# NDVI to Variable Nitrogen Application Map – QGIS plugin

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**(Version 0.9** for ***Education purposes*****)**

- Satellite images download – Copernicus Browser
  - Copernicus Data Space Ecosystem (CDSE), Modified Copernicus Sentinel data 2024 processed in Copernicus Browser. https://browser.dataspace.copernicus.eu/
- QGIS-based NDVI analysis and N prescription map processing
  - QGIS 2024. QGIS.org, Geographic Information System. QGIS Association. http://www.qgis.org

## 1. Conceptual framework (Precision Agriculture)

To enable site-specific variable management of nitrogen fertilizer (production input) site-specific variability hast to be ***quantifiable*** and ***manageable***. Quantifiable refers to specific means and methods for quantifying site-specific biomass variability (e.g. satellite image based NDVI and/or EVI etc.). Manageable in a sense of being able practically via fertilizer spreader to reduce/increase fertilizer application amounts on a site-specific level.

With this open-source plugin the user can use NDVI (EVI) to identify in-field variability based on index value on site-specific level. There are two methods to utilize the index-based indication about site-specific level-based biomass variability. If it's ***hypothesized*** that higher NDVI index value indicates better plant growth conditions a user can aim at: 1) agronomic yield maximizing or 2) agronomic yield equalizing site-specific variable nitrogen application.

In developed countries maximum nitrogen application amount per hectare in one season is limited due to environmental pollution concerns. This implies that if farmer wants to manage field nitrogen application on a site-specific level, it can be done only by reducing nitrogen applied in some areas of the field and increasing it in others.

***Agronomic yield maximization*** would prescribe more fertilizer to be applied in the areas where plants "grow better" (e.g. higher NDVI) and less in the areas where index "indicates" less favourable conditions for plant growth.

***Agronomic yield equalizing (homogenizing)*** variable N application would prescribe more fertilizer to be applied in the areas of the field with lower index values, under the assumption that plant need more nutrients in order to "catch up" with the rest of the field. It is assumed that this would lead to more equal biomass spread in the field at the end of season.

## 2. Required inputs

Two important geospatial input layers are required for running the plugin:

**1)** site-specific units delineating Input Layer (shape file delineating sub-field units – polygons) (***should be unzipped before adding to QGIS layer legend, in case if shape file is in zipped directory! This file should not be located on part of hard drive where QGIS plugin has no permission to access directory.***),

**2)** georeferenced NDVI input raster (.TIF) that can be downloaded for specific dates via Copernicus Browser. In addition, via Copernicus Browser raw data (e.g. B02, B04 and B08) can be downloaded and NDVI can be calculated with QGIS Raster Calculator or experimental plugin "NDVI and EVI Index Calculator". The index layer naming convention has to follow instructed in order for plugin to process the data:

- Input raster - Input  layer of NDVI or EVI (file name has to end with date string e.g.: ...NDVI_03-24-2023) (layerName_M-D-Y) (add underscore before date!).

## Guide to user:

1. - **Input layer** - site-specific units delineated (e.g. shape file) based on which zonal statistics are calculated. THIS INPUT CANNOT BE IN ZIPPED FILE AND IT CANNOT BE ON LOCATION WHRE QGIS PLUGIN DOESNT HAVE PREMISSION OF ACCESS.

   - **Input raster** - raster image providing pixel-based info (e.g. NDVI .TIFF file) for deliniated areas used for zonal statistics.

2. - **Image analysis** - produces raster based on initial site-specific polygon delineation. Here user can setup number of index classes that are calculated based on layer-specific index min and max, or from 0 to 1, with colour.

3. - **Calculate time-series trends** (optional - works only if date strings are in raster names included) - raster values added into time-series figure, and saved in FigureSaved dir.

4. - **Initializing analysis**, either **4.1 Variable N application setup** (N) or **4.2 Variable Yield potential setup** (Y) - based on variable index values.

   **4.1 - Variable N application setup (N)** - based on in-field variability a user can define min and max (N) prescription that will be allocated to index values in relative terms, or user automatically generated min and max N, which are based on percentage difference between index mean and min and max.\n\n'

   **4.2 - Variable Yield potential setup (Y)** - based on in-field variability a user can define min and max yield (Y) potential zones that will be allocated to index values in relative terms, or user automatically generated min and max yield, which are based on percentage difference between index mean and min and max.

   - Method selection - "**Maximising**" for (4.1 selection) - N application rates method. Yield maximising N application rate will allocate more N to polygons with higher index values, and "Equalising" for (4.1 selection) will allocate more N to the polygons with lower index values.

   - Method selection - "**Maximising**" for (4.2 selection) - Yield potential rates. "Maximising" yield potential rates will allocate more Yield to polygons with higher index values.

   - **Process Maps** - push button will process data and produce maps and save them in SavePDFs directory, which is located in main output directory.

   - Convert N kg/ha recommendations to fertilizer amounts kg/ha (e.g. CAN fertilizer has 27% N and based on given % plugin conducts conversion).

   - Scale amounts to actual size of a grid - push button recalculates amounts based on real "area" size of defined delineated grids.

### 3. Running plugin

Sample files for testing QGIS plugin can be found in GitHub:

https://github.com/memicemir/ndvi_to_variable_N_application/tree/main/SampleImage-TestPlugin

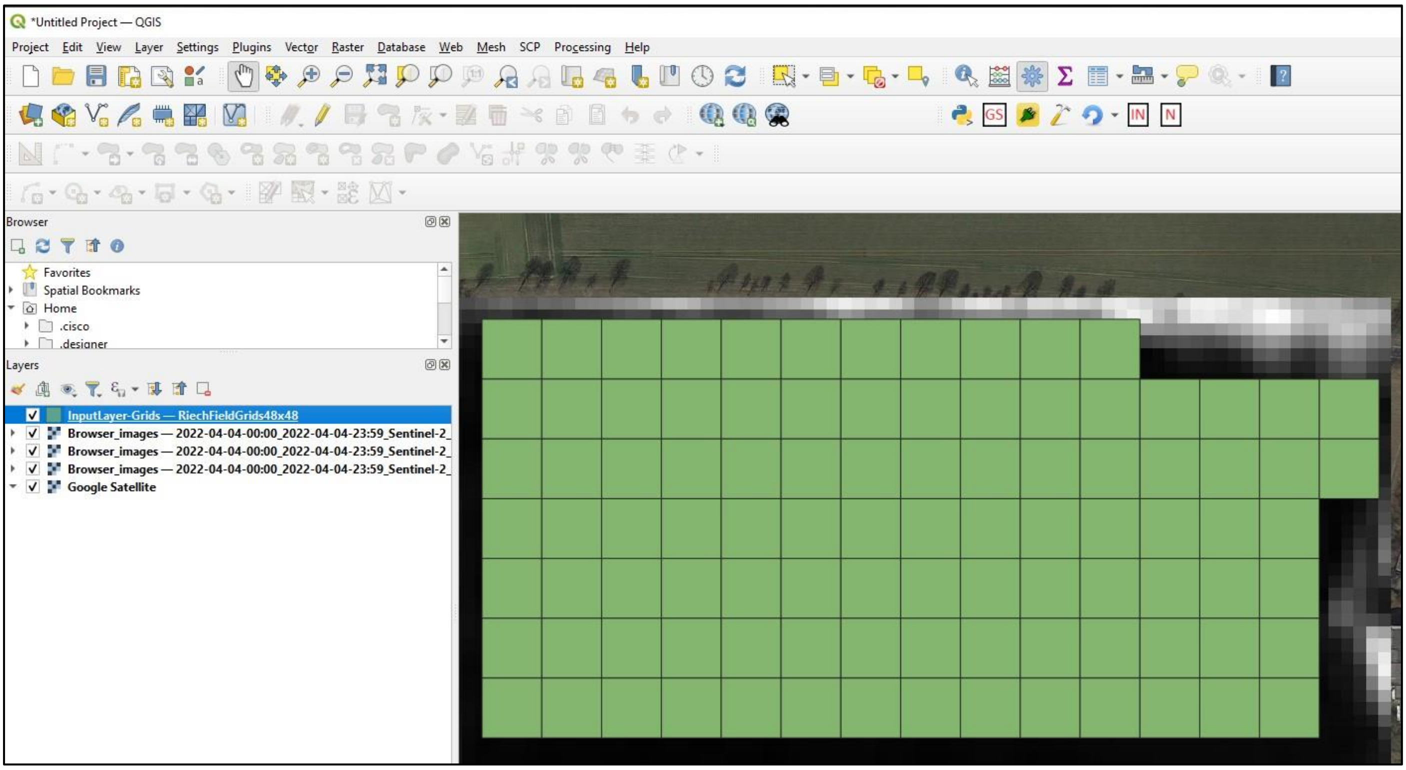


**Figure 1.** Input layers required for running plugin: geospatial grid (shape layer) and Sentinel 2 raw bands (in this case from Copernicus Browser). The shape file can be created in QGIS: Vector -> Research tools -> Create Grid

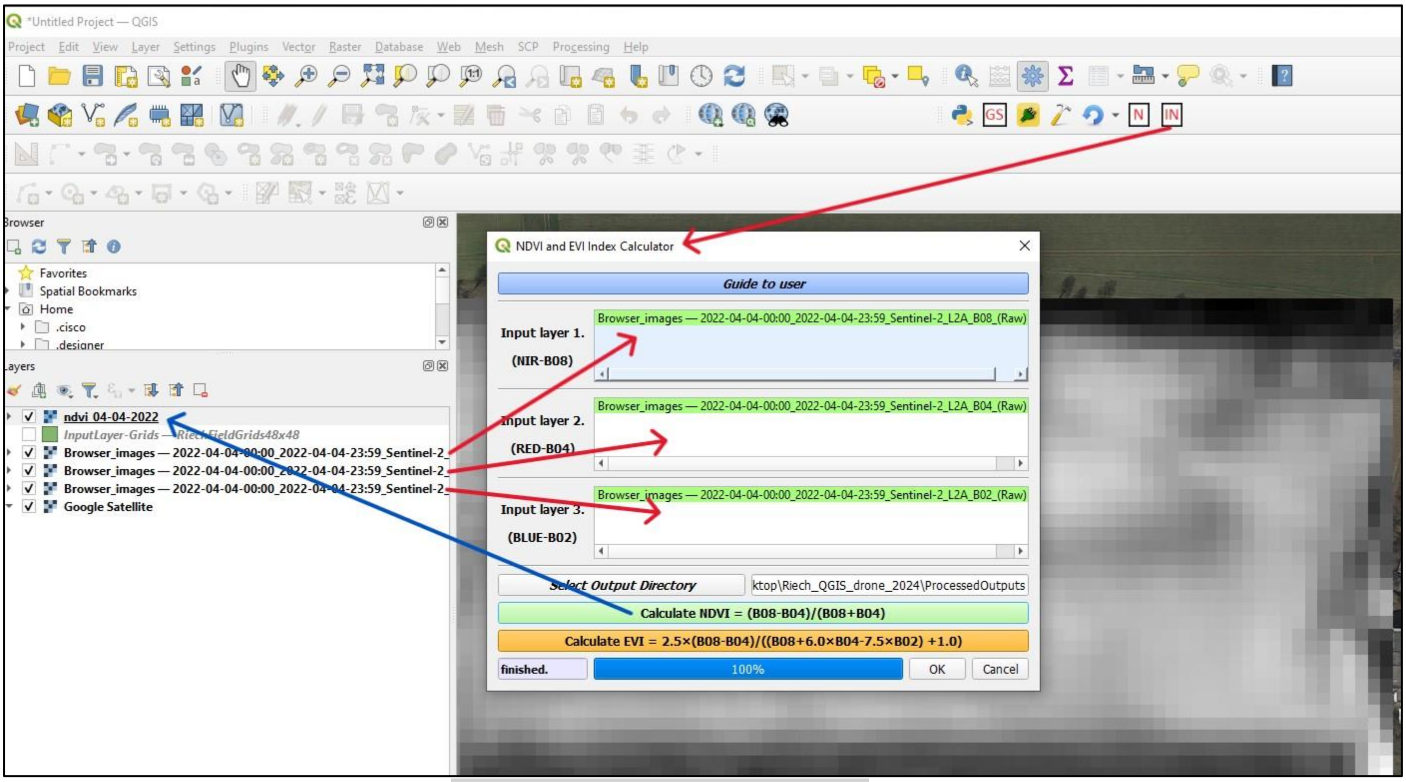


**Figure 2.** Using already published NDVI and EVI Index Calculator plugin a user can produce NDVI index layer from Red (B04) and Near infrared (B08) bands.

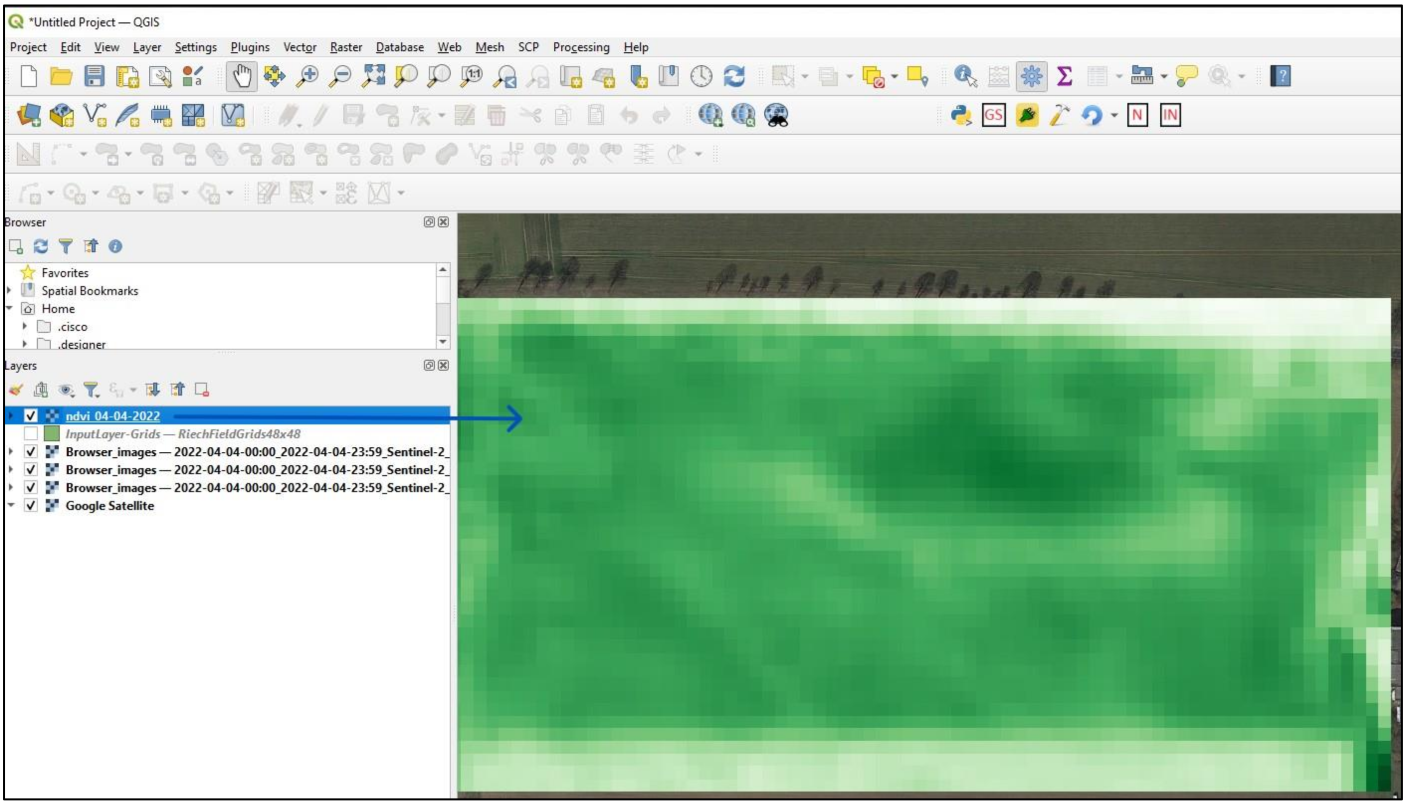


**Figure 3.** The NDVI index layer in QGIS (naming -> layername_M-D-Y e.g. ndvi_04-23-2022)

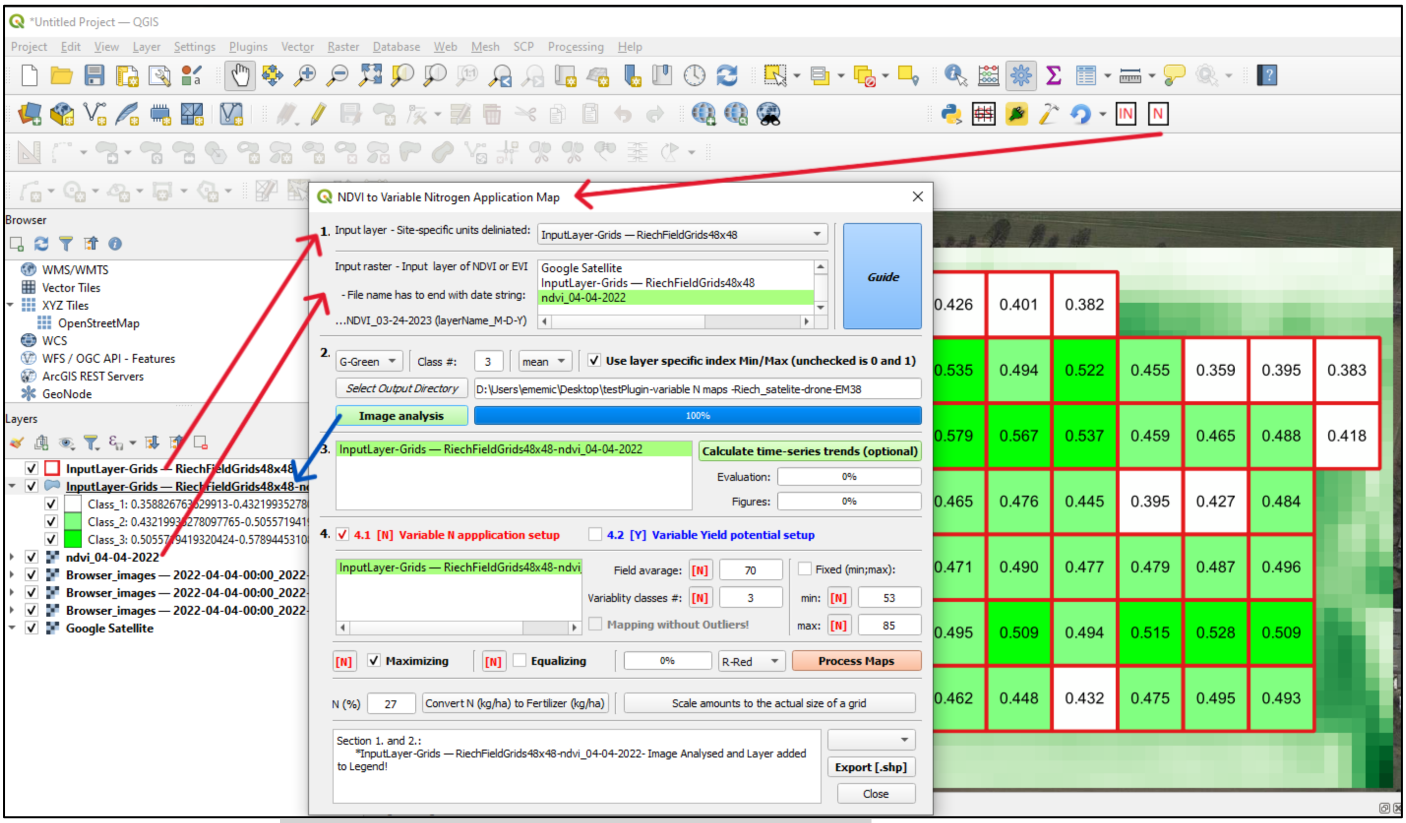


**Figure 4.** Initializing NDVI to Variable Nitrogen Application Maps plugin will open interface. In the interface section 1 in Input layer the user selects grid shape file and in Input raster the user selects NDVI index layer. Once Image analysis push button in section 2 in the interface is pressed, it will produce a new layer with grid (polygon) based index values. In Figure 5 the options from interface section 2 are described.

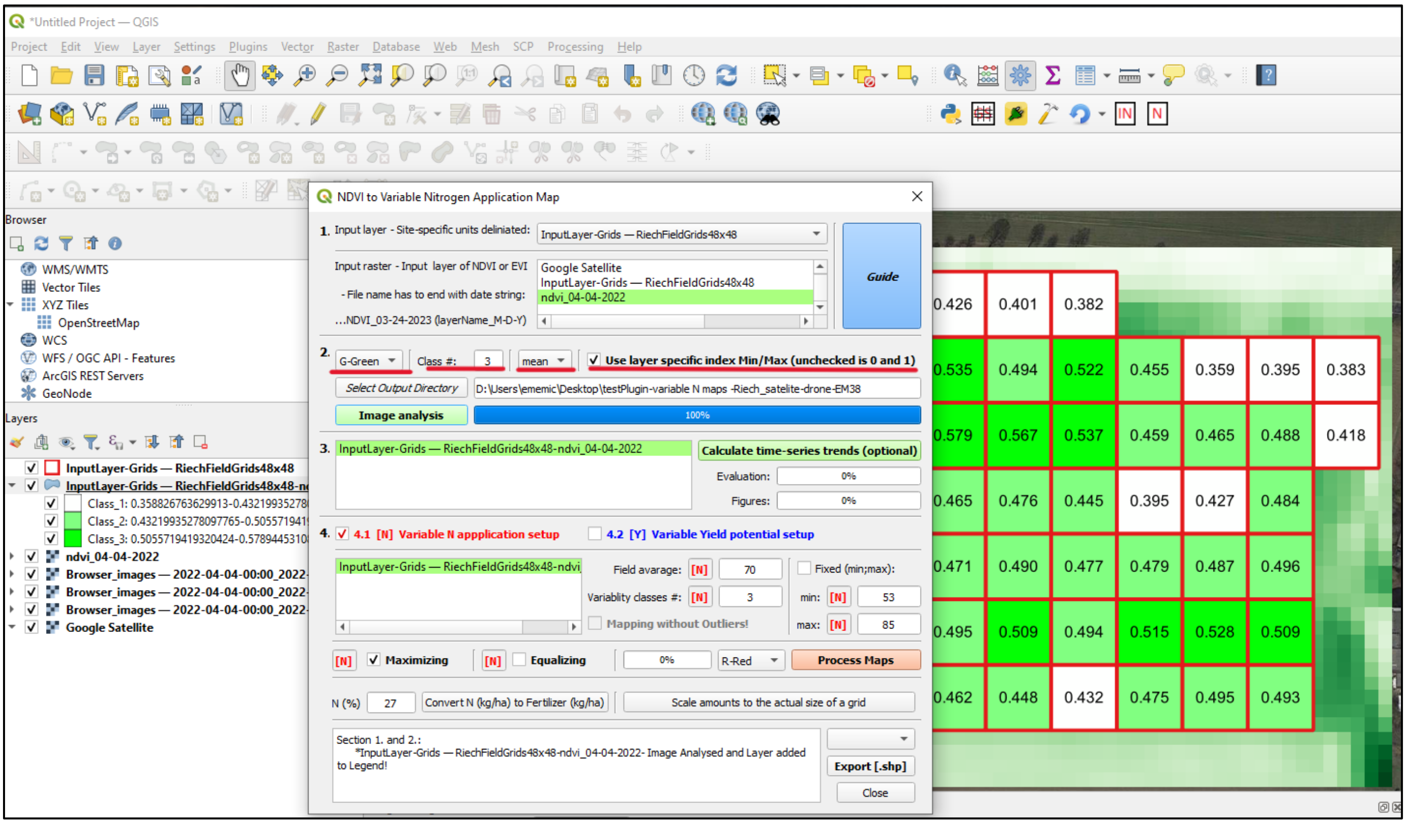


**Figure 5.** In section 2 in the interface the user can initialize the color of the heat map that will be used (e.g. red, green, blue) and number of index classes (categories). With in the interface Class #: 3 the plugin will assign all index values to three classes based on index min/max by splitting it in three equal interval categories. The option **mean** is the targeted field in the Attribute table used for analysis. Categories are based on the mean values from Attribute table. The user can also select processed files output directory or continue using automatically generated (automatic is generated based on Input layer from section 1). Path should not contain zipped directories in it or be located at part of hard disk where QGIS plugin has no permission to access.

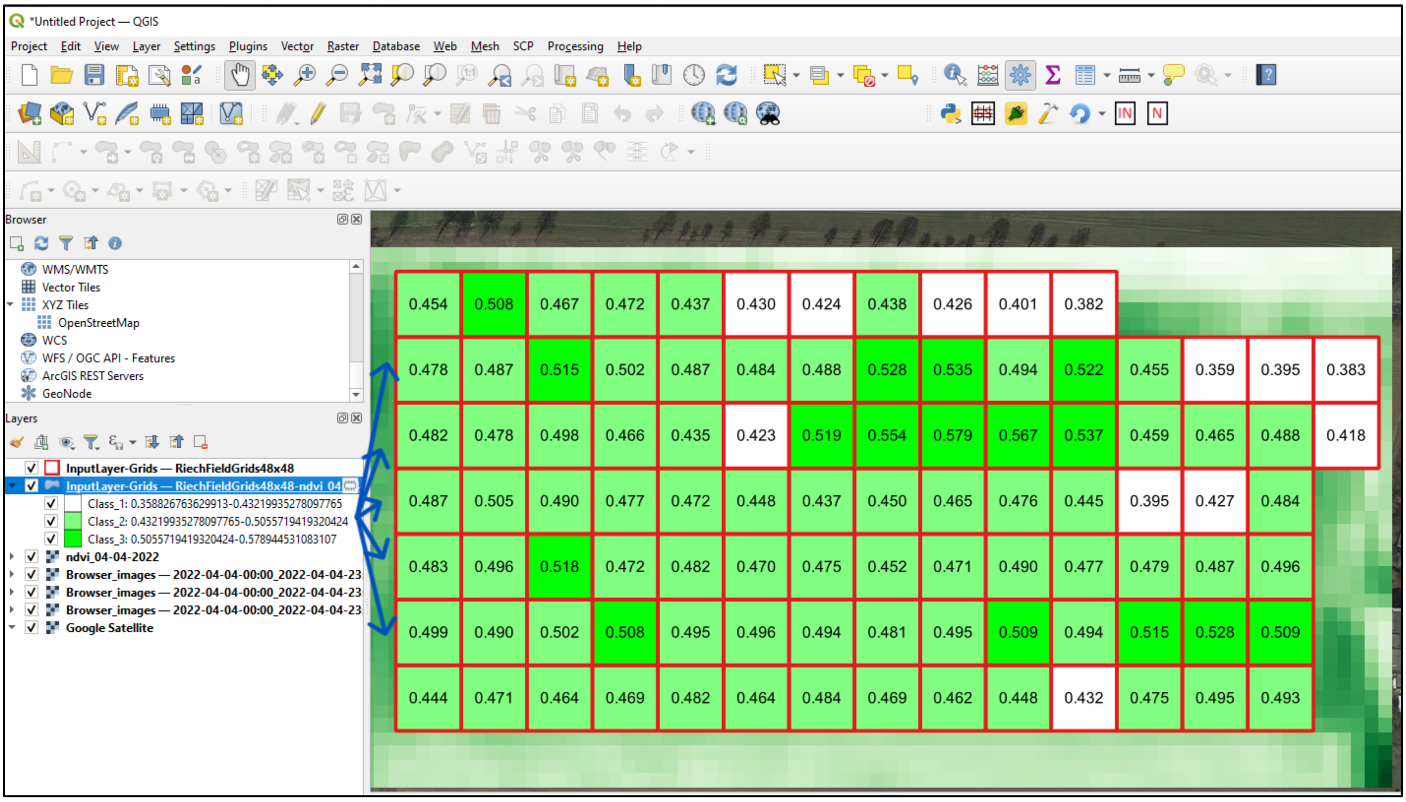

**Figure 6.** The output heat map is based on three categories of newly produced layer (in this example).

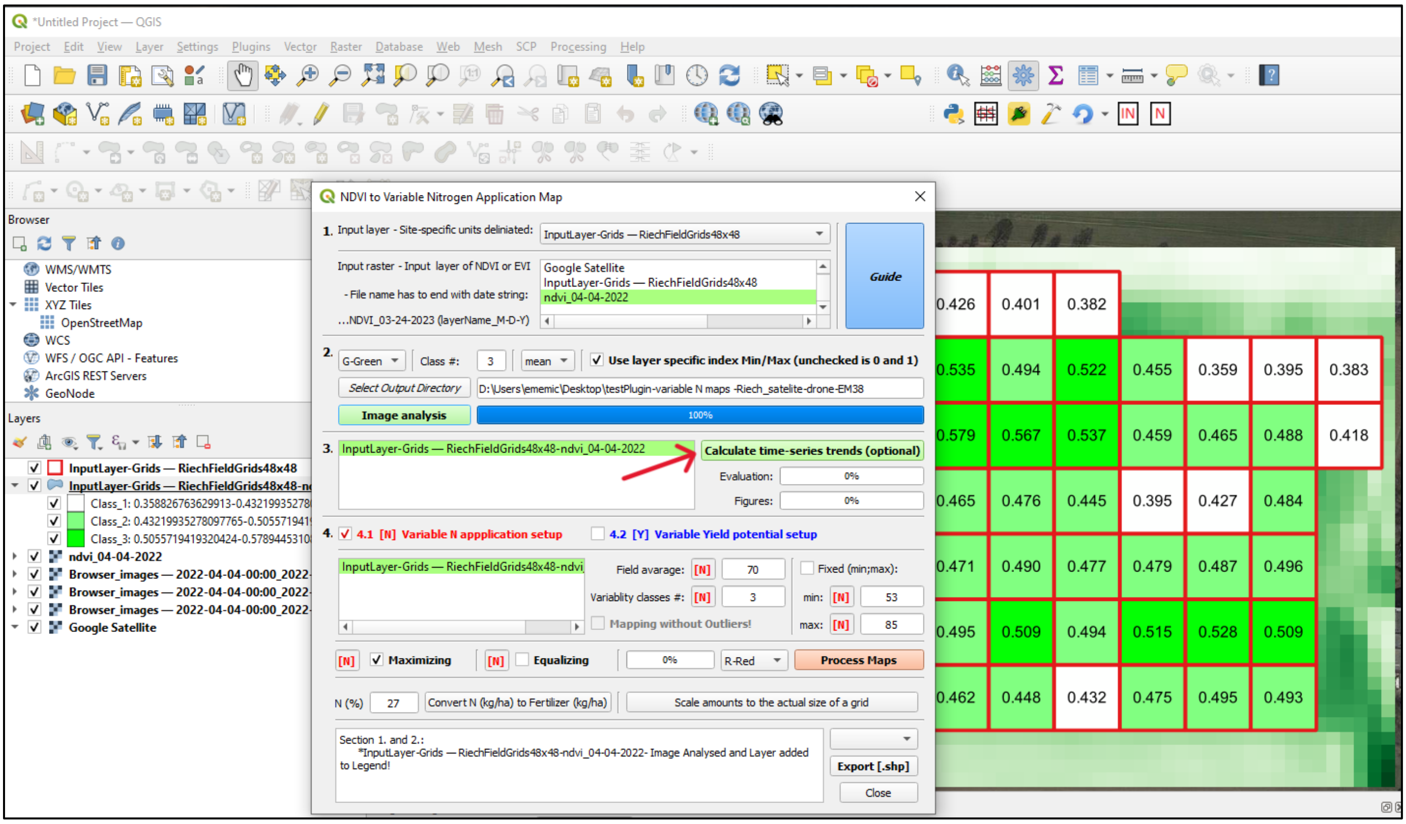


**Figure 7.** In the interface section 3 newly produced layer is added to the list widget window and is used for calculating time-series trends of all available indices. Output values are saved in the SaveFigures directory, which is located in directory defined in section 2 of interface. Layer map of index distribution is saved automatically as photos (.png) of the layers in SavePDFs directory. This calculation is optional and meaningful if user has more than one index layer, or in the case of creating maps without OUTLIERS (demonstrated in Figures 13-16).

In the section 4 – **4.1 Variable N application setup (N)** - of the plugin interface there are multiple options that have to be considered before clicking Process Maps push button to create site-specific N application map.

The user can enter Field average N application amount. The filed-specific N refers to N application on field scale if user would apply uniform N throughout all field. Variability classes # refers to how many N variability classes user wants to create (if its 3, as in example the plugin will create three N application rates such as: low yielding, medium yielding and high yielding N application zones). Classes number 3 will classify index values in three groups based on field specific index minimum and maximum with equal interval ranges, as can be seen in layer legend.

min and max N bounds are created based on relative difference of index mean to index minimum;maximum. Relative difference between field index mean and lowest index value in the field is multiplied with Field-specific N value and min N is populated with that relative difference. Same is the case for max N. If the user change Field-specific N, then min and max N bounds are automatically modified based on relative difference between index mean and min;max. If the user is not satisfied with the automatically generated min and max N bounds the user can modify the bounds manually and by checking the Fixed (min;max) check box fix them for creating N application map.

Yield maximizing and equalizing N optimization options were described at the beginning of this document.

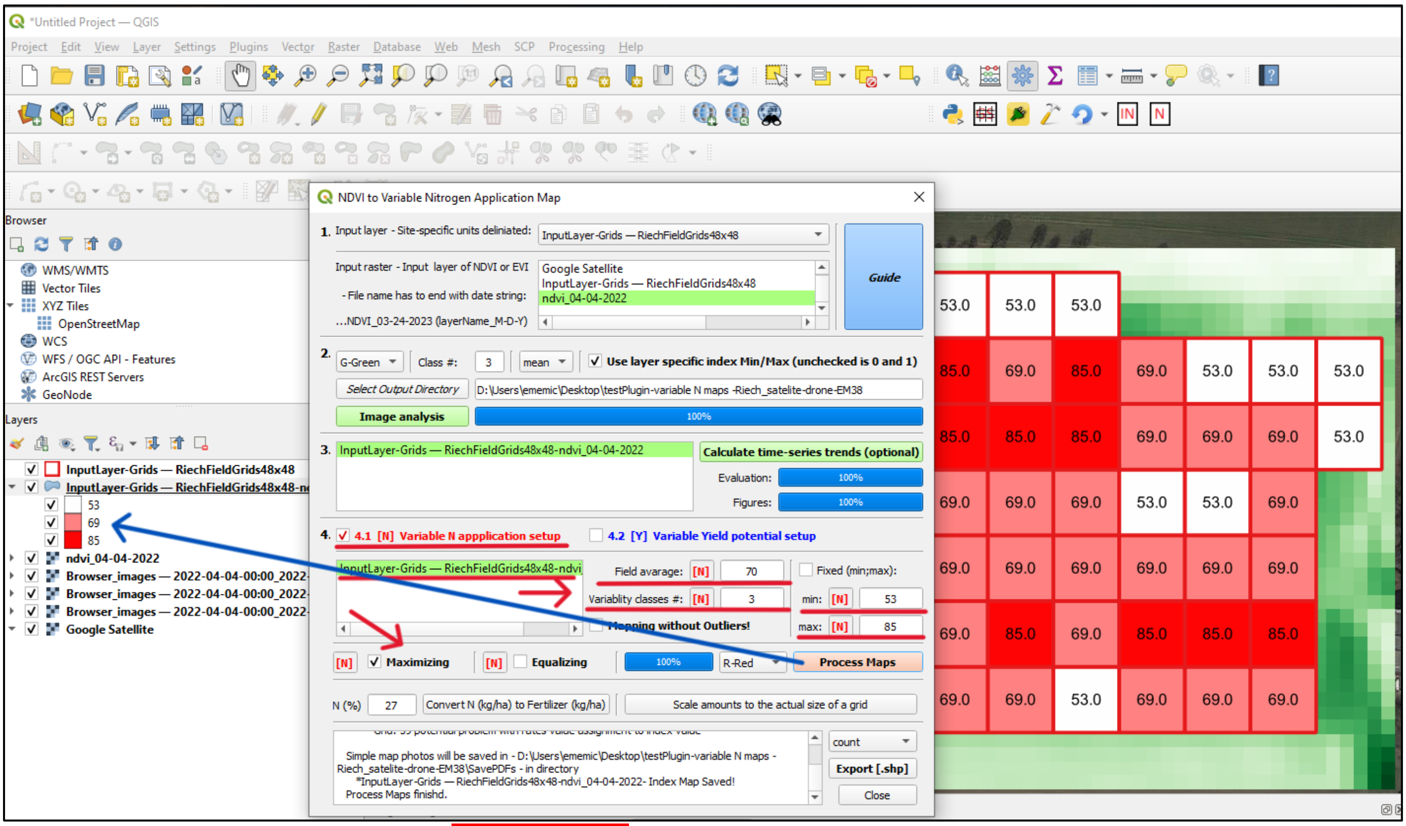


**Figure 8.** In section 4 site-specific Process Maps are created and layer is saved as image (.png) in SavePDFs automatically. The Process Maps push button will produce information about distribution (Figure 9) of the N application values, in the SavePDFs directory.

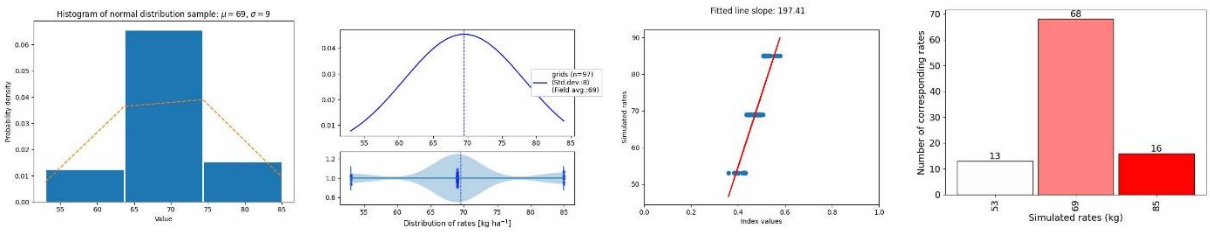


**Figure 9.** This information will give a user a better idea of how many grids belong to which category.

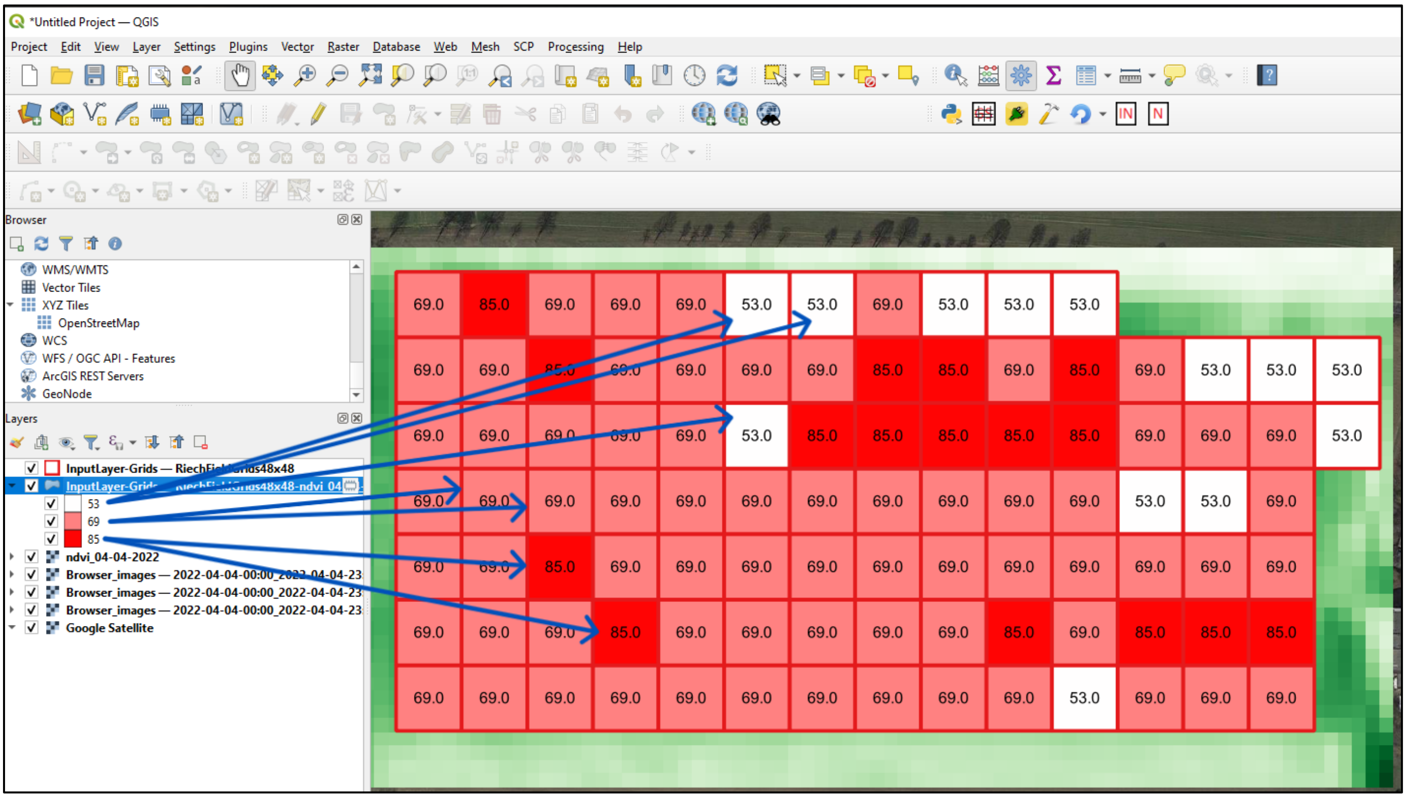


**Figure 10.** Output heat map of site-specific N recommendations. This is hectare scale recommendation.

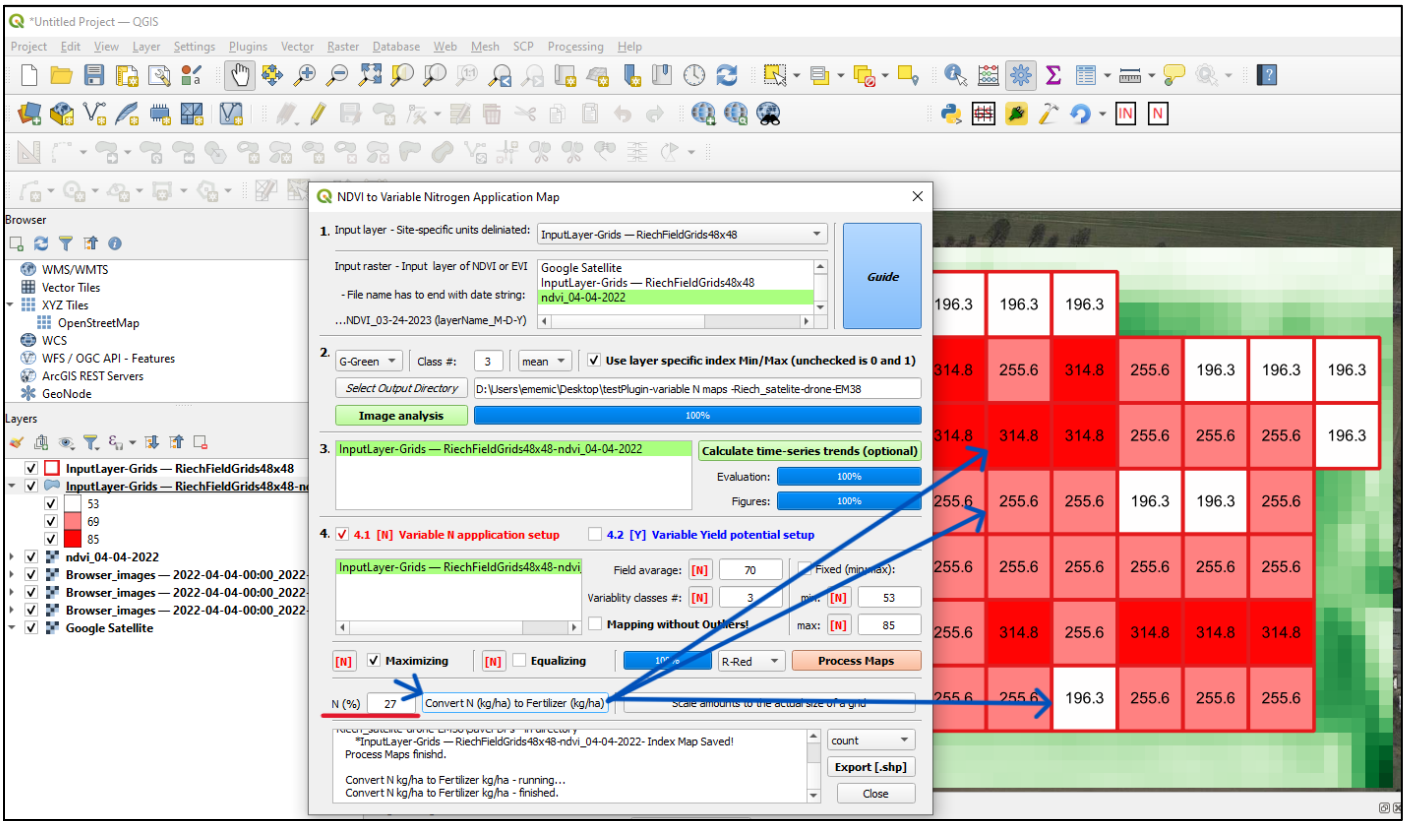


**Figure 11.** Converting N kg ha$^{-1}$ recommendations into fertilizer amount kg ha$^{-1}$, e.g. CAN fertilizer with 27% N as in interface example.

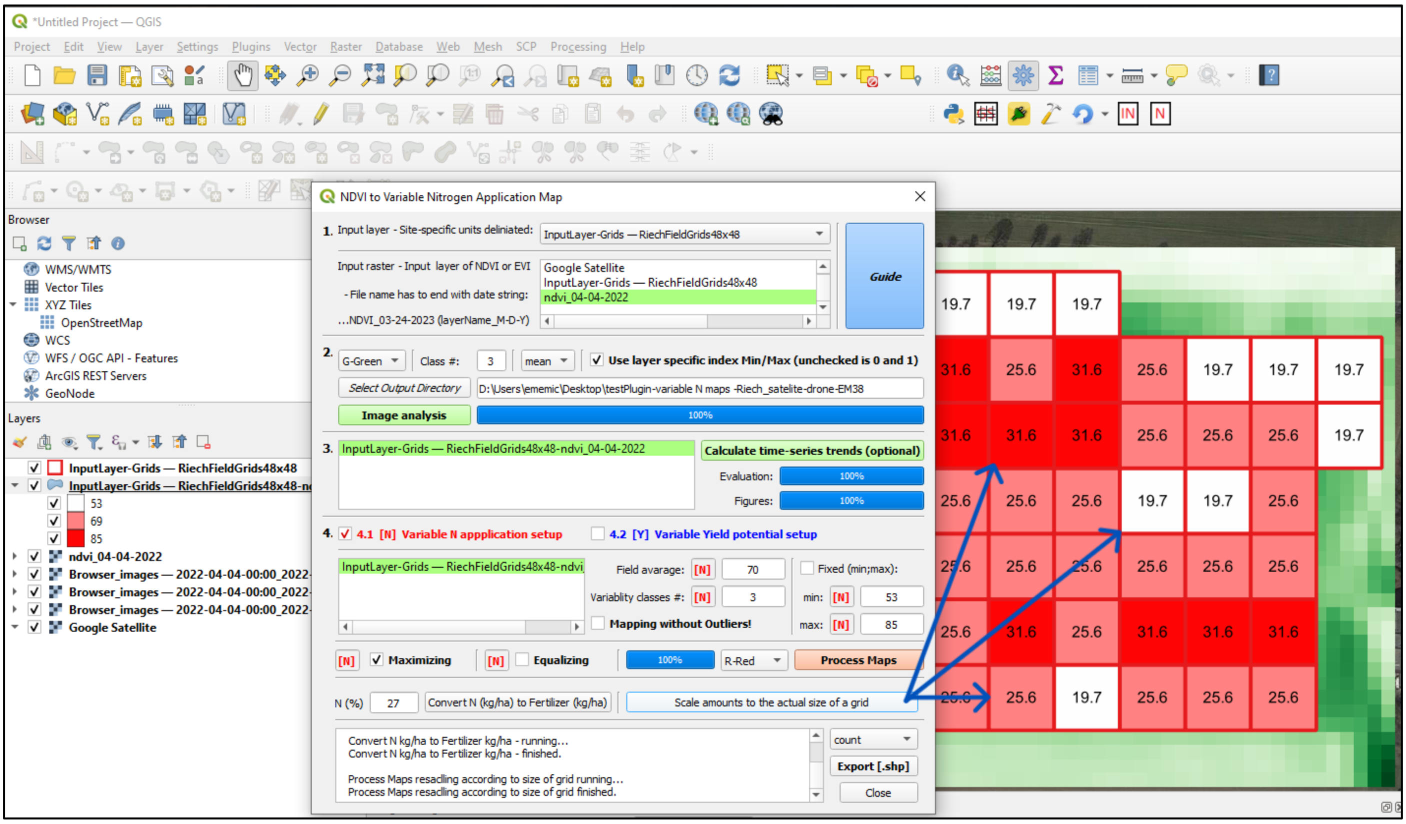


**Figure 12.** If the user wants to see what nitrogen recommendation would be depending on the size of the grid (rescaled according to size of site-specific unit) user can achieve that by pressing the push button Scale amounts to actual size of grid. This push button will create an additional field in the Attribute table named “actualNkg”.

In the section 4 – **4.2 Variable Yield potential setup (Y)** - of the plugin interface there are multiple options that have to be considered before clicking Process Maps push button to create site-specific yield potential map (**Figure 13**).

The user can enter Field average Y -yield potential. The filed-specific Y refers to Y potential on field scale, based on historical data. Variability classes # refers to how many Y variability classes user wants to create (if its 3, as in example the plugin will create three rates such as: low yield, medium yield and high yield zones). Classes number will classify index values in three groups based on field specific index minimum and maximum with equal interval ranges, as can be seen in layer legend.

min and max Y bounds are created based on relative difference of index mean to index minimum;maximum. Relative difference between field index mean and lowest index value in the field is multiplied with Field average Y value and min is populated with that relative difference. Same is the case for max. If the user change Field average Y min and max Y bound are automatically modified based on percentage difference between index mean and min/max. If the user is not satisfied with the automatically generated min and max Y bounds the user can modify the bounds manually and by checking the Fixed (min;max) check box use it in producing site-specific yield map.

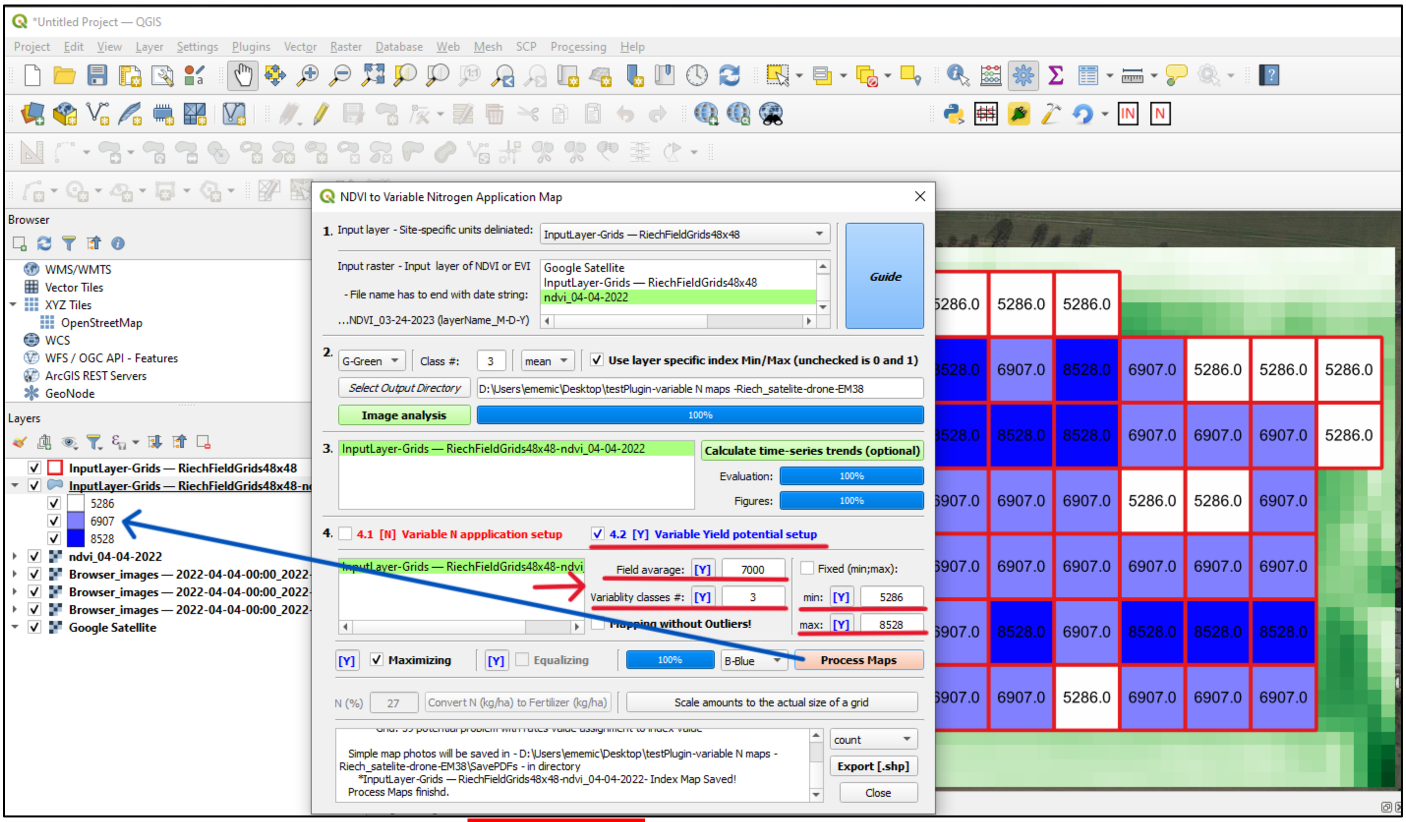

**Figure 13.** In section 4 site-specific Process Maps are created and layer is saved as image (.png) in SavePDFs automatically.

## NEW option! Map creation without outliers:

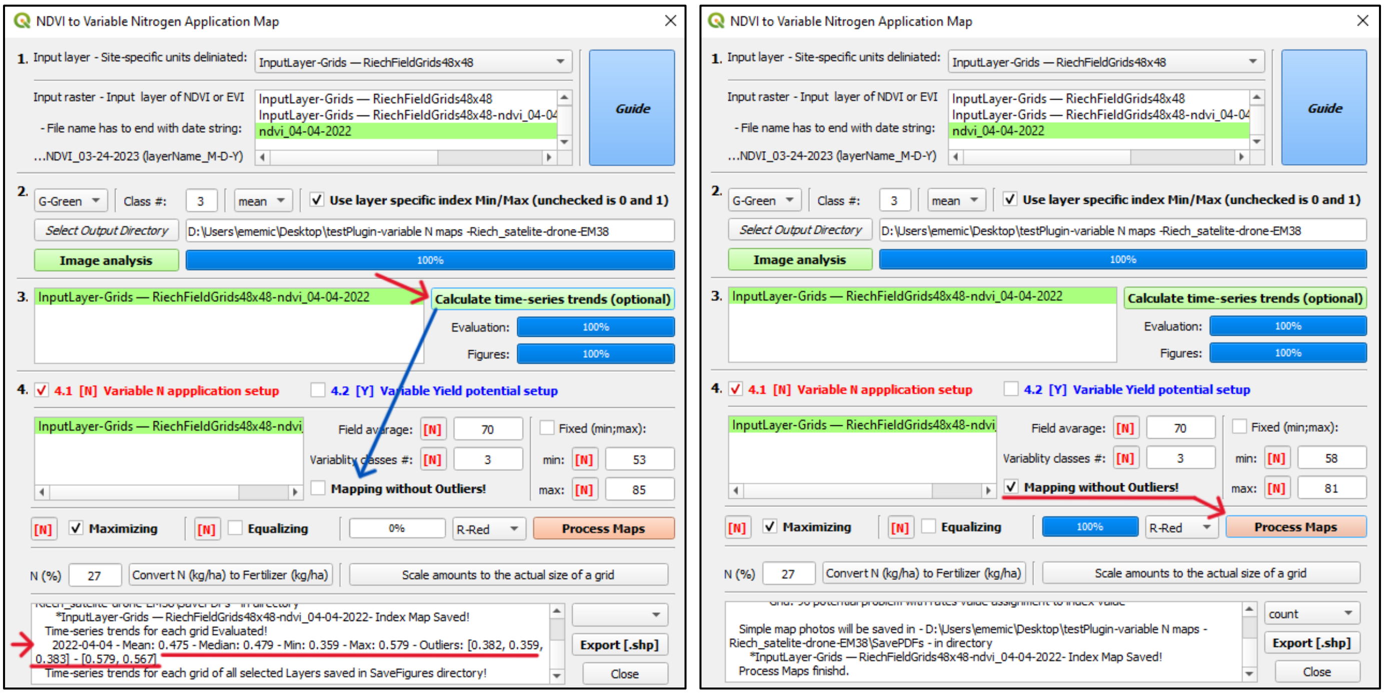

**Figure 14**. In order to use the option "Mapping without Outliers" a user has to execute "Calculate time-series trends" option in section 3. even if they might have only one index record. "Calculate time-series trends" option will conduct specific calculations required for later map creation without outliers.

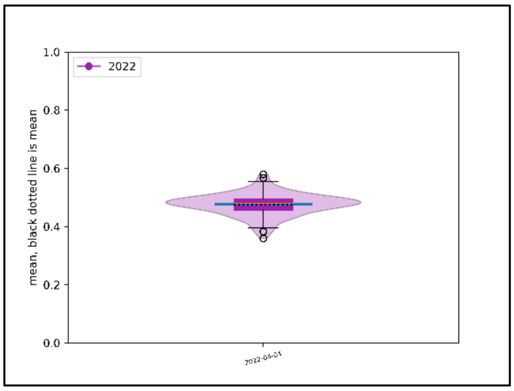


**Figure 15.** When time-series trends push button is executed it will produce BoxPlot.png in SaveFigures output directory


**Figure 16.** This is site-specific N variable map produced without excluding outliers.


**Figure 17.** This is site-specific N variable map produced with excluding outliers.

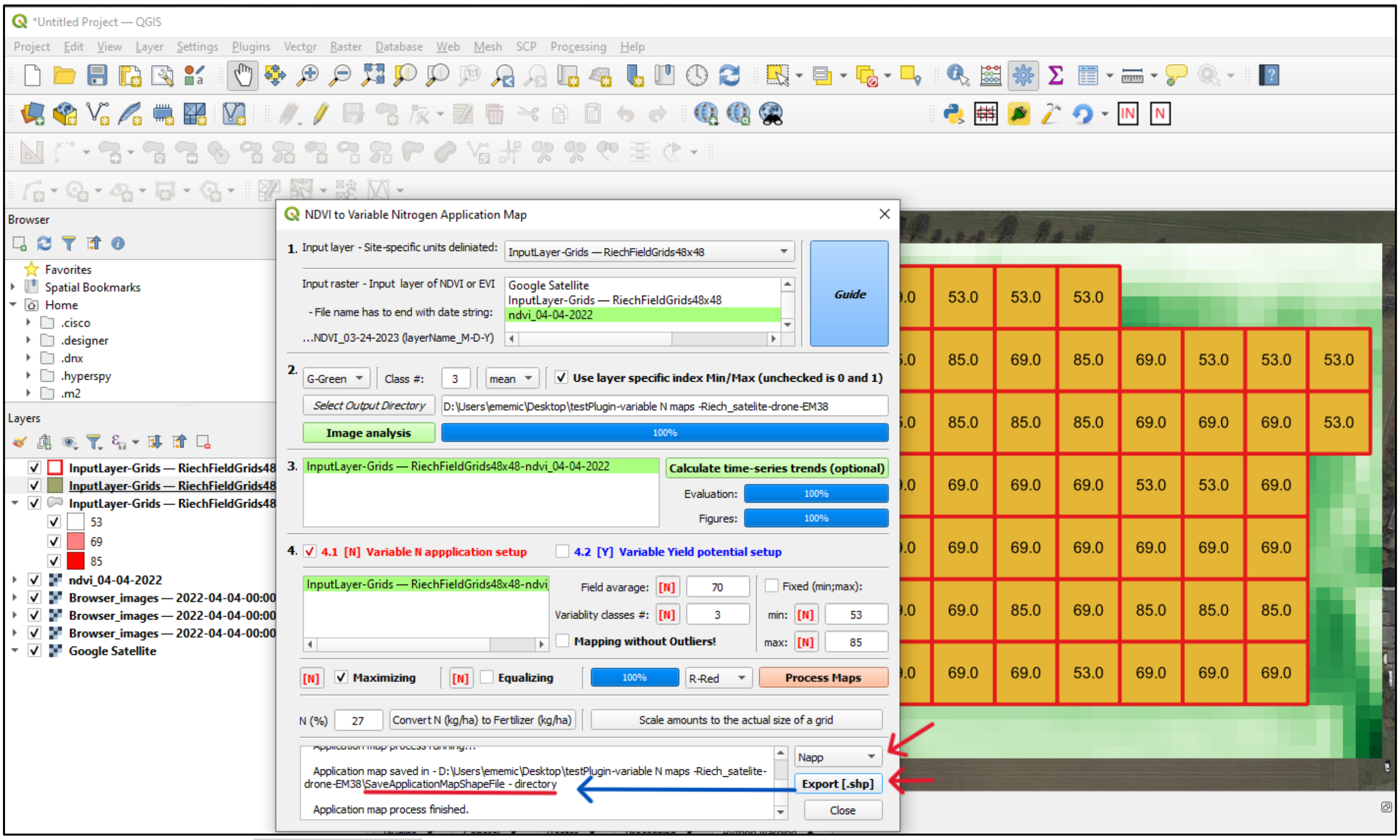


**Figure 18**. Saving (Export [.shp]) application map as shape layer by selecting the N application column (Napp) from combobox widget and pressing Export push button.