1. Overview

AgroEye is an advanced Open Source application for Polish Agency for Restructuring and Modernisation of Agriculture (Eng. ARMA, pl. ARiMR). **AgroEye** is designed to support verifying agricultural lands in terms of European Union Good Agricultural and Environmental Conditions (GAEC). Application provides fast, accurate and simple way to check the dynamic of agricultural changes in order to help ARMA control rules related with direct payments. Many of GAEC rules require field evaluation couple of times within a year, together with spatiotemporal analysis. With remote sensing approach, it is possible with reasonable financial expenditures.

More generally, this system is designed to easy use spatial analysis system for agriculture which can be used not only by ARMA. **AgroEye** application will also be offered to other agencies (like National Parks, Polish State Forest National Holding, General and Regional Directorate for Environmental Protection). Prepared user friendly application that gives what is need for decision making will popularise both satellite imagery and will the trust in quality of spatial analysis.

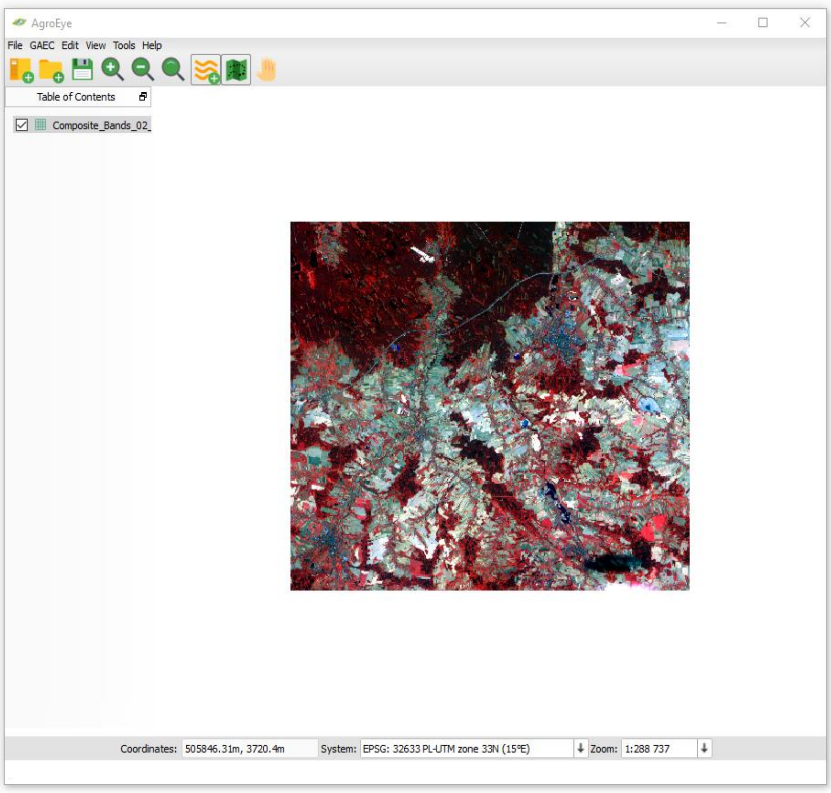


Figure 1. *Main Window of AgroEye (Image – Sentinel-2 11.01.2016 ESA).*

1.1. About the software

The **AgroEye** is developed with Python programming language, with only use the Open Source modules and libraries. The application is not limited to only one operating system, it runs both

on Windows and on different GNU/Linux flavours. The **AgroEye** is redistributed in number of ways. Firstly, the source code is available to download from Bitbucket. The end-user can download python scripts, compile the C++ modules and run with Python Interpreter. The other way of distributing application is the prepared package containing all necessary modules (and precompiled if necessary) plus preconfigured Python Interpreter. The second manner is aimed to regular Windows users.

2. Basic Concepts

This chapter introduces elementary terms of analysis with **AgroEye**.

2.1. Raster and Raster Bands

Raster is a set of raster image data. Each *raster band* represents a type of information. The most common *raster bands* are Red, Green and Blue (RGB) bands. The Sentinel-2 contains 13 spectral bands: four bands at 10 metres, six bands at 20 metres and three bands at 60 metres spatial resolution.

Table 1 Sentinel 2 bands with resolution and wavelength.

Sentinel-2 Bands	**Central Wavelength (nm)**	**Resolution (m)**
Band 1 – Coastal aerosol	443	60
Band 2 - Blue	490	10
Band 3 – Green	560	10
Band 4 – Red	665	10
Band 5 – Vegetation Red Edge	705	20
Band 6 – Vegetation Red Edge	740	20
Band 7 – Vegetation Red Edge	783	20
Band 8 - NIR	842	10
Band 8A – Vegetation Red Edge	865	20
Band 9 – Water vapour	940	60
Band 10 – SWIR - Cirrus	1375	60
Band 11 - SWIR	1610	20
Band 12 - SWIR	2190	20

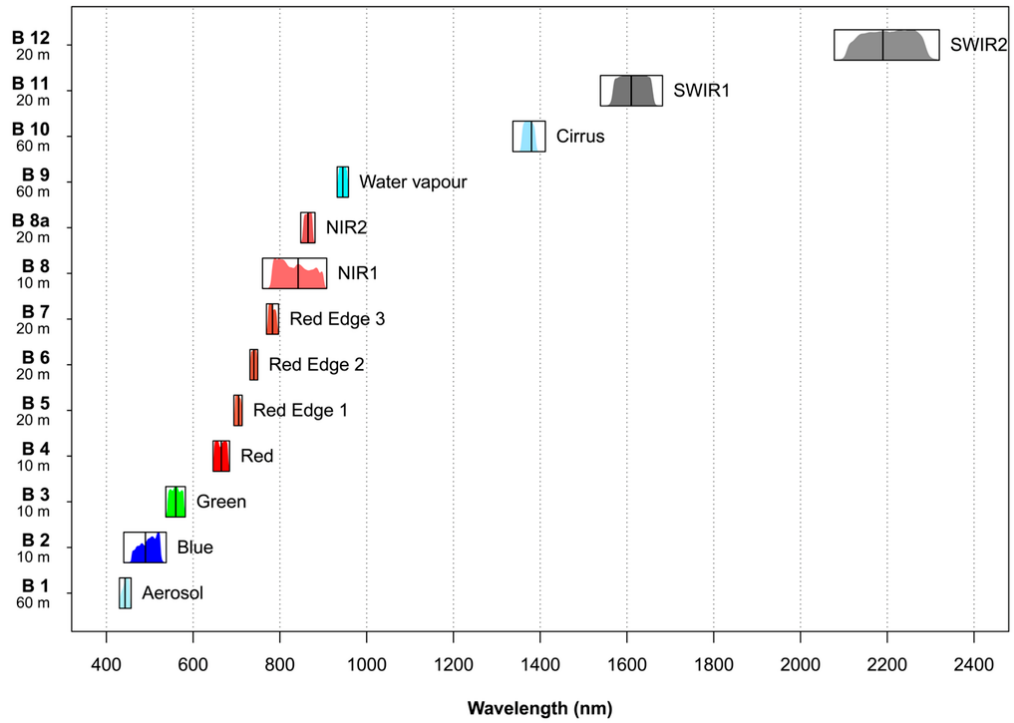


Figure 2. *Figure 2 Spectral and spatial resolution of Sentinel-2 imagery (source: http://www.mdpi.com/2072-4292/8/3/166/htm)*

Sentinel-2 images are stored in format JPEG2000 with *.jp2 files extension. **AgroEye** can open raster file stored as .tiff, .jp2 or other raster file format with supporting georeferencing.

Inside **AgroEye** images are represented by *layers*.

2.2. View Area

AgroEye loads raster and vector data into *View Area. View Area* consists of one or more *layers* or *bands* of one image file. *View Area* include additional information related to the file, such as coordinate system. Each *View Area* representing one set of data used in **AgroEye** software is managed in *project*.

2.3. Layer

AgroEye loads image data as *layers*, which means that each layer represents one raster or vector file. The *layer* consists of one or more *image bands*. Layer can include additional information related to the file, such as metadata or geoinformation.

2.4. Project

Project file stores references to the opened layers and related information about coordinate system and *View Area* settings. During creation of a *project*, *layers* are referenced into project. The results of GAEC is not added to project. Layers from classification are saved into temporary directory. The project file is saved as an .xml project file.

2.5. Table of Contents

Table of Contents is a container for layers. It contains raster and vector data references. In the *Table of Contents,* you manage the loaded files. Here you manage all data of your project.

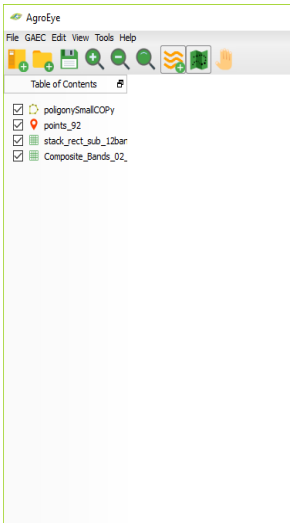


Figure 3. *Table of Contents with loaded files as drop-down menu.*

2.6. Segment Objects

The image *layer* is transformed into *segment objects* during the process of segmentation which is one step of GAEC rules. *Segment objects* are stored in SpatiaLite database. Every single *segment object* can provide information about this geometry and precalculated statistics (mean value or standard deviation). Storing the *segment objects* in database simplifies and speeds up the process of classification.

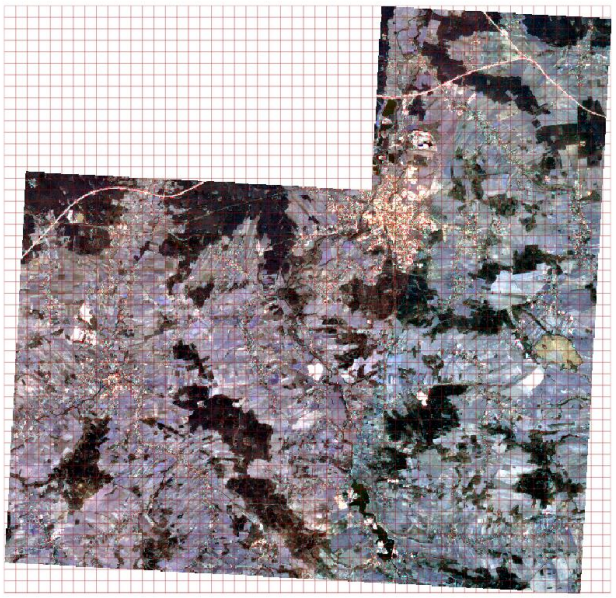


Figure 4. *Outlines of segments processed by Agroeye.*

2.7. Vector

AgroEye software enables the possibility to work with *vector* data. *Vector* is consisted of points, that may be grouped into objects representing lines and polygons. Vector objects at top level are called *features*. **AgroEye** loads vector data as *layers*.

There are four major vector data formats supported by **AgroEye**:

- ESRI Shapefile
- KML (Keyhole Markup Language)
- GPX (GPS eXchange Format)
- SpatiaLite DB

2.7.1. ESRI Shapefile

Shapefiles store geometry and attribute information about features. The geometry of feature is stored as a shape comprising a set of vector coordinates. Shapefile is nontopological what makes faster drawing and edit ability. It requires less disk space than raster data and is easier to read and write. In **AgroEye** reading *Shapefile* is necessary in order to ARiMR database which contains a polygon set with attributes on special fields. In the environment with juridical consequences, the explicit dataset needs to be delivered under supervision of the responsible control agency and we cannot use our own interpretation of the GIS layers.

2.7.2. KML

KML files are used to display data in an Earth browser such as Google Earth, they store vector coordinates and more detailed information. The results of classification contains fields with anomalies that may be extracted as a *KML* file. That function enables the usage locations directly, in mobile phone, tablet without any special devices or conversion in other GIS application.

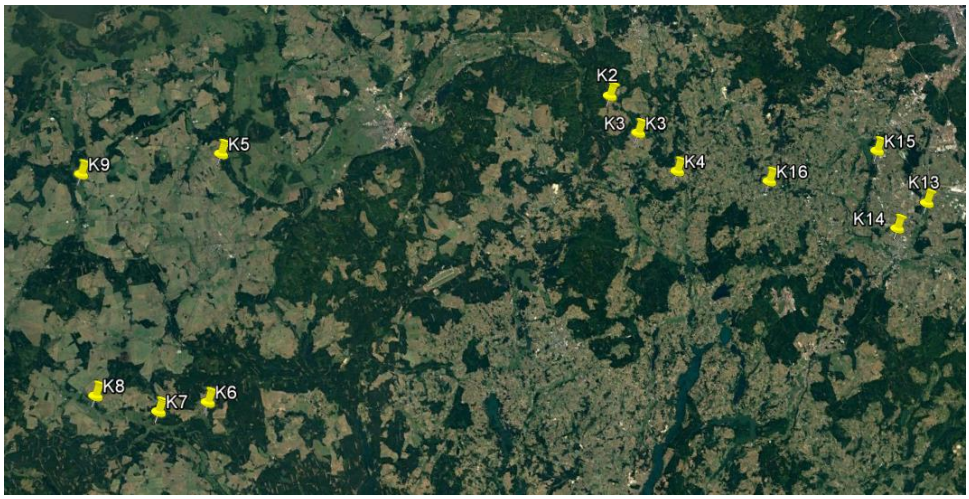


Figure 5. *KML file with anomalies opens in Google Earth.*

2.6.3. GPX

It is data format for interchange of GPS data (waypoints, routes and tracks) between software and GPS devices. It stores coordinate data. Results of classification contains fields with anomalies may be extracted as GPX file. It is useful in the case of use GPS device, which are used in control agency.

2.6.4. SpatiaLite Database

SpatiaLite is extension of regular SQLite database system. It contains not only the geometry data with attributes (like ESRI Shapefiles) but also index them spatially and adds spatial functionalities. That enables to execute queries based on spatial attributes and relationship rather than query values in SQLite approach.

2.7. Class and Classification

Classification is a procedure that associates *segment objects* with an appropriate class labeled by colour. Information contained in *segment object* is used as a filter for *classification*. Based on this, *segment objects* can be analysed according defined criteria and assigned to appropriate classes. The classes are provided by **AgroEye** and depend on the *GAEC rules*.

2.8. GAEC rules

GAEC rules represents a predefined workflow with blocks. Configured workflow can perform different tasks like *segmentation,* classification, statistics or export of results to file. Workflow is sequenced and represents ready to use solution to GAEC rules. Standard workflow consists of set of processes with defined parameters. Workflow can be designed only by **AgroEye** Developers.

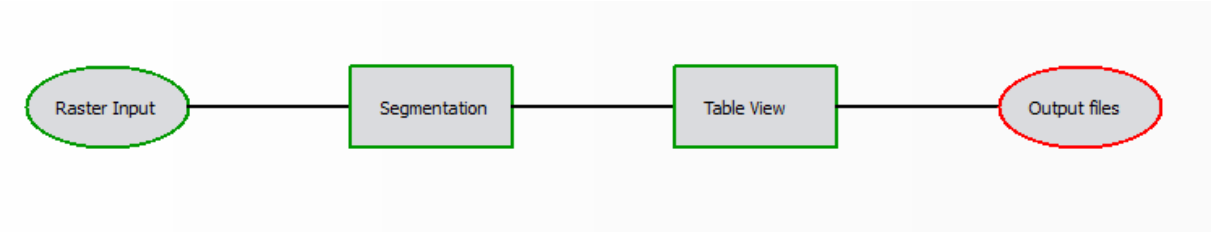


Figure 6. *Example of workflow with blocks for GAEC no.1.*

2.9. Algorithm

The *algorithm* defines the operation the process will perform. This can be generating new *layer*, segmenting, merging raster data with vector data, classifying fields, and so on. The two main functions are segmenting and classifying segment objects. Other algorithms help to define all necessary operations to set up *GAEC rules*. The following functional categories of algorithm exist:

- Segmentation algorithms
- Classification algorithms
- Export algorithms
- Raster layer operation algorithms
- Vector layer operation algorithms

2.10. Segment size

The *segment size* describes the objects size which are generated in Chessboard Segmentation. Value of 1 will generate objects of 1x1 pixel. The size is predefined by the user.

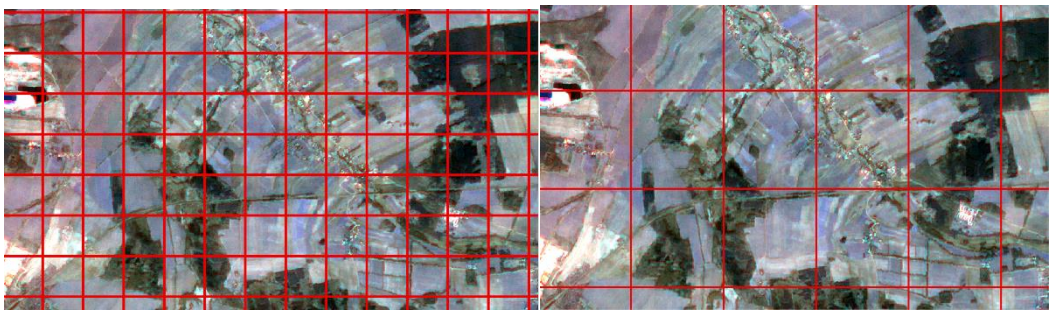


Figure 7. *Outline of segment objects with different object size (left: 50, right:120).*

2.11. Threshold

Threshold value describes the upper boundary of objects size which are generated in Quadtree Segmentation. The threshold is defined by the user.

3. Workflow

This chapter presents an overview of the workflow and sequences the basic operational steps.

3.1. Load and Manage Data

Raster and vector data can be analysed in a single project which can contains several files. All files are stored in *Table of Contents*. In the *Table of Contents*, you manage your files. To run an automated *GAEC rule*s you first have to import data to **AgroEye**.

3.1.1. Work with Project

A single project is used to analyse image data.

3.1.1.1. Open project

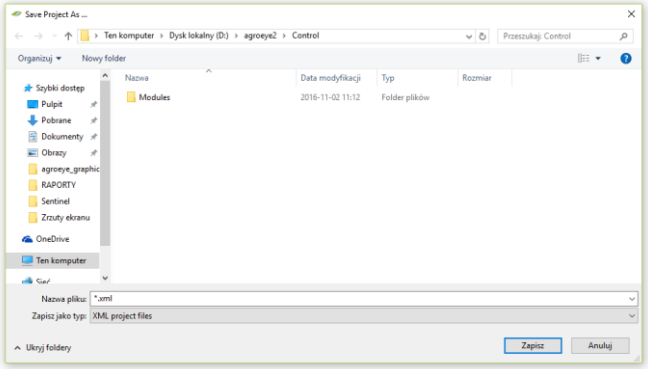
You can open *project* and investigate it in the *View Area.* You need an .xml file containing project. To view *project* that is not a part of **AgroEye**, you must open it from .xml file.

- Choose *File* → *Open Project* on the main menu bar. The *Open Project* dialog box opens.
- Select a project stored as the .xml file.
- Click open and the project will display in the *View Area*.

If an existing project or its data have been moved, the references to the file data may have got lost. If you try to open second *project* in **AgroEye** instance, the other one closes automatically. To open and view more than one project simultaneously, you have to start multiple **AgroEye** instances.

3.1.1.2. Save project

You can save a project. The output can be created as an .xml file. The project contains information about current *View Area* – spatial reference system, range of view, pixel size, loaded files and other relevant settings.




```
<?xml version='1.0' encoding='UTF-8'?>
<!DOCTYPE AGROEYE>
<AGROEYE VERSION='0.1'>
<file type='raster'>
     <source>C:\Users\Anna\Desktop\Rastry\2013-05-19_
8bit.tif</source>
     <visible>True</visible>
</file>
<viewarea>
     <EPSG>32634</EPSG>
     <location>444134.522773;5478660.56845</location>
     <pixel_size>21.508801346</pixel_size>
</viewarea>
<toolbars>
     <main>
          <pan>False</pan>
          <layers>True</layers>
          <coordinates>True</coordinates>
     </main>
</toolbars>
```

Figure 8. *Left: Save project window; Right: Example of .xml project file.*

3.1.2. Work with file

3.1.2.1. Supported Raster Formats

Table 2 Supported Raster Formats.

Import File Format (Driver)	**File extension**
JPEG 2000	.jp2
Tagged Image File (GeoTIFF)	.tif
KEA Image Format	.kea
IMG	.img

3.1.2.2. Supported Vector Formats

Table 3 Supported Vector Formats.

Import File Format (Driver)	**File extension**
ESRI Shapefile	.shp
Keyhole Markup Language	.kml, .kmz
GML	.gml
GPS eXchange Format	.gpx
Geography Markup Language	.gml
SpatiaLite database	.spatialite

3.1.2.3. Georeferencing

Georeferencing is automatically detected by **AgroEye** or can be set up manually. Files with no spatial projection are not loadable. AgroEye has the ability to reproject layers on-the-fly, therefore all layers can be displayed in one coordinate system. If the coordinate system is supported, geographic coordinates from inserted files are detected automatically.

View Area has the global coordinate system. If new files are added, they are automatically displayed using the same coordinate system as the *View Area*. The *View Area* coordinate

system does not need to be the same as the data that the you are applying, because it will project the data on the fly. When AgroEye is started with a new, empty *View Area*, the default coordinate system is not defined. The first file added to an empty map sets the coordinate system.

3.1.2.3.1. Change coordinate system

You can change coordinate system at any time but you need to be aware that projecting on the fly can take longer to draw. Drop down menu in *View Area* contains the list of the most frequently used in Poland coordinate systems. You can add other coordinate system using EPSG Code.

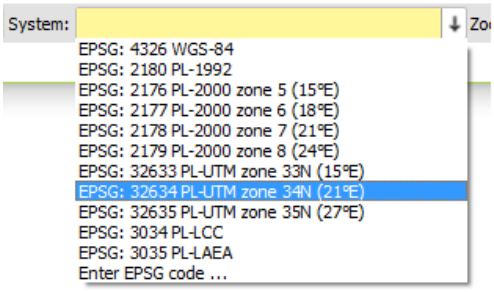


Figure 9. *Drop-down menu with coordinate system.*

3.1.2.3.2. View Area coordinate system

The current coordinate system for *View Area* is shown at the bottom of the **AgroEye** in drop down menu.

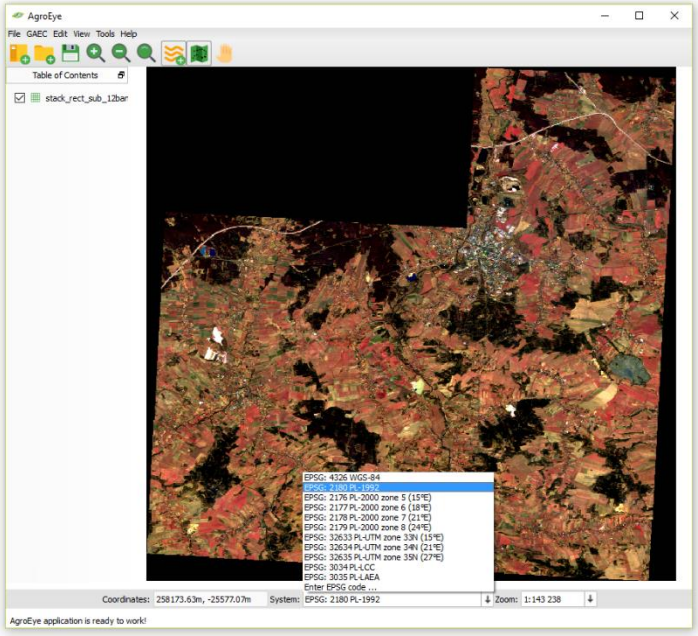


Figure 10. *Coordinate system in View Area.*

3.1.2.3.3. File coordinate system

In order to see the predefined coordinate system to the file, you can click in the *Table of Content*s and click *Properties*. You can read information about EPSG Code, Projection name and Projection definition.

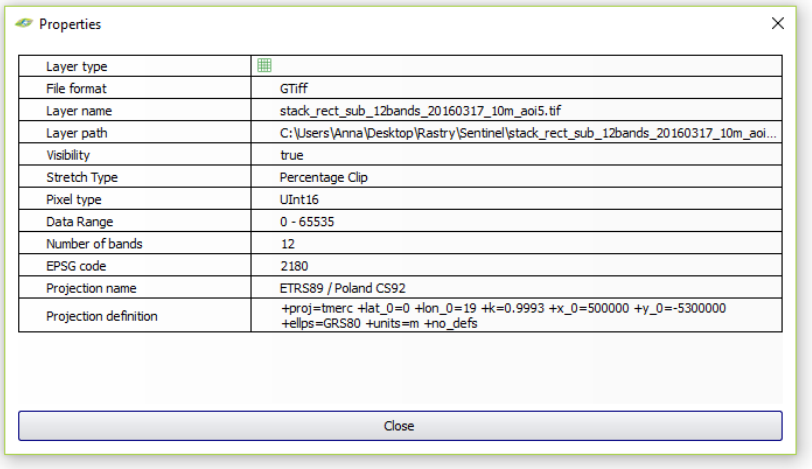


Figure 11. *Properties with information about coordinate system.*

3.1.2.3.4. Remove file

To remove a file, select file in the *Table of Content*s and click *Remove layer.*

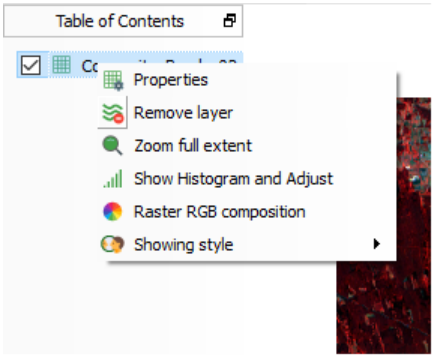


Figure 12. *Table of Contents with remove Layer.*

3.1.2.3.5. File naming

File in *Table of Contents* has names that include the path to the file or only the same name. To set the showing style select file in the *Table of Content*s and click *Showing Style.* Next you can choose two variants.

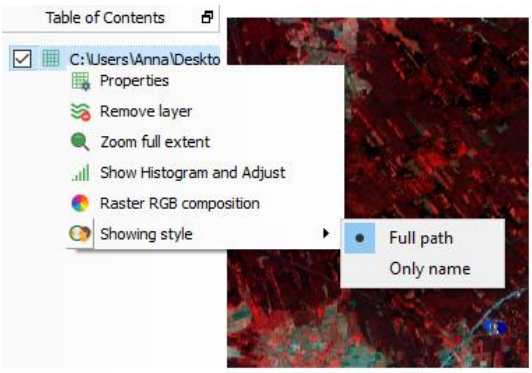


Figure 13. *Table of Contents with Showing Style.*

3.2. View Data in Project

You have several options for viewing data. Some of the visualization tools are dependent on the file format.

3.2.1. Change Display of Image Layers

You can define the colour composition for the display of *image bands*. Go to the *Table of Contents* and select raster file and click right mouse button. In the displayed context menu click on *Raster RGB Composition*. *Raster RGB Composition* set display options.

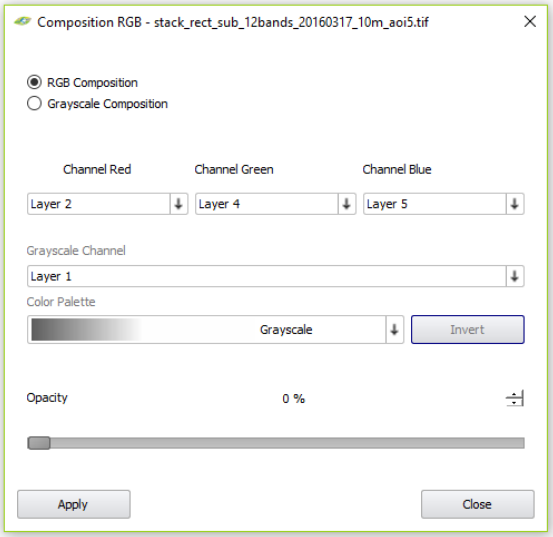


Figure 14. *Composition RGB window.*

3.2.1.1. Greyscale Composition

Raster are automatically assigned RGB (Red+Green+Blue) colours by default when an raster with three or more bands is loaded. Use the *Greyscale Composition* button in *RGB Composition* to display

the *image bands* separately in greyscale. Next choose the band which will be displayed in greyscale using *Greyscale Channel.*

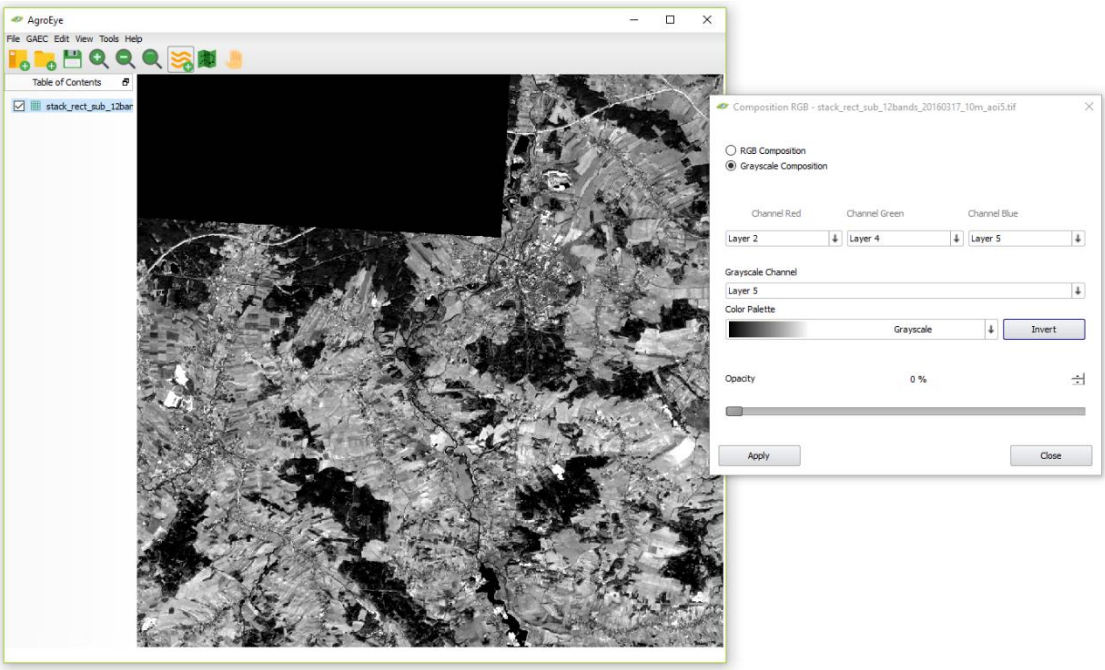


Figure 15. *Greyscale project view of sample image.*

3.2.1.2. Three Layers RGB

Display three bands to see raster in RGB (Red+Green+Blue) mode. By default, layer 3 is assigned to the Red channel, layer 2 to Green, and layer 1 to Blue. These are additively mixed do display the raster in *View Area*.

3.2.1.3. Edit Raster Layer Composition

You can define the colour composition for the visualization of raster bands for display in *View Area*. You can choose from different options. To change the composition of layers, open the *Raster RGB Composition* dialog box and change *Channel Red, Channel Green, Channel Blue.* Save result by clicking *Apply*. One layer can be displayed in more than one colour.

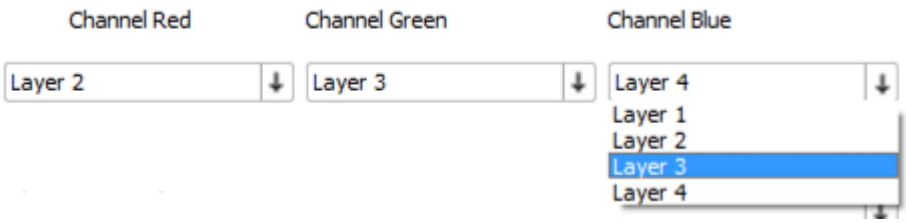


Figure 16. *Set Channel Red, Channel Green, Channel Blue.*

3.2.1.4. Edit Colour Palette

You can define the colour palette for the visualization of raster bands for display in *View Area.*

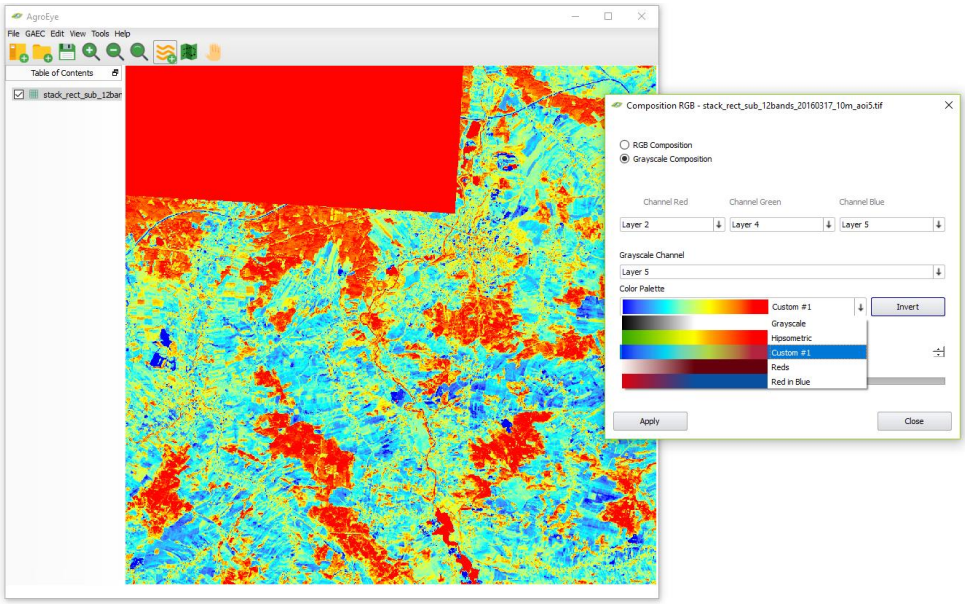


Figure 17. *Project view of sample image using colour palette.*

3.2.1.5. Edit opacity

You can define value of opacity of raster bands for display in *View Area*. To change opacity, open the *Raster RGB Composition* dialog box. Use the opacity slider to adjust the opacity of the Raster or enter value. Opacity is helpful in visualizing the transitions between layers.

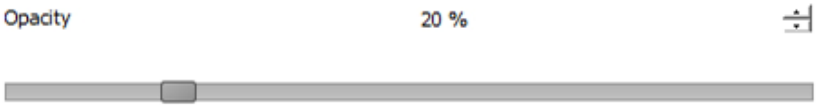


Figure 18. *The opacity slider.*

3.2.1.6. Layers Histogram

The raster bands provides information about the distribution of values on single image bands To open histogram go to the *Table of Contents* and select raster file and click right mouse button. In the displayed context menu click on Show *Histogram and Adjust.*

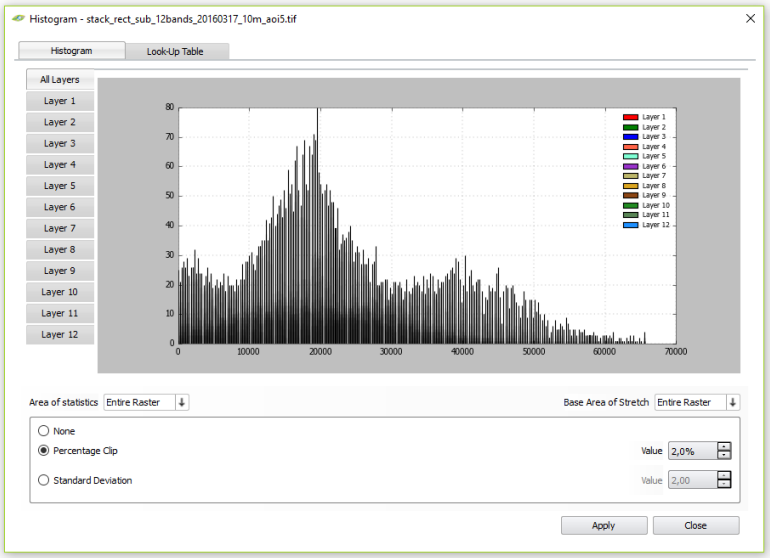


Figure 19. *Histogram window.*

3.2.1.7. Layers stretch

Users can apply a stretch when raster display appears dark. User can check if stretch all raster or only current extent. In the second way, the statistics of layers are computed for current extent, too.

There are different modes for image stretching:

None

No stretching allows you to see the image data it is.

Standard Deviation

The Standard Deviation stretch type applies a linear stretch between the values defined by the standard deviation (n) value.

Percentage Clip

Percentage Clip stretch is the default setting for raster files and it is used to brighten raster data that normally appear dark. The Percent Clip stretch type applies a linear stretch between the percent clip minimum and percent clip maximum pixel values defined

To set Stretch parameters go to the Show *Histogram and Adjust* and change type of Stretch or value of it.

Figure 20. *Parameters for stretching.*

Example

Compare the following displays of the same layers:

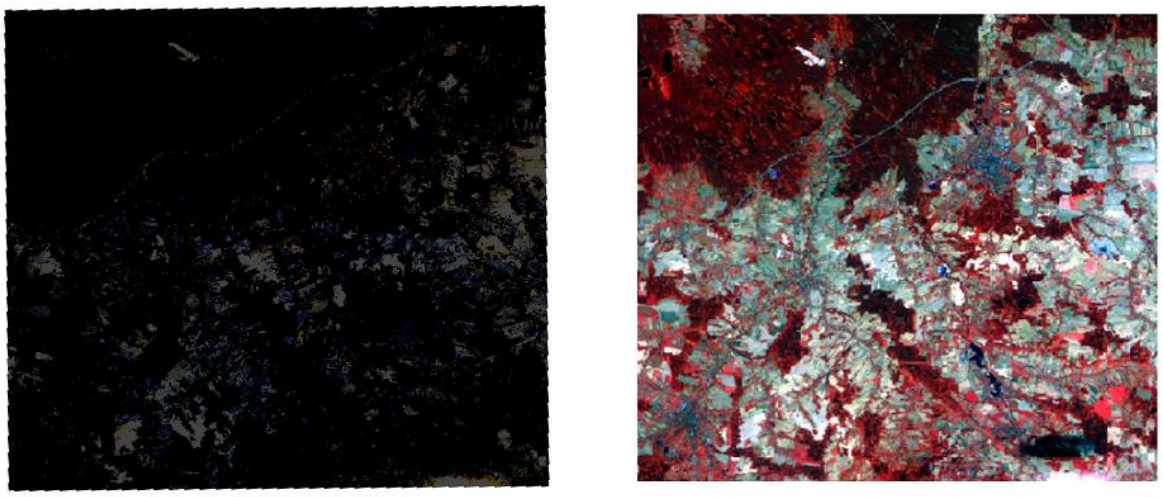


Figure 21. *Left: Three layer mix (red, green, blue) without stretching. Right: Three layer with Standard Deviation (2.0).*

3.2.1.8. Look-up Table

*Y*ou can see Look-up Table which is great tool to make up the difference between source file and result of computation. To open Look-up Table go to the *Table of Contents* and select raster file and click right mouse button. In the displayed context menu click on Show *Histogram and Adjust* and change bookmark to *Look-up Table.*

3.2.2. Change Display of Vector Layers

You can define the colour and style for the display of vector layers. Go to the *Table of Contents* and select vector file and click right mouse button. In the displayed context menu click on *Edit Style.* User can change three basic choices for all vector.

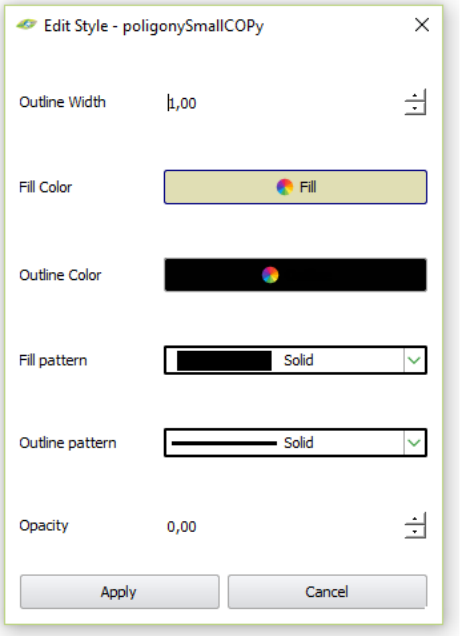


Figure 22. *Edit style window for vector.*

3.2.2.1. Edit Point

For points it is size of point, fill colour and symbol of point. The various symbols are available on the dropdown list. The default symbol is circle.

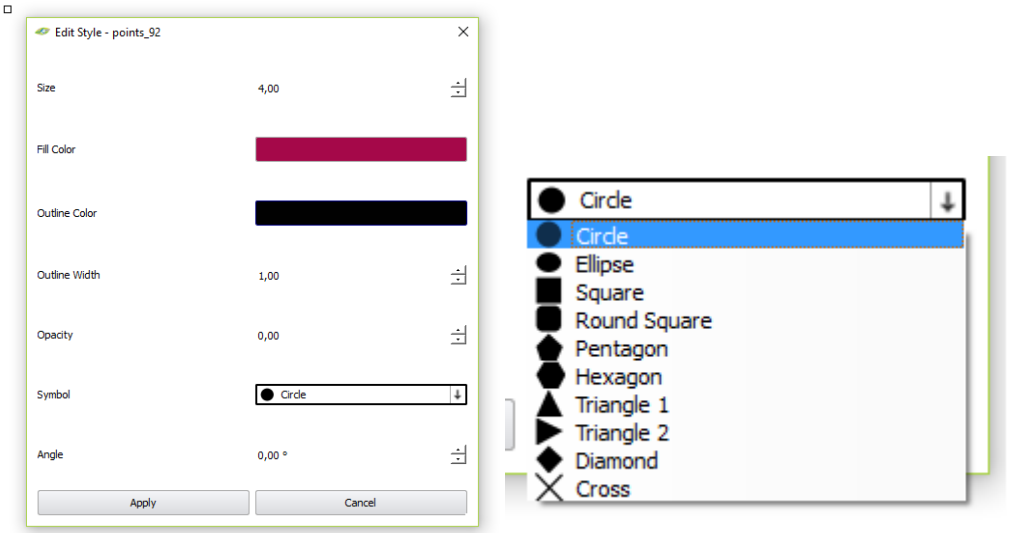


Figure 23. *Left: Edit style window for point; Right: Dropdown list with available symbols for point.*

3.2.2.2. Edit Line

For lines it is fill colour, line thickness, style of line, line join and line cap. The default style is solid line but user can choose other which are on the dropdown menu.

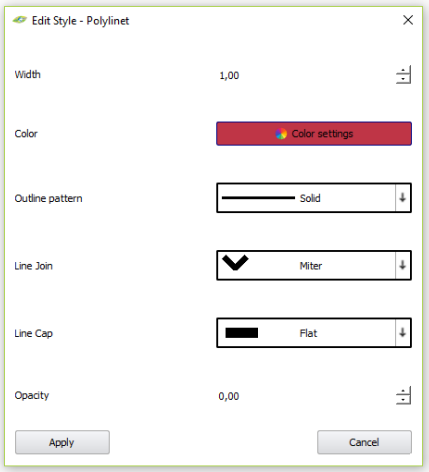


Figure 24. *Edit style window for line.*

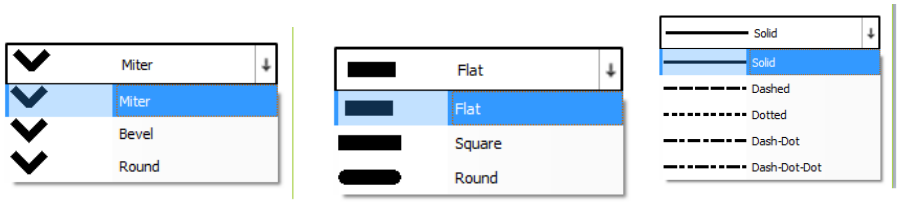


Figure 25. *Dropdown lists with available style for line, line join and line cap.*

3.2.2.3. Edit Polygon

For polygons it is fill colour, outline colour, outline thickness and pattern fill. The default pattern is solid but user can choose other which are on the dropdown menu.

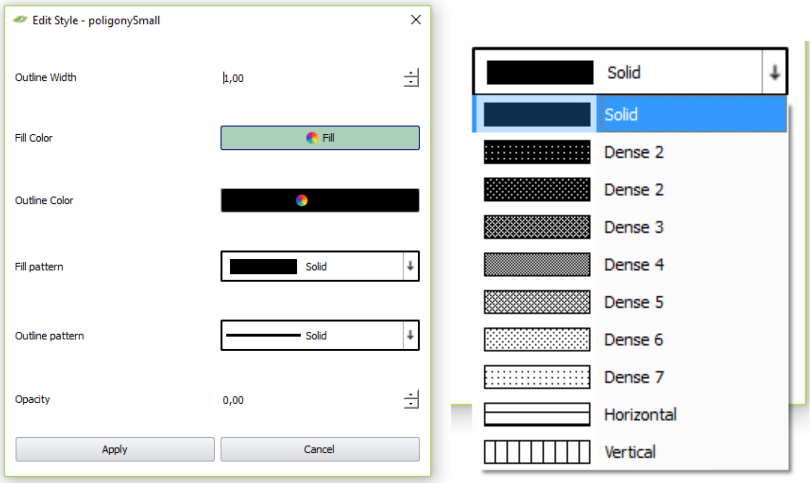


Figure 26. *Left: Edit style window for polygon; Right: Dropdown list with available fill pattern for polygon.*

3.1.3.Zoom within project

To navigate within display of a project, you can use the various zoom and pan functionalities.

To navigate the project display in the *View Area,* do one of the following:

- Select button from the Zoom toolbar
- Click in the *View Area* and use the mouse wheel
- On the main menu bar, choose View->Zoom

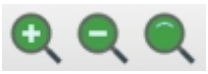


Figure 27. *Zoom toolbar.*

3.1.3.1. Zoom 100%

Click the *Zoom 100%* button to display the file at its original scale.

3.1.3.2. Zoom using the Mouse Wheel

If your mouse has a scroll wheel, use it for zooming. Click in *View Area*. Scroll the mouse wheel to the front to zoom in. Scroll the mouse wheel to the back to zoom out.

3.1.3.3. Zoom In

Select the *Zoom In* and click in the *View Area* to enlarge your file from a point. This means you can enlarge the specific area of interest.

3.1.3.4. Zoom out

Select *Zoom Out* and click into *View Area* to zoom out from a point. This means you can specifically zoom out from the region of interest.

3.1.3.5. Select Zoom Value

Select or enter a zoom value to change the display in the project view.

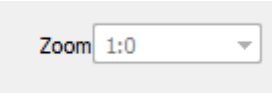


Figure 28. *Zoom toolbar.*

3.2.3.6. Panning

To move within View Area, use the Panning cursor. To activate the panning mode click *Pan* button from the *View Toolbar*.

3.2.4. Coordinates in Layer

While holding the mouse pointer over the layer, its coordinates are displayed in the box in the bottom menu in **AgroEye.**

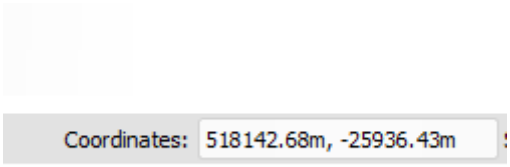


Figure 29. *Coordinates box in AgroEye.*

3.3. GAEC rules

This chapter introduces the technology and development workflow for GAEC rules and explains the basic tools. You can use basic GAEC rules.

3.3.1. Start with GAEC rules

To start work with GAEC rules choose *GAEC→Choose rules* on the main menu bar. You can also use the Ctrl+K to open GAEC rules window. In the top you can choose the number of rules which you can analyse. Next you can click on the green block to set parameters and run calculations.

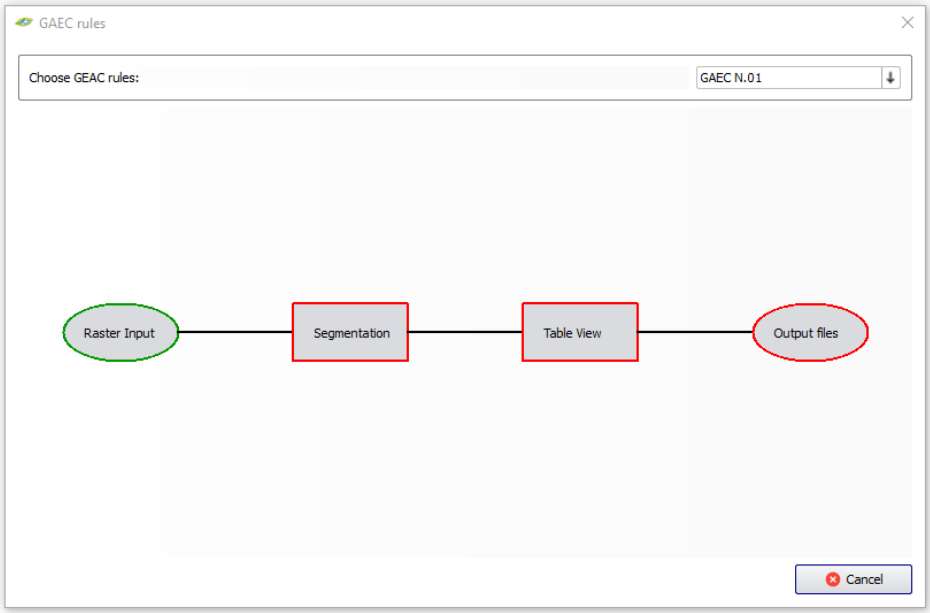


Figure 30. *GAEC window.*

3.3.1.1. Raster Input

You can set the file to GAEC rules and choose directory to save new layers.

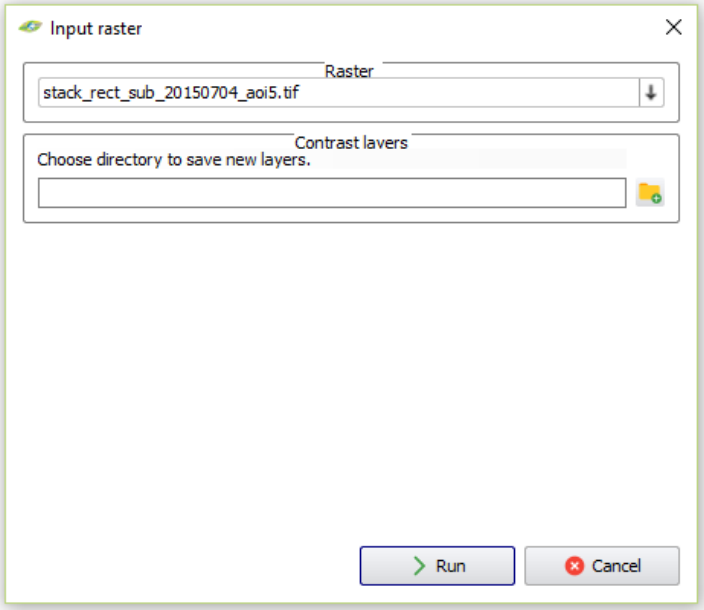


Figure 31. *Input files window.*

3.3.1.2. Segmentation

The fundamental step of GAEC rules is a segmentation of raster file. Thus, initial segmentation is the subdivision image into segment represented by image objects. Different segmentation algorithms provide several methods of creating of image objects. In **AgroEye** you can set Quadtree, Chessboard or Shephard Segmentation.

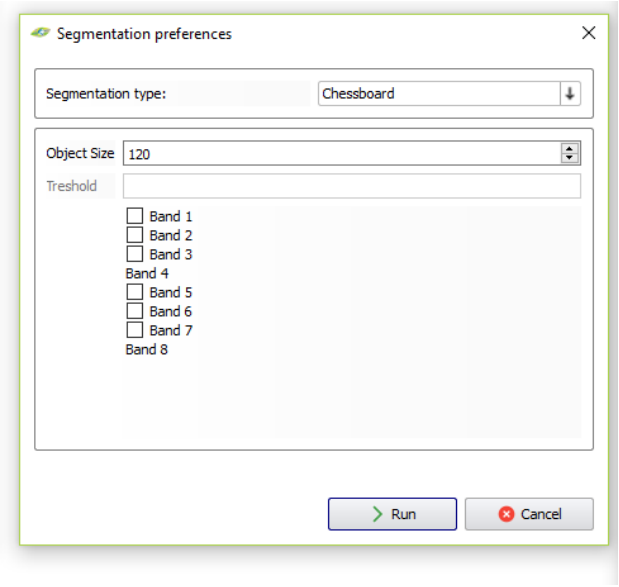


Figure 32. *Segmentation window.*

3.3.1.3. Table View

After segmentation you can see the results of computation. The table shows the NDVI. You can set minimum and maximum value of the NDVI.

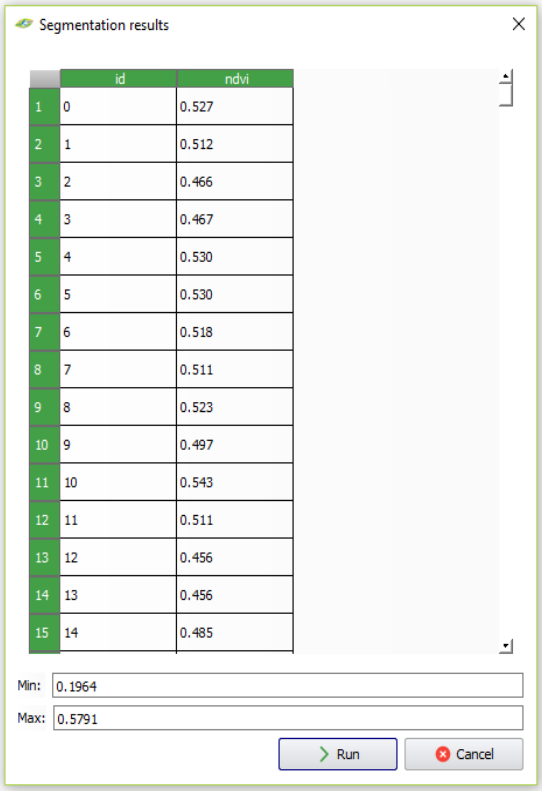


Figure 33. *Table View.*

3.4. Additional Features

3.4.1. Measure distance and area

To start work with measure tools choose *Tools → Measure or Tools → Measure Area.*

You can measure the area of a polygon or the length of a line. This functionality calculates shortest distance or area using the planar measurement type which is 2D Cartesian mathematics. You draw line or polygon on the layer to get its length or area. You can change the default units of measurement. If you change units after making measurement, the current result will be converted to the newly selected unit. Tools are available only if view area has defined coordinate system.

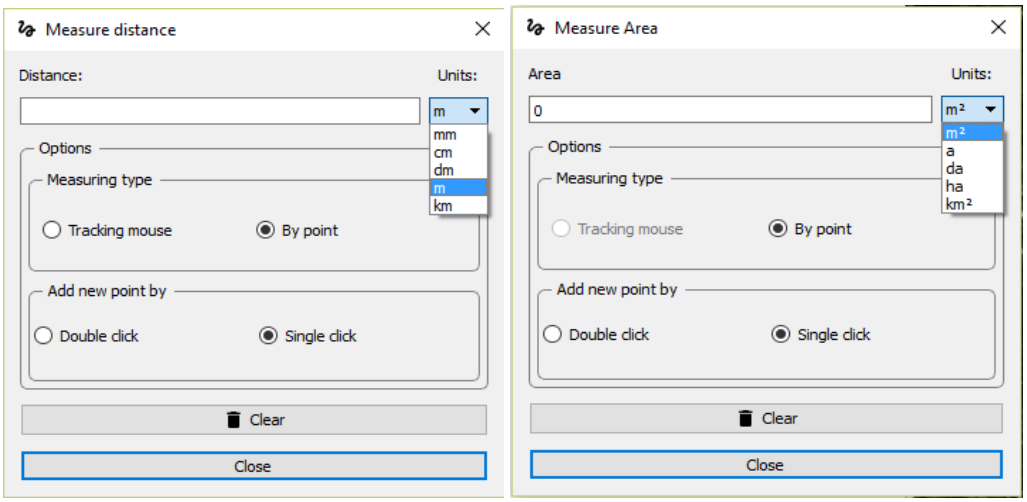


Figure 34. *GUI for measure distance and area.*

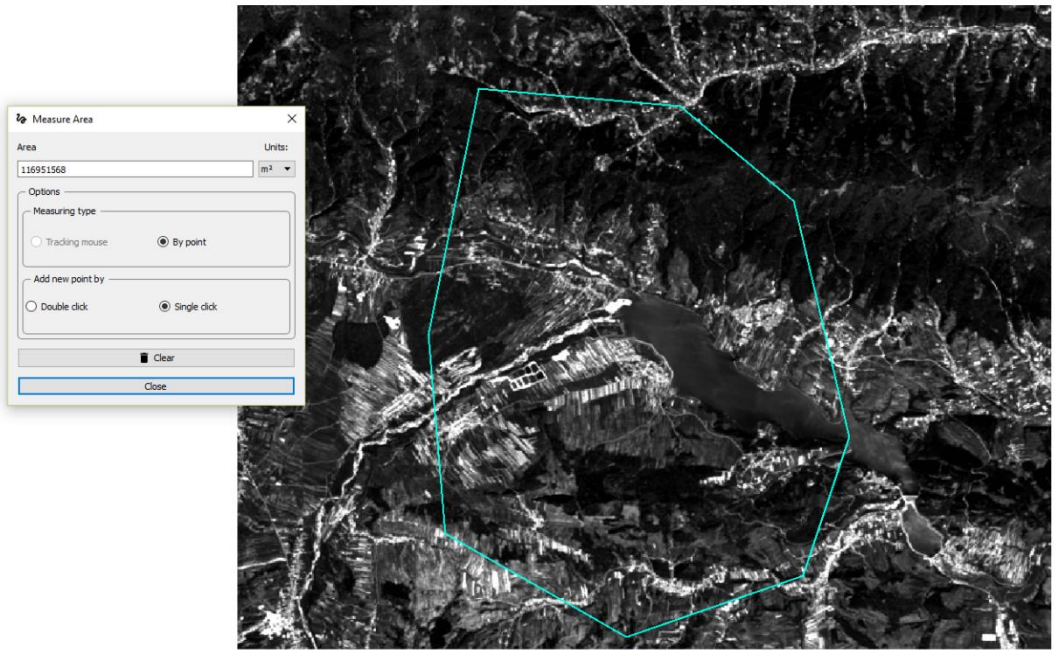


Figure 35. *Example of measuring.*

3.4.2. Raster Calculator

To start work with raster calculator choose *Raster calculator.*

It allows to create Map Algebra expression that will output a raster. Raster calculator window contains four areas. The first is list of bands of all loaded raster files. Second area contains calculator buttons with operators. By clicking any of these buttons, operator enters into the expression where the pointer is currently positioned. The next area is section with expression to be executed. The expression have to be entered with valid syntax. Last area is tool for set range of display value. After click button *Ok* you set name and path of new raster file.

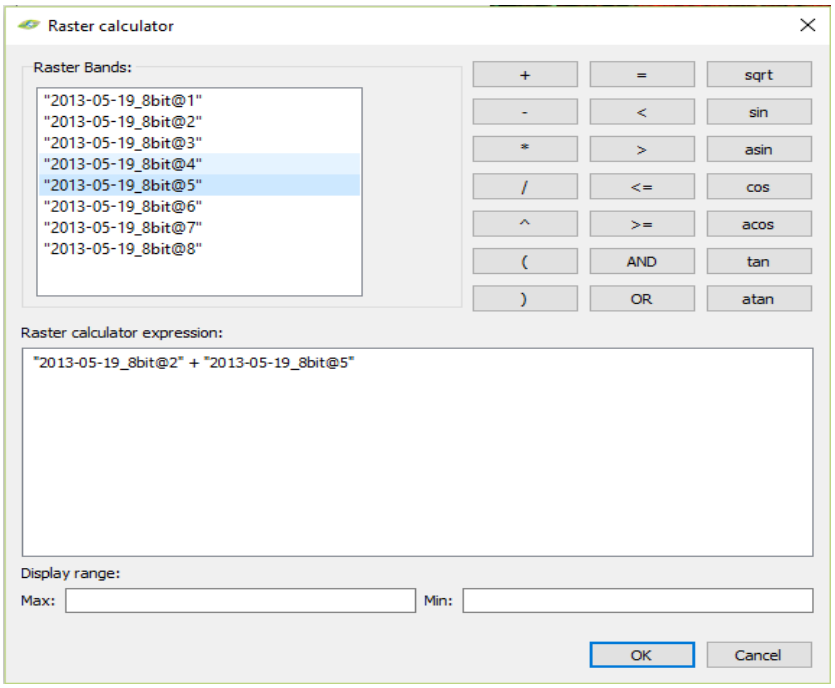


Figure 36. *Raster calculator.*

3.4.3. Create new vector layer

You can add own vector layer, for example to mark boundary line. Before you can add new vector object, it is necessary to create vector dataset to add it to. Option *Create New Layer* is in the *Tools* menu. Following dialog will be presented:

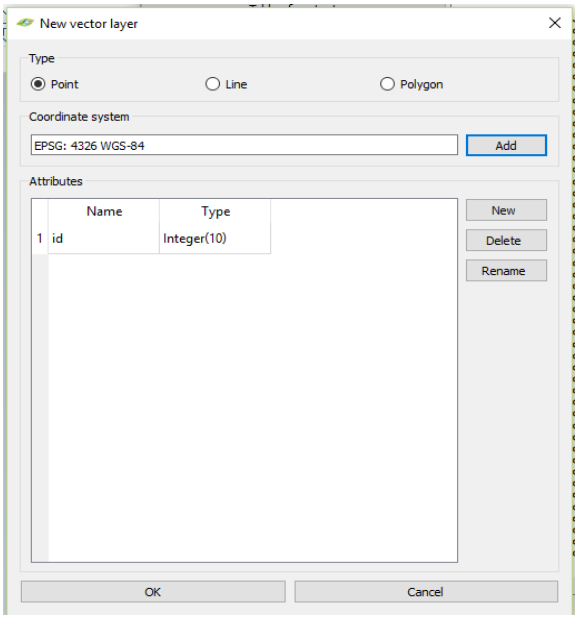


Figure 37. *Dialog for add new vector layer.*

It is important to decide which kind of geometry type it will be created. Each different type has other properties, so change its type after create dataset will not be possible. You can

choose Point, Line and Polygon type. The next step allows to specify the coordinates system. The default coordinate system is WGS84. You can change SRS by clicking on the Add Button and set new SRS from the list.

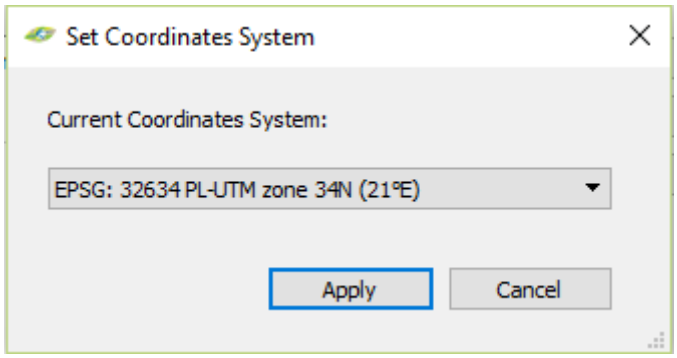


Figure 38. *Dialog for set coordinates system.*

Next properties to set is a collection of fields. By default, a new layer has only one attribute, the ID field. However you can add new field, delete and rename existing.

When new dataset will be created, the next step is add object It is as follows:

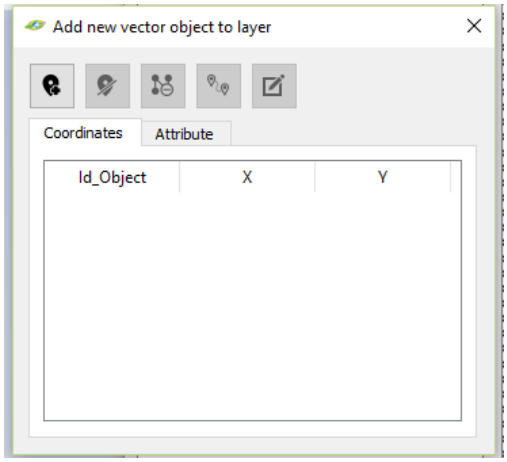


Figure 39. *Dialog for add to layer new object with coordinates table.*

User can see coordinates and attributes of added object. User mark the object on the *ViewArea.*

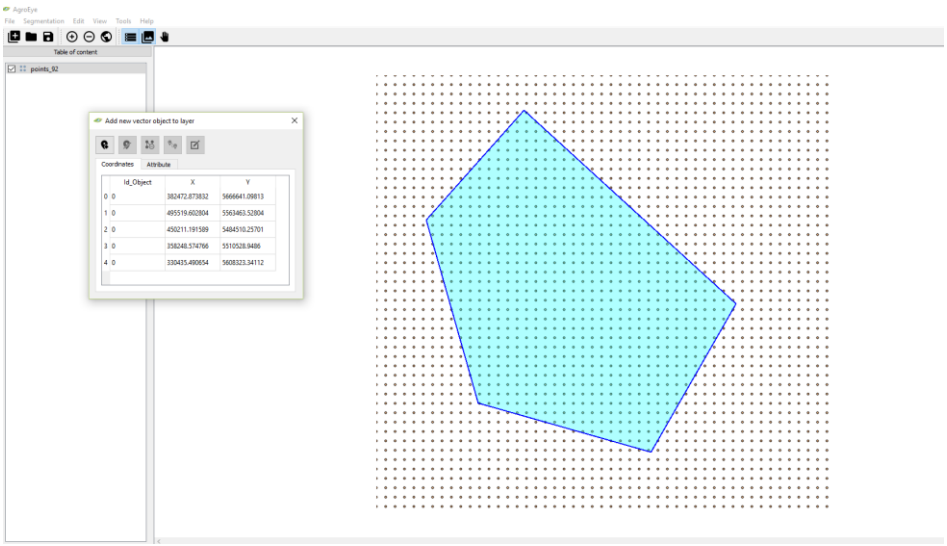


Figure 40. *Drawing new object*

When the drawing command finishes, the user can set attribute for new object.

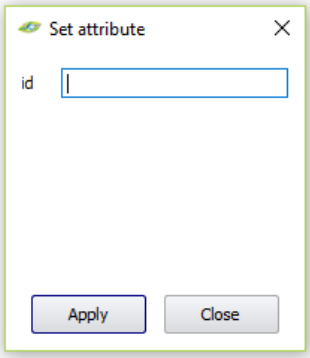


Figure 41. *Set attribute for a new object*

Coordinates and attributes of new object are automatically added to the table. User can edit this table but only after complete drawing.

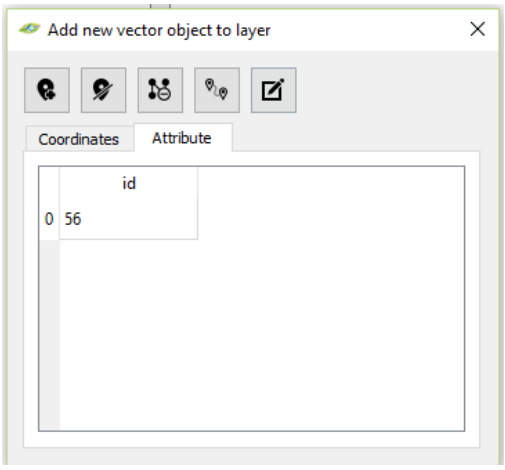


Figure 42. *Edit attribute of new object.*