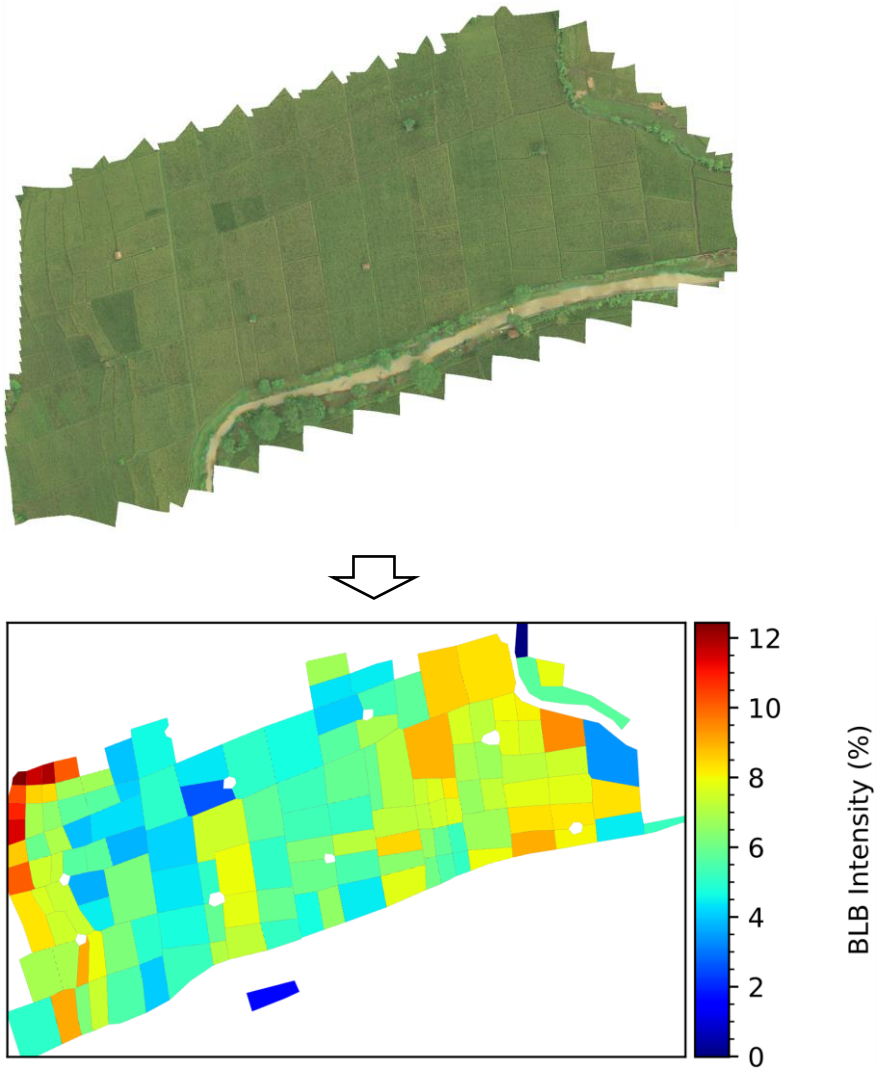
Drone-version BLB Damage Assessment Tool

Quick Start Guide

Drone Tool Version 1.0



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1. Introduction

The drone-version BLB damage assessment tool (hereinafter referred to as Drone Tool or simply as tool) is a tool for estimating BLB damage intensity related to rice color information (spectral reflectance and vegetation index) obtained from drone images. In addition to estimating BLB damage intensity, the tool has the ability to combine multiple drone images into a single image (an orthomosaic image), the ability of geometric correction to align the drone image to the parcel data of the plots, and the ability to identify BLB scoring locations in the drone image. This quick start guide explains how to use the Drone Tool mainly with the initial settings (default settings), while detailed instructions on how to change settings are provided in a separate manual.

2. Screen Structure

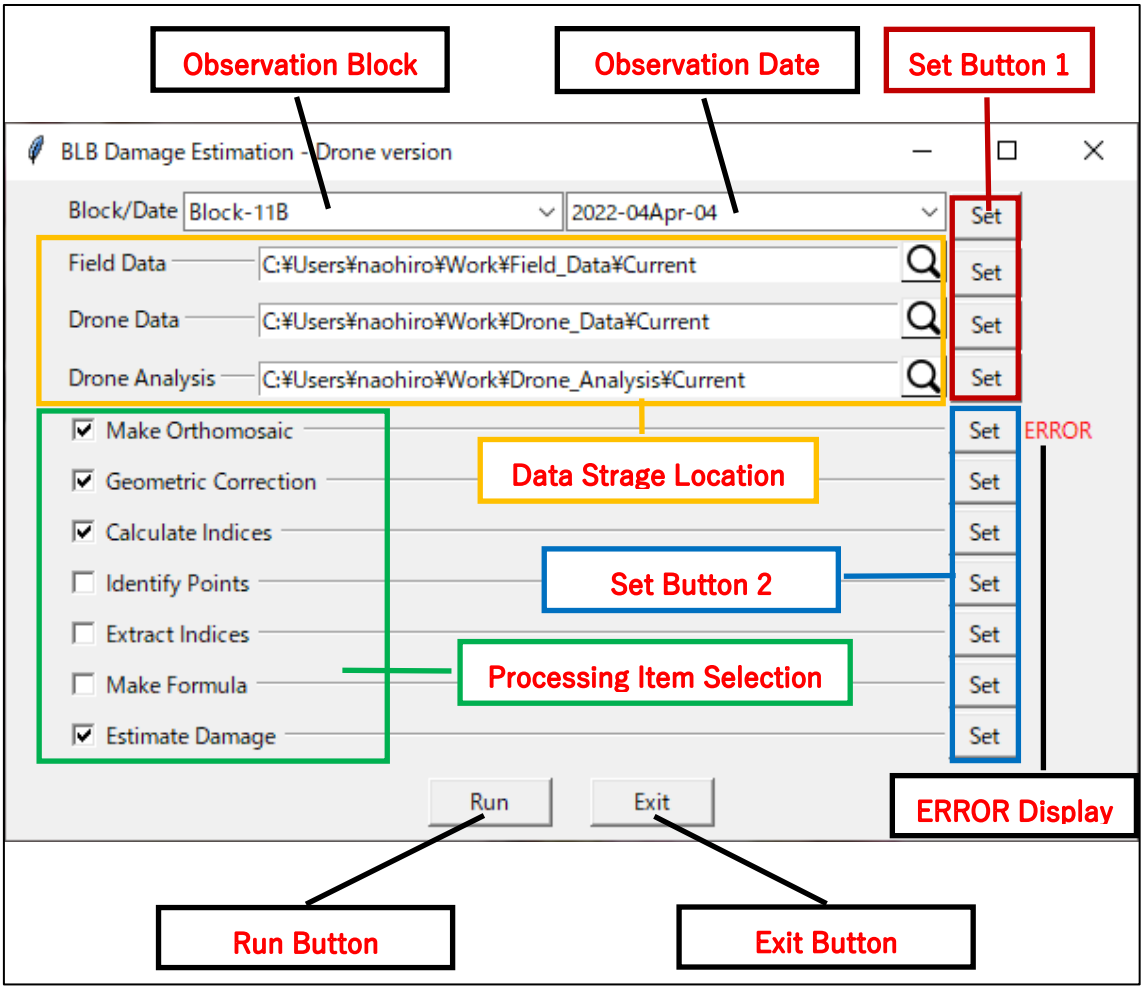

Fig.1 Main screen of Drone Tool

Fig. 1 shows the main screen of the Drone Tool. In this screen, you can make basic settings for the processing performed by the tool.

- Observation Block/Observation Date

  Enter the observation block name and observation date※ of the data to be processed. In the following description, the respective setting values are referred to as OBS_BLOCK and OBS_DATE. These values are used to automatically create the names of files and folders that the tool references or creates. Enter directly in the input field, or click the arrow at the right end of the input field and select the value you want to enter from the displayed candidates. After inputting, you need to click Set button 1 on the right side of the input field to reflect the settings. When the settings are reflected, the related detailed settings of each processing item are also changed. Settings that do not reflect the changes are displayed in red.

  ※ Since the acquisition date of the field observation data is included in the data created by the tool, it is recommended to enter the acquisition date of the field observation data if the acquisition date of the drone image and that of the field observation data are different.

- Data Storage Location

  Enter the storage locations of the field observation data, drone raw data, and drone analysis data. Enter directly in the input field, or click the search icon at the right end of the input field and select the value you want to enter from the displayed candidates. In the following description, the respective setting values are referred to as FIELD_DATA, DRONE_DATA, and DRONE_ANALYSIS. If the location pointed to by the Windows environment variable USERPROFILE (usually C:¥Users¥user-name) is expressed as HOME, the default settings are as follows.
  FIELD_DATA = HOME¥Work¥Field_Data¥Current
  DRONE_DATA = HOME¥Work¥Drone_Data¥Current
  DRONE_ANALYSIS = HOME¥Work¥Drone_Analysis¥Current

  As with the observation block/observation date, it is necessary to click the Set button 1 on the right side of the input field to reflect the setting after input. Fig. 2 shows the default data storage location. Appendix 2 shows the main file and folder names that the tool references or creates.

  ※ **The files enclosed in red frames in Fig. 2 must be prepared before processing starts.**

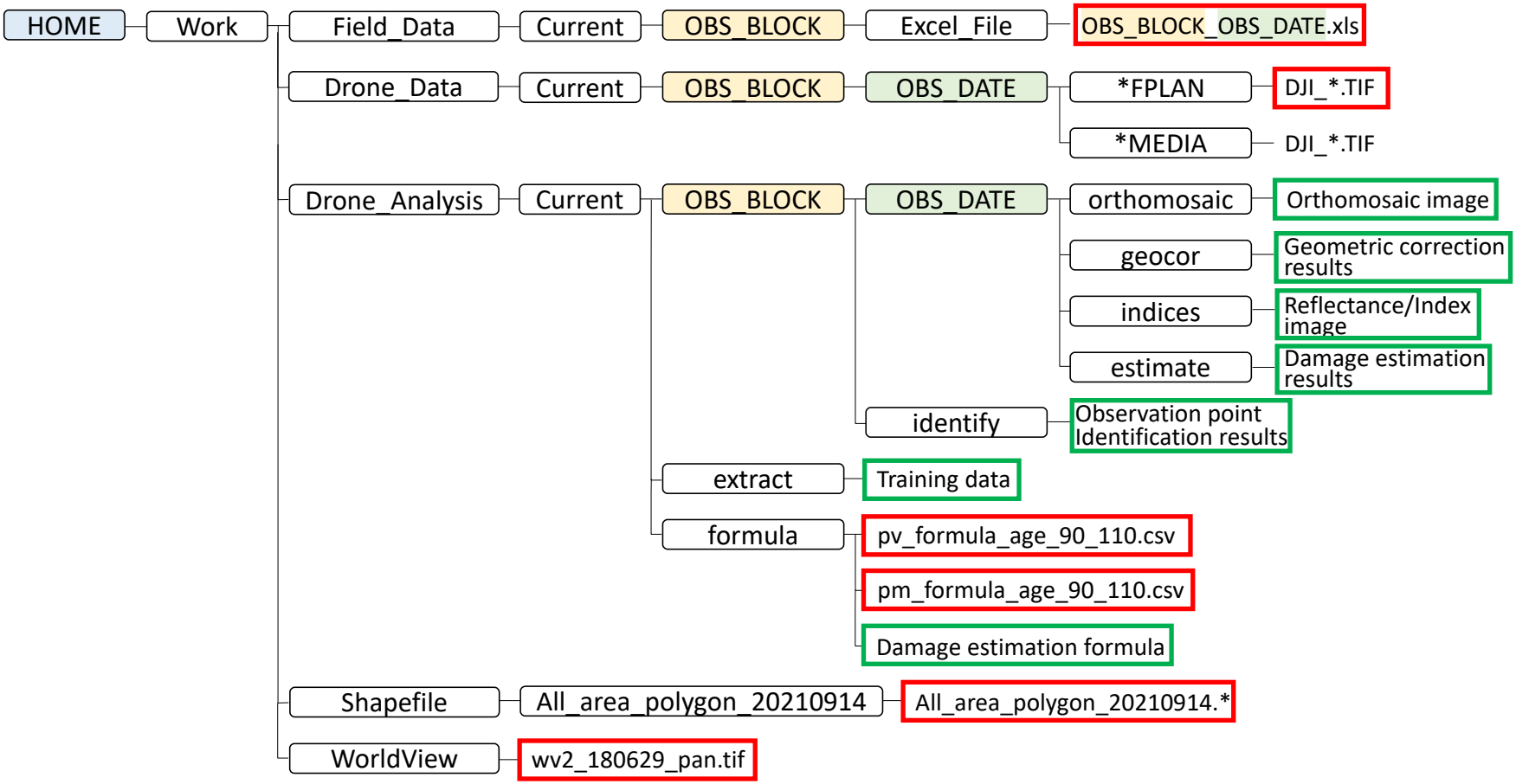

Fig.2 Data storage location with the default settings

※ HOME, OBS_BLOCK, and OBS_DATE are variables that depend on the analysis environment and the analysis target. (Ex: HOME = C: ¥Users¥satreps, OBS_BLOCK = Block-11B, OBS_DATE = 2022-04Apr-04)

※ "*" (asterisk) means any character string.

※ Files enclosed in red frame must be prepared beforehand. Files enclosed in green frame are automatically created by the tool.

- Processing Item Selection

  The Drone Tool has seven processing items listed in Table 1.

Table 1. Processing items of the Drone Tool

Processing Item	Short Name	Processing Content
Make Orthomosaic	orthomosaic	Create orthomosaic image
Geometric Correction	geocor	Geometric correction of orthomosaic image
Calculate Indices	indices	Create reflectance and index images
Identify Points	identify	Identify observation points
Extract Indices	extract	Prepare training data for damage estimation
Make Formula	formula	Create damage estimation formula
Estimate Damage	estimate	Estimate Damage

Check the check boxes for the processing items that you want to process. When the Set button 2 on the right side of each processing item is clicked, a sub-screen for performing detailed setting is displayed. If there is a fatal error in the detailed settings of the checked processing items, the red text of ERROR is displayed on the right side of Set button 2. If this happens, the cause may be that the file or folder required for the processing does not exist, so click the Set button 2 to check the detailed settings.

As an example, Fig. 2 shows a sub-screen of Make Orthomosaic. If the file or folder referenced by the tool does not exist, the red text of ERROR is displayed on the right side of the input field. In this example, Input Folders does not exist, so enter the correct folder name directly in the input field, or click the search icon at the right end of the input field and select the folder you want to enter from the displayed candidates. For setting items whose input field height is larger than one line as in this example, multiple candidates can be selected, and one selected candidate is displayed for each line. If you want to delete the entered folder, you can delete it by directly editing the input field. If there is no problem with the set value, the ERROR display disappears and changes to a green circle. If there is no file or folder that does not need to exist in advance, such as Panel Reflectance File on the same screen, a red x mark is displayed on the right side of the input field.

When setting/checking of setting items is completed, click Set Button 3 at the bottom of the sub screen to apply the setting and close the sub screen. In this case, if the ERROR display remains, the sub-screen cannot be closed. Click the Cancel Button to ignore the ERROR and close the sub screen. If the changes have not been applied, you can reset them by clicking the Reset button. When using the tool with the default settings, there is no need to change the detailed settings unless the red text of ERROR is displayed.

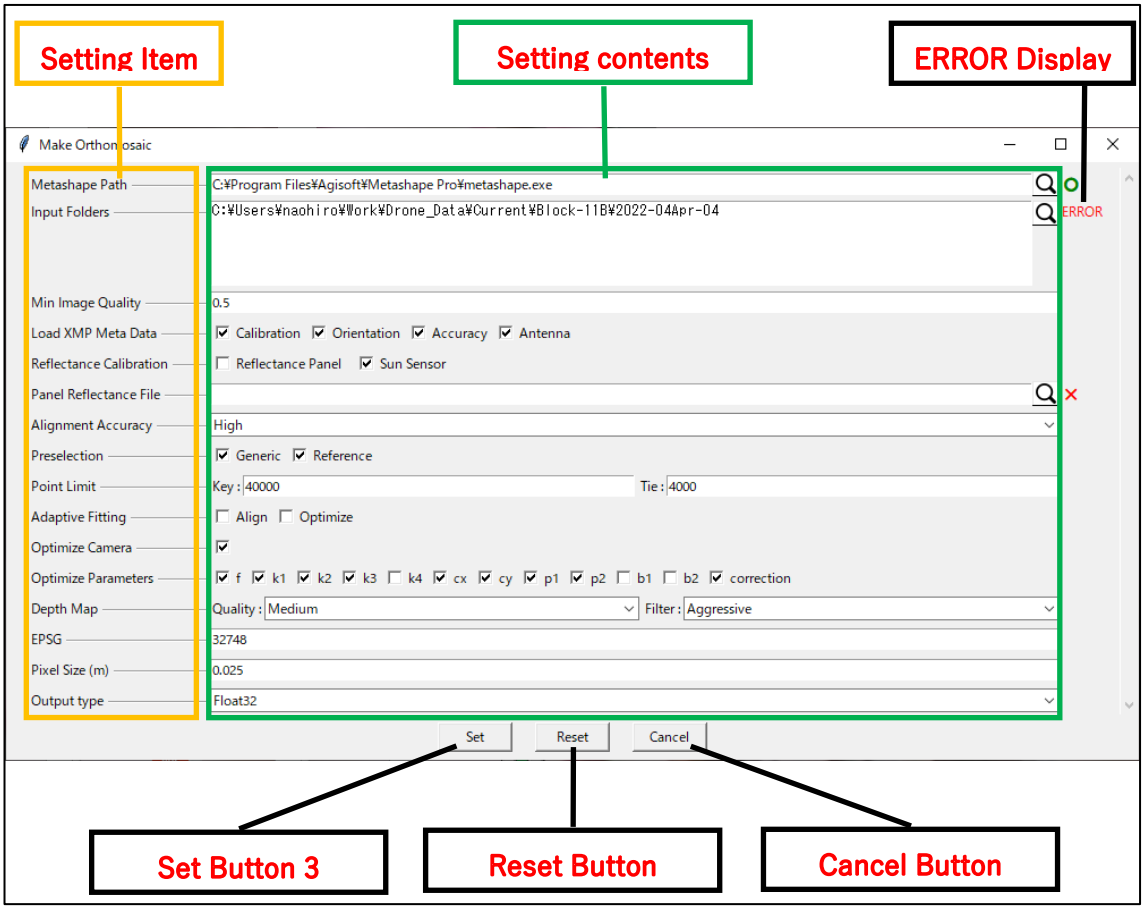

Fig.3. Drone Tool sub-screen example (Detailed setting screen of Make Orthomosaic)

- Run/Exit Button

  When you click the Run Button on the main screen, the checked processing items are processed in order. Click the Exit Button to close the main screen. However, since screen operations will not be accepted during processing of the processing items, click the x mark at the top right of the screen or enter Ctrl+C on the console screen to forcibly terminate.

3. Preparation before using Drone Tool

Before using the Drone Tool, it is necessary to prepare in advance five data sets (files enclosed in red frames in Fig. 2): field observation data, drone raw data, damage estimation formula, parcel data of the plots, and WorldView satellite data for geometric correction reference.

The following examples are for user name: satreps, observation block: Block-11B, observation date: 2022-04Apr-04.

① Field observation data

Folder: FIELD_DATA¥OBS_BLOCK¥Excel_File

File: OBS_BLOCK_OBS_DATE.xls

Ex: C: ¥Users¥satreps¥Work¥Field_Data¥Current¥Block-11B¥Excel_File¥Block-11B_2022-04Apr-04.xls

② Drone raw data

Parent Folder: DRONE_DATA¥OBS_BLOCK¥OBS_DATE

Folder: *FPLAN

File: DJI_*.TIF

Ex: C: ¥Users¥satreps¥Work¥Drone_Data¥Current¥Block-11B¥2022-04Apr-04¥101FPLAN¥DJI_0011.TIF

※ In the detailed setting screen of Make Orthomosaic, set the folder names (*FPLAN) that contain TIF files.

③ Damage estimation formula

Folder: DRONE_ANALYSIS¥formula

File(Point-value): pv_formula_age_90_110.csv

File(Plot-mean): pm_formula_age_90_110.csv

Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥formula¥pv_formula_age_90_110.csv

Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥formula¥pm_formula_age_90_110.csv

※ Damage estimation formula can be created using the Drone Tool, but it requires creating training data from a large number of drone images and field observation data. Therefore, the damage estimation formulas created in advance are used by default.

※ Two types of damage estimation formulas are required: Point-value and Plot-mean.

④　Parcel data of the plots

Parent Folder: HOME¥Work¥Shapefile

Folder: All_area_polygon_20210914

File: All_area_polygon_20210914.*

Ex: C: ¥Users¥satreps¥Work¥Shapefile¥All_area_polygon_20210914¥All_area_polygon_20210914.shp

⑤　WorldView satellite data for geometric correction reference

Folder: HOME¥Work¥WorldView

File: wv2_180629_pan.tif

Ex: C: ¥Users¥satreps¥Work¥WorldView¥wv2_180629_pan.tif

Once you have completed the above preparations, you can use the Drone Tool. Typical applications include the following:

- Calculate rice reflectances and indices from drone image and estimate BLB damage using existing BLB damage estimation formula (§4)
- Identify the observation points from drone images (§5)
- Extract the values at the observation points from the reflectance/index images and create training data for estimating BLB damage. (§6)
- Create BLB damage estimation formula from the training data (§7)

The following sections briefly explain how to do them.

4. How to estimate BLB damage (using the existing damage estimation formula)

To estimate BLB damage from the drone image using the existing estimation formula, check the processing items on the main screen as follows.

☑ Make Orthomosaic
☑ Geometric Correction
☑ Calculate Indices
☐ Identify Points
☐ Extract Indices
☐ Make Formula
☑ Estimate Damage

For the drone image, use the one at the growth stage (default is the harvest time) appropriate for the estimation formula. If you are ready as described in § 3, just click the Run button and everything will be processed automatically. However, if ERROR is displayed, check the detailed settings of the corresponding processing item. Figs 4 to 7 show examples of detailed setting screens for each processing item. Particular attention should be paid to the required files and folders in red frame. If ERROR is displayed, place the required file or folder in the location as set, or change the setting to refer to the correct file or folder. If the tool confirms the existence of the file or folder, a green circle will be displayed.

Since the files and folders in green frames are automatically created when the processing items are executed sequentially, they do not need to exist before processing. (If the existence of the file or folder is confirmed by the tool, a green circle is displayed, otherwise a red cross is displayed.)

However, when necessary processing is skipped, for example, by skipping the processing of Make Orthomosaic and starting with the processing of Geometric Correction, the file and folder in green frames must exist before the processing. If the file or folder that is supposed to be created automatically by following the normal procedure does not exist, ERROR is not displayed, but a red x is displayed. Since the process cannot be executed normally in this state, be sure to place the necessary file/folder in the specified location or change the settings to refer the correct file/folder, and confirm that the green circle is displayed before starting the process.

- Detailed settings of Make Orthomosaic

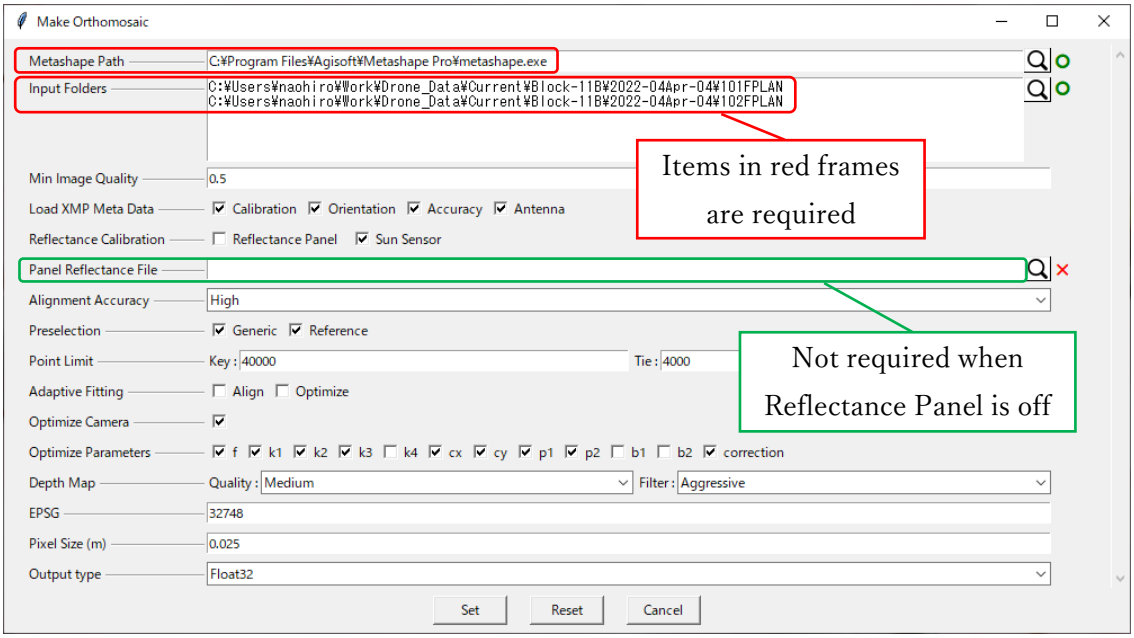

Fig.4. Detailed setting screen of Make Orthomosaic

- Detailed settings of Geometric Correction

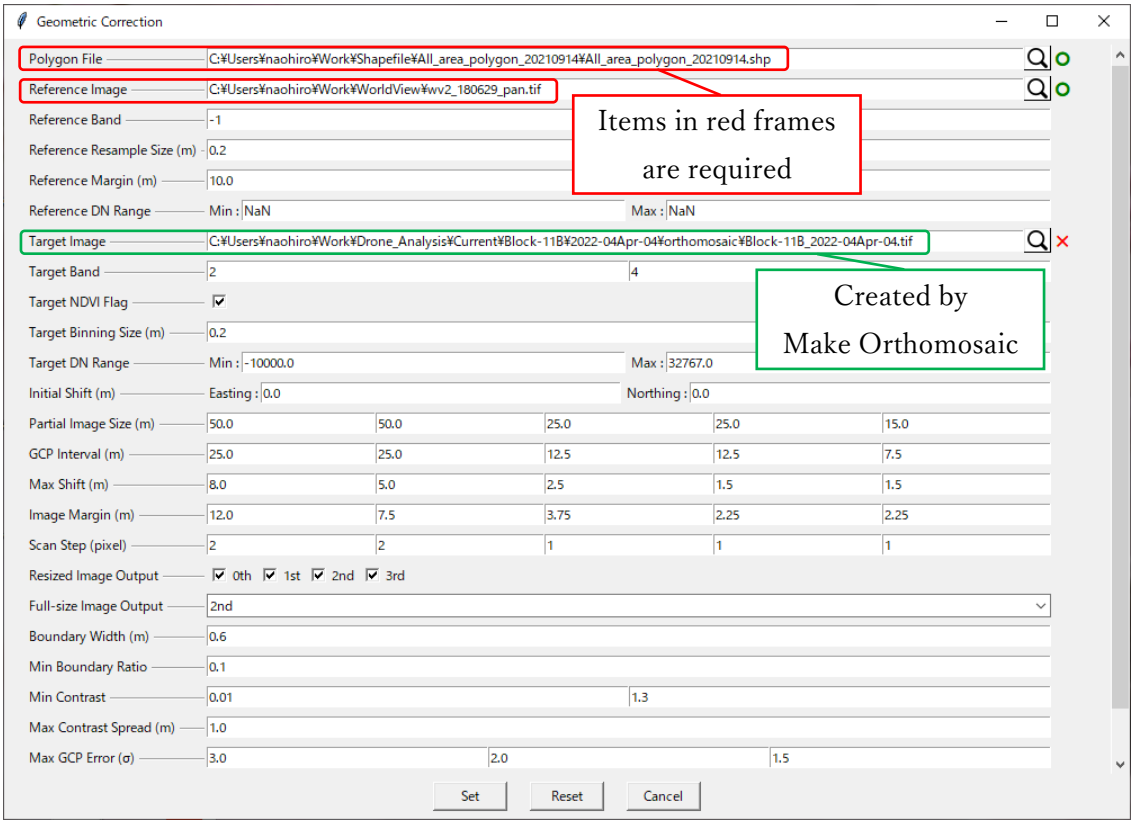

Fig.5. Detailed setting screen of Geometric Correction

- Detailed settings of Calculate Indices

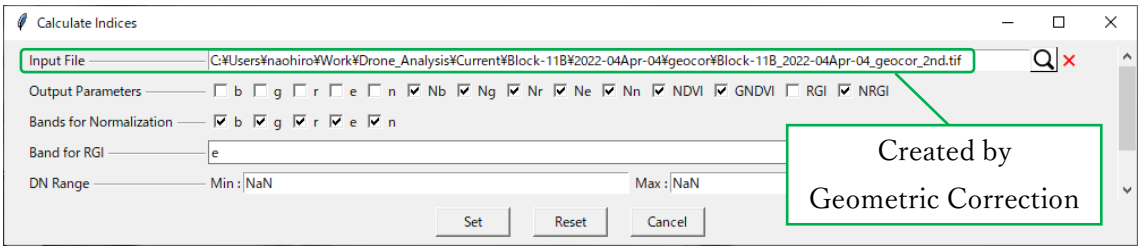

Fig.6. Detailed setting screen of Calculate Indices

- Detailed settings of Estimate Damage

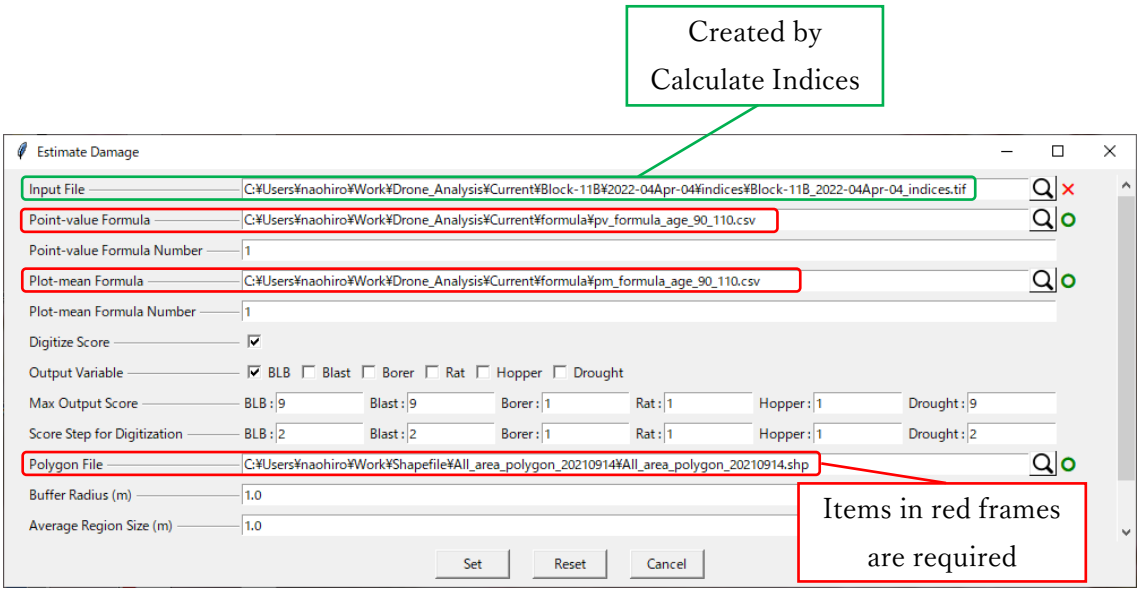

Fig.7. Detailed setting screen of Estimate Damage

Here are some points to check if each process has been completed successfully.

- Check the result of Make Orthomosaic
  - ✓ Check the report file created by the orthomosaic image creation software (Agisoft Metashape) to see if there are any problems with the camera calibration, camera position, etc.

  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥orthomosaic

  File: report.pdf

  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥orthomosaic¥report.pdf

- Check the result of Geometric Correction
  - ✓ Check the geometric correction result image and make sure that there is no large shift in the parcel position of the plots.

※ The parcel data of the plots was created using WorldView image acquired on June 29, 2018, and does not reflect plots that have changed since then.

Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥geocor

File: OBS_BLOCK_OBS_DATE_resized.pdf

Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥geocor¥Block-11B_2022-04Apr-04_resized.pdf

※ By default, images of geometric correction order 0th, 1st, 2nd, and 3rd are created, but only 2nd is used in the subsequent analyses.

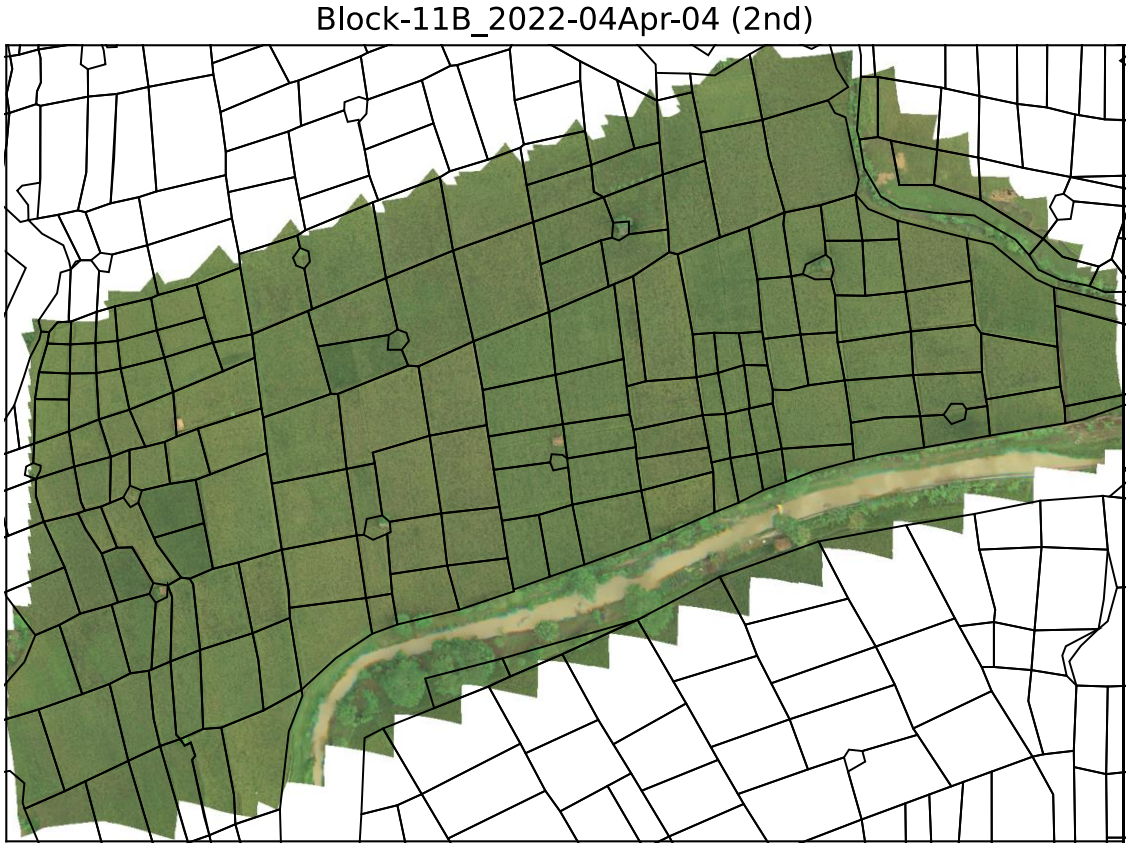

Fig.8. Example of geometric correction result image

- Check the result of Calculate Indices
  - ✓ Check the reflectance/index images to see if there is any problem in the reflectance/index values.

  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥indices

  File: OBS_BLOCK_OBS_DATE_indices.pdf

  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥geocor¥Block-11B_2022-04Apr-04_indices.pdf

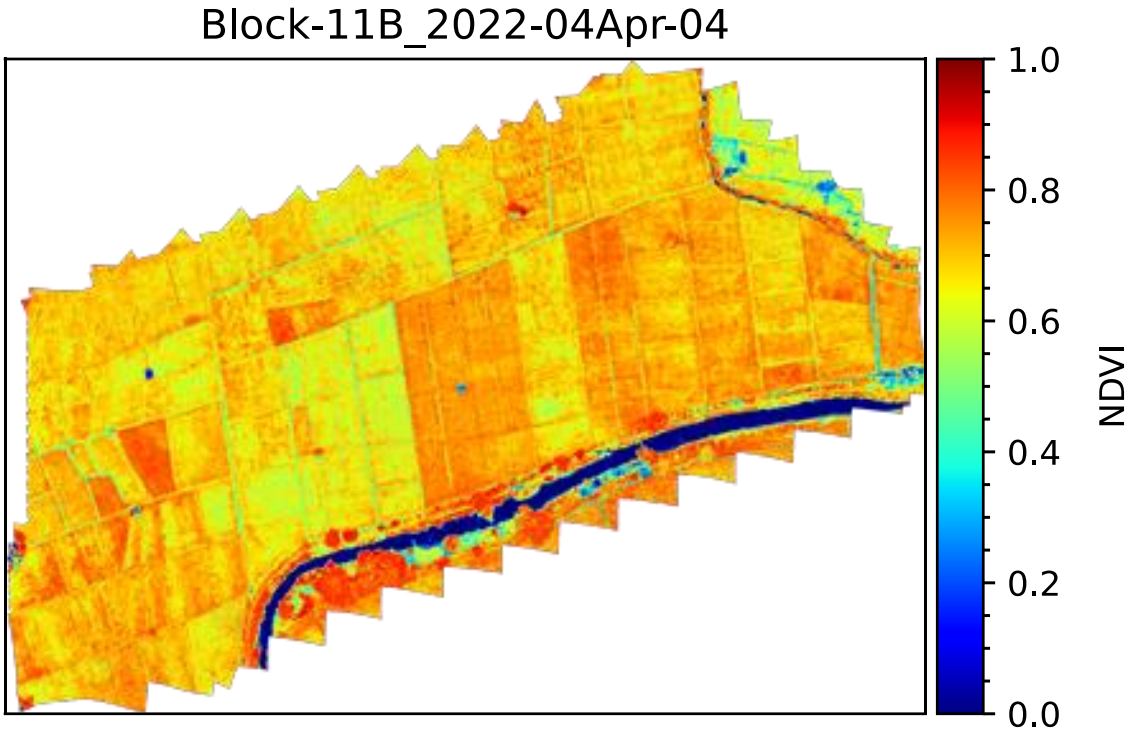

Fig.9. Example of reflectance/index image

- Check the result of Estimate Damage

  There are two methods to estimate the damage: one is by using an estimation formula created from the damage scores (10 of point-values per plot), and the other is by using an estimation formula created from the damage intensity (plot-mean calculated from the mean of 10 damage scores per plot).

  For both methods, the estimation formula is applied to the reflectance/index images averaged by 1-m mesh to estimate damage score (point-value) or intensity (plot-mean), and then damage intensity of each plot is calculated from the average of the estimated damage scores/intensities of the 1-m mesh within the plot. Therefore, each of the two methods produces estimates for 1-m mesh and plot to be checked.

✓ Check the estimated damage score/intensity of the 1-m mesh by point-value/plot-mean to see if there are any abnormalities.

Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥estimate

File(Point-value): OBS_BLOCK_OBS_DATE_pv_mesh.pdf

File(Plot-mean): OBS_BLOCK_OBS_DATE_pm_mesh.pdf

Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥estimate¥Block-11B_2022-04Apr-04_pv_mesh.pdf

Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥estimate¥Block-11B_2022-04Apr-04_pm_mesh.pdf

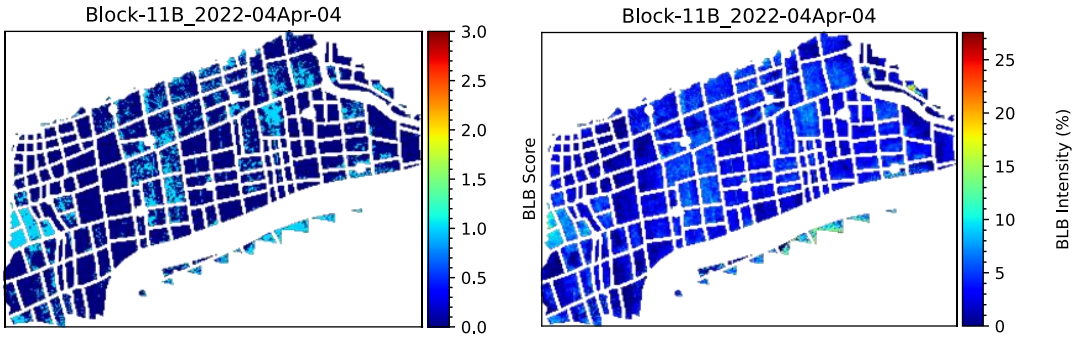

Fig.10. Example of estimated damage score(left)/intensity(right) of the 1-m mesh by point-value/plot-mean.

✓ Check the estimated damage intensity of the plots by point-value/plot-mean to see if there are any abnormalities.

Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥estimate

File(Point-value): OBS_BLOCK_OBS_DATE_pv_plot.pdf

File(Plot-mean): OBS_BLOCK_OBS_DATE_pm_plot.pdf

Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥estimate¥Block-11B_2022-04Apr-04_pv_plot.pdf

Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥estimate¥Block-11B_2022-04Apr-04_pm_plot.pdf

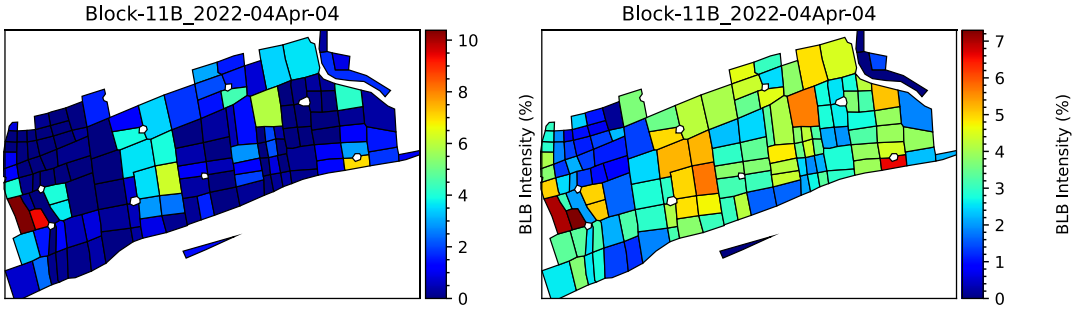

Fig.11. Example of estimated damage intensity of the plots by p-v(left)/p-m(right)

5. How to identify BLB score observation points

Before creating your own estimation formula, you need to identify the observation points in the drone image. Check the processing items on the main screen as follows.

☑ Make Orthomosaic
☑ Geometric Correction
☐ Calculate Indices
☑ Identify Points
☐ Extract Indices
☐ Make Formula
☐ Estimate Damage

The drone image should include the red observation point marker. (If the observation points are the same, an image of a different observation date with the image used to create the estimation formula may be used. The following example is for observation date: 2022-03Mar-01.) If you are ready as described in § 3, just click the Run button and everything will be processed automatically. However, if ERROR is displayed, check the detailed settings of the corresponding processing item. Fig. 12 is an example of detailed setting screen of Identify Points. Other detailed settings are the same as in § 4.

- Detailed settings of Identify Points

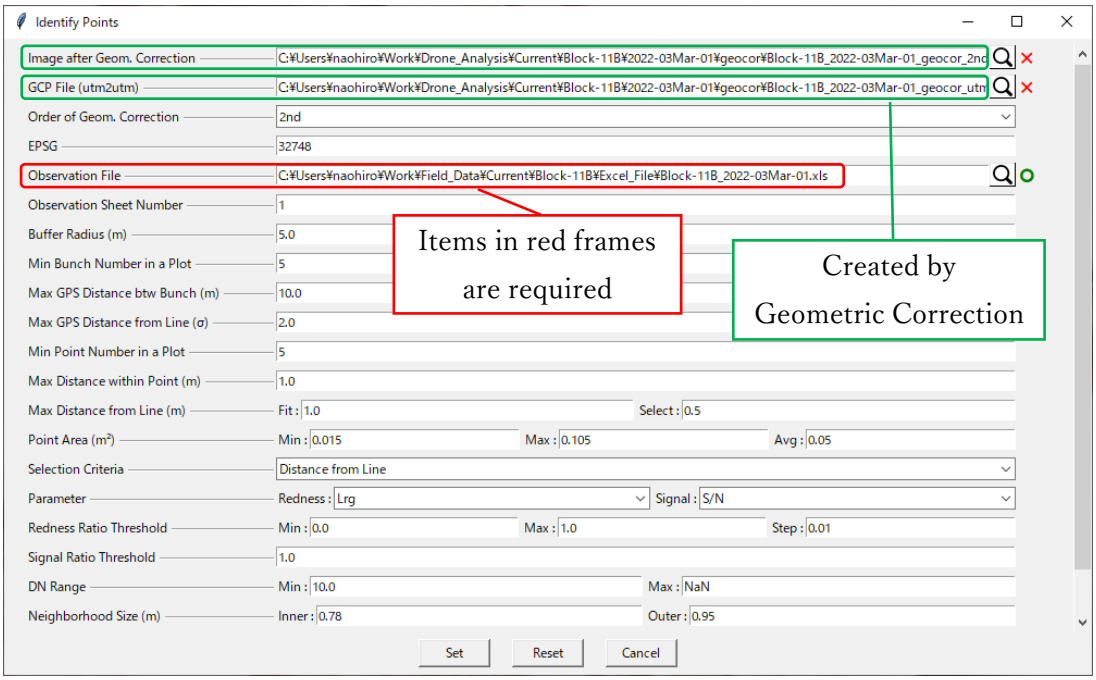

Fig.12. Detailed setting screen of Identify Points

Here are some points to check if Identify Points has been completed successfully.

- Check the result of Identify Points

In Identify Points, first, the rough position and the arrangement direction of the observation points are read from the GPS information in the observation data, and a subset image near the observation points of each plot is created from the geometrically-corrected orthomosaic image. Next, the redness ratio and the signal ratio are calculated from the subset image, and select points in a band-shaped region having appropriate area where the signal ratio is larger than a threshold value and the redness ratio is large.

✓ Check the RGB images before and after the observation-point identification and make sure that the identified observation points and the arrangement direction (numbering) are correct.

Folder: DRONE_ANALYSIS¥OBS_BLOCK¥identify

File(before identification): OBS_BLOCK_OBS_DATE_subset.pdf

File(after identification): OBS_BLOCK_OBS_DATE_identify.pdf

Ex(before identification): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥identify¥ Block-11B_2022-03Mar-01_subset.pdf

Ex(after identification): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥identify¥ Block-11B_2022-03Mar-01_identify.pdf

※ RGB images are on even pages (odd pages are band-shaped redness ratio images).

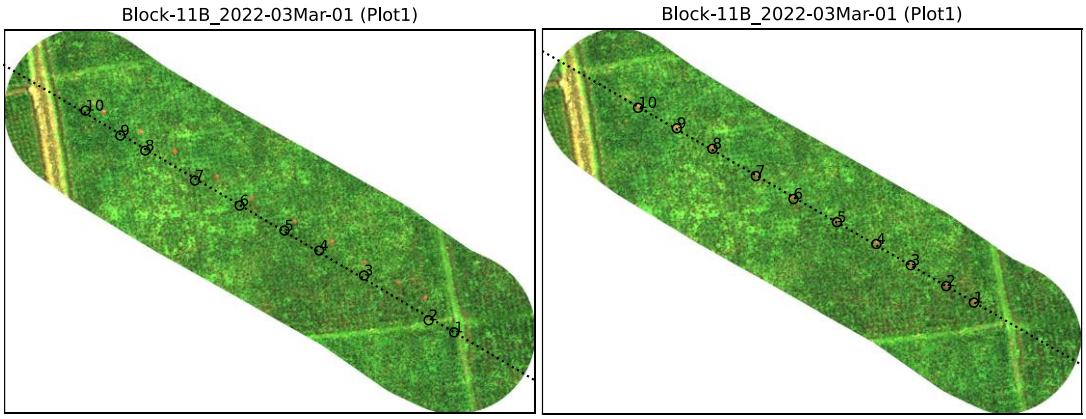

Fig.13. Examples of RGB images before (left) and after (right) the observation-point identification

✓ Check the redness/signal ratio images to see if there is any problem.

Folder: DRONE_ANALYSIS¥OBS_BLOCK¥identify

File: OBS_BLOCK_OBS_DATE_plot*_rr.pdf

Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥identify¥ Block-11B_2022-03Mar-01_plot1_rr.pdf

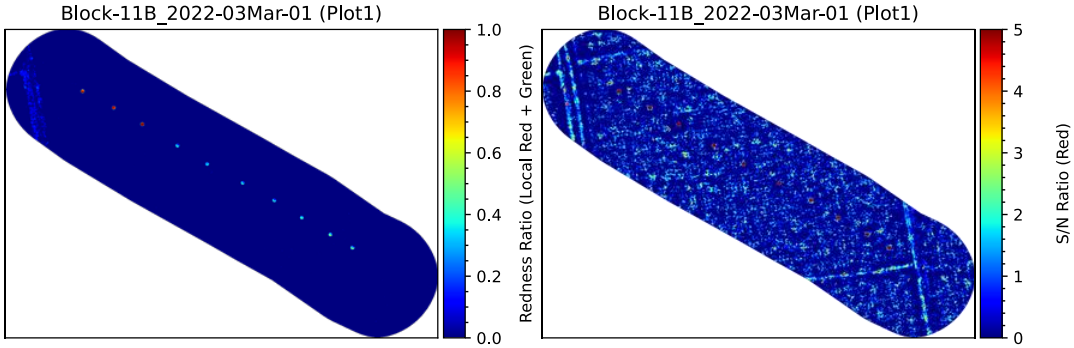

Fig.14. Example of redness ratio (left) and signal ratio (right) images

✓ Check the band-shaped redness ratio image to see if there is any problem.

Folder: DRONE_ANALYSIS¥OBS_BLOCK¥identify

File: OBS_BLOCK_OBS_DATE_identify.pdf

Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥identify¥ Block-11B_2022-03Mar-01_identify.pdf

※ Band-shaped redness ratio images are on odd pages (even pages are RGB images)

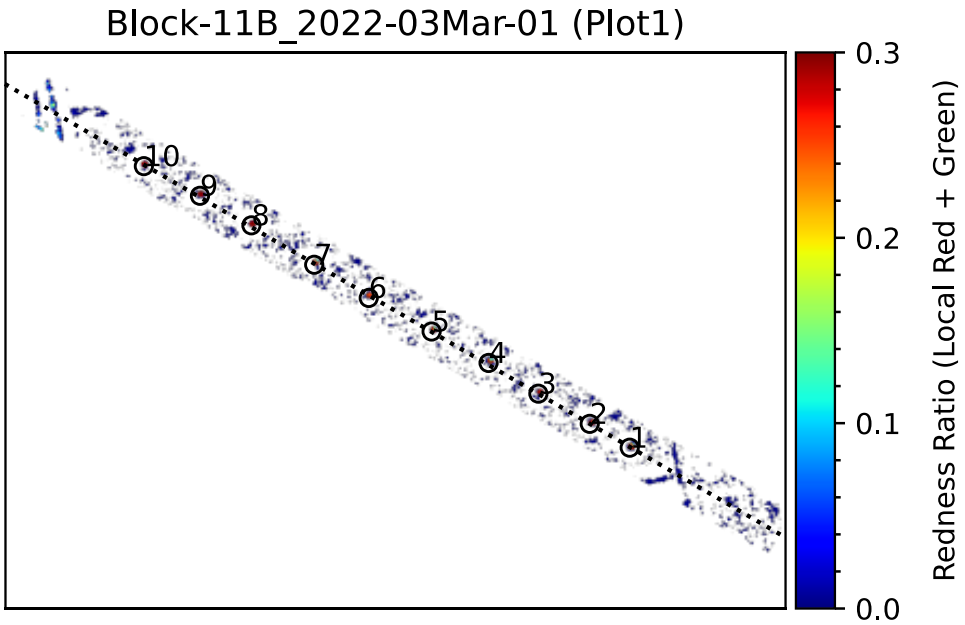

Fig.15. Example of band-shaped redness ratio image

6. How to create training data for BLB damage estimation

The Drone Tool estimates BLB score/intensity from reflectance and vegetation index of rice obtained from a Drone image, assuming linear relationship between BLB score/intensity and reflectance/index as shown in Figure 16. The damage estimation formula is a mathematical expression representing this straight line, and in order to make a formula, it is necessary to create scatter plots of reflectance/index and BLB score/intensity, as shown in Fig. 16, from a large number of observation data and Drone images.

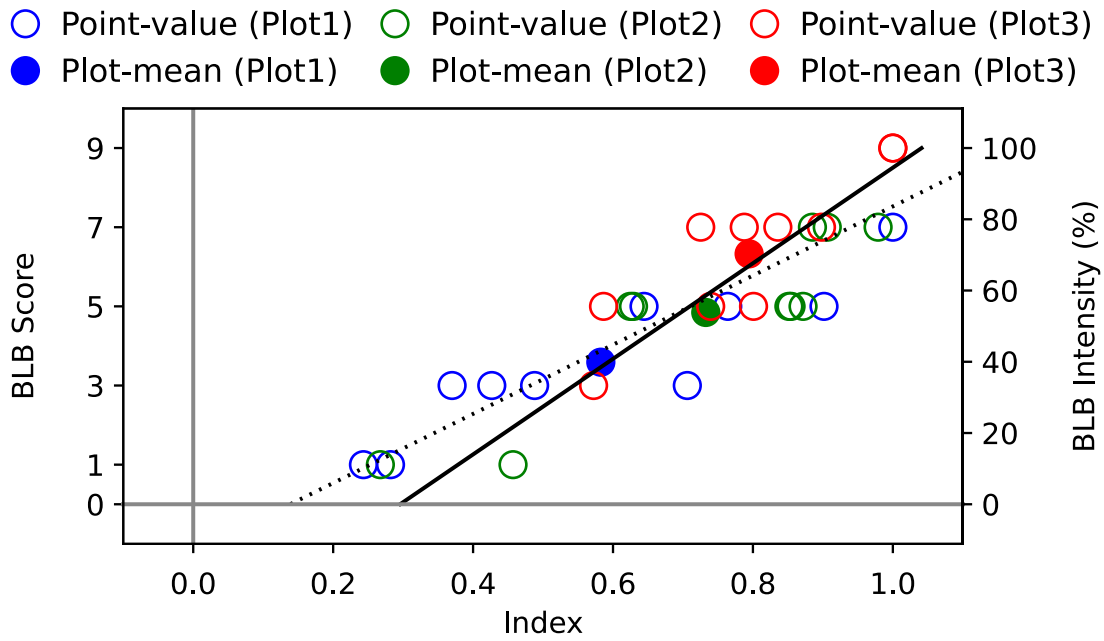

Fig.16. Image of BLB score/intensity estimation

A scatter plot showing the distribution of an index (horizontal axis) obtained from a drone image and the BLB score/intensity (vertical axis) obtained from a field observation. Black dotted line: Point-value BLB score estimation formula, Black solid line: Plot-mean BLB intensity estimation formula. In this figure, only points in one block are plotted, but in reality, more points in many blocks are needed.

Only one sample of plot-mean can be obtained from a plot (3 samples from a block), while 10 samples of point-value can be obtained from a plot (30 samples from a block). Therefore, a large number of field observation data/Drone images are required to create a scatter plot of plot-mean. As shown in Fig. 16, **it is desirable that BLB scores/intensities of observation data are evenly distributed from small values to large values. Otherwise, estimates may be biased toward some BLB scores/intensities**. For example, a damage estimation formula that never gives BLB scores above 5 may be created.

The data, on which the relationship between the BLB score/intensity and reflectance/ index is known, used to create the scatter plot is called training data. In order to create training data from a drone image after identifying the observation points, check the processing items on the main screen as follows.

☑ Make Orthomosaic
☑ Geometric Correction
☑ Calculate Indices
☐ Identify Points
☑ Extract Indices
☐ Make Formula
☐ Estimate Damage

For the drone image, use the one at the growth stage appropriate for the estimation formula to be created. (If the observation points are the same, an image of a different observation date with the image used to identify the observation points may be used.) If you are ready as described in § 3, just click the Run button and everything will be processed automatically. However, if ERROR is displayed, check the detailed settings of the corresponding processing item. Fig. 17 is an example of detailed setting screen of Extract Indices. Other detailed settings are the same as in § 4.

- Detailed settings of Extract Indices

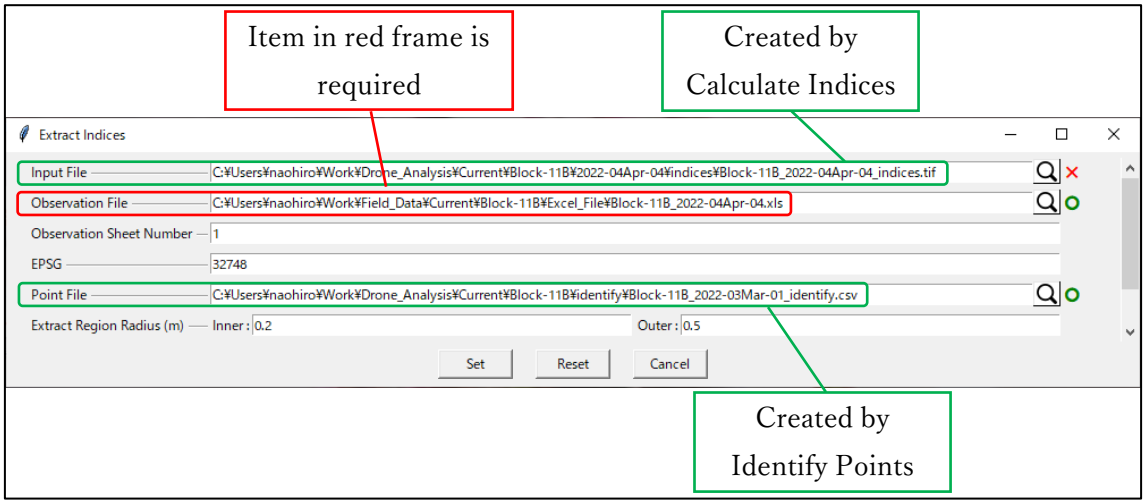

Fig.17. Detailed setting screen of Extract Indices

※ The first file found in the DRONE_ANALYSIS¥OBS_BLOCK¥identify folder is used

for the observation-point identification result (Point File).

Here are some points to check if Extract Indices has been completed successfully.

- ✓ Check the reflectance/index images and make sure that there is no problem with the reflectance/index extraction points.

Folder: DRONE_ANALYSIS¥extract

File: OBS_BLOCK_OBS_DATE_extract.pdf

Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥extract¥ Block-11B_2022-04Apr-04_extract.pdf

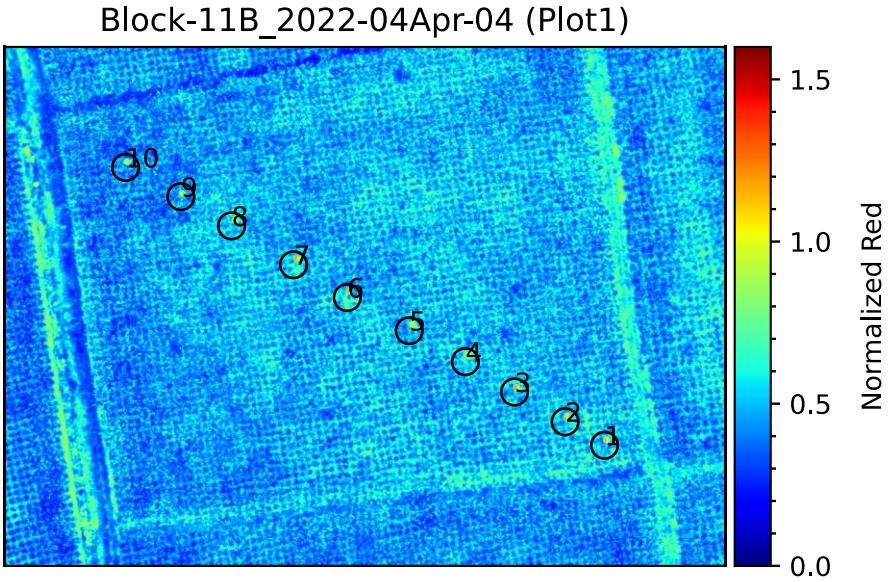

Fig.18. Example of reflectance/index image

7. How to create BLB damage estimation formula

If a sufficient number of training data are created from field observation data/drone images in multiple blocks, you can create a damage estimation formula. Check the processing items on the main screen as follows.

☐ Make Orthomosaic
☐ Geometric Correction
☐ Calculate Indices
☐ Identify Points
☐ Extract Indices
☑ Make Formula
☐ Estimate Damage

This process only requires training data. By default, all training data found in the DRONE_ANALYSIS¥extract folder will be used. Since it is desirable that the conditions which can affect the leaf color of rice plants other than the BLB damage (Growth stage, climate conditions, damage by diseases other than BLB and insects, amount of fertilizer, etc.) are the same as much as possible, training data should be prepared and selected with this in mind. By default, observation points with a damage intensity of 0.2 or higher other than BLB are excluded. The age range is 100 days before transplanting to 150 days after transplanting (i.e. not limited), but it can be limited by changing Age Range in the detailed settings.

Training data will contain multiple observation blocks and observation dates, but you don't have to enter them on the main screen. Instead, when the Age Range is limited to 80 to 100 days for example, set OBS_BLOCK = age and OBS_DATE = 80_100, then damage estimation formula having names such as pv_formula_age_80_100 .csv and pm_formula_age_80_100.csv will be created.

After selecting the training data, just click the Run button and everything will be processed automatically. However, if ERROR is displayed, check the detailed settings of Make Formula. Fig. 19 is an example of detailed setting screen of Make Formula.

- Detailed settings of Make Formula

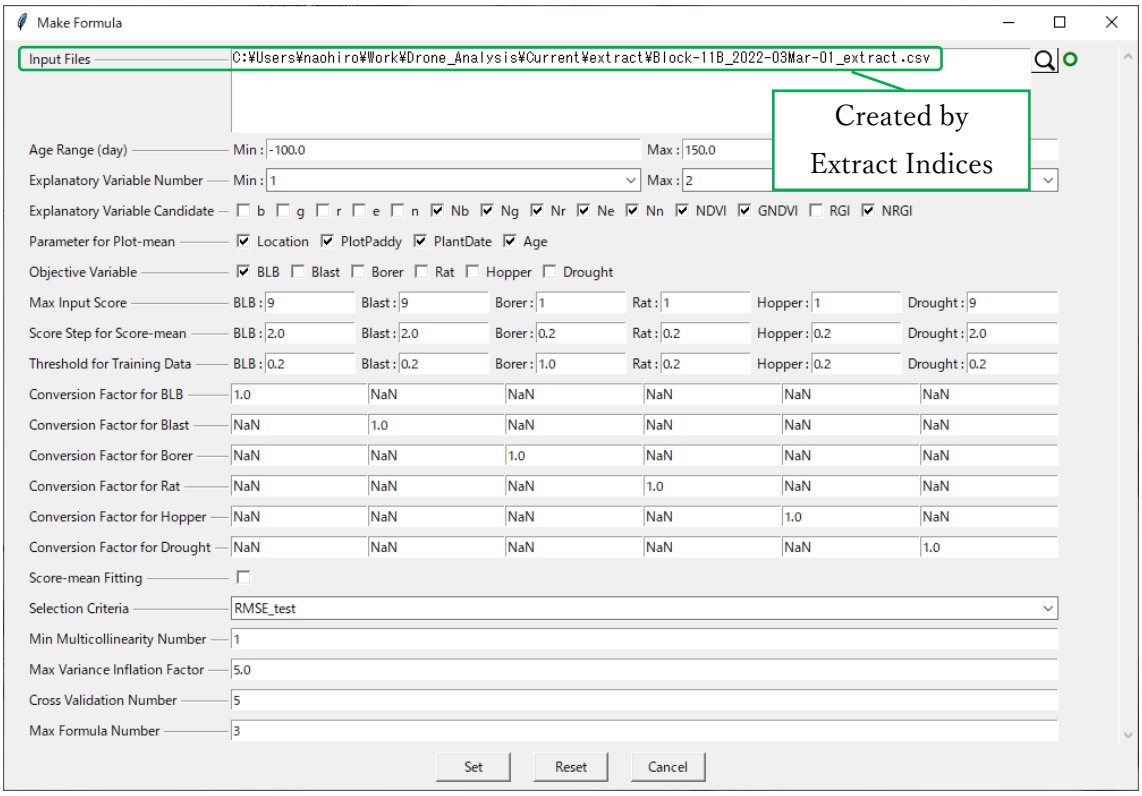

Fig.19. Detailed setting screen of Make Formula

Here are some points to check if Make Formula has been completed successfully.

✓ Check the scatter plots of reflectance/index and observed BLB score for point-value/plot-mean and make sure that there is a reflectance/index that has a high correlation with the observed BLB score, and that there is no bias in the distribution of observed BLB score.

Folder: DRONE_ANALYSIS¥formula

File(Point-value): pv_formula_OBS_BLOCK_OBS_DATE.pdf

File(Plot-mean): pm_formula_OBS_BLOCK_OBS_DATE.pdf

Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥intensity¥pv_formula_age_80_100.pdf

Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥intensity¥pm_formula_age_80_100.pdf

※ Scatter plots of reflectance/index and observed BLB score are in the first half of the PDF (last half are scatter plots of observed and estimated BLB scores).

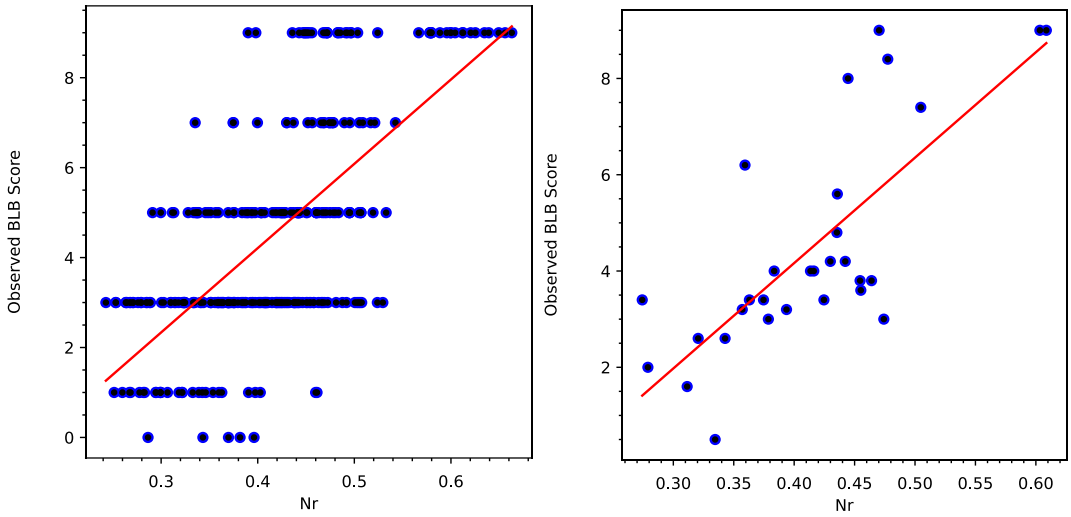

Fig.20. Examples of scatter plots of reflectance/index and observed BLB score by point-value (left) and plot-mean (right).

- ✓ Check the scatter plots of observed and estimated BLB scores by point-value/plot mean and make sure that there is no large estimation error.

Folder: DRONE_ANALYSIS¥formula

File(Point-value): pv_formula_OBS_BLOCK_OBS_DATE.pdf

File(Plot-mean): pm_formula_OBS_BLOCK_OBS_DATE.pdf

Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥intensity¥pv_formula_age_80_100.pdf

Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥intensity¥pm_formula_age_80_100.pdf

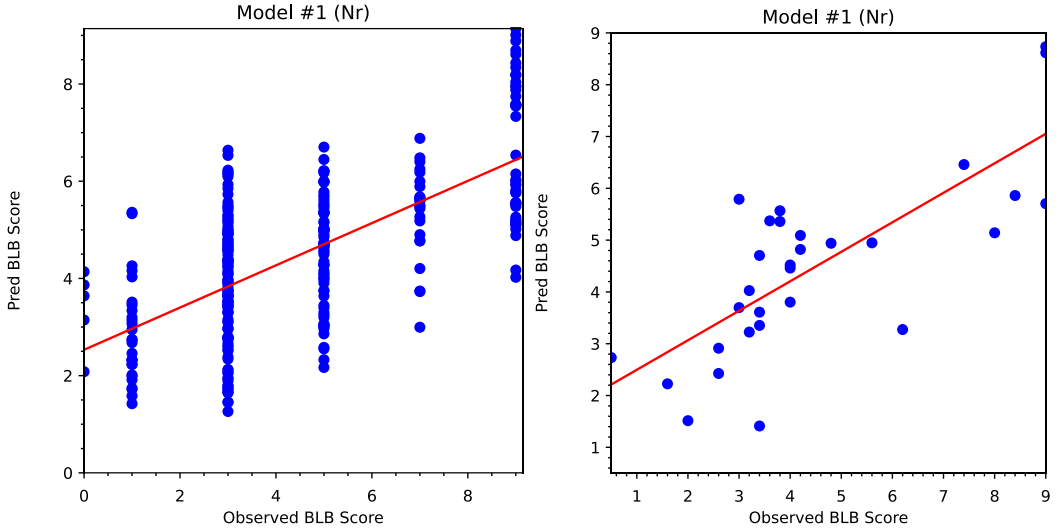

Fig.21. Examples of scatter plots of observed and estimated BLB score by point-value (left) and plot-mean (right)

Appendix 1. Troubleshooting

Here are some of the problems that can occur when using the Drone Tool with the default settings and how to troubleshoot them.

- File or folder is not recognized by the tool and an ERROR or x mark is displayed.
  - Do not include spaces in the names of files and folders, as this can cause problems. Note the difference between "-" (hyphen) and "_" (underscore).

- Processing is aborted due to an error.
  - If there is no enough free space to save the processing results, the processing will be aborted, so secure enough free space to prevent it. If the result confirmation image created by the same process performed previously is opened in a viewer, the image cannot be overwritten and the process will be aborted. In this case, close the viewer screen and then start the process. Similarly, when a previously created CSV file, etc. is opened, the file cannot be overwritten and the processing will be aborted. Also, when a necessary preprocessing is skipped and subsequent processing is performed (to execute a continuation of the processing previously performed, for example), an error may occur and the processing may be aborted if a file or folder that is supposed to be created by the preprocessing does not exist. If you want to skip the required preprocessing, check the detailed settings and make sure that the tool confirms the files and folders that should have been created by the preprocessing (marked with a green circle).

- There is a large shift in the results of the geometric correction.
  - Possible causes of the shift in the geometric-correction result are that (1) there are too few plots in the drone image, (2) the boundary of the plot is covered with rice or weeds and the contrast with the inside of the plot is small, (3) the shift of the Drone image from the reference image exceeds the expected range, and (4) there are many plots whose boundary have been changed after the creation of the parcel data of the plots. One possible solution is to change the values for Partial Image Size, Min Contrast (the second input field), Max GCP Error, Max Contrast Spread, Max Shift, and Initial Shift in the detailed settings of Geometric Correction. (If the Partial Image Size is changed, the GCP Interval should be half to the same value.) If the shift is small for the order other than 2nd in the geometric-correction result image, the value of Full-size Image Output may be changed to the order with small shift.

- The identified observation points are wrong.
  - If there is a red object about 10 ~ 30 cm in diameter near the observation point markers, it may be mistakenly identified as an observation point marker. As a workaround, in the detailed settings of Identify Points, reduce the value of Max Distance from Line (Select), change the values of Point Area (Min, Max, Avg), set Selection Criteria to Point Area, and change the value of Parameter (Redness) so that only the observation-point markers are selected. As a final means, it is also possible to visually identify the observation-point marker using GIS software like ArcGIS, and manually rewrite the coordinates (EastingI, NorthingI) of the observation-point identification result.

- Damage estimation formula is not created.
  - If the number of training data is too small, the damage estimation formula may not be created. In this case, increase the number of training data and then create the damage estimation formula. Even if the number of training data is large, the number of remaining training data may be small if data with large damage intensities other than BLB, such as Blast, are excluded. Basically, the solution in this case is to increase the number of training data with small damage intensity other than BLB. However, if you really want to use training data with large damage intensity other than BLB, you can change the values of Threshold for Training Data in the detailed settings of Make Formula. (If the threshold of the corresponding damage intensity is set to 1, the training data will not be excluded by the damage intensity.)

    Note that if the damage other than BLB is large in the target field, the BLB intensity estimated by applying the BLB damage estimation formula is the damage intensity other than BLB converted to the damage intensity equivalent to BLB.

- Only one reflectance or index is included in the damage estimation formula.
  - The Drone Tool checks the correlation (multicollinearity) between reflectance and indices and excludes reflectance and index pairs that include variables with an index called Variance Inflation Factor (VIF) greater than the threshold. By default, one damage estimation formula includes up to two reflectances/indices, but depending on the threshold of VIF, only one reflectance/index may be included. If the value of Min Multicollinearity Number is increased or the value of Max Variance Inflation Factor is increased in the detailed settings of Make Formula, the damage estimation

formula will include many reflectances and indices.

- The distribution of reflectance/index and observed BLB score for creating the damage estimation formula is to wide.
  - The reason why the distribution of reflectance/index and observed BLB score widens is considered to be the difference in the conditions of the training data used (conditions that can affect leaf color of rice other than BLB damage rate, such as growth stage). It is necessary to select training data with the same conditions other than BLB damage as much as possible. By changing the values of Age Range and Threshold for Training Data in the detailed settings of Make Formula, it is possible to limit the number of days after transplanting and the damage other than BLB.

Appendix 2. Main file/folder names referenced/created by the tool

※ Reference-only files and folders are not automatically created by the tool and must be prepared in advance.

- Observation data (Reference only):
  Folder: FIELD_DATA¥OBS_BLOCK¥Excel_File
  File: OBS_BLOCK_OBS_DATE.xls
  Ex: C: ¥Users¥satreps¥Work¥Field_Data¥Current¥Block-11B¥Excel_File¥Block-11B_2022-04Apr-04.xls

- Storage folder for drone raw data (Reference only):
  Parent Folder: DRONE_DATA¥OBS_BLOCK¥OBS_DATE
  Folder: *FPLAN
  Ex: C: ¥Users¥satreps¥Work¥Drone_Data¥Current¥Block-11B¥2022-04Apr-04¥101FPLAN

- Orthomosaic image (Create, Reference):
  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥orthomosaic
  File: OBS_BLOCK_OBS_DATE.tif
  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥orthomosaic¥Block-11B_2022-04Apr-04.tif

- Geometrically corrected orthosaic image (Create, Reference):
  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥geocor
  File: OBS_BLOCK_OBS_DATE_geocor_2nd.tif
  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥geocor¥Block-11B_2022-04Apr-04_geocor_2nd.tif
  ※ The “2nd ” part depends on the detailed setting of Geometric Correction.

- Reflectance/Index image (Create, Reference):
  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE¥indices
  File: OBS_BLOCK_OBS_DATE_indices.tif
  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥indices¥Block-11B_2022-04Apr-04_indices.tif

- Observation-point identification results (Create, Reference):
  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥identify
  File: OBS_BLOCK_OBS_DATE_identify.csv
  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥identify¥Block-11B_2022-03Mar-01_identify.csv

- Training data for damage estimation (Create, Reference)
  Folder: DRONE_ANALYSIS¥extract
  File: OBS_BLOCK_OBS_DATE_extract.csv
  Ex: C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥extract¥Block-11B_2022-04Apr-04_extract.csv

- Damage estimation formula (Create):
  Folder: DRONE_ANALYSIS¥formula
  File(Point-value): pv_formula_OBS_BLOCK_OBS_DATE.csv
  File(Plot-mean): pm_formula_OBS_BLOCK_OBS_DATE.csv
  Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥formula¥pv_formula_age_80_100.csv
  Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥formula¥pm_formula_age_80_100.csv

- Damage estimation results (Create)
  Folder: DRONE_ANALYSIS¥OBS_BLOCK¥OBS_DATE ¥estimate
  File(Point-value): OBS_BLOCK_OBS_DATE_pv_plot.csv
  File(Plot-mean): OBS_BLOCK_OBS_DATE_pm_plot.csv
  Ex(Point-value): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥estimate¥Block-11B_2022-04Apr-04_pv_plot.csv
  Ex(Plot-mean): C: ¥Users¥satreps¥Work¥Drone_Analysis¥Current¥Block-11B¥2022-04Apr-04¥estimate¥Block-11B_2022-04Apr-04_pm_plot.csv