inputs include:

- Name and contact for combine operator
- Harvest date
- Equipment used
- Grain test weight (density)
- Grain moisture
- Records of scale weights from a weigh wagon or truckload
- In-field notes
- Location of raw and processed data files
- Name and contact information of the person who cleaned the data
- Notes about cleaning steps performed
- Configuration filename

29.5 Save the session as a .yes file, which allows future access in Yield Editor. Be sure to indicate this is the clean version by adding "CLEAN" to the filename.

Note

Save the session file as a .yes file is important because it allows the cleaned map to be reloaded and data to be re-exported in a different format at any time.

30 Export the data to continue analysis outside Yield Editor. Select the <Export Data> button.

30.1 A pop-up window will list all files. Under the filename, select the file type. Select .csv to save data in Excel and .txt to import data into ArcGIS Pro.

30.2 Add the exported .txt file to ArcGIS Pro. Further data manipulation will be briefly discussed in the *Making yield maps using GIS software* section below.

Making yield maps using GIS software

31 Open the table for the file you have imported into ArcGIS Pro. Right-click on the layer in the contents pane and select <XY Table to Point>**.** This tool converts the data from the file into a shapefile which will contain the field data plotted on the field map.

31.1 To view variation in the map more clearly, we recommend modifying the symbology. We used graduated colors, the natural breaks (Jenks) classification method, and 10 classes (Figure 9). For the color scheme, the same colors used in Yield Editor were selected to provide the same view in ArcGIS. In addition, all symbols were formatted to decrease their size and remove their black outline.

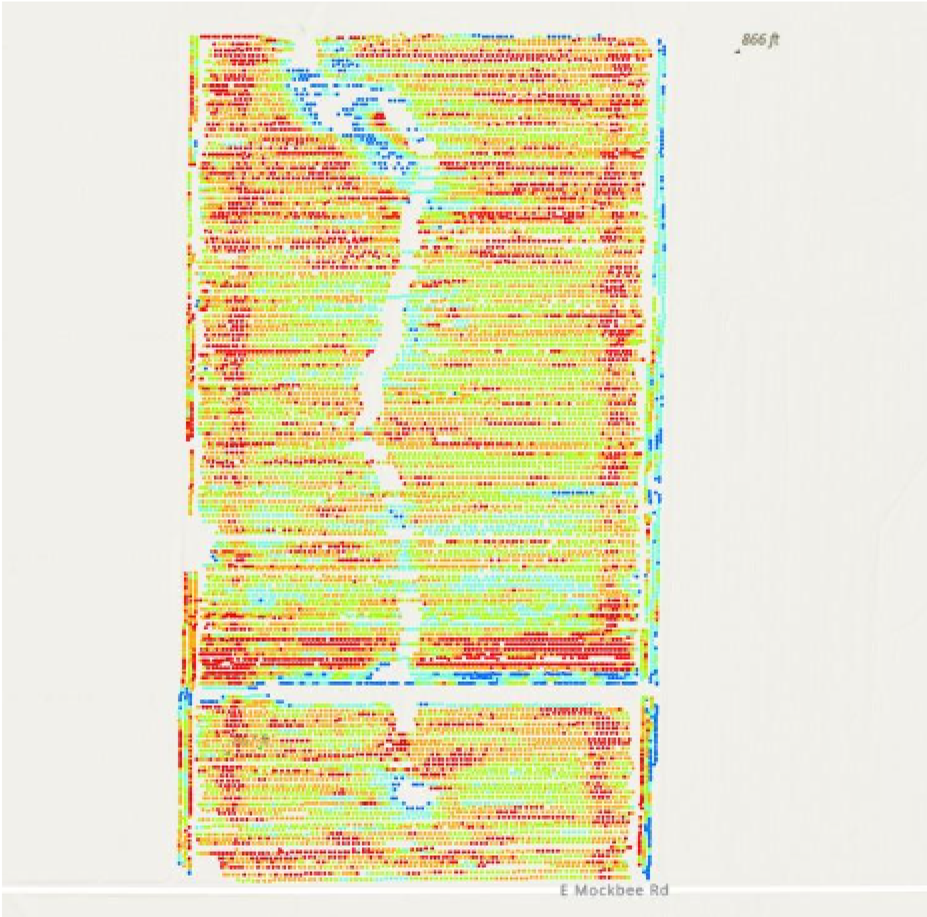

Figure 9. Here is an example of what a map might look like in ArcGIS after modifying the symbology and zooming to the field extent.

31.2 Next, create data layers of the chosen interpolation methods. In general, five options are available for interpolating point data: simple, ordinary, empirical Bayesian kriging, inverse distance weighting, and natural neighbor.

31.3 Using the <Geostatistical Wizard>, these options can be assessed by keyword searching within the geoprocessing pane. A comparative analysis of the five interpolation methods (performed by the authors) indicated a slight advantage for the natural neighbor method.

31.4 Add the shapefile (.shp) that contains specific points in the field you want to assess.

31.5 Next, begin the process of extracting the values from the interpolation data layers at your specific field points.

- Right-click on the interpolation layer, hover over the <Export layer>, and select <To Points>.
- The feature <GA Layer to Points> will automatically populate your geoprocessing window. Two options will be available, <Parameters> and <Environments>. First, use the

<Parameters> option.

- In the <Input geostatistical layer> dropdown, select the interpolation layer you wish to extract from. In the <Input point observation locations> dropdown, select the shapefile containing the specific field points.
- Next, under the <Environments> option, ensure the <Output Coordinate System> matches the layer coordinate system.
- Select the <Run> option and a new data layer will populate with values from your interpolation layer at the specified points. Right-click on your new layer and select <Attribute Table>. Here, you will see each point and its corresponding coordinates and predicted yield values. For some interpolation methods, you will have a standard error.
- Record the yield and error values for each point using Excel.

Calculations

32 Equation 1. Yield in bushel/acre using harvest conditions. This is based on a harvest mass flow rate ($m_{harvest}$) with harvest moisture. Rather than using $m_{harvest}$ you can use the mass flow rate based on market moisture of the specific crop. Calculate m_{market} using Equation 2 and insert that value into Equation 1 instead of $m_{harvest}$.

$$Y = \frac{m_{harvest} \times t_{sample}}{d \times w \times \rho_{grain}} \times \frac{144\ in^2}{1 ft^2} \times \frac{43{,}560 ft^2}{1\ acre}$$

$m_{harvest}$ = harvest mass flow rate (lb/sec)
tsample = data logging interval (sec)
d = distance traveled (in)
w = width of combine header (in)
ρgrain = mass grain density (lb/ac)

33 Equation 2. Convert harvest (wet) mass flow rate to market mass flow rate. Use this flow rate in place of $m_{harvest}$ in Equation 1.

$$m_{market} = \frac{100\% - MC_{harvest}}{100\% - MC_{market}} \times m_{harvest}$$

m_{market} = corrected mass flow rate (lb/sec)
$m_{harvest}$ = mass flow rate of moist grain (lb/sec)
$MC_{harvest}$ = moisture content of the moist grain (%)
MC_{market} = marketable moisture basis (e.g. 15.5% for corn, 13% for soybean)

Quality assessment and quality control

34 To ensure the clean data are reasonable based on observations associated with neighboring fields, consult the field operator or farmer. This consultation is especially useful when there are areas of particularly low or high yield.

34.1 Ask if the operator encountered any problems with the combine or had to make an adjustment due to obstacles in the field, such as a ditch.

34.2 Ask the operator/farmer to provide their thoughts about the map given their expertise and historical knowledge of the field. The farmer will also have information about planting, fertilization, or other factors contributing to yield values.

35 Another way to ensure data are reasonable is to compare yield monitor totals with measured grain weights. These weights may have been obtained using a weigh wagon or through weight tickets received from a local elevator. When the field is finished, compute the total grain weight of the field.

36 Once the field data has been cleaned using Yield Editor, use Equation 3 to compare the 'clean' monitor grain weight to the in-field grain weight.

Equation 3. Percent error between yield monitor and scale weights. Ensure weights are in the same units whether it is US (imperial) or metric.

$$\frac{(monitor\ weight - scale\ weight)}{scale\ weight} \times 100$$

monitor weight = value from the yield monitor
scale weight = value from the scale

37 Using Yield Editor, the statistics of the cleaned yield data can be analyzed by selecting individual points or groups of points within a field. The yield distribution can be viewed as a histogram using the <query> option.

37.1 Inspect the histogram and whether data are within three standard deviations (STDs), this is the general recommendation for removing outliers.

37.2 Select several areas, each with at least 200 points, to ensure the entire field has been adequately cleaned.

Archiving

38 Follow all instructions in the *Data export from cleaning software* section as this outlines the necessary steps to having a robust file archive and documentation.

39 Yield values need to be converted from bu/ac to kg/ha for reporting in metric units. Some common conversions include:

Corn/Grain Sorghum
1 bu/acre = 62.77 kg/ha
1 kg/ha = 0.0159 bu/acre

Soybean/Wheat
1 bu/acre = 67.25 kg/ha
1 kg/ha = 0.0149 bu/acre

40 The shape file and extracted data should be moved to local servers or the cloud for long-term storage.

Protocol references

Owen, O. K., Sudduth, K. A., & Abendroth, L. J. (2024). USDA LTAR Common Experiment measurement: Collection of grain yield data using a yield monitor. https://doi.org/10.17504/protocols.io.rm7vzjm1rlx1/v1

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USDA ARS Yield Editor 2.0.7 software and manual.
https://agdatacommons.nal.usda.gov/articles/model/Yield_Editor_2_0_7/24664038

AgLeader
Ag Leader Integra manual **https://portal.agleader.com/community/s/contentdocument/069f400000DTJ2QAAX?language=en_US**

ArcGIS Pro *Interpolation:*
- https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/understanding-interpolation-analysis.htm
- https://pro.arcgis.com/en/pro-app/latest/tool-reference/spatial-analyst/an-overview-of-the-interpolation-tools.htm