Satellite-version BLB Damage Assessment Tool

Satellite Tool Version 1.0

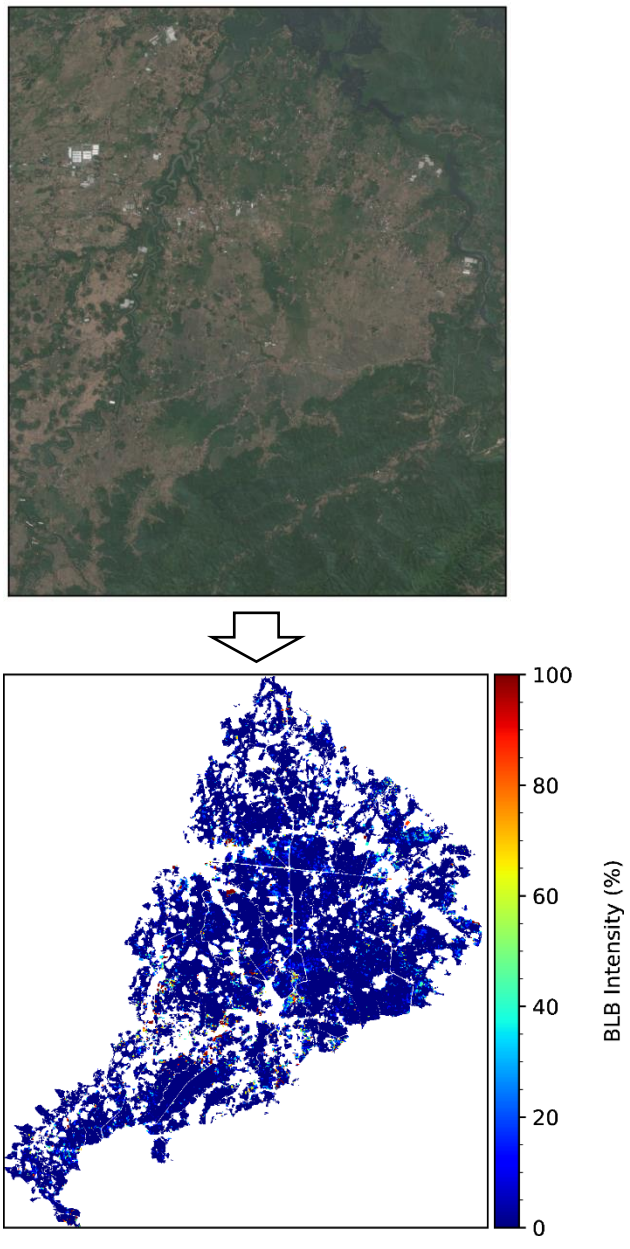

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Table of contents

1. Introduction....2
2. Main screen....3
3. Processing item....6
4. How to preprocess satellite data....10
5. How to estimate damage intensity at the time of damage assessment for each field using existing estimation formula....21
6. How to estimate damage intensity on specific satellite-image acquisition date using existing estimation formula....26
7. How to create training data using interpolated data....27
8. How to create training data using specific satellite images....30
9. How to create a damage intensity estimation formula....32
Appendix 1. Data Storage Location....35
Appendix 2. How to estimate the growing stage....36
Appendix 3. How to set the growth stage of Make Formula and Estimate Damage....37
Appendix 4. Change of target area....38

1. Introduction

The satellite version of the BLB damage assessment tool (Hereafter referred to as Satellite Tool or simply Tool) has the 6 functions shown in Figure 1 -1, and it is a tool to estimate the BLB damage intensity related to them from the information of rice color (spectral reflectance and vegetation index) obtained from the Sentinel-2 satellite image (Below, Sentinel-2 images). The quick start guide explains how to use the Satellite Tool primarily for initial setup (the default setting), while a separate manual explains how to make detailed configuration changes. By default, the target area is Cihea, but it is possible to estimate BLB damage intensities in areas other than Cihea, such as Bojongsoang, by changing the polygon data (details are explained in Appendix 4).

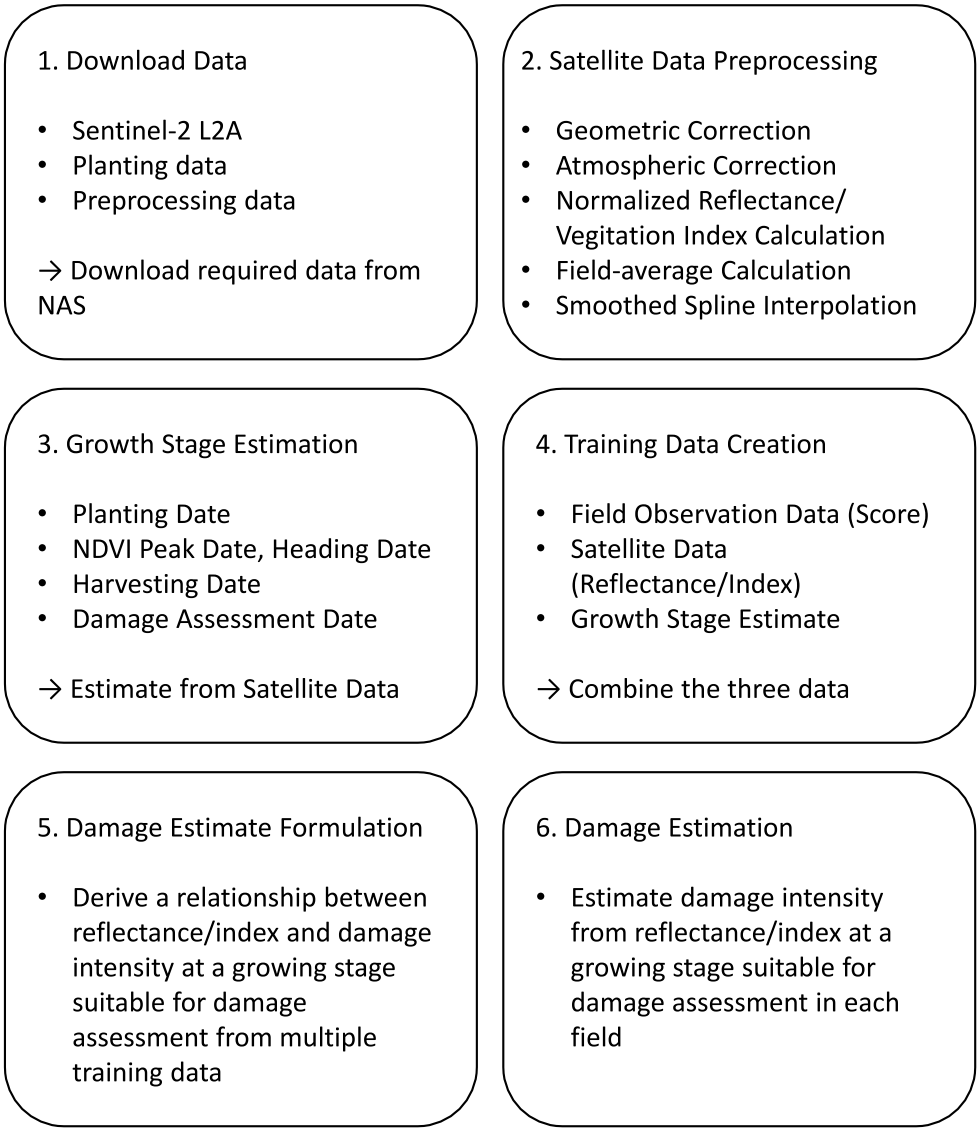


Fig. 1-1. Six functions of Satellite Tool

2. Main screen

Sentinel-2 image and drone image have the differences listed in Table 2-1 and Satellite Tool have a slightly different user interface than the drone version damage assessment tool (Below, Drone Tool) (Figure 2 -1).

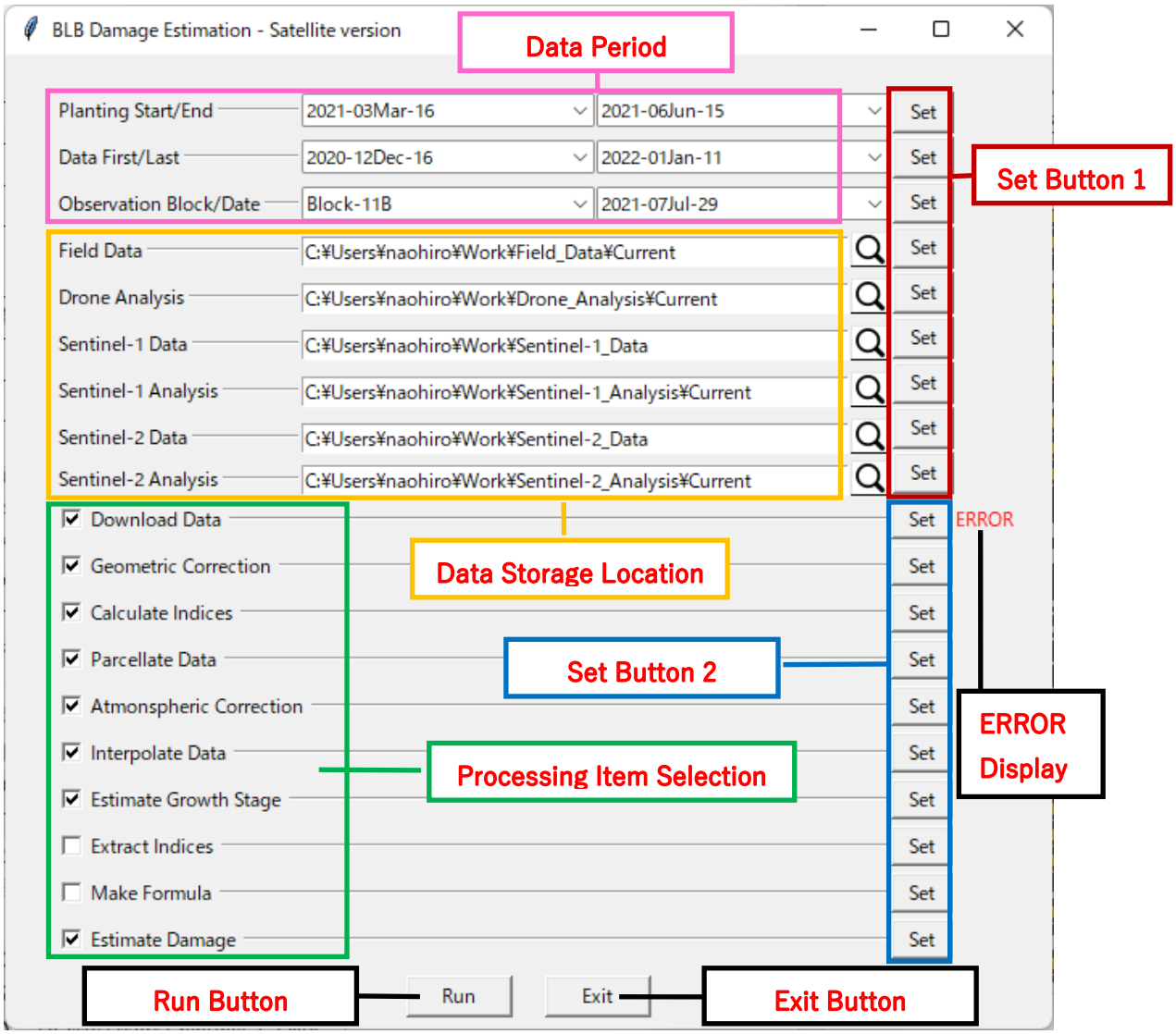


Fig. 2-1. Main screen of Satellite Tool

For Planting Start/End, enter the first and last days of the transplanting period (different from the cultivation period, hereafter referred to as START_DATE and END_DATE), for Data First/Last, enter the first and last days of the satellite data acquisition period (FIRST_DATE, LAST_DATE), and for Observation Block/Date, enter the block and date of field observation data (OBS_BLOCK, OBS_DATE) (details will be explained in sections 4 to 9, depending on the nature of the process).

Table 2-1. Differences Between Drone Image and Sentinel-2 Image

	Drone Image	Sentinel-2 Image
Data Acquisition	Obtained by Pest Observer	Download from Web
Spatial Resolution	About 2.5 cm	About 10 m
Image range	Single Image : About 40 m x 40 m All images : 1 irrigation block	Whole Cihea
Effects of cloud scattering	Insusceptible	Susceptible
Influence of cloud shadows	Susceptible	Susceptible
BLB damage assessment timing	Known for each irrigation block	Estimation required for each field

In the data storage location, enter the storage locations of field survey data, drone analysis data, Sentinel-1 preprocessing data, Sentinel-1 analysis data, Sentinel-2 preprocessing data, and Sentinel-2 analysis data. (Drone analysis data is not used by default.) It is better to separate field survey data and analysis data of drone, Sentinel-1 and Sentinel-2 from those with different years and crop seasons. By default, the analysis data for the target year and crop season is saved in the Current folder. When a year or crop period changes, it is advisable to rename the Current folder to a folder name where the year or crop period can be understood (e.g., 2021-03Mar_2021-09Sep) and save the analysis data of the new year or crop period in the newly created Current folder. On the other hand, preprocessing data for Sentinel-1 and Sentinel-2 should be stored in the same place regardless of the year or crop season. In the following descriptions, each storage location is referred to as FIELD_DATA, DRONE_ANALYSIS, S1_DATA, S1_ANALYSIS, S2_DATA, S2_ANALYSIS. If the location pointed to by the Windows environment variable USERPROFILE (usually C:¥Users ¥username) is expressed as HOME, the default setting is as follows (see Appendix 1 for details) :

FIELD_DATA = HOME¥Work¥Field_Data¥Current
DRONE_ANALYSIS = HOME¥Work¥Drone_Analysis¥Current
S1_DATA = HOME¥Work¥Sentinel-1_Data
S1_ANALYSIS = HOME¥Work¥Sentinel-1_Analysis¥Current
S2_DATA = HOME¥Work¥Sentinel-2_Data
S2_ANALYSIS = HOME¥Work¥Sentinel-2_Analysis¥Current

Advanced Note : You can also change the data storage location by editing the configuration file named satellit e_config.ini in the Python script storage location (HOME¥SatelliteTool by default). You can change each location individually, but if you change the value of top_dir from% (HOME) s/Work to F:¥Work, for example, you can change the location to F drive all at once. A # at the beginning of the line means comment out and the setting is disabled. All default settings can also be changed via satellite_config.ini (See Appendix 4 for examples of satellite_config.ini).

#top_dir = %(HOME)s/Work
top_dir = F:¥Work
field_data = %(top_dir)s/Field_Data/Current
drone_analysis = %(top_dir)s/Drone_Analysis/Current
s1_data = %(top_dir)s/Sentinel-1_Data
s1_analysis = %(top_dir)s/Sentinel-1_Analysis/Current
s2_data = %(top_dir)s/Sentinel-2_Data
s2_analysis = %(top_dir)s/Sentinel-2_Analysis/Current

After entering the data period and data storage location, you need to click the Set button 1 on the right side of the entry field to apply the settings. Reflecting the settings will also change the relevant detailed settings for each processing item. Settings that don't reflect changes are shown in red text.
Advanced Note : If, for example, you want to use data from a different storage location than the default, you can add "! " at the beginning of the settings in satellite_config.ini to disable automatic changes.
Ex. geocor.l2a_dir = !F:¥Work/Sentinel-2_Data/Bojongsoang/L2A

3. Processing item

Satellite Tool has 10 processing items listed in Table 3-1. Some of the processing items are not in the Drone Tool and are new to the Satellite Tool.

The Sentinel -2 image (L2A product) for the target region is downloaded from NAS on the web. Planting date estimation data necessary for BLB damage assessment time estimation, which will be described later, is also downloaded from the NAS. The five items of Geometric Correction, Calculate Indices, Parcell Data, Atmospheric Correction and Interpolate Data are pre-processing for BLB damage intensity estimation. They can also be downloaded from the NAS instead of performing it yourselves (Download Data).

Geometric correction and calculations of normalized reflectance and vegetation index are similar to the Drone Tool. Since Sentinel-2 images have poor spatial resolution compared to drone and do not provide detailed field information, the average reflectance and index values for each field are calculated and used in the analysis (Parcellate Data). In addition, since it is not possible to identify observation points placed at intervals of several meters, the process item (Identify Points) for identifying survey points in the Drone Tool does not exist in the Satellite Tool.

The L2A product provides atmosphere-corrected bottom of atmosphere reflectance, but it does not completely remove the effects of scattering from cirrus clouds and other sources. Therefore, the atmospheric correction is performed so that the reflectance of the reference point around the field, where the reflectance originally does not change with time, is constant. (Atmospheric Correction).

Since the relationship between BLB damage intensity and reflectance/index varies depending on the growth stage of rice plants grown in the target area, it is necessary to use reflectance/index data at a specific growth stage to assess BLB damage using a specific relationship. However, because there is no data on the growth stage of the entire target area, time series data such as NDVI are prepared (Interpolate Data), and the appropriate time for BLB damage assessment for each field is estimated from the time-series data (Estimate Growth Stage). In the generation of time-series data, smoothed spline interpolation is used to reduce the influence of noise due to errors in atmospheric correction, etc., and to obtain the reflectivity and index of days not observed by satellites.

Others, i.e. Extract Indices, Make Formula and Estimate Damage, are similar to the Drone Tool.

Table 3-1. Processing items of Satellite Tool

#	Processing item	Short Name	Processing content
1	Download Data	download	Download required data
2	Geometric Correction	geocor	Align satellite images with field polygon data
3	Calculate Indices	indices	Calculate normalized reflectance and Vegetation index
4	Parcellate Data	parcel	Calculate field average of reflectance/index
5	Atmospheric Correction	atcor	Remove cirrus and haze effects from reflectance/index
6	Interpolate Data	interp	Remove noise from time series data of reflectance/index and interpolate data at 1-day intervals
7	Estimate Growth Stage	phenology	Estimate the growth stage (planting date, NDVI peak date, heading date, harvesting date, damage intensity assessment date) for each field
8	Extract Indices	extract	Create training data by associating field observation data with reflectivity/index data and growth stage data
9	Make Formula	formula	Create damage intensity estimation formula from training data at the appropriate time for damage assessment
10	Estimate Damage	estimate	Estimate damage intensity from reflectance/ index at the appropriate time for damage assessment for each field

#1, 4, 5, 6, 7 are not in the Drone Tool, and are newly added in the Satellite Tool.

#2～6 are preprocessing, and results pre-processed by a calculation server can also be downloaded from the NAS

The files listed in Table 3-2 are required and must be prepared before using the Satellite Tool.

Check the processing item selection on the main screen according to the processing. Click the Set button 2 to the right of each processing item to display a sub-screen for making detailed settings. If there is a fatal error in the detailed settings of a checked processing item, a red character for ERROR appears to the right of the Set button 2. In this case, it is thought to be because the file or folder required for processing does not exist, so click Set button 2 to check the detailed settings.

Table 3-2. Files required to use Satellite Tool

File	Processing item which require the file
Netrc file	Download Data
Field polygon data	Parcellate Data Atmospheric Correction Estimate Growth Stage Extract Indices Estimate Damage
Reference image for geometric correction	Geometric Correction
Damage estimation formula	Estimate Damage
Field observation data	Extract Indices

When you click the Run button on the main screen, the checked items are processed in order from the top. The Exit button closes the main screen. However, since screen operations will not be accepted while processing a processing item, if you want to kill it, click the cross in the upper right corner of the screen or enter Ctrl + C on the console screen.

The result of preprocessing is stored under the S2_DATA¥proc¥yyyy folder with a File name beginning with yyyymmdd_proc (proc is a short name of the processing item, yyyy is the year, and yyyymmdd are numbers representing the year, month, and day). All other processing results are stored under the S2_ANALYSIS¥proc folder. (Some results of Interpolate Data are also stored under the S2_DATA/tentative_interp and some results of Estimate Growth Stage are also stored under the S1_ANALYSIS folder.)

Typical uses of the Satellite Tool include :

- preprocess satellite data (§ 4)
- Estimate damage intensity at the time of damage assessment for each field using existing estimation formulas (§ 5)
- Estimate damage intensity at a specific satellite image acquisition date using an existing estimation formula (§ 6)
- Create training data using interpolated data for creating damage intensity equations (§ 7)
- Creating training data using specific satellite images for creating damage intensity estimation equations (§ 8)
- Create a damage intensity Estimation Formula (§ 9)

The following sections briefly describe those methods.

4. How to preprocess satellite data

The Satellite Tool can be used to pre-process satellite data. However, because preprocessing takes a lot of computation time, pre-processed results can also be downloaded from the NAS (As discussed in section 5 and later, section 4 processing is not required when pre-processing results are downloaded from a NAS.). If you want to preprocess satellite data yourself, set the data period (first day and last day) in Data First/Last on the main screen. Planting Start/End and Observation Block/Date are not used in this case and do not need to be set. The processing item selection on the main screen is set as follows.

☑ Download Data	☑ Interpolate Data
☑ Geometric Correction	☐ Estimate Growth Stage
☑ Calculate Indices	☐ Extract Indices
☑ Parcellate Data	☐ Make Formula
☑ Atmospheric Correction	☐ Estimate Damage

Check only L2A for Download Flag on the detailed setting screen of Download Data.

☐ planting	☐ parcel
☑ L2A	☐ atcor
☐ geocor	☐ interp
☐ indices	☐ tentative_interp

Detailed settings for other processing items can be left at their defaults. After making the above settings, click the Run button on the main screen and everything will be processed automatically. However, if an ERROR message is displayed, check the detailed settings of the corresponding processing item. Figures 4-1 to 4-6 show examples of the detailed setting screens for each processing item. Be especially careful of the mandatory files and folders indicated in the red box. If you see an ERROR message, put the required file or folder in the correct location or change the settings to reference the correct file or folder. If the tool confirms the existence of a set file or folder, it will display a green circle.

The files and folders indicated by the green box are automatically created during processing when the above processing items are executed in order, so they do not need to exist before processing. (If the tool confirms the existence of a file or folder, it will display a green circle, and if not, a red cross.)

However, if necessary processing is to be skipped, for example, by skipping the Geometric Correction processing and starting with the Calculate Indices processing, the files and folders indicated by the green box must exist before processing. If a file or folder does not exist, which is automatically created if you follow the procedure, an ERROR is not displayed, but a red X is displayed. In this state, the process does not work properly, so be sure to place the necessary files and folders in the correct locations before starting the process, or change the settings to reference the correct files and folders and make sure that a green circle is displayed. The data required for Satellite Tool processing is summarized in Table 4-1. Data abbreviated to a Satellite Tool processing item (e.g., geocor) is created by executing that processing item. (tentative _ interp is created by executing an interp.)

Table 4-1. Data required to use Satellite Tool

Processing item	Short Name	Required data
Geometric Correction	geocor	L2A
Calculate Indices	indices	geocor
Parcellate Data	parcel	geocor, indices
Atmospheric Correction	atcor	geocor, indices, parcel
Interpolate Data	interp	atcor, (parcel※1)
Estimate Growth Stage	phenology	planting, interp, tentative_interp
Extract Indices	extract	interp, tentative_interp, phenology
Make Formula	formula	extract
Estimate Damage	estimate	interp, tentative_interp, phenology, formula, (atcor※2, parcel※3)

※1 When Atmospheric Correction is off in the detailed setting of Interpolate Data

※2 When Data Selection Criteria is set to Specific Non-interpolated Data in the detailed setting of Estimate Damage (in this case, interp, tentative_interp, and phenology are not required)

※3 In case ※2 and when Atmospheric Correction is off

When each process ends normally, result confirmation images are created, so check accordingly. Fig. 4-7 to Fig. 4-13 show examples of result confirmation images of each process.

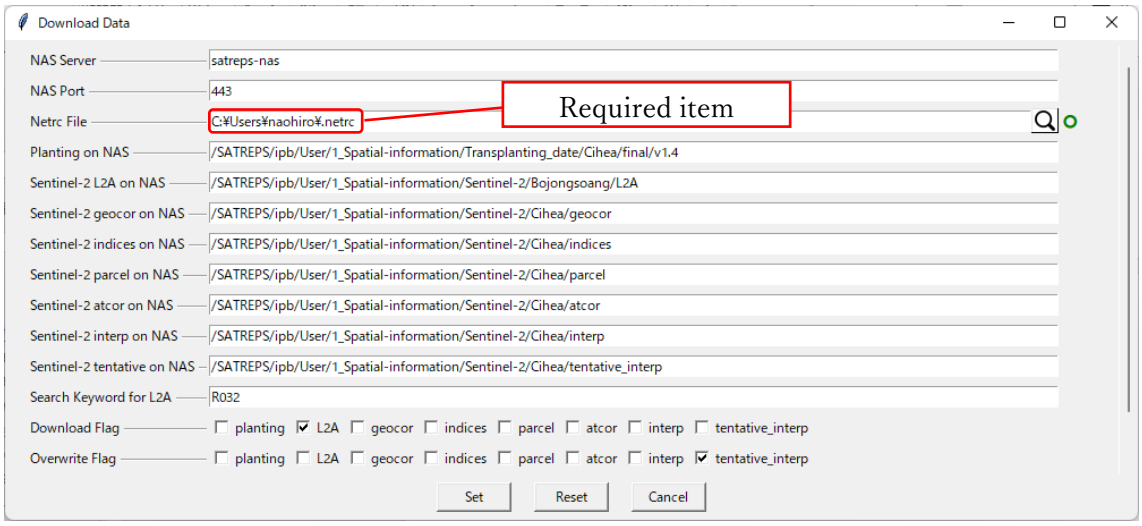


Fig. 4-1. Detailed setting screen of Download Data

Check point : Check Download Flag for required data

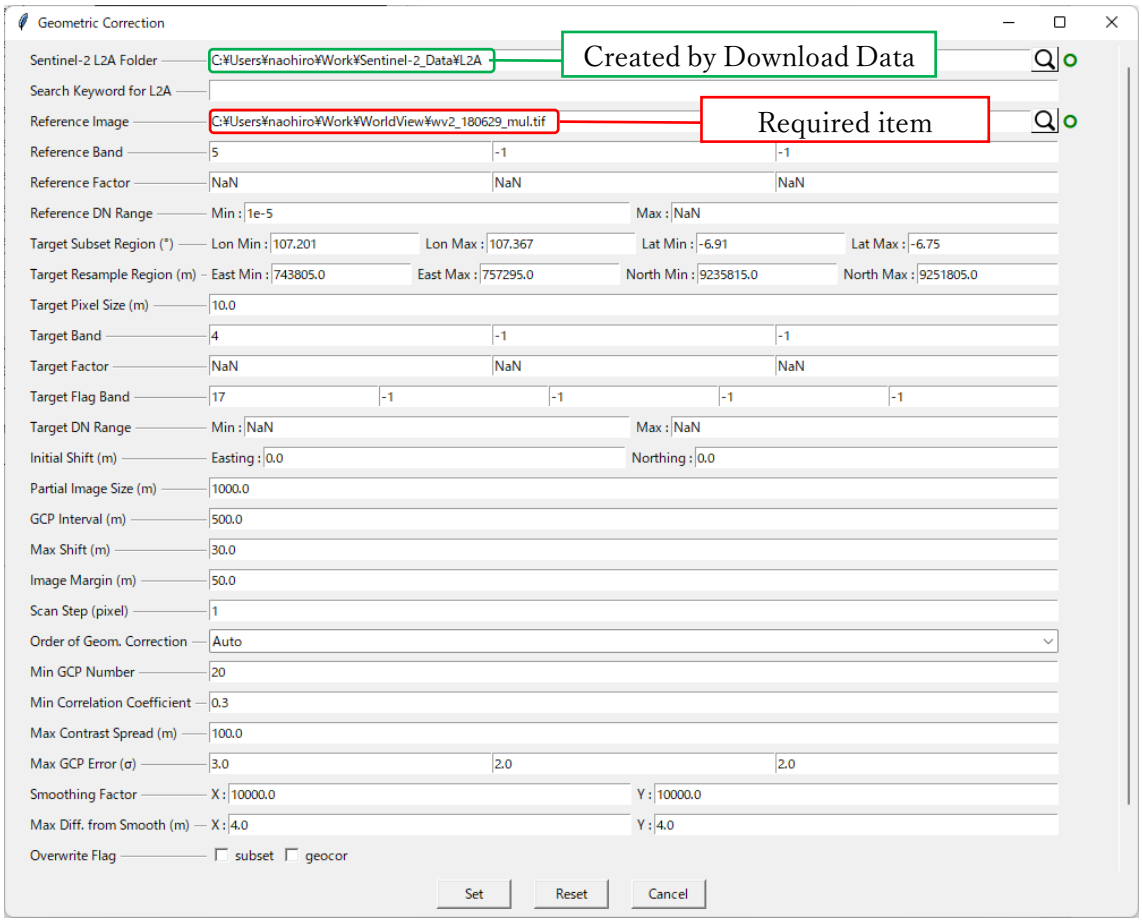


Fig. 4-2. Detailed setting screen of Geometric Correction

Advanced Note : Red band is suitable for geometric correction.

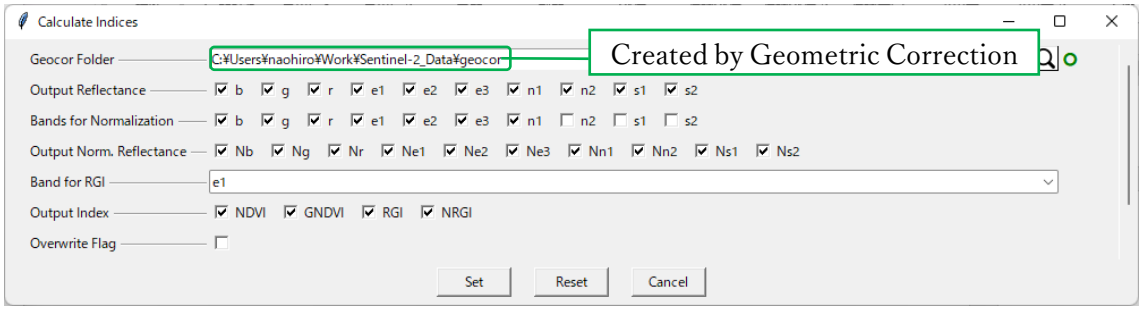


Fig. 4-3. Detailed setting screen of Calculate Indices

Check point : Check required reflectance, normalized reflectance and index's Output

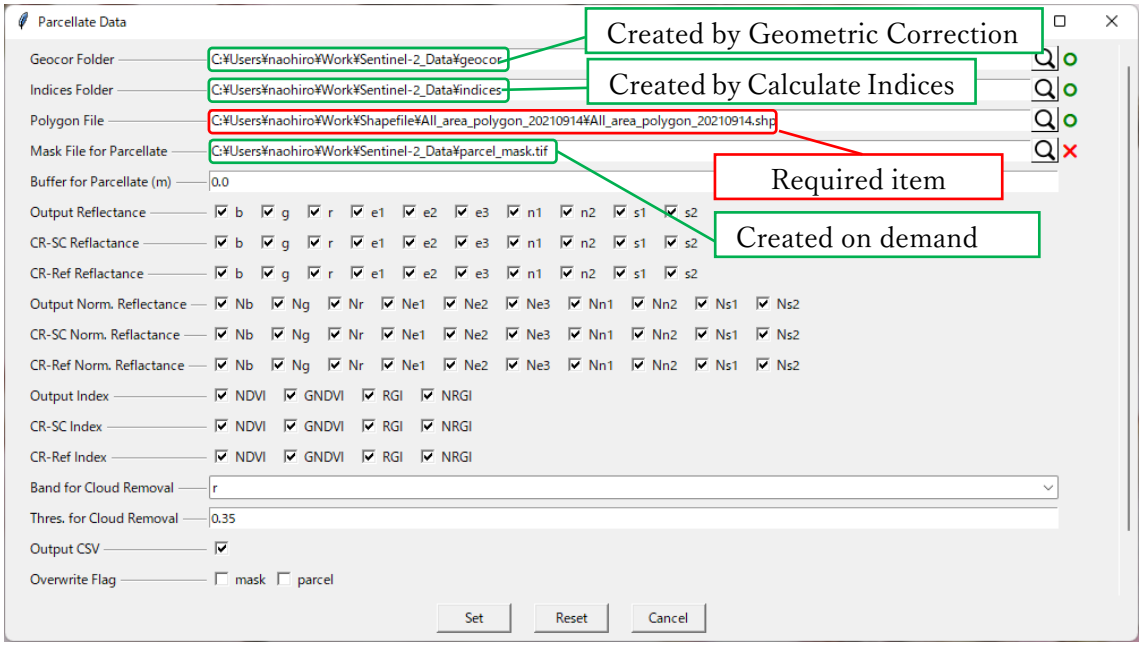


Fig. 4-4. Detailed setting screen of Parcellate Data

Check point : Check required reflectance, normalized reflectance and index's Output.

Advanced Note : Unchecking Output CSV saves processing time and disk space when CSV data is not needed (CSV data is not used for subsequent processing). The Scene Classification (SC) of Sentinel-2 L2A data stores labels classified as shown in Table 4-2. For parameters checked for SC-based cloud removal (CR-SC), pixels labeled 0, 1, 3, 8, 9, 10, and 11 are excluded. On the other hand, data without SC-based cloud removal are used for atmospheric correction. If Atmospheric Correction is to be performed after Parcellate Data, matching the cloud removal settings to the Atmonsphereic Correction settings (Uncheck all CR-SC, check all reflectance-based cloud removal (CR-Ref), match Band for Cloud Removal and Thres. for Cloud Removal settings) will speed up atmospheric correction processing.

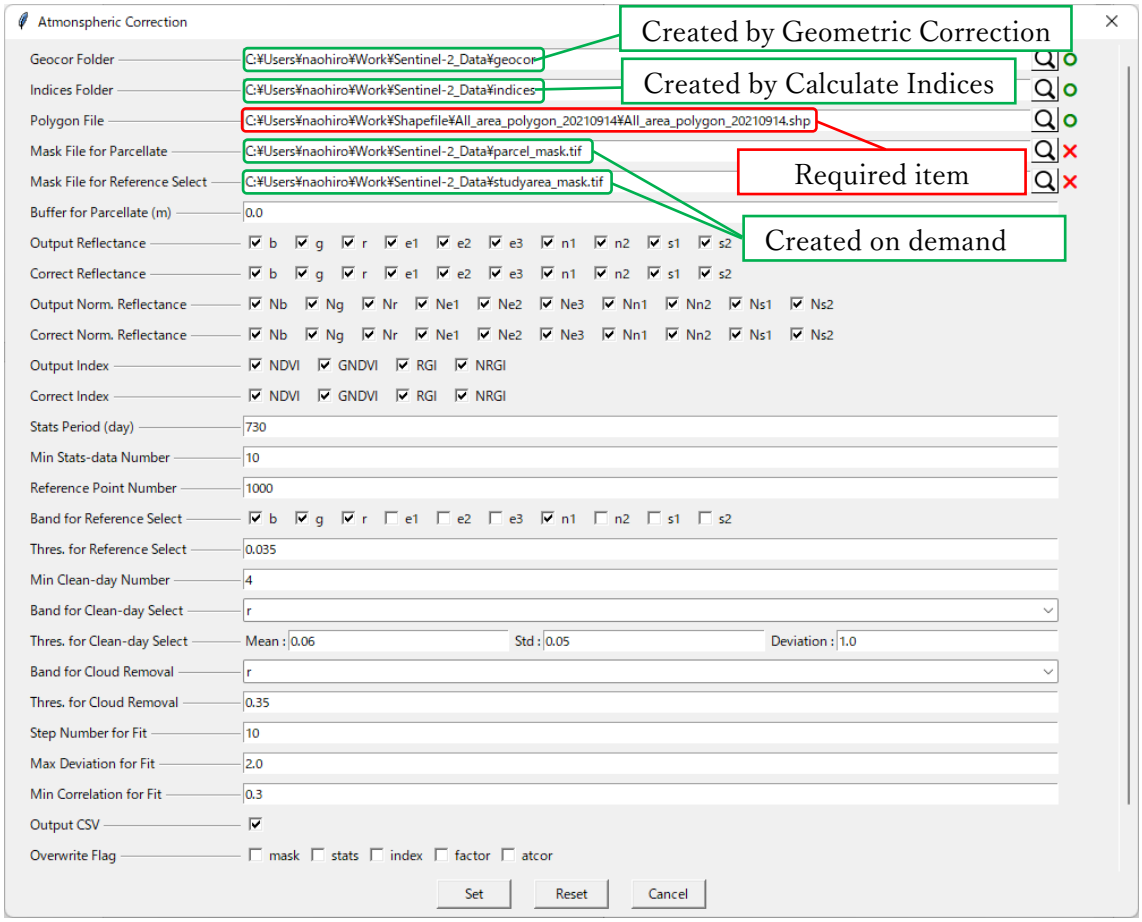


Fig. 4-5. Detailed setting screen of Atmospheric Correction

Check point : Check required reflectance, normalized reflectance and index's Output.

Advanced Note : For Reflectance, Normalized Reflectance, and index without a check mark on Correct, it will use the raw results of Parcellate Data. Uncheck Output CSV if you do not need the CSV data (it will not be used for further processing).

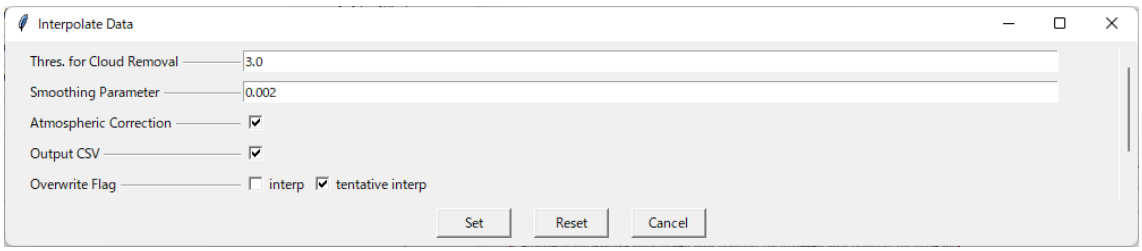


Fig. 4-6. Detailed setting screen of Interpolate Data

Advanced Note : Uncheck Output CSV if you do not need the CSV data (it will not be used for further processing). Data close to both ends of the data acquisition period will have smoothed spline interpolation results varying with the number of days from both ends, so interpolated data within 90 days of both ends will be stored in the tentative_interp folder.

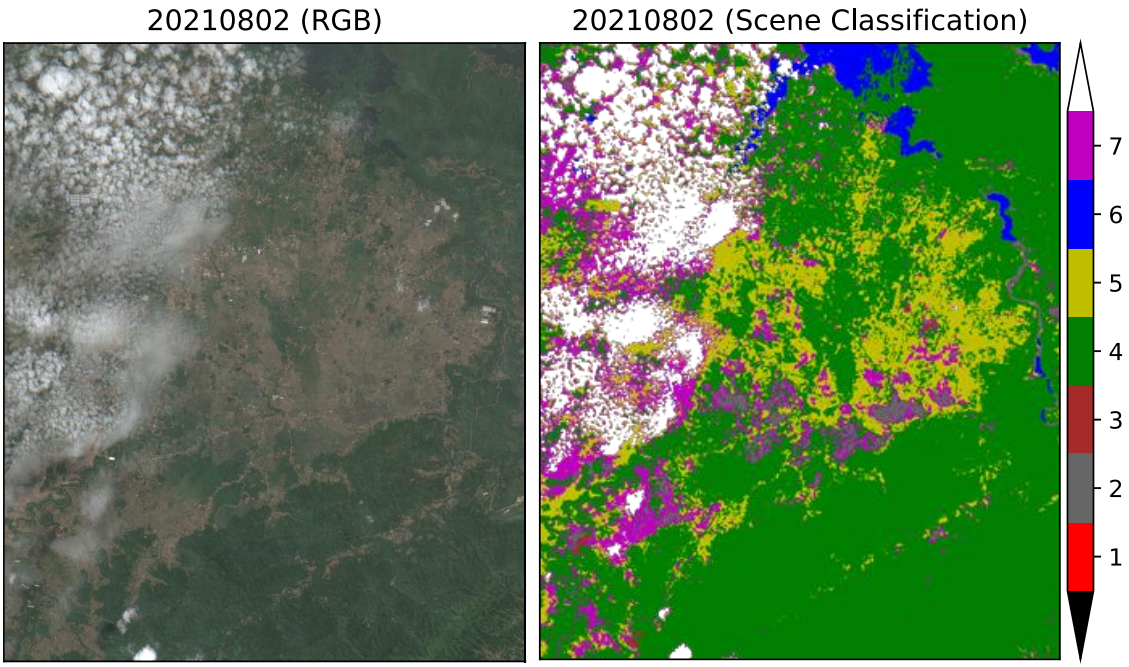


Fig. 4-7. Example of Geometric Correction result confirmation image (an image with clouds was chosen intentionally)

Folder Name : S2_DATA¥geocor¥yyyy

File name : yyyymmdd_geocor.pdf

Check point : Whether there are clouds in the target area and whether there are any misalignments compared to the geometrically corrected images of other observation days.

Table 4-2. Scine Classification in Sentinel-2 L2A

Label	Classification
0	NO_DATA
1	SATURATED_OR_DEFECTIVE
2	CAST_SHADOWS
3	CLOUD_SHADOWS
4	VEGETATION
5	NOT_VEGETATED
6	WATER
7	UNCLASSIFIED
8	CLOUD_MEDIUM_PROBABILITY
9	CLOUD_HIGH_PROBABILITY
10	THIN_CIRRUS
11	SNOW or ICE

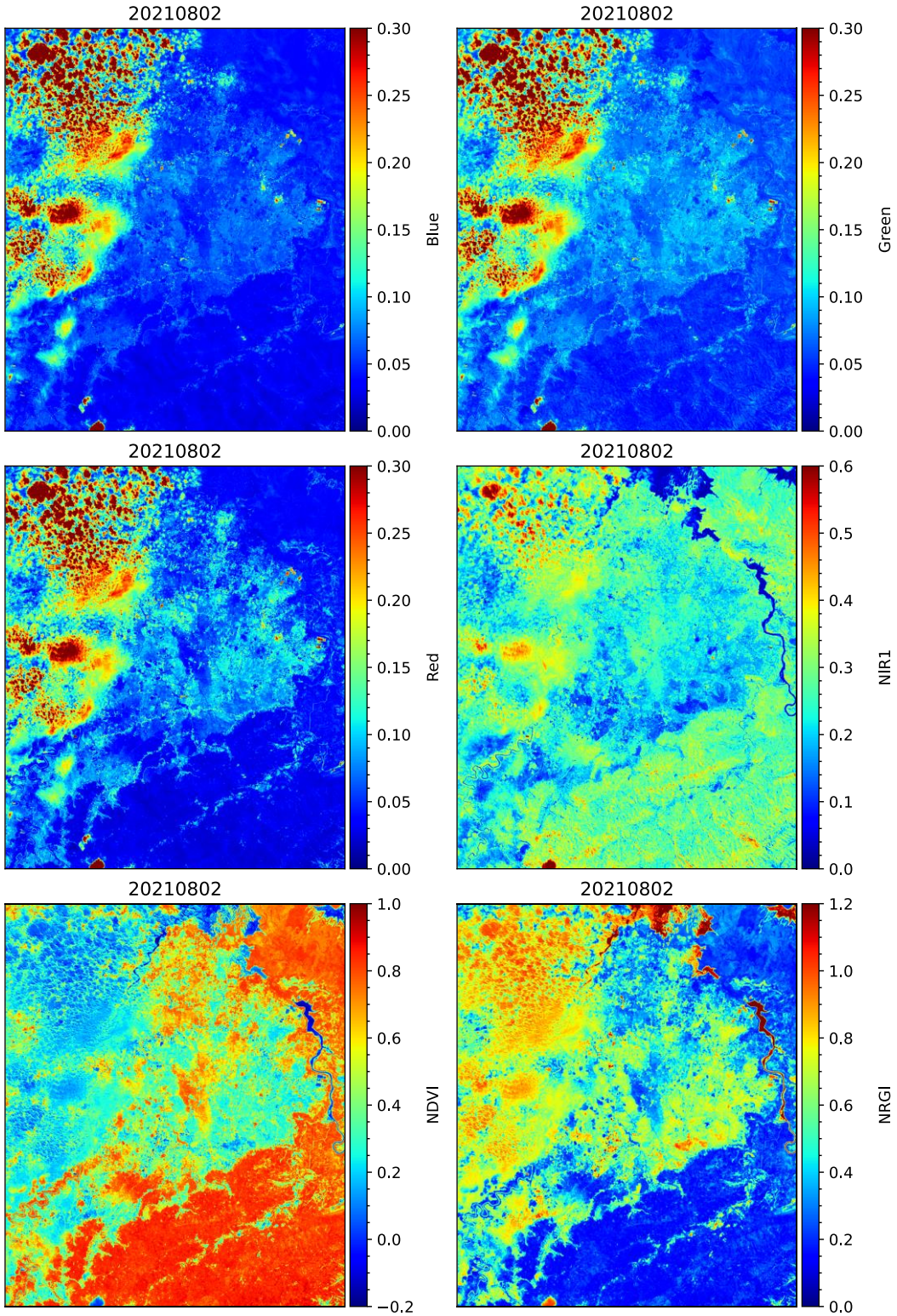


Fig. 4-8. Example of Calculate Indices result confirmation image

Folder Name : S2_DATA¥indices¥yyyy

File name : yyyymmdd_indices.pdf

Check point : Whether the clouds influence

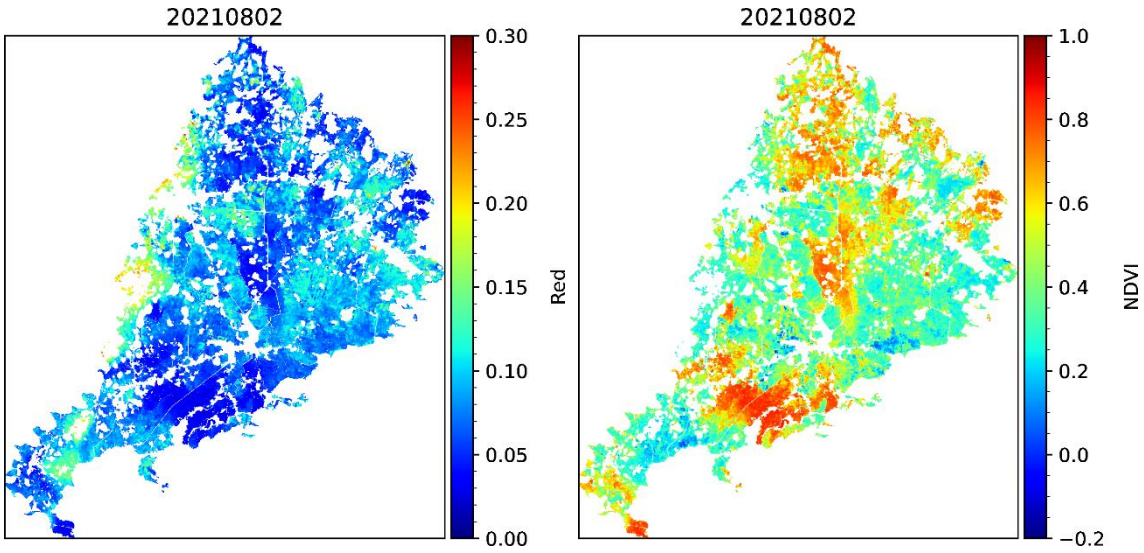


Fig. 4-9. Example of Parcellate Data result confirmation image (reflectance/index before atmospheric correction)

Folder Name : S2_DATA¥parcel¥yyyy

File name : yyyymmdd_parcel.pdf

Advanced Note : SC-based/reflectance-based cloud removal can cause data loss.

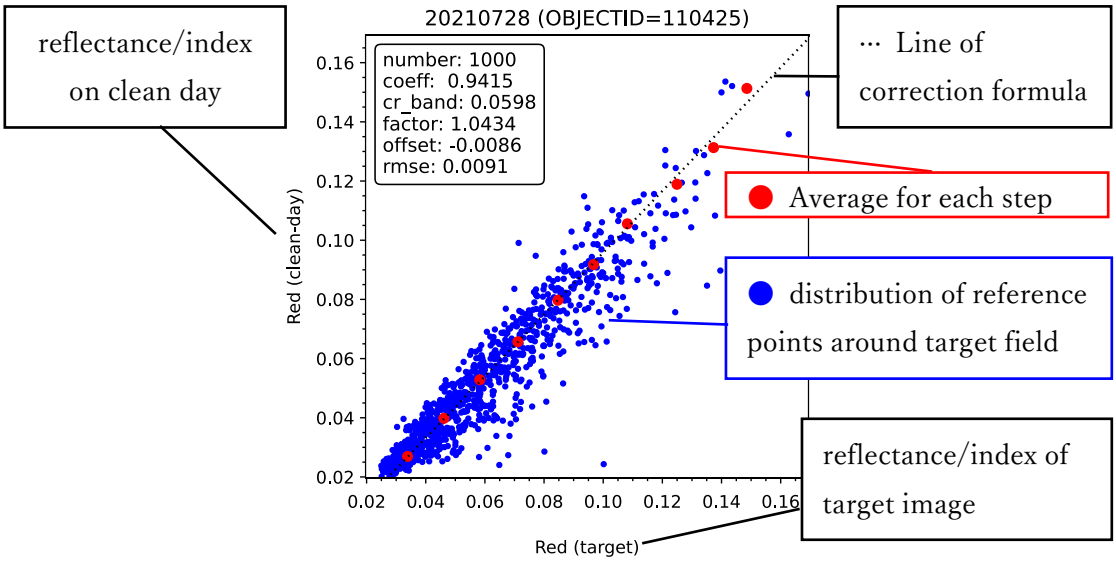


Fig. 4-10. Example of Atmospheric Correction result confirmation image (atmospheric correction coefficients)

Folder name : S2_DATA¥atcor¥yyyy

File name : yyyymmdd_factor.pdf

Advanced Note : In atmospheric correction, multiple reference points with little temporal variation in reflectance are selected for each field, and the line of the correction formula that converts the reflectance/index of the target image into the value on a clean day is obtained.

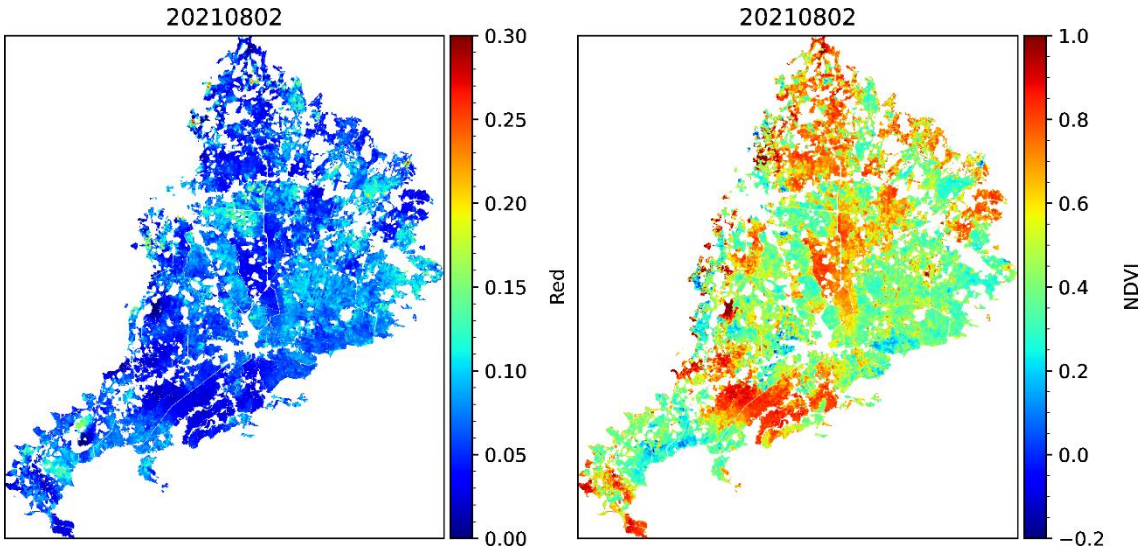


Fig. 4-11. Example of Atmospheric Correction result confirmation image (reflectance/index after atmospheric correction)

Folder Name : S2_DATA¥atcor¥yyyy

File name : yyyymmdd_atcor.pdf

Advanced Note : Reflectance-based cloud removal can cause data loss. If the correlation coefficient obtained from a scatter plot, such as that in Figure 4-10, is smaller than the threshold (Min Correlation for Fit), the corresponding reflectance/index data of the field are excluded.

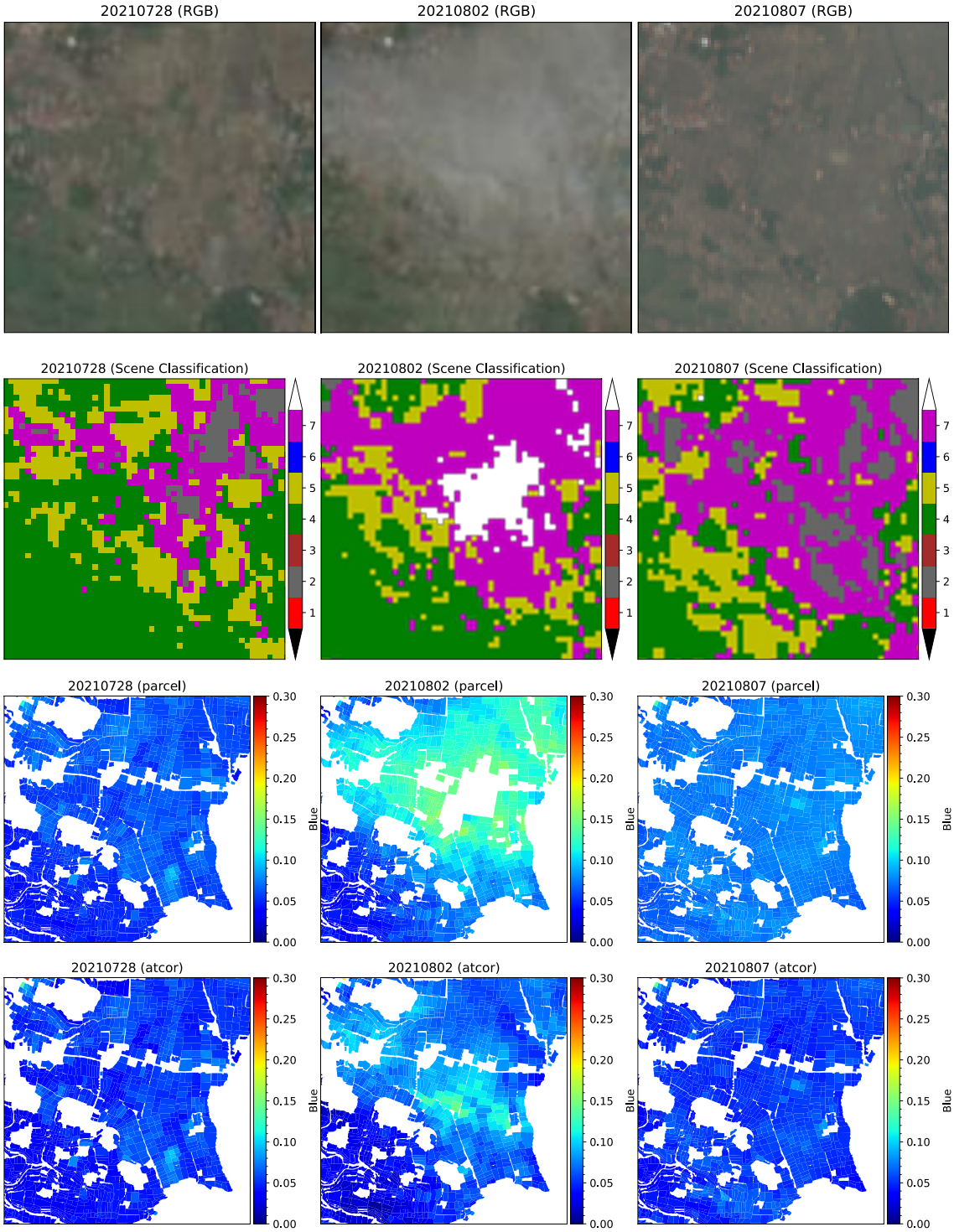


Fig. 4-12. Comparison before and after atmospheric correction (enlarged view of upstream area)

Check point : Thin clouds can be seen in the 20210802 RGB image. Due to SC-based cloud removal, the data of Parcellate Data is partially missing, and significant cloud effects remain in areas that were not excluded. The Atmospheric Correction data, on the other hand, has

no missing data and is closer to the observed values on previous and subsequent days (20210728, 20210807) with reduced cloud impact.

Advanced Note : Index data for reference points used for atmospheric correction (nearest _ inds.npz) and reflectance/index data for days with clean air (atcor_stat.tif) are created under the S2_DATA/atcor/yyyy folder each time the year changes. By default, it requires data (geocor and indices) for about two years before the beginning of the year. The required data period can be changed by setting Stats Period in Atmospheric Correction, and data after the beginning of the year can also be used by setting a negative value if no data before the beginning of the year exists.

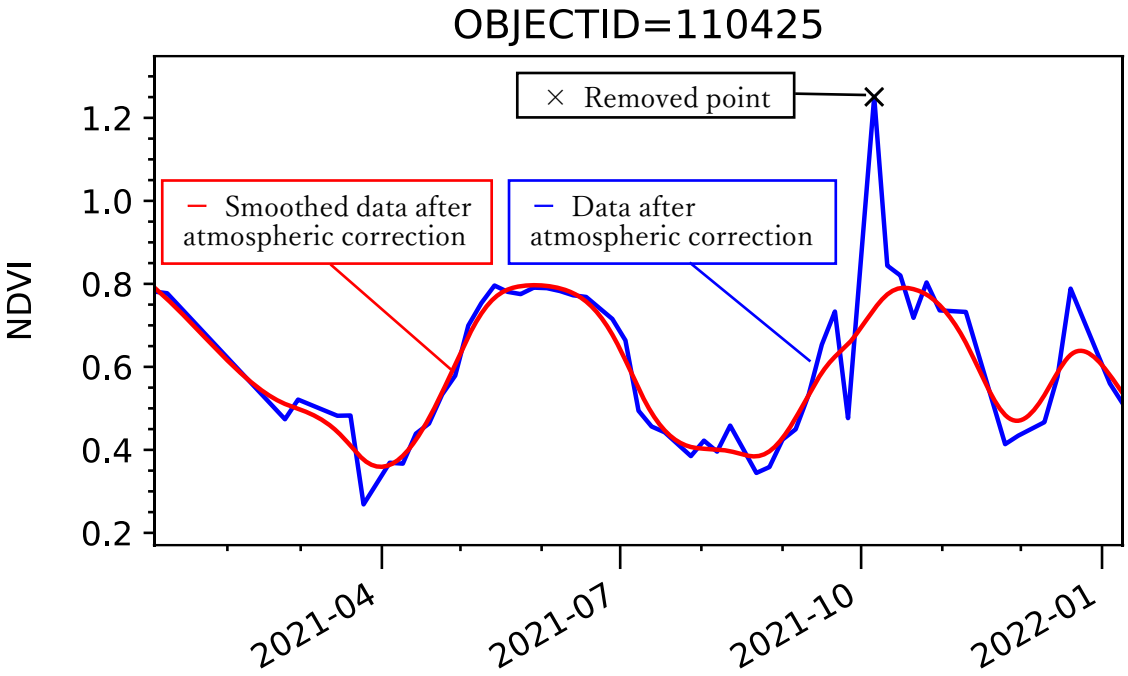


Fig. 4-13. Example of Interpolate Data result confirmation image

Folder Name : S2_DATA¥interp

File name : FIRST_DATE_LAST_DATE_interp.pdf

Check point : Whether the points where the atmospheric correction error is considered to be large are excluded (marked with X)

5. How to estimate damage intensity at the time of damage assessment for each field using existing estimation formula

In BLB damage intensity estimation, since the relationship between damage intensity and reflectance changes depending on the growth stage, it is necessary to use satellite images at the time of damage assessment according to the growth stage of each field. When estimating the damage intensity at the time of damage assessment for each field using an existing estimation formula, set the planting date search period (earliest planting date and latest planting date) of the target area to Planting Start/End on the main screen. Care should be taken that the length of the planting date search period does not exceed approximately 100 days, as two or more cropping periods may be included in the same field if the difference between these dates is too large. A sufficient data period is required before and after the planting date search period for interpolating the reflectance/index time-series data and estimating the timing of damage assessment. When you set Planting Start/End, Data First is automatically set 90 days before Planting Start and Data Last is automatically set 210 days after Planting End. (It can be changed manually after automatic setting.) Since Observation Block/Date are not used in this case, they do not need to be set. Process item selection on the main screen is set as follows.

☑ Download Data	☐ Interpolate Data
☐ Geometric Correction	☑ Estimate Growth Stage
☐ Calculate Indices	☐ Extract Indices
☐ Parcellate Data	☐ Make Formula
☐ Atmospheric Correction	☑ Estimate Damage

Set the Download Flag in the detailed setting screen of Download Data as follows :

☑ planting	☐ parcel
☐ L2A	☐ atcor
☐ geocor	☑ interp
☐ indices	☑ tentative_interp

After making the above settings, click the Run button on the main screen and everything will be processed automatically. However, if an ERROR message is displayed, check the detailed settings of the corresponding processing item. Figure 5 -1 and Figure 5 -2 show examples of detail settings for Estimate Growth Stage and Estimate Damage. Fig. 5 -3 to Fig. 5 -5 show examples of result confirmation images of each process.

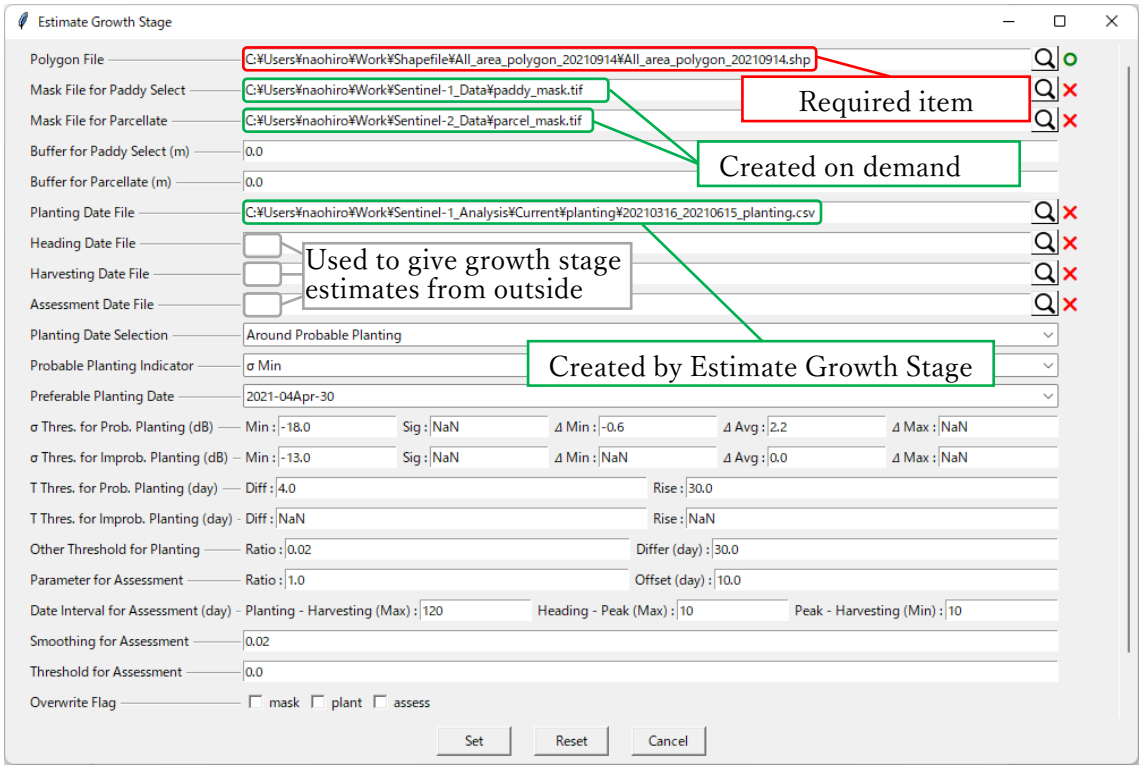


Fig. 5-1. Detailed setting screen of Estimate Growth Stage

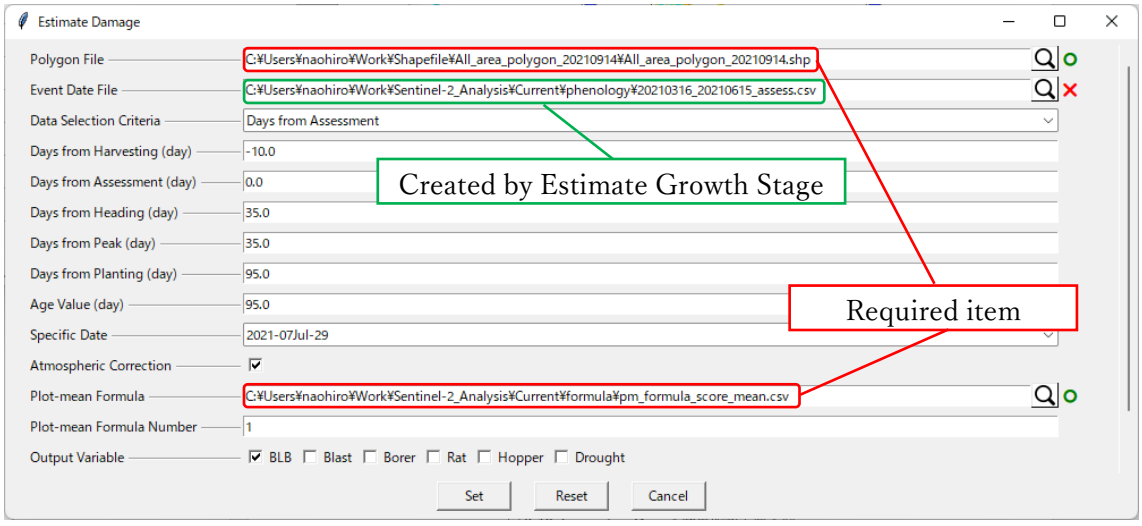


Fig. 5-2. Detailed setting screen of Estimate Damage

Check point : Set the number of days corresponding to the Data Selection Criteria. (Days settings that do not correspond to Data Selection Criteria are ignored.)

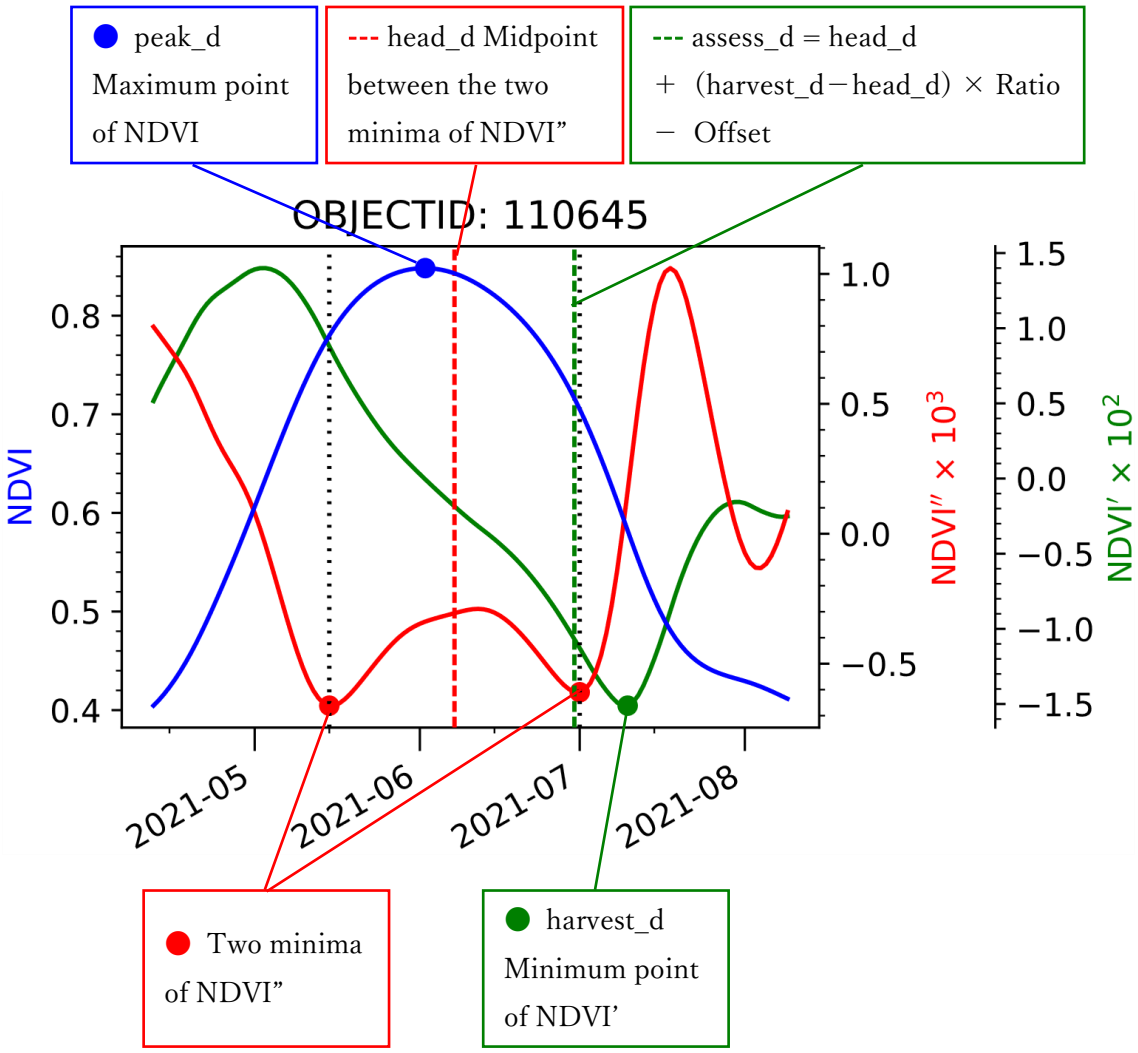


Fig. 5-3. Example of Estimate Growth Stage result confirmation image (time-series)

Folder name : S2_ANALYSIS¥phenology

File name : START_DATE_END_DATE_assess.pdf

Advanced Note : Planting date (plant_d) is estimated using time-series data of backscattering coefficient obtained from the Sentinel-1 satellite (see Appendix 2 for details). The NDVI maximum date (peak_d), heading date (head_d), harvesting date (harvest_d) and damage assessment date (assess_d) are estimated using NDVI time-series data obtained by the Sentinel-2 satellite (Fig. 5-3). If the latter parameters are not found after plant_d and before the threshold (Planting-Harvesting of Data Interval for Assessment), it is considered not present. If the minimum point of NDVI' is not found after the threshold (Peak-Harvesting of Data Interval for Assessment) from peak_d, or if the minimum value of NDVI' is greater than the threshold (Threshold for Assessment), harvest_d is not considered to exist. If the midpoint between the two minima of NDVI is farther than the threshold (Heading-Peak of Data Interval for Assessment) from peak_d, then head_d = peak_d.

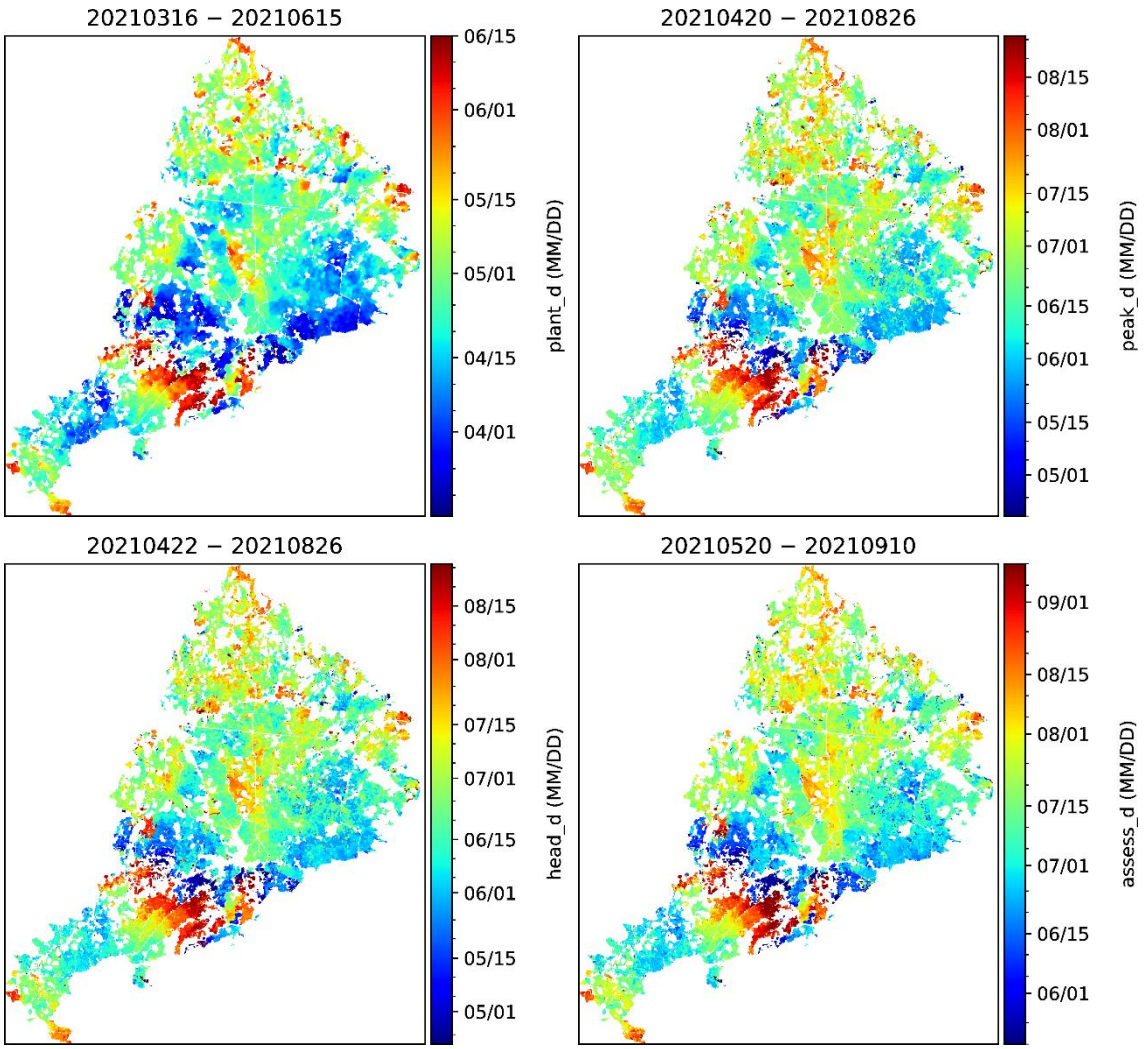


Fig. 5-4. Example of Estimate Growth Stage result confirmation image (map)

※ The result confirmation image of harvest_d is omitted since assess_d = harvest_d – 10 by default (Ratio = 1 and Offset = 10 day in Parameter for Assessment).

Folder name : S2_ANALYSIS¥phenology

File name : START_DATE_END_DATE_phenology.pdf

Check point : The growth rate doesn't vary much from place to place, so all four images should have similar spatial patterns.

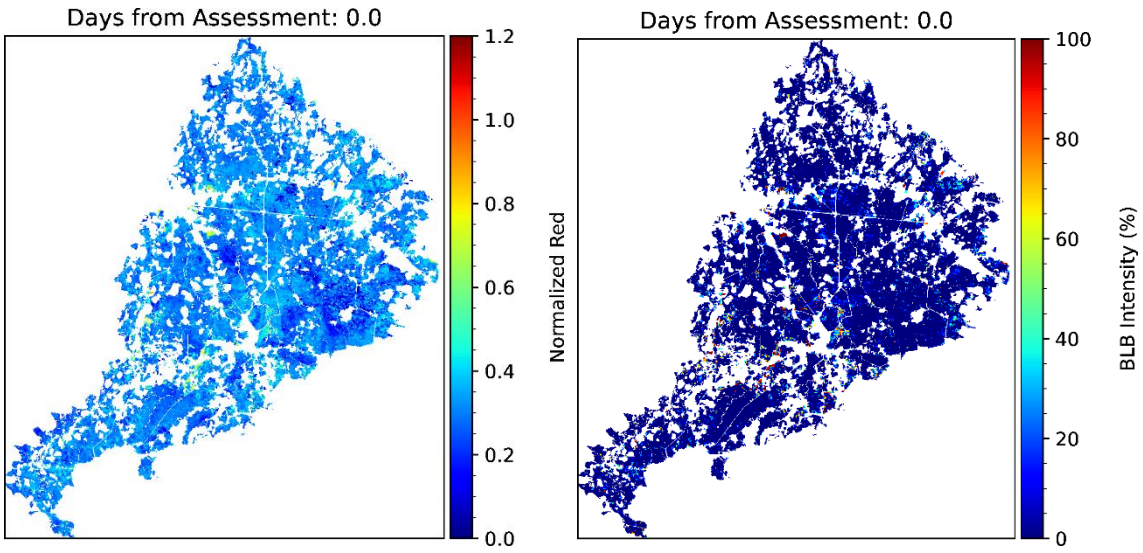


Fig. 5-5. Example of Estimate Damage result confirmation image

Left : Reflectance/index on selected days, Right : damage intensity on selected days

Folder Name : S2_ANALYSIS¥estimate

File name (Left) : CRITERIA_DATE_select.pdf

File name (Right) : CRITERIA_DATE_estimate.pdf

CRITERIA_DATE is a variable that varies depending on the detailed settings of the Make Formula (Ex : If Data Selection Criteria = Days from Assessment and Days from Assessment = 0.0, CRITERIA_DATE = assess_0.0)

Check point : When the growth stages are aligned based on the Data Selection Criteria, the reflectance and index are considered to be roughly the same if there is no damage from pests and diseases.

6. How to estimate damage intensity on specific satellite-image acquisition date using existing estimation formula

Satellite Tool can also estimate BLB damage intensity using specific satellite image (e.g., the latest satellite image). This method is effective only for fields where the date of satellite image acquisition is the time of damage assessment. (Note that there is a possibility of being affected by noise due to errors in atmospheric correction, etc.) In this case, set the satellite image acquisition date (First and Last are the same) in Data First/Last on the main screen. Planting Start/End and Observation Block/Date are not used in this case and do not need to be set. The processing item selection on the main screen is set as follows.

☑ Download Data	☐ Interpolate Data
☐ Geometric Correction	☐ Estimate Growth Stage
☐ Calculate Indices	☐ Extract Indices
☐ Parcellate Data	☐ Make Formula
☐ Atmospheric Correction	☑ Estimate Damage

Check only atcor for Download Flag on the detailed setting screen of Download Data.

☐ planting	☐ parcel
☐ L2A	☑ atcor
☐ geocor	☐ interp
☐ indices	☐ tentative_interp

Change detailed settings of Estimate Damage as shown in Table 6-1.

Table 6-1. Settings change of Estimate Damage

Setting item	Setting contents
Data Selection Criteria	Specific Non-interpolated Data
Specific Date	Satellite image acquisition date

After making the above settings, click the Run button on the main screen and everything will be processed automatically. However, if ERROR is displayed, check detailed settings of the corresponding processing item.

7. How to create training data using interpolated data

Training data is a combination of BLB damage intensity data from field observation and reflectance/index data from satellite observations. Since there are not necessarily satellite images of the days of field observation, we use time-series data obtained by smoothed spline interpolation for reflectance/index. (Smoothed spline interpolation not only interpolates data for days not observed by satellites, but also reduces the effect of noise caused by errors in atmospheric correction.) In addition, planting date, NDVI peak date, heading date, damage assessment date and harvesting date obtained by growth stage estimation are added to the training data so that the training data of growth stage suitable for damage assessment can be selected when the estimation formula is created. As in section 5, set planting date search period for the target area in Planting Start/End on the main screen. When Planting Start/End is set, Data First/Last period is automatically set. (It can also be changed manually after auto-configuration.) In Observation Block/Date, set the name of observation block and the observation date. The processing item selection on the main screen is set as follows.

☑ Download Data	☐ Interpolate Data
☐ Geometric Correction	☑ Estimate Growth Stage
☐ Calculate Indices	☑ Extract Indices
☐ Parcellate Data	☐ Make Formula
☐ Atmospheric Correction	☐ Estimate Damage

Set the Download Flag in the detailed setting screen of Download Data as follows.

☑ planting	☐ parcel
☐ L2A	☐ atcor
☐ geocor	☑ interp
☐ indices	☑ tentative_interp

Individual field observation data is stored with a file name like bellow :
FIELD_DATA¥ OBS_BLOCK¥Excel_File¥OBS_BLOCK_OBS_DATE.xls
Ex : C:¥Users¥satreps¥Work¥Field_Data¥Current¥Block-11B¥Excel_File¥Block-11B_2022-04Apr-04.xls

However, if you save a file directly under FIELD_DATA with a file name that fits one of the following three patterns, it will be automatically renamed to the correct file name when you set the data period on the main screen. The block_name can be in upper or lower case, and it doesn't matter if there's a "Block-" or not. yyyy is the year, mm is the month, and dd is the day.

pattern1 : dd+delimiter+mm+delimiter+yyyy+delimiter+block_name.xls
The delimiter can be a space, a dot (.), a comma (,), a hyphen (-), or an underscore (_).
Ex : 26.03.2022 2a.xls

pattern2 : any_string+delimiter+block_name+(yyyymmdd).xls
The delimiter can be either a hyphen (-) or an underscore (_).
Ex : CIHEA - 2 A (20220326).xls

pattern3 : block_name+delimiter+yyyy+delimiter+mm+month_name+delimiter+dd.xls
The delimiter can be a space, a dot (.), a comma (,), a hyphen (-), or an underscore (_). The month_name is a string representing the month listed in Table 7-1, and it is okay if either mm or month_name is included.
Ex1 : Block-2A_2022-03Mar-26.xls
Ex2 : 2A_2022-03-26.xls
Ex3 : 2A-2022.Mar.26.xls

Table 7-1. Correspondence between month numbers and month names

#	1	2	3	4	5	6	7	8	9	10	11	12
Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

All of the files in the three pattern examples above are renamed to the following file name :
FIELD_DATA¥Block-2A¥Excel_File¥Block-2A_2022-03Mar-26.xls

After making the above settings, click the Run button on the main screen and everything will be processed automatically. However, if ERROR is displayed, check detailed settings of the corresponding processing item. Figure 7 -1 shows an example of an Extract Indices detailed setting screen. Figure 7 -2 shows an example of a result confirmation image of Extract Indices.

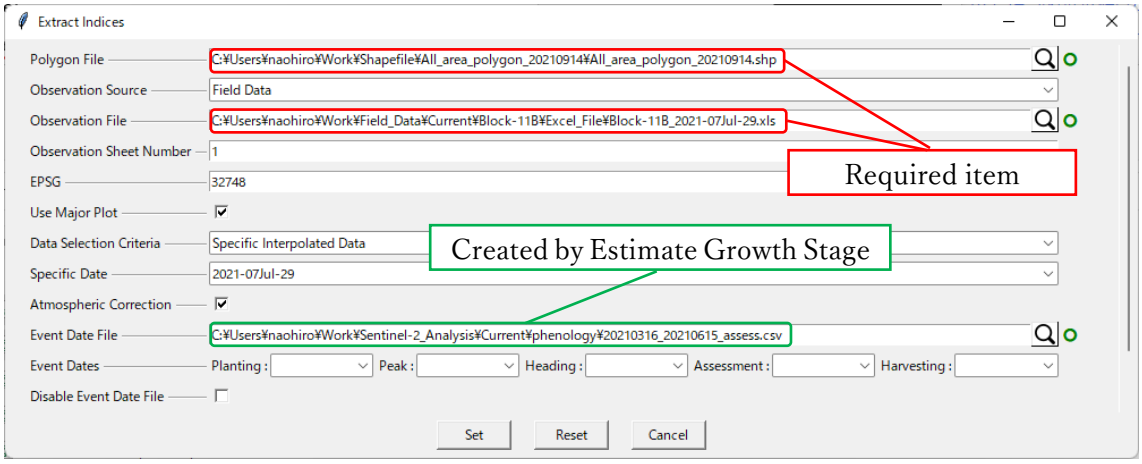


Fig.7-1. Detailed setting screen of Extract Indices

Check point : When selecting Field Data as the Observation Source, be sure to check Use Major Plot.

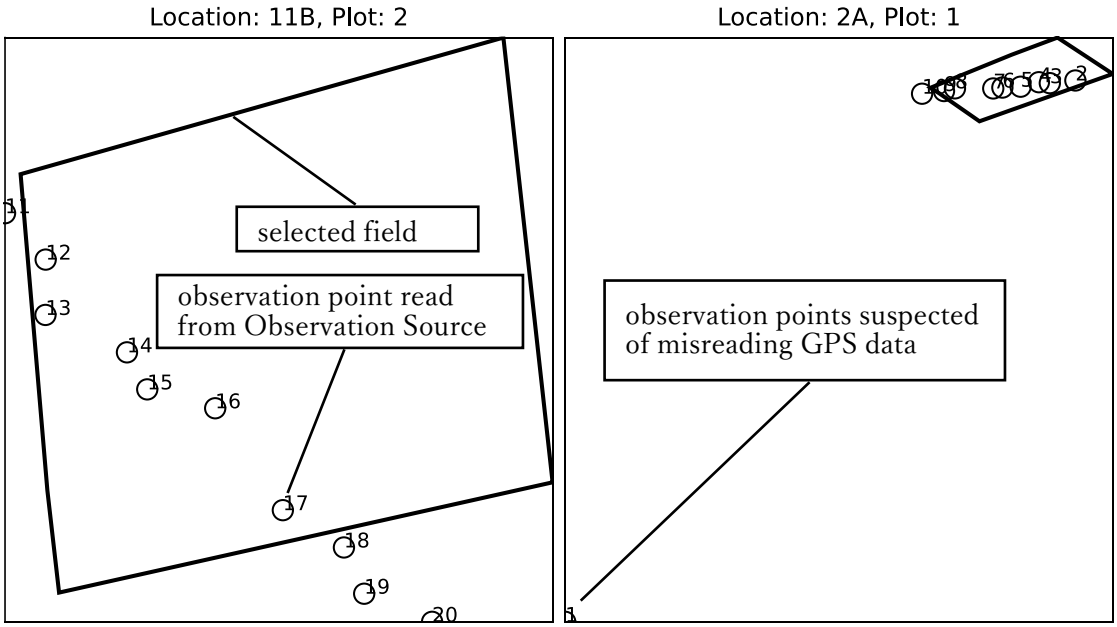


Fig. 7-2. Example of Extract Indices result confirmation image

Folder Name : S2_ANALYSIS¥extract

File name : OBS_BLOCK_OBS_DATE_extract.pdf

Check point : The location of observation points based on GPS data includes errors, and since observation points can extend out of the field by a few meters, it's OK as long as a certain number of observation points are in the correct field. Misreading of GPS data is suspected when part of observation points extends far beyond the selected field as shown in the figure on the right (Location : 2A, Plot : 1), but there is no problem as long as most of observation points is in the correct field.

8. How to create training data using specific satellite images

The Satellite Tool also allows users to generate training data using specific satellite image (such as satellite image on field observation date). It is also possible to add planting date, NDVI peak date, heading date, damage assessment date and harvesting date obtained in field observation, etc. to the training data instead of estimating the growth stage. Because this method does not involve the interpolation of time series data or the estimation of growth stages, it is easier to generate training data than the method described in section 7. (However, it may be affected by noise due to errors in atmospheric correction.) In Observation Block/Date in the main screen, set the name of field observation block and observation date. Planting Start/End and Data First/Last are not used in this way, so you don't have to configure them specifically. The processing item selection on the main screen is set as follows.

☑ Download Data	☐ Interpolate Data
☐ Geometric Correction	☐ Estimate Growth Stage
☐ Calculate Indices	☑ Extract Indices
☐ Parcellate Data	☐ Make Formula
☐ Atmospheric Correction	☐ Estimate Damage

Check only atcor for Download Flag on the detailed setting screen of Download Data. Also, change the detailed settings of Extract Indices as shown in Table 8-1.

☐ planting	☐ parcel
☐ L2A	☑ atcor
☐ geocor	☐ interp
☐ indices	☐ tentative_interp

Table 8-1. Setting change of Extract Indices

Setting item	Setting contents
Data Selection Criteria	Specific Non-interpolated Data
Specific Date	Date of satellite image acquisition
Event Dates	Enter the date required to create the estimation formula※1
Disable Event Date File	put a check

※1 For example, if you set the Data Selection Criteria of Make Formula to Days from Assessment, enter the date of the Assessment.

After making the above settings, click the Run button on the main screen and everything will be processed automatically. However, if ERROR is displayed, check detailed settings of the corresponding processing item.

9. How to create a damage intensity estimation formula

With a sufficient number of training data (more than 30 fields as a guide), a damage intensity estimation formula can be created. The processing item selection on the main screen is set as follows.

☐ Download Data	☐ Interpolate Data
☐ Geometric Correction	☐ Estimate Growth Stage
☐ Calculate Indices	☐ Extract Indices
☐ Parcellate Data	☑ Make Formula
☐ Atmospheric Correction	☐ Estimate Damage

This process requires only training data. By default, all training data found by searching the S2_ANALYSIS ¥extract folder is used. However, conditions other than BLB damage intensity that can affect leaf color in rice (Growth stage, climatic conditions, damage intensity other than BLB, fertilizer level, etc.) should be as similar as possible, and training data should be prepared and selected with that in mind. For example, if Days From Assessment is restricted from -15 days to 15 days, setting Observation Block/Date on the main screen to OBS_BLOCK = assess and OBS_DATE = -15_15 will produce a damage intensity Estimation formula with a name like pm_formula_assessment_-15_15 .csv.

After making the above settings, click the Run button on the main screen and everything will be processed automatically. However, if an ERROR indication appears, check detailed settings of Make Formula. Figure 9 -1 shows an example of detailed setting screen for Make Formula. Figure 9 -2 shows an example of the result confirmation image of Make Formula.

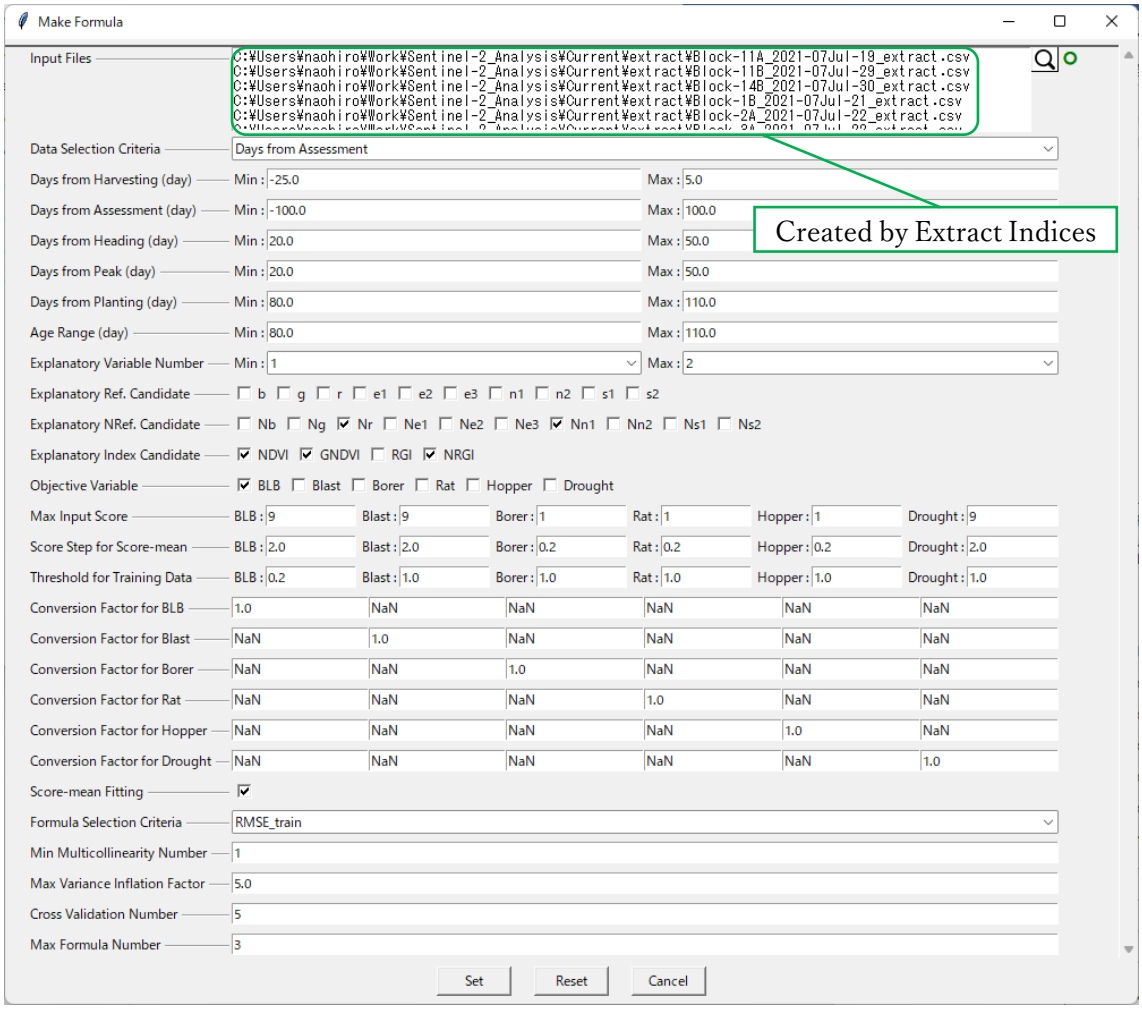


Fig. 9-1. Detailed setting screen of Make Formula

Check point : Input Files must contain enough data for a sufficient number of fields (30 or more as a guide). Correct the range corresponding to the Data Selection Criteria. (Range settings that do not correspond to the Data Selection Criteria are ignored.)

Advanced Note : Even if the number of fields in the Input Files is sufficient, the number of fields used to create the estimation formula may be insufficient because fields for which damage intensity of the objective variable other than the target objective variable (BLB) exceeds the value specified in the Threshold for Training Data are excluded.

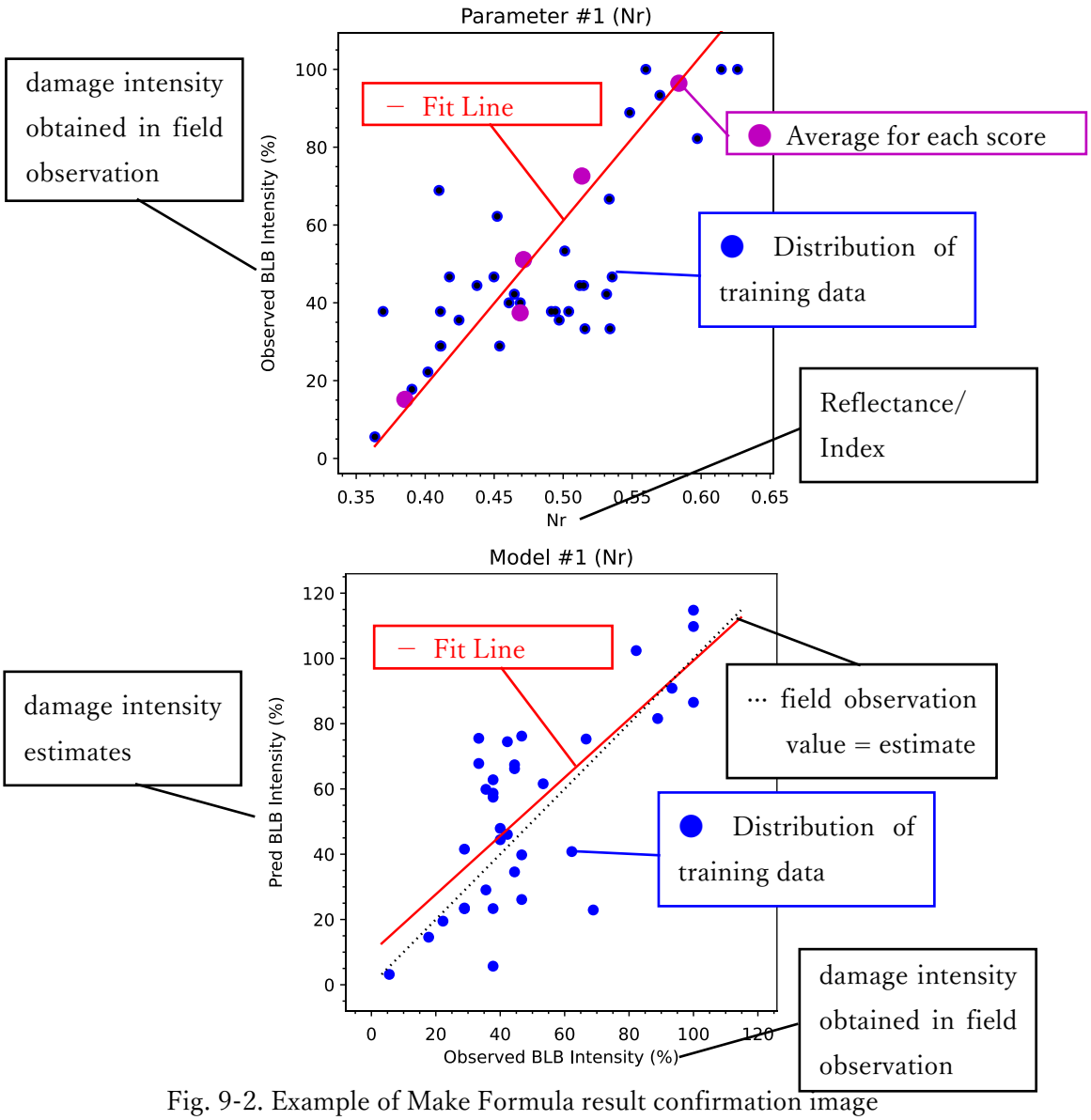


Fig. 9-2. Example of Make Formula result confirmation image

Folder Name : S2_ANALYSIS¥formula

File name : pm_formula_OBS_BLOCK_OBS_DATE.pdf

Check point : It is desirable that damage intensity obtained from field surveys is distributed evenly from small to large values.

Advanced Note : When Make Formula's Score-mean Fitting is checked (the default), average reflectance/index value for each score is used in the regression analysis. This gives equal treatment to the weight of error for each score, and allows damage intensity to reduce differences between field surveys and estimates from small to large

Appendix 1. Data Storage Location

The data storage location when using Satellite Tool with default settings is shown in Figure A1-1.

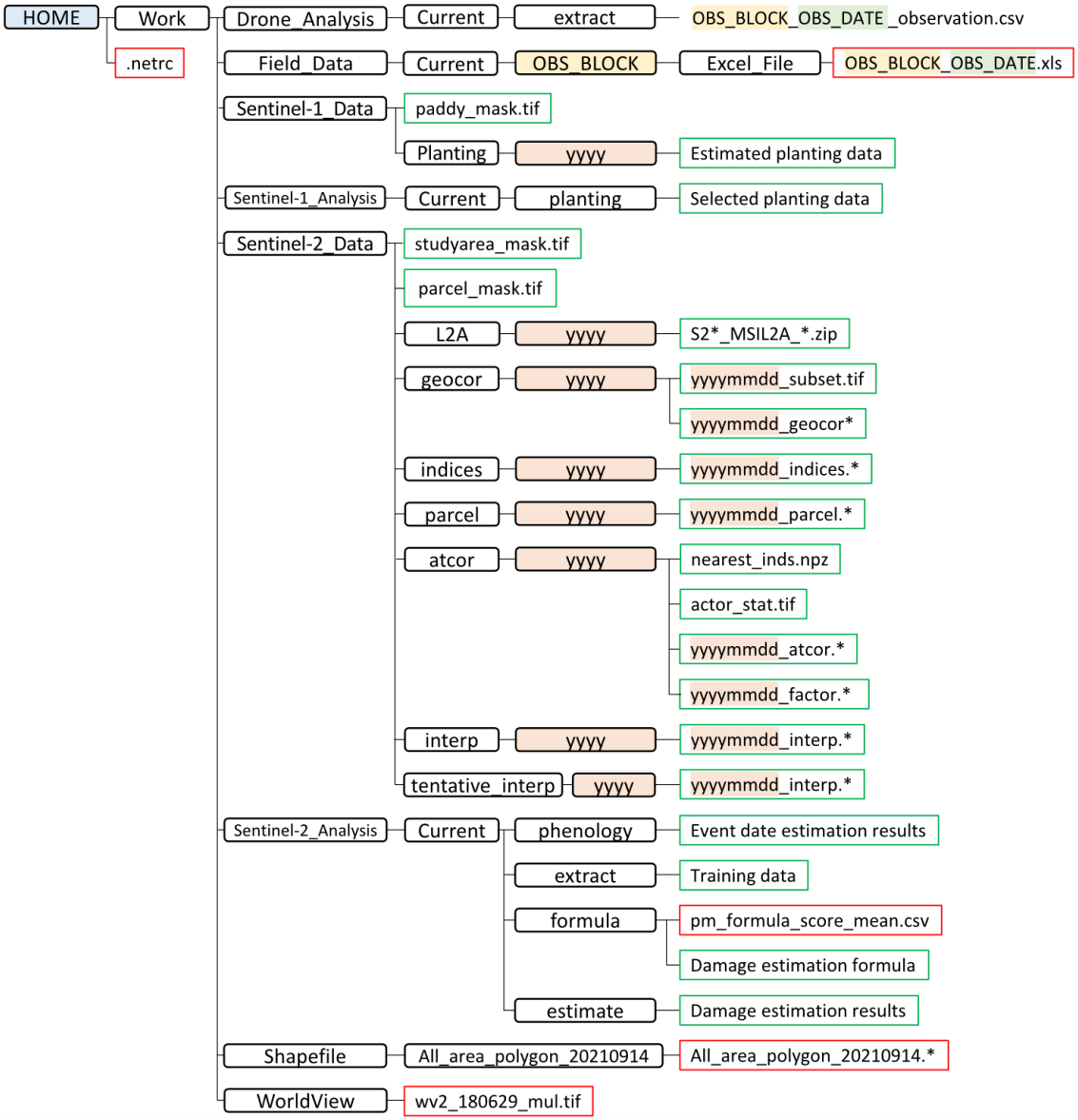


Fig. A1-1. Data storage location of Satellite Tool

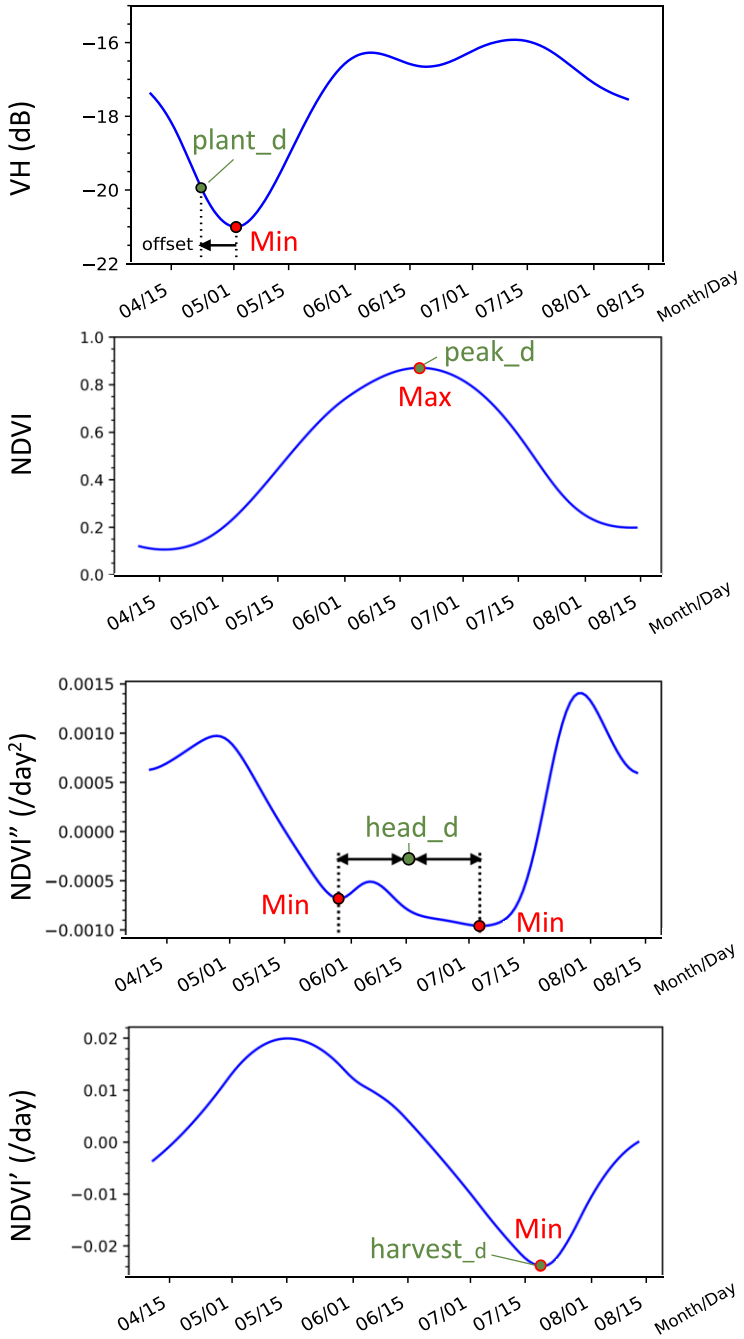
※ HOME, OBS_BLOCK, OBS_DATE, yyyy, and yyyymmdd are variables that varies depending on the analysis environment and target. (Ex : HOME = C:¥Users¥satreps, OBS_BLOCK = Block-11B, OBS_DATE = 2021-07Jul-29, yyyy = 2021, yyyymmdd = 20210729).

※ "*" (asterisk) means any string.

※ Files in red frames must be prepared in advance. Files in green frames are automatically created by the tool.

Appendix 2. How to estimate the growing stage

In the Estimate Growth Stage, the growth stage of rice in each field is estimated by the method shown in Figure A2 -1 from the time series data of backscattering coefficient (VH) obtained by the Sentinel -1 satellite and NDVI obtained by the Sentinel -2 satellite.



planting date (plant_d) : the day when the backscattering coefficient (VH) is minimum minus the offset (9 day)

NDVI peak date (peak_d) : Maximum point of NDVI time series data

heading date (head_d) : The midpoint between the two minimum points of NDVI time series data second derivative (NDVI

harvesting date (harvest_d) : Minimum point of NDVI time series data first derivative (NDVI ')

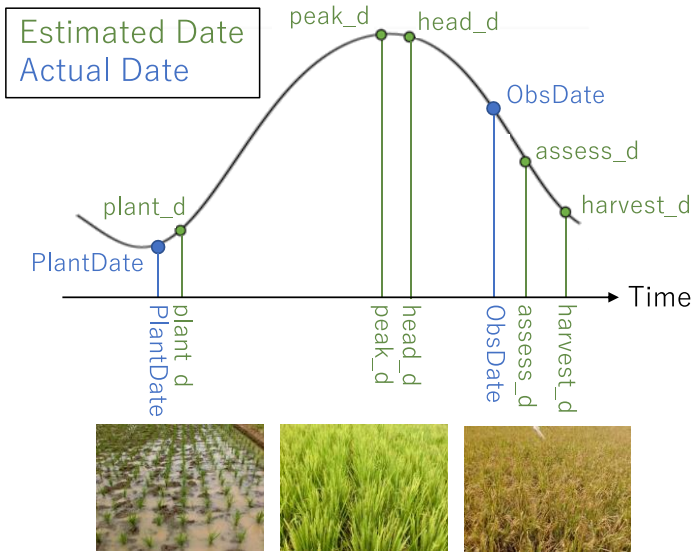
Fig. A2-1. Method for estimating growth stage

The damage assessment date (assess_d) is calculated using the following formula : (Default : Ratio = 1, Offset = 10 day)

assess_d = head_d + (harvest_d − head_d) × Ratio − Offset

Appendix 3. How to set the growth stage of Make Formula and Estimate Damage

Make Formula requires selecting training data for growth stages that are suitable for damage assessment. First, base dates are set according to Data Selection Criteria settings (e.g., Days from Assessment). It then selects training data with a specified number of days between the base date and field observation date. In addition to the damage assessment date (assess_d) obtained from the growth stage estimation, the base date can be selected from harvesting date (harvest_d), heading date (head_d), maximum NDVI date (peak_d) and planting date (plant_d). It is also possible to select training data by specifying an Age Range of days from the PlantDate obtained in field observation, rather than by growth stage estimation. Figure A3-1 shows a schematic of these dates.



Days from Assessment = ObsDate – assess_d

Days from Harvesting = ObsDate – harvest_d

…

Days from Planting = ObsDate – plant_d

Age = ObsDate – PlantDate

Fig.A3-1. Schematic of growth stage estimation and dates obtained in field observation.

Similarly, in Estimate Damage, it is necessary to select reflectance and index data of growing stages suitable for damage assessment for each field, and the damage intensity is estimated using data on days determined based on the Data Selection Criteria setting (e.g. Days from Assessment).

Appendix 4. Change of target area

Satellite Tool targets Cihea by default, but you can change the target region by replacing the files listed in Table A4-1 and changing the setting items for each process listed in Table A4-2.

Table A4-1. Location-dependent files

File	Processing item	Setting item	Parameter in satellite_config.ini
Field polygon data	Parcellate Data	Polygon File	gis_fnam (DEFAULT section)
	Atmospheric Correction		
	Estimate Growth Stage		
	Extract Indices		
	Estimate Damage		
Reference image for geometric correction	Geometric Correction	Reference Image	geocor.ref_fnam
Mask image for field-average calculation※	Parcellate Data	Mask File for Parcellate	parcel.mask_parcel
	Atmospheric Correction		atcor.mask_parcel
	Estimate Growth Stage		phenology.mask_parcel
Mask image for clean-day selection※	Atmospheric Correction	Mask File for Reference Select	atcor.mask_studyarea
Mask image for paddy field extraction※	Estimate Growth Stage	Mask File for Paddy Select	phenology.mask_paddy

※ Each type of mask image is automatically generated using field polygon data as needed. It is not necessary to change the File name setting, but if the existing mask image does not correspond to the target area, the mask image must be recreated.

Table A4-2. Location-dependent setting items

Processing item	Setting item	Setting contents	parameter in satellite_config.ini
Parcellate Data	Polygon File	Field polygon data	gis_fnam (DEFAULT section)
Atmospheric Correction			
Estimate Growth Stage			
Extract Indices			
Estimate Damage			
Download Data	Planting on NAS	Planting date data path	download.trans_path
	Sentinel-2 L2A on NAS	L2A data path	download.l2a_path
	Sentinel-2 geocor on NAS	geocor data path	download.geocor_path
	Sentinel-2 indices on NAS	indices data path	download.indices_path
	Sentinel-2 parcel on NAS	parcel data path	download.parcel_path
	Sentinel-2 atcor on NAS	atcor data path	download.atcor_path
	Sentinel-2 interp on NAS	interp data path	download.interp_path
	Sentinel-2 tentative on NAS	tentative interp date path	download.tentative_path
	Search Keyword for L2A	L2A search keyword	download.search_key
Geometric Correction	Reference Image	Reference image for geometric correction	geocor.ref_fnam
	Target Subset Region	Latitude-longitude range of the target area	geocor.trg_subset
	Target Resample Region	UTM coordinate range for the target area	geocor.trg_resample
Atmospheric Correction	Thres. for Clean-day Select	Threshold for selecting clean days	atcor.clean_thr

Here are examples of a configuration file (satellite_config.ini, changes only) for changing the target area.

When the target area is Cihea (L2A data is common to Bojongsoang, select only those with R032 in File name)

```
[DEFAULT]
gis_fnam = %(top_dir)s/Shapefile/All_area_polygon_20210914/All_area_polygon_20210914.shp

[download]
download.trans_path = /SATREPS/ipb/User/1_Spatial-information/Transplanting_date/Cihea/final/v1.4
download.l2a_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/L2A
download.geocor_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/geocor
download.indices_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/indices
download.parcel_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/parcel
download.atcor_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/atcor
download.interp_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/interp
download.tentative_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/tentative_interp
download.search_key = R032

[geocor]
geocor.ref_fnam = %(top_dir)s/WorldView/wv2_180629_mul.tif
geocor.trg_subset = [107.201,107.367,-6.910,-6.750]
geocor.trg_resample = [743805.0,757295.0,9235815.0,9251805.0]

[atcor]
atcor.clean_thr = [0.06,0.05,1.0]
```

When the target area is Bojongsoang

```
[DEFAULT]
gis_fnam = %(top_dir)s/Shapefile/Bojongsoang/Bojongsoang.shp

[download]
download.trans_path = /SATREPS/ipb/User/1_Spatial-information/Transplanting_date/Bojongsoang/final/v1.0
download.l2a_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/L2A
download.geocor_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/geocor
download.indices_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/indices
download.parcel_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/parcel
download.atcor_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/atcor
download.interp_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/interp
download.tentative_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/tentative_interp
download.search_key =

[geocor]
geocor.ref_fnam = %(top_dir)s/WorldView/wv2_190816_mul.tif
geocor.trg_subset = [107.54,107.75,-7.04,-6.95]
geocor.trg_resample = [790585.0,799555.0,9224425.0,9229335.0]

[atcor]
atcor.clean_thr = [0.08,0.05,1.0]
```

When the target area is Testsite (For Geometric Correction and Calculate Indices, use preprocessing results of Cihea downloaded from NAS)

```
[DEFAULT]
gis_fnam = %(top_dir)s/Shapefile/Testsite_polygon_20210914/Testsite_polygon_20210914.shp

[download]
download.trans_path = /SATREPS/ipb/User/1_Spatial-information/Transplanting_date/Cihea/final/v1.4
download.l2a_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Bojongsoang/L2A
download.geocor_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/geocor
download.indices_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Cihea/indices
download.parcel_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Testsite/parcel
download.atcor_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Testsite/atcor
download.interp_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Testsite/interp
download.tentative_path = /SATREPS/ipb/User/1_Spatial-information/Sentinel-2/Testsite/tentative_interp
download.search_key = R032

[geocor]
geocor.ref_fnam = %(top_dir)s/WorldView/wv2_180629_mul.tif
geocor.trg_subset = [107.201,107.367,-6.910,-6.750]
geocor.trg_resample = [743805.0,757295.0,9235815.0,9251805.0]

[atcor]
atcor.clean_thr = [0.06,0.05,1.0]
```