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Precision Agriculture Tools (PAT) Plugin for QGIS

User Manual

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Wine Australia

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Contents

Precision Agriculture Tools (PAT)

The Precision Agriculture Tools (PAT) plugin is a suite of open source tools developed by CSIRO for Precision Agriculture data analysis. The tools run within Quantum Geographic Information System (QGIS), a free and open-source desktop geographic information system that supports viewing, editing, and analysis of geospatial data. PAT aims to provide an easy to use interface for processing data through an established workflow developed for constructing maps using on-the-go data (e.g. from yield monitors or EM38 surveys) as shown in Figure 1 and Table 1 (Bramley and Williams 2001; Taylor *et al.* 2007; Bramley *et al.* 2008; Bramley and Jensen 2014). Over time more tools or how-to instructions will be added to expand the functionality and usefulness for both practical and research purposes.

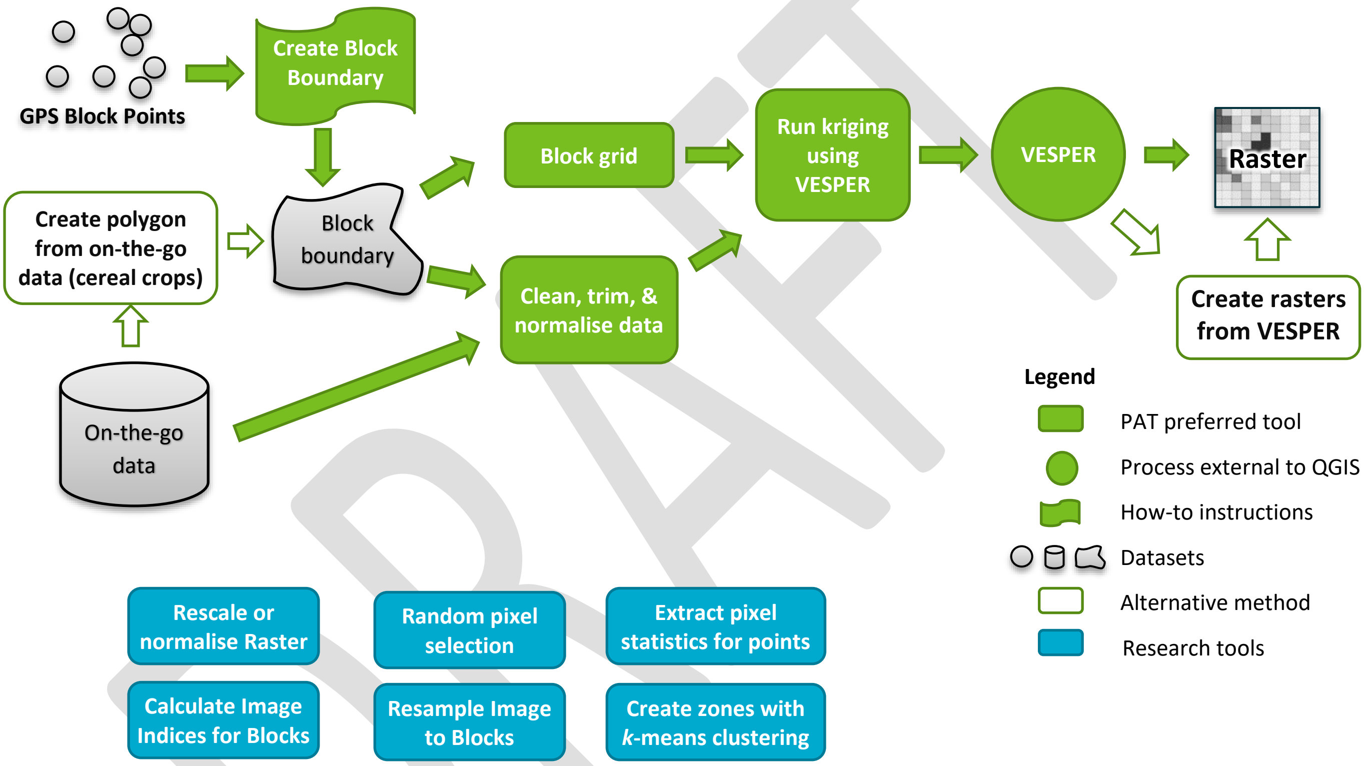


Figure 1 Existing tools available in PAT used for processing on-the-go data.

Table 1 Brief description of tools available in PAT

	PAT TOOLS	DESCRIPTION
	Block Grid	Convert polygon features to • a GeoTIFF raster and • a VESPER text grid file of X,Y point values used by VESPER.
	Clean, Trim, Normalise Point Data	Process an on-the-go data file (e.g. from yield monitors) by applying clipping, cleaning and filtering rules and output as a CSV file.
	Run Kriging Using VESPER	Create a VESPER control file and data files and run VESPER kriging.
	Import VESPER Results	Convert VESPER outputs to raster GeoTIFF format.
	Create Polygon from On-The-Go GPS Point Trail Data	Generate a polygon block boundary from on-the-go data (e.g. from yield monitors) containing GPS points. The GPS points must cover the entire block (not just be a set of points around the boundary)
	Rescale or Normalise a Raster	Create rasters by • rescaling (standardised) values between a fixed range (i.e. 0-1, or 0-255) • normalising values to a mean of 0 and standard deviation of 1
	Generate Random Pixel Selection	Generate a selection of random pixels from a raster and save to a points Shapefile.
	Extract Pixel Statistics for Points	Extract pixel statistics using a square neighbourhood footprint from multiple rasters at set locations.
	Calculate Image Indices for Blocks	Resample and smooth imagery to a larger pixel size, as well as calculate indices such as PCD and NDVI
	Resample Image Band for Blocks	Resample image band for blocks
	Create Zones with *k*-means Cluster	Create zones with *k*-means clustering
	Settings	User settings for PAT. This provides information on the currently installed release and provides the ability to set data directories and the location of VESPER (if installed).
	About	About Precision Agriculture Tools (PAT). This provides information on the currently installed release, and relevant open source licences.
	Help	Display the PAT user manual.

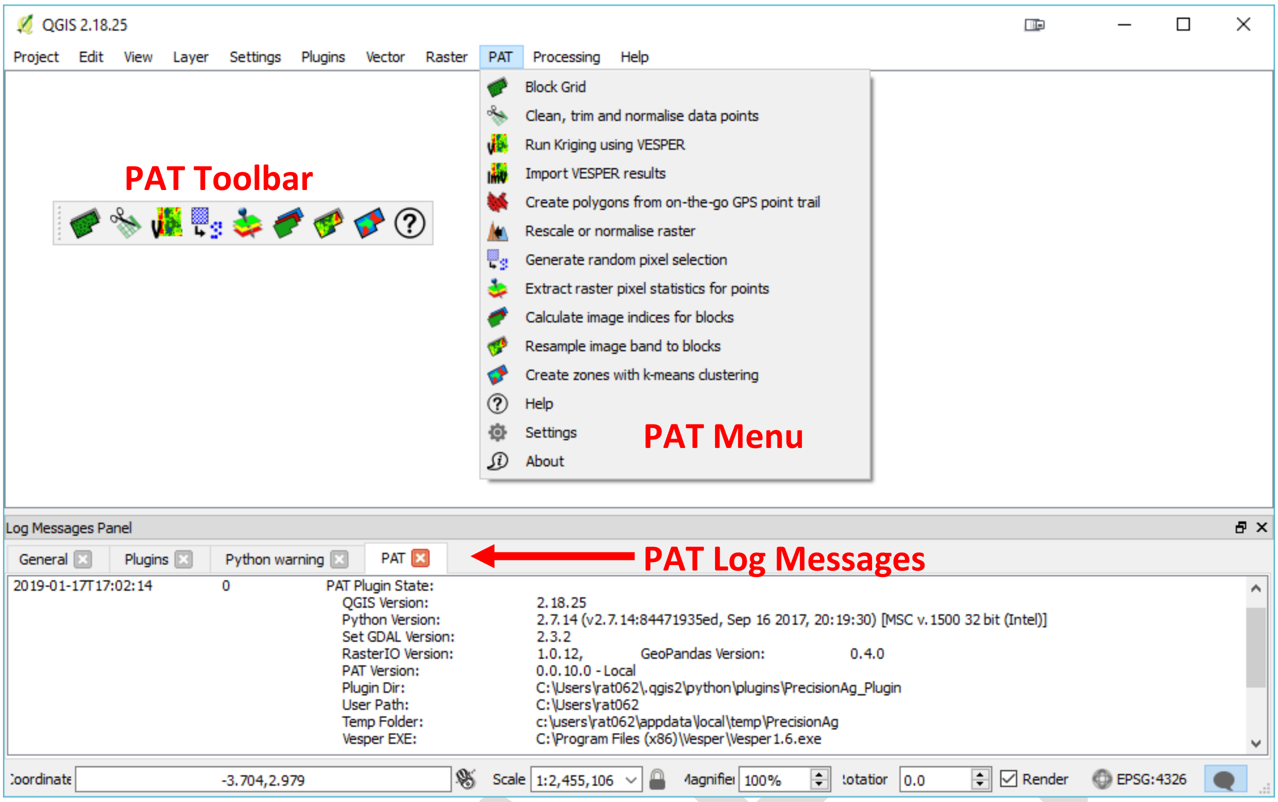


Figure 2 PAT toolbar, menu and log messages panel within QGIS

1 Installing, Upgrading and Uninstalling

1.1 Install PAT

Requirements

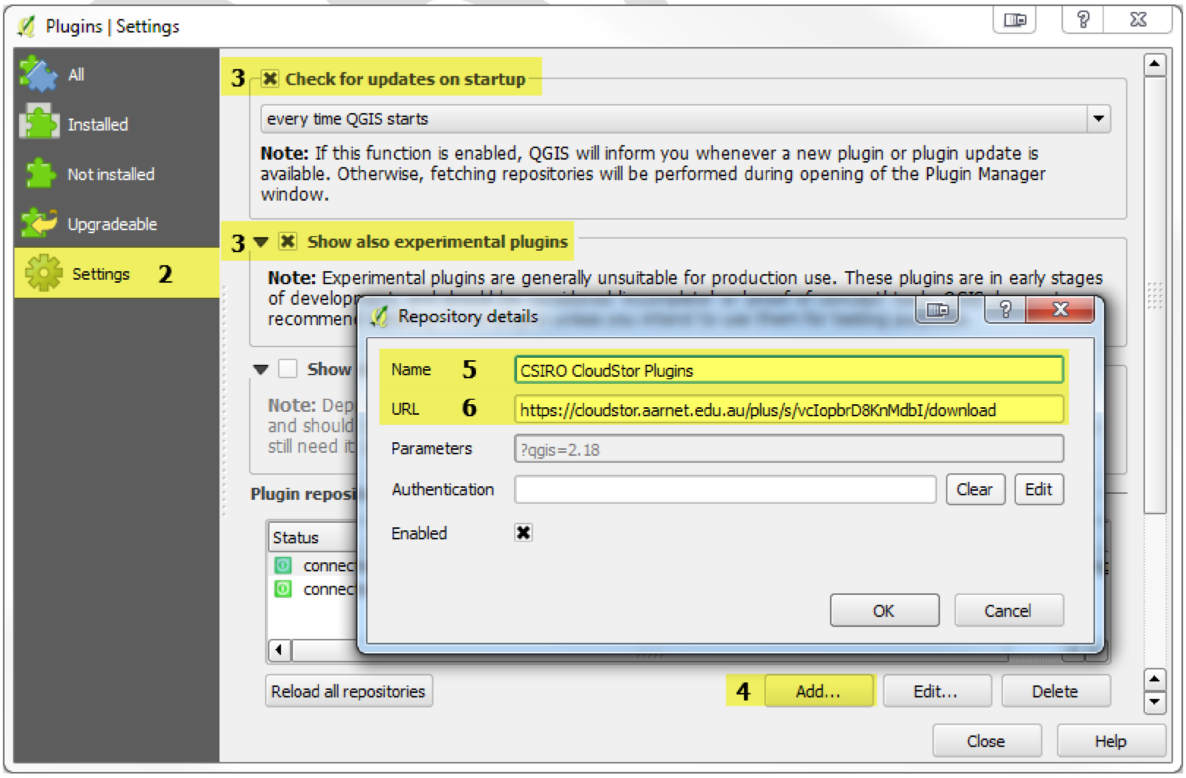
VESPER: VESPER is a kriging program (Minasny *et al.* 2005) and needs to be installed independently if you would like to undertake kriging of maps using VESPER. VESPER is **not** distributed with this plugin but is the recommended map interpolation tool. To download or view more information on VESPER visit https://sydney.edu.au/agriculture/pal/software/vesper.shtml.

QGIS LTR 2.18.12+: Download and install the QGIS standalone long term release (version 2.18.12 or newer) from the QGIS download page. Note that the PAT tools do not currently work with QGIS version 3 or later.

Additional Python Packages: QGIS includes Python and numerous Python packages, however, PAT requires the following additional packages: ***pandas, geopandas, fiona, rasterio*** and ***unidecode***. These packages have been included with the plugin and instructions on how to install them are included.

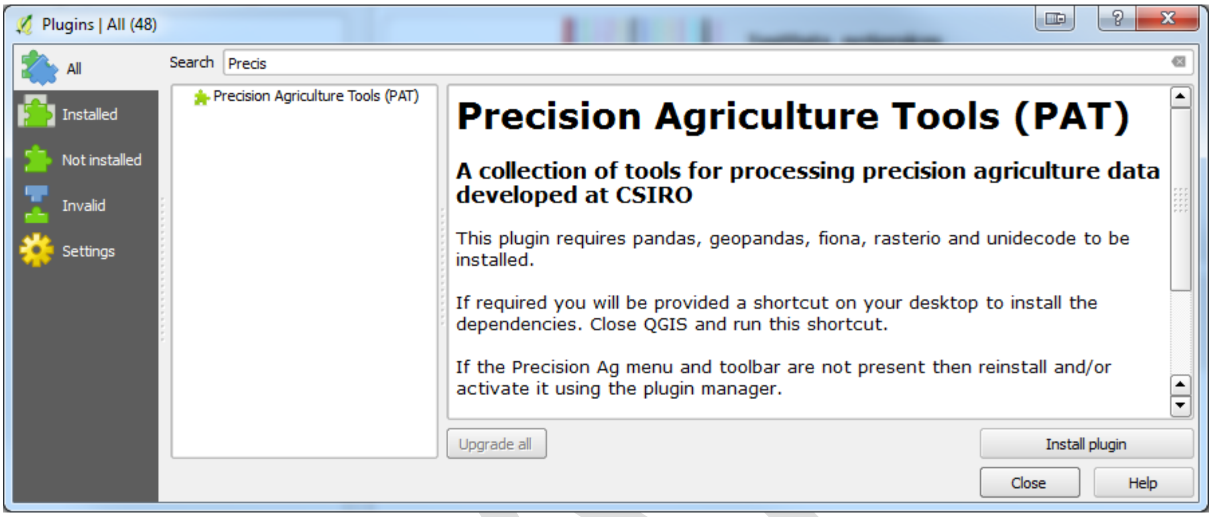
Connect to the CSIRO Cloudstor Plugin Repository

1. In QGIS open the plugin manager ***(Plugins Menu → Manage and Install Plugins)***
2. Select the ***Settings*** Section.
3. Tick ***Check for Updates*** and ***Show Experimental Plugins*** options.
4. Click ***Add***
5. Enter the ***Name:*** **CSIRO CloudStor Plugins**.
6. Enter the following ***URL:***
   `https://cloudstor.aarnet.edu.au/plus/s/vcIopbrD8KnMdbI/download`
7. Leave authentication blank
8. Click ***OK***.



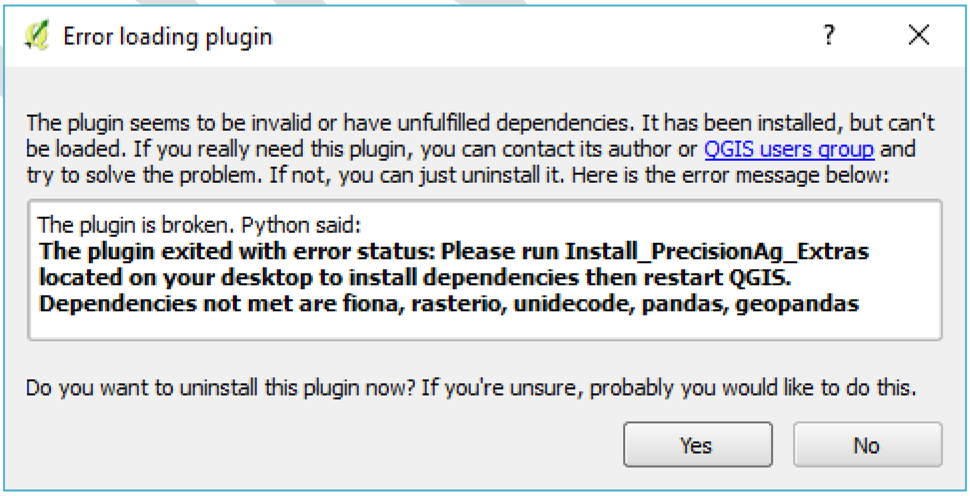
Install the Precision Agriculture Tools (PAT) Plugin.

1. In QGIS open the plugin manager.
   Plugins Menu → Manage and Install Plugins
2. Select the ***All*** section
3. Search for and select **Precision Agriculture Tools (PAT)**.
   Do not use **BETA Precision Agriculture Tools (PAT)** which is used for releasing temporary bug fixes for testing.
4. Click ***Install plugin***.



Installing or Upgrading PAT Python Dependencies

While installation or upgrading PAT, a check will be undertaken to ensure certain Python packages are installed on your system. If this check fails, a message box and an ***Error loading plugin*** dialog (as displayed) will appear warning you that the plugin is broken. This is normal. If this occurs. Click **No** to dismiss this box and **Quit** QGIS.



A shortcut will appear on your desktop named ***Install_PAT_Extras***. Quit QGIS and **run the shortcut** to install the missing components choosing **YES** to any other messages which may appear. Restart QGIS and the check will run again to ensure the installation occurred correctly. If the Precision Ag menu and toolbar are not present then reinstall and/or check/activate it using the plugin manager. QGIS should now contain the PAT menu, toolbar and log panel similar to Figure 2.

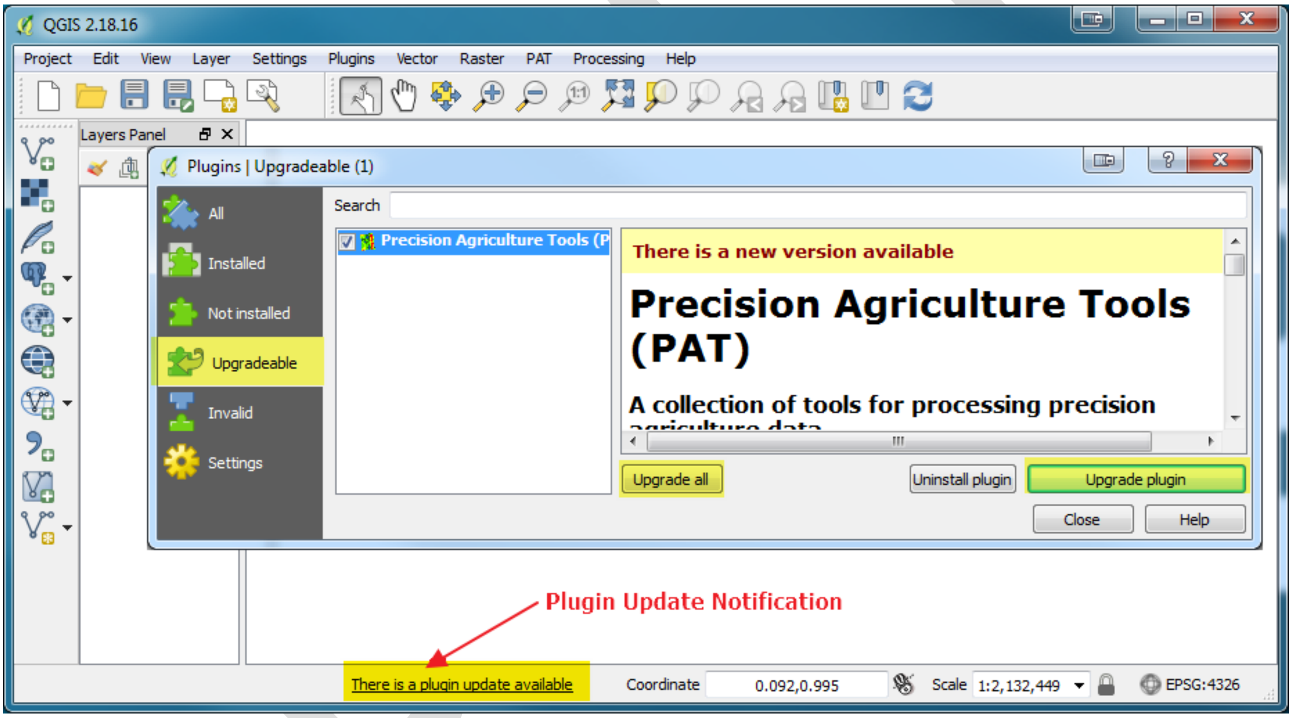
1.2 Update PAT

If the ***Check for Updates*** option is checked on in the plugin manager, QGIS will advise the user if new plugins are available, or if installed plugins have been updated. This notification is displayed in the QGIS interface's status bar as shown below.

To Update

1. In QGIS open the plugin manager by clicking on the link in the status bar or via ***Plugins Menu → Manage and Install Plugins***
2. Either select the ***Upgradeable*** left side tab or search for your plugin
3. Upgrade by
   a. select a plugin and click ***Upgrade plugin.***
   b. or click ***Upgrade all.***

A check will be run to ensure the Python packages required by PAT are installed and are of the correct version. If this check fails follow the instructions in *Installing or Upgrading PAT Python Dependencies* to upgrade the dependencies.



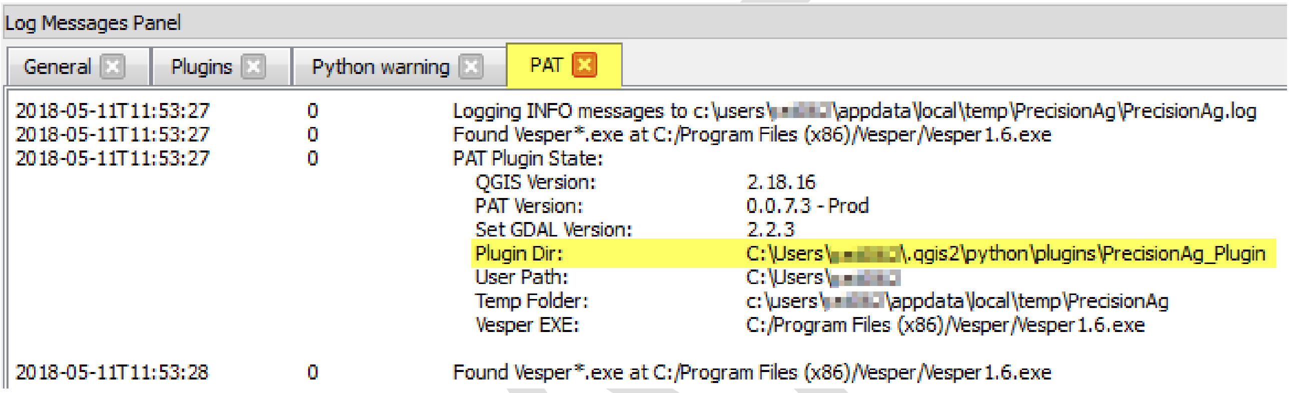
1.3 Uninstall PAT

If you wish to uninstall PAT and its Python dependencies due to conflicts with other QGIS plugins you must first uninstall the Python dependencies, then the plugin as instructed below.

The python packages removed are only those installed for PAT and not core QGIS python packages. The removal of these packages, may break other 3rd party QGIS plugins. This can be resolved by following the installation instructions of the 3rd party plugin.

1.3.1 Uninstall PAT Python dependencies for all users.

1. Navigate to the current users PAT installation directory. This folder is listed against the plugin directory (Plugin Dir) entry as shown in QGIS's ***Log Messages Panel PAT Tab***



2. Find the ***UnInstall_PAT_Extras.bat*** file in the python_packages folder.
3. **Right click** the file and select ***Run as Administrator*** and choose ***Yes*** for any messages which may appear.

1.3.2 Uninstall PAT Plugin.

If required, the PAT Python dependencies should be uninstalled PRIOR to uninstalling the PAT plugin. The plugin can be uninstalled in one of two ways.

1. **Via the QGIS Plugin Manager**
   a. In QGIS, open the plugin manager, and find the PAT plugin.
   b. Click Uninstall plugin
2. **Via Windows Explorer.**
   a. Navigate to the current users PAT installation directory as show in 1.3.1.1 above.
   b. Delete the entire PrecisionAg_Plugin folder.

2 Individual Tools

2.1 Block Grid

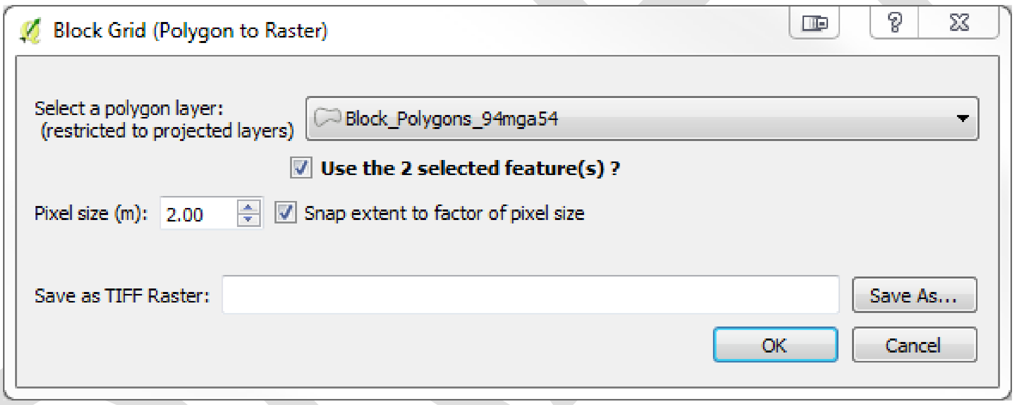
Summary

This tool converts polygon features to a raster using a set pixel size. This is a critical part of setting up the analysis environment for creating maps from on-the-go data because it generates the base grid onto which maps will be interpolated, by using the outer most extent of the block boundary as the grid. The raster outputs created are:

- a GeoTIFF raster and
- a VESPER grid file of X,Y point values used by VESPER for kriging.

Areas inside the polygon will be assigned a value of 1 while areas outside will be assigned with a *no data* value of -9999.

Dialog



Block Grid (Polygon to Raster)		
Select a polygon layer		A layer containing polygon features in a projected coordinate system to be converted to the raster outputs.
Use selected features	Default is unchecked	If checked, will only use the selected features, if unchecked, all the features will be used
Pixel size (m)	0.00m to 6 km Default is 2 m	The pixel size to assign to the raster outputs. This is expressed in meters. Recommended Values: Viticulture: 2 m Sugar: 2 m Broadacre grains: 5 m
Snap extent to factor of pixel Size	Default is checked	Snap the output raster extent to a factor of the pixel size. This will ensure adjacent rasters use a common origin which is important for future analysis.
Save as GeoTIFF raster	Default derived from input layer	The output raster GeoTIFF file to be created. The VESPER grid file will have a suffix of _v.txt

2.2 Clean, Trim, Normalise Point Data

Summary

This tool processes on-the-go data files (e.g. from a yield monitor or EM38 survey) containing GPS coordinates recorded as latitude and longitude in decimal degrees, to output point values in a projected coordinate system, and applies cleaning and filtering rules

This tool:

- retains all columns (except coordinate columns) from the original file
- converts coordinate columns to a projected coordinate system and renames them to Easting and Northing. An additional column (EN_EPSG) will be created and assigned the EPSG number for the projected coordinate system used to reproject data
- optionally saves a Shapefile version matching the output CSV file. A second Shapefile will also be saved containing the string *_removed* in its filename. This Shapefile will contain all the points the filter *discards* and will be attributed by filter type. The description of the values can be found in Table 2

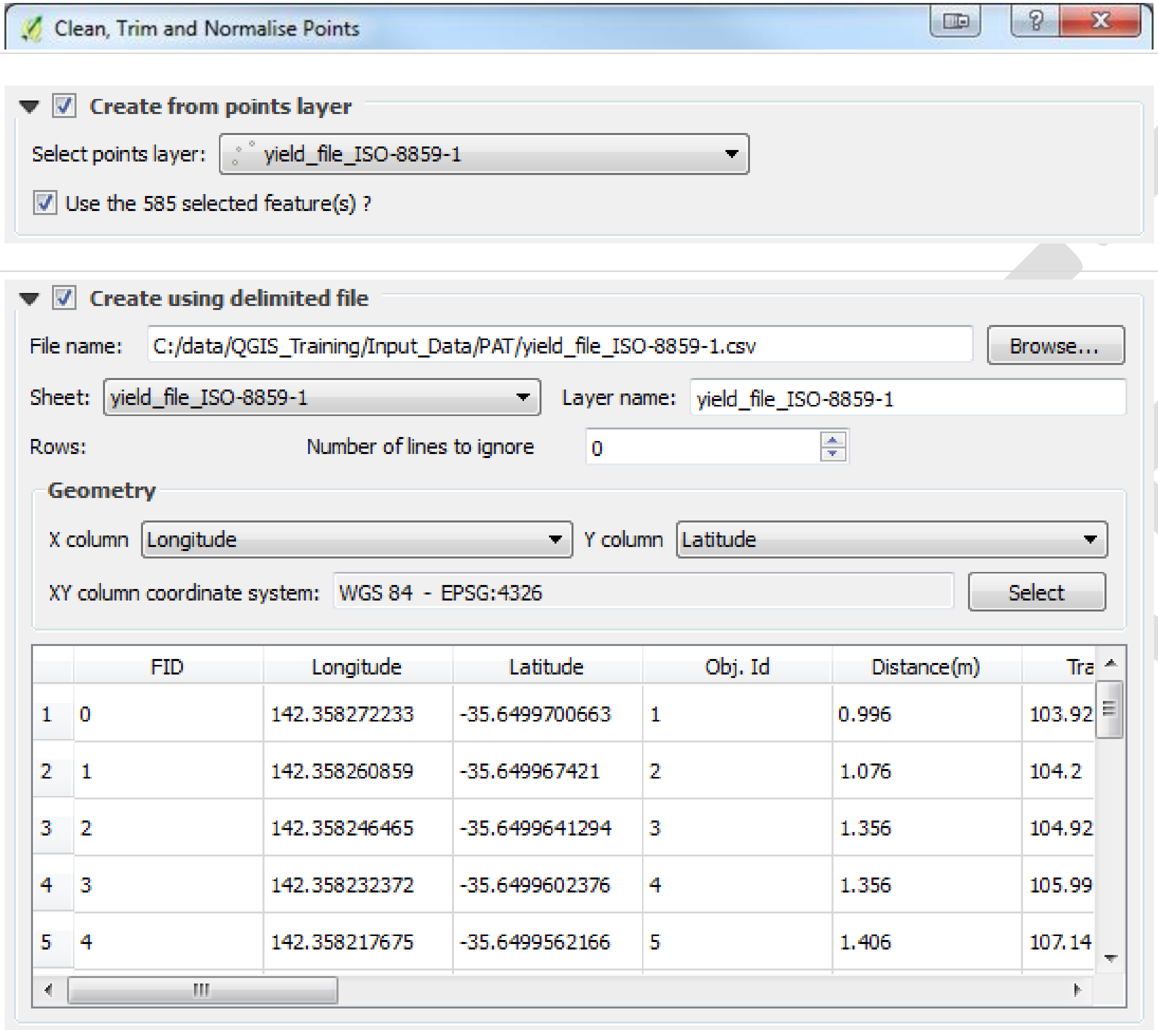
Filters data by:

- optionally clipping the data to a Shapefile boundary
- optionally removes where values from a given column are null (missing) or are less than or equal to zero
- create a normalised column using a prefix of *nrm_* and calculate for set column where the normalised value of column Z is calculated as (Z - mean(col Z))/(s.d.(col Z))
- optionally trim normalised outliers based on a set number of standard deviations. This trim can optionally be performed iteratively with the normalised value re-calculated for each iteration
- optionally thin data by removing points closer than a set distance

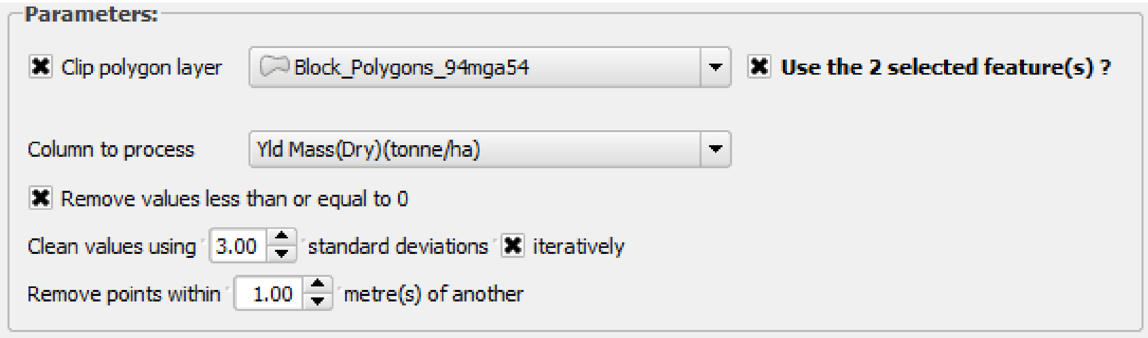
As part of the filtering process, the tool may rename some data columns to adhere to Shapefile column name limitations. The new names are displayed as a PAT log message and written to the log file. For more information on the location of the saved log file and temporary folder refer to the Technical Notes section.

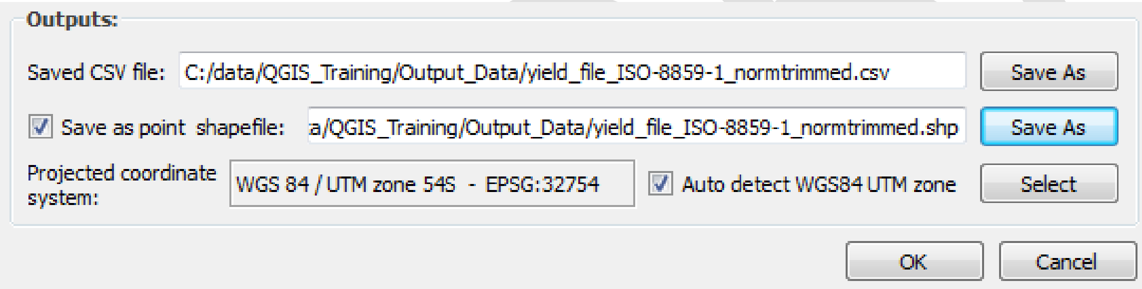
Once processing is complete, the results of filtering are shown as a PAT log message. Only filters which remove points are listed. When iteratively filtering, results of all iterations are shown. An explanation of these is shown in Table 2.

Dialog



Choose whether to use GPS data currently loaded in QGIS as a Points Layer		
Select points layer:		A point layer currently loaded in QGIS.
Use selected features	Default is unchecked	If checked, use only the selected features to generate a polygon If unchecked, all the features will be used
Or alternatively using a delimited text file		
Filename	Options include XLS, TXT, CSV	The filename of the table file.
Sheet		The sheet containing data. If the file type doesn't support sheets, then the filename will be used.
Layer name	Default is the sheet name.	The QGIS layer name for the output point and/or polygon files.
Number of lines to ignore	Default is 0	The number of lines at top of file to ignore. Can be used for skipping header text.
X column Y column	The tool will display a guess of these columns	The columns representing the X and Y coordinates within the input file.
XY columns coordinate system		The coordinate system of the XY columns. Note: GPS most commonly record data in WGS 1984 (EPSG: 4326)
Clip polygon layer	Default is unchecked	A layer containing polygon features used to clip the points data. Any points that fall outside the polygon features will be removed.





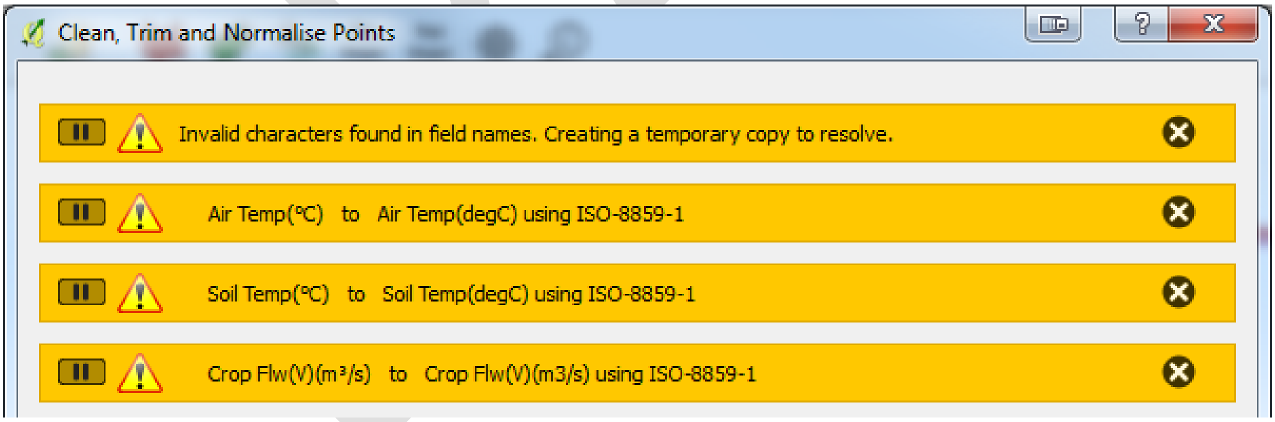
Use selected features	Default is unchecked	If checked, use the selected features to clip the input points. If unchecked, all the features will be used
Column to process		The column to normalise, trim and clean.
Remove values less than or equal to 0	Default is checked	If checked, rows from the chosen column will be removed where the value is null or less than or equal to zero.
Clean values using X standard deviations	0.00 to 5.00 Default is 3 Use 0 to omit	Points where the normalised value is outside a set number of standard deviations will be removed.
Iteratively	Default is checked	Clean the points iteratively using the set number of standard deviations until all values are within +/- the set standard deviation.
Remove points within X metres of another	0.00 to 20.00 Default is 1 Use 0 to omit	Any points spaced at less than this distance apart will be removed.
Save CSV file	Derived from layer name	The name and path of the output CSV file containing the final data points.
Save as point Shapefile	Default is unchecked. Derived from layer name	If checked, save a Shapefile version of the output CSV file. A second point Shapefile will be saved with a suffix of _***removed*** containing the points discarded and attributed by a filter column.
Projected coordinate system		The output projected coordinate system of the Shapefile.
Auto detect WGS84 UTM zone	If Auto detect is checked the following rules will apply: - Will try to match the input if it is a projected coordinate system - If the inputs are in Geographic's (lat/long) it will calculate the relevant UTM Zone Note: If in Australia then MGA GDA 1994 zones, will be used.	

Notes

Table 2 A description of the filter type used when reporting filtering results.

ORDER	FILTER TYPE	DESCRIPTION
01	clip	Points removed when clipping by a polygon.
02	zero	Nulls and/or Zeros removed.
03	3.0 std iter 1	Points removed during the standard deviation (std) iteration (iter) number 1 and uses 3 standard deviations.
04	3.0 std iter 2	Points removed during the standard deviation (std) iteration (iter) number 2 and uses 3 standard deviations.
05	3.0 std iter 3	Points removed during the standard deviation (std) iteration (iter) number 3 and uses 3 standard deviations.
06	pointXY (1.0 m)	Points removed which are spaced at less than the specified distance apart, in this case **1m**
07	pointX (1.0 m)	Points removed after sorting by the X coordinate, which are spaced at less than the specified distance apart, in this case **1 m**
08	pointY (1.0 m)	Points removed after sorting by the Y coordinate, which are spaced at less than the specified distance apart, in this case **1 m**
	Pts remaining	The number of points left after filtering occurs.
	Total	The total number of points in the dataset

- The following notification occurs when a delimited text file contains invalid characters in a column name. A copy of the file will be made in the PAT temporary folder containing corrected column names as specified in the PAT log message and to file. For more information on the location of the saved log file and temporary folder see the Technical Notes section.



2.3 Run Kriging Using VESPER

Summary

This tool will create a VESPER control file and collate the files required for kriging. The following files will be created in a VESPER sub-folder located in the specified output folder.

- the VESPER control file. The control filename will be used as a base to derive other VESPER output files like the kriged map result.
- a subset of data to krige. All non-required columns are deleted.
- a Windows batch file (*Do_VESPER.bat)* which can be used to launch VESPER processing for all control files in the VESPER sub-folder. This process can be run outside of QGIS and the Python/pyPrecAg environment.

Any files matching the control file name will be deleted from the VESPER sub-folder including VESPER kriged results, to ensure that the files remaining belong to the newly create control file. If you want to retain old versions, use a different name for the control file.

The coordinate system of the CSV file will be determined by interrogating the EN_EPSG or ENEPSG columns generated as a by-product of running the ***Clean, Trim, Normalise Point*** tool. If the resulting value cannot be found or is incorrect, the coordinate system can be set manually. The resulting EPSG number will be stored within the control file and later used when converting VESPER outputs into raster GeoTIFF format.

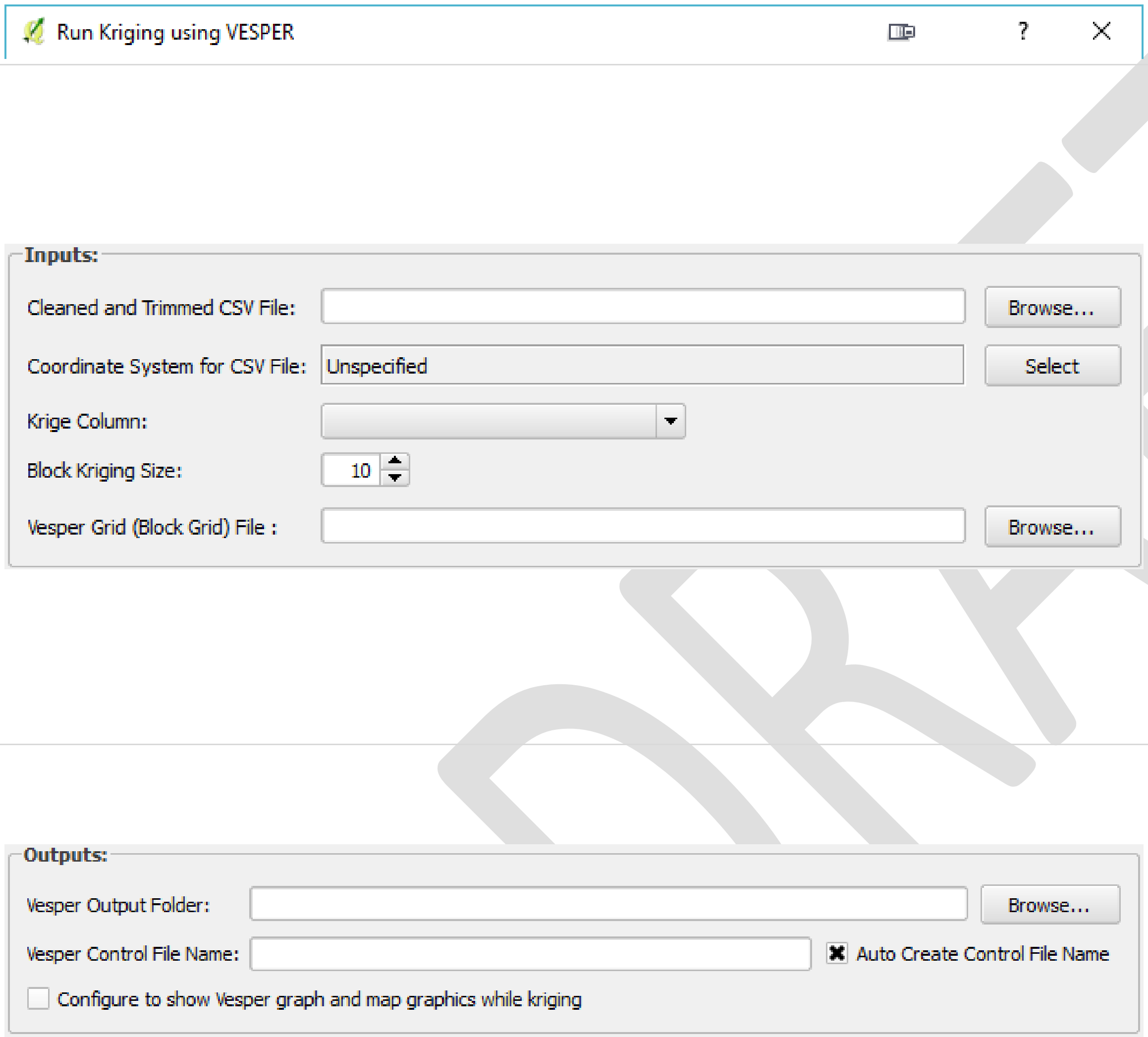
To krige (run) VESPER control files from within QGIS, VESPER must already be installed on the PC and configured in the PAT settings

If the **Run VESPER Kriging Now** option is checked the output control file will be launched in VESPER and kriged immediately. Running this tool multiple times will add each output control file to the VESPER queue and run consecutively. The QGIS status bar is used to manage the queue; currently the queue can only be displayed and cleared. On the completion of each VESPER run, if the **Convert VESPER Files to Raster and Load in QGIS** option is checked the kriged results will be import to GeoTIFF files and loaded into QGIS.

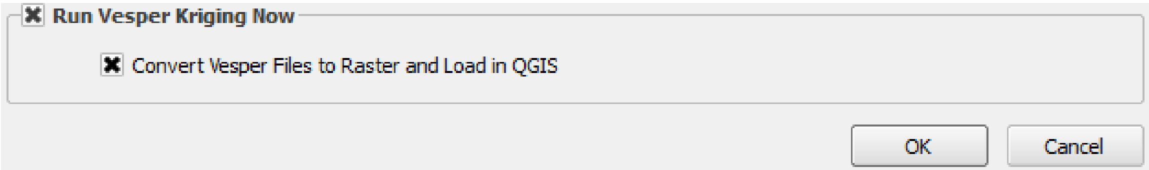
If the **Run VESPER Kriging Now** option is unchecked the tool will create the VESPER control, data and batch files in the selected folder allowing the user to run VESPER in their own time.

When **Run VESPER Kriging Now** or **Convert VESPER Files to Raster and Load in QGIS** options are unchecked the ***Import VESPER Results*** (post VESPER) tool can be used to import VESPER kriged results to GeoTIFF's then loaded into QGIS.

Dialog



Cleaned and trimmed CSV file		A CSV file containing the data to krige. Use the ***Clean, Trim, Normalise Point*** tool to generate this input.
Coordinate system for CSV file:		This is the coordinate system of the coordinate columns in the CSV file. By default the value of the EN_EPSG or ENEPSG column in the input CSV file will be used.
Krige column		The column containing values to krige.
Block kriging size	0 to 1000 Default is 10 Use 0 for Punctual Kriging	The value in meters to set as block size when using VESPER block kriging. This value should be approximately 5 times the pixel value. Recommended Values: Viticulture: 10 m Sugar: 10 m Broadacre grains: 30 m
VESPER grid (block grid) file		The VESPER grid file representing the area to be kriged. Use the ***Block Grid Tool*** to generate this input.
VESPER output folder		The output folder for the VESPER files. A sub-folder called VESPER will be created if required.
VESPER control filename		The name to use as the VESPER control file. This will be appended to the output folder.
Auto create control file name		If checked, the name will be generated from the first 20 characters of the input CSV file, the string '*control*' and the Krige column. Uncheck this option to prevent manual edits from being overwritten when changing source CSV file or Krige column.



Configure to show VESPER graph and map graphics while kriging	Default is unchecked	Checking this option will display the map and graph while VESPER kriging is running but will increase the processing time.
Run VESPER kriging now	Default is checked	Add the control file to the VESPER Queue for processing.
Convert VESPER Files to Raster and Load in QGIS	Default is checked	On completion of VESPER processing, convert the outputs to raster GeoTIFF formats.

File Naming Conventions

- <> denotes an existing element or input
- non-alphanumeric characters are removed with the exception of hyphens (-) and underscores (_).

DESCRIPTION	FILENAME	EXTENSION	EXAMPLE
*Files **required** by VESPER and copied to the VESPER output folder*			
VESPER control file	*<first 20 characters CSV file>_< first 10 characters of krige column>*_control	.txt	swblock_YldMassDry_control.txt
VESPER grid file	*<control file name>* where control is replaced by vespergrid	.txt	swblock_YldMassDry_vespergrid.txt
VESPER data file	*<control file name>* where control is replaced by vesperdata	.csv	swblock_YldMassDry_vesperdata.csv
*Files **created** by VESPER and saved to the VESPER output folder*			
VESPER Krige file (contains Prediction and SE)	*<control file name>* where control is replaced by kriged	.txt	swblock_YldMassDry_kriged.txt
VESPER parameter file	*<control file name>* where control is replaced by parameter	.txt	swblock_YldMassDry_parameter.txt
VESPER report file	*<control file name>* where control is replaced by report	.txt	swblock_YldMassDry_report.txt
*If **converting VESPER files to raster** is checked or the **Create Rasters from VESPER Results** tool is used*			
Kriged Prediction GeoTIFF source: VESPER Krige result above	*<control file name>* where kriged is replaced by PRED	.tif	swblock_YldMassDry_PRED.tif
Standard Error TIF source: VESPER Krige result above	*<control file name>* where kriged is replaced by SE	.tif	swblock_YldMassDry_SE.tif
Confidence Interval (CI) metadata text file	*<control file name>* where control is replaced by CI	.txt	swblock_YldMassDry_CI.txt

2.4 Import VESPER Results

Summary

This tool converts the output files generated by VESPER into raster TIF's. Once the VESPER run is complete, it can be used to create rasters from the results.

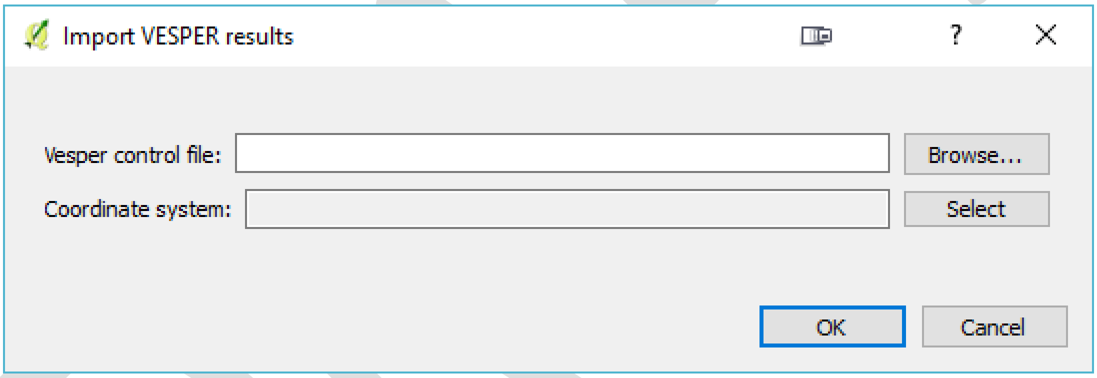
The output filenames will be created using the control file name as a base. The names of output file are demonstrated the ***Prepare Data for Kriging using VESPER Tool - File Naming Conventions*** section.

The files created include:

- a GeoTIFF file representing the predicted value
- a GeoTIFF file representing the standard error of the prediction
- a text file containing the calculated Median prediction SE and the 95% confidence interval

The coordinate system to be assigned to the rasters will be extracted from the value stored within the control file. If the coordinate system cannot be found or is incorrect, it can be selected manually.

Dialog



Import VESPER Results		
VESPER Control File:		A VESPER control file used to identify VESPER results files and convert to rasters.
Coordinate System for CSV File:	By default it is extracted from the input control file.	This is the coordinate system of the VESPER results.

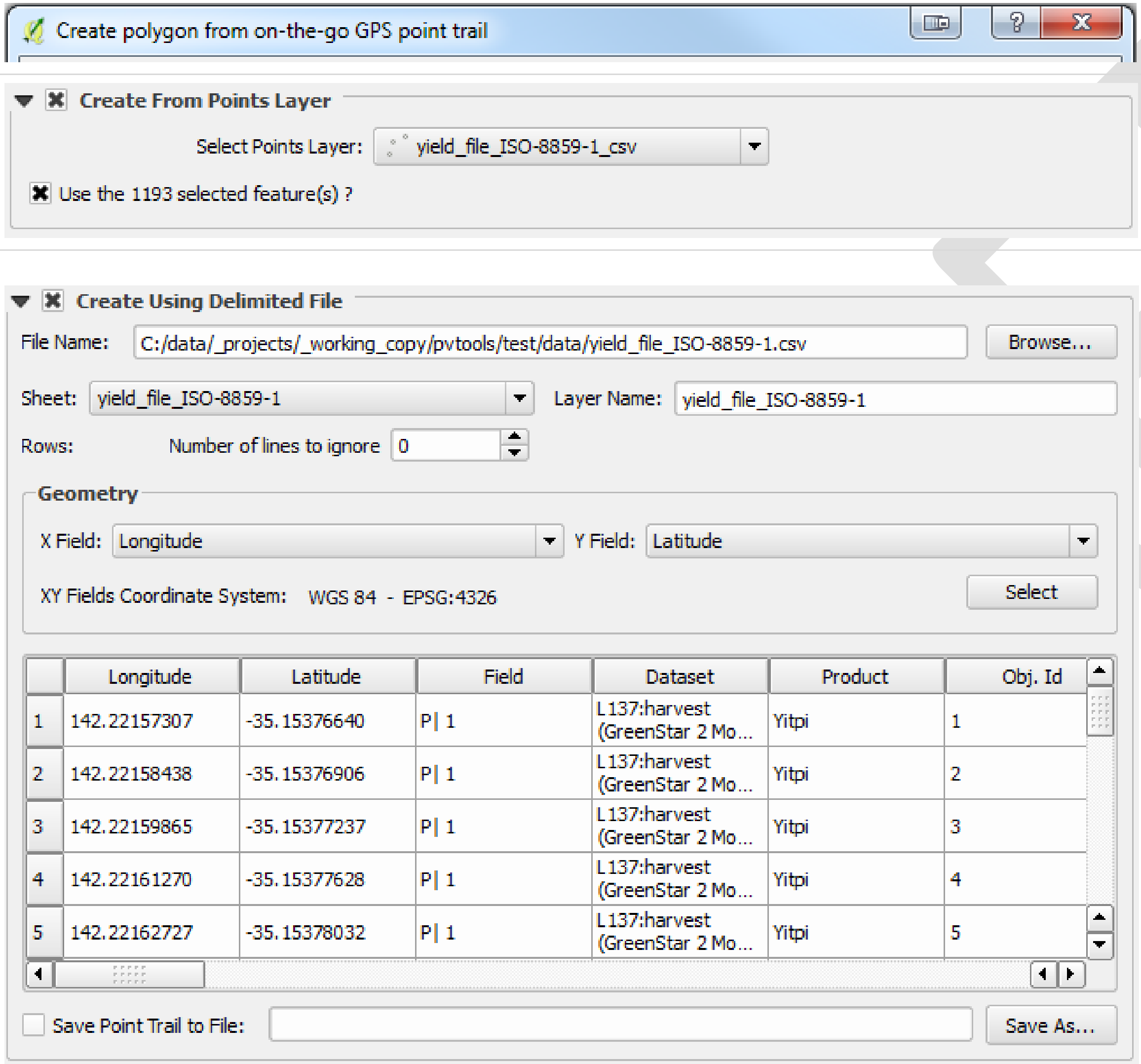
2.5 Create Polygon from On-The-Go GPS Point Trail Data

Summary

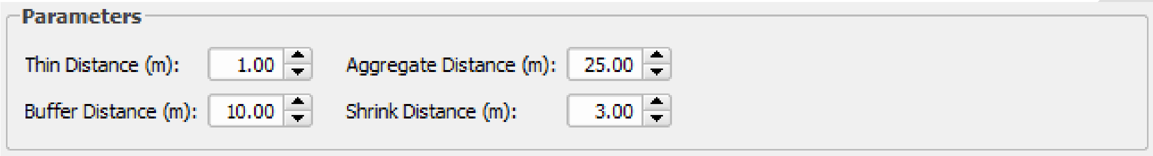
Having a block boundary polygon is central too much of the PAT processing steps. Boundary polygons are used to constrain data to a fixed extent. It is preferably that a boundary polygon is created by collecting accurate GPS points around the block and editing them in QGIS to create polygons (refer to **How-To - Create a block boundary polygon from a CSV of GPS collected points** for instructions on this method). However, if accurate GPS data collection is not available, then a <u>less accurate</u> block boundary polygon can be created using this tool, based upon a file of on-the-go GPS points (i.e. from a yield monitor or EM38 survey).

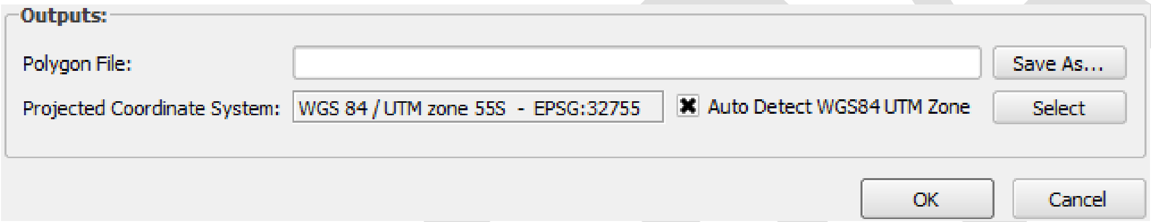
As the process involves a dot-to-dot approach, it is critical that the input file of points are in order (i.e. sorted by an increasing time sequence). For efficiency, points can be thinned by removing points closer than a set distance apart as justified by the accuracy of the GPS. Resulting points will be connected to form lines and then converted to polygons.

Dialog



Choose whether to use GPS data currently loaded as a QGIS Points Layer		
Use selected features		If checked, only uses the selected features to generate a polygon
Or alternatively using a delimited text file		
Filename	Options include XLS, TXT, CSV	The filename of the table file.
Sheet		The sheet containing data. If the file type doesn't support sheets, then the filename will be used.
Layer name	Default is the sheet name.	The name used when displaying QGIS layers, and as the default value for the output point and/or polygon files.
Number of lines to ignore	Default is 0	The number of lines at top of file to ignore. Can be used for skipping header text.
X column Y column	By default will attempt to match to X,Y, longitude, latitude; lon, lat etc.	The columns representing the X and Y coordinates within the input file.
XY columns coordinate system		The coordinate system of the XY Columns. Note: GPS normally records data in WGS 1984 (EPSG: 4326)
Save point trail to file	Default is unchecked	If checked, save the input delimited file as a points Shapefile in the output coordinate system

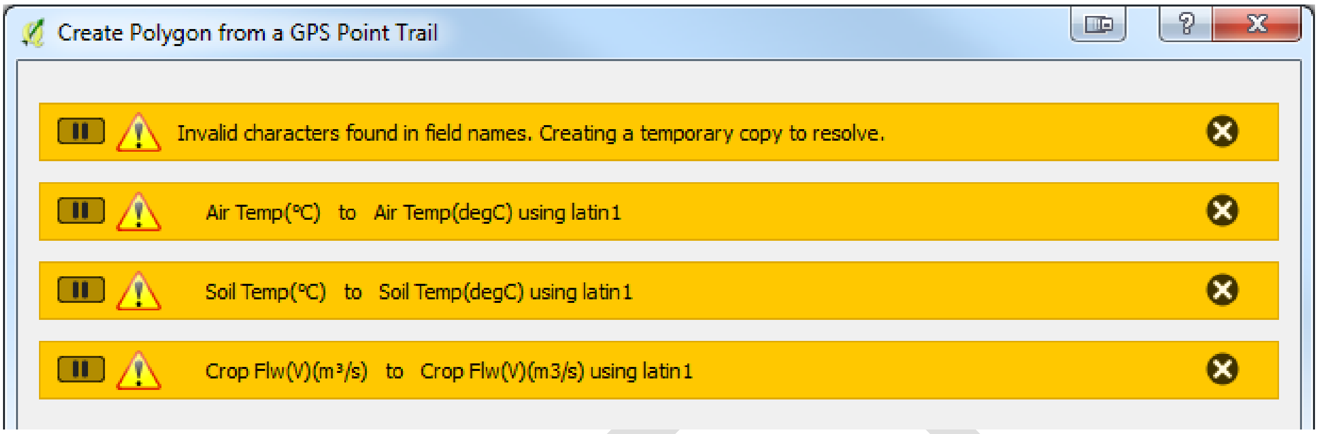




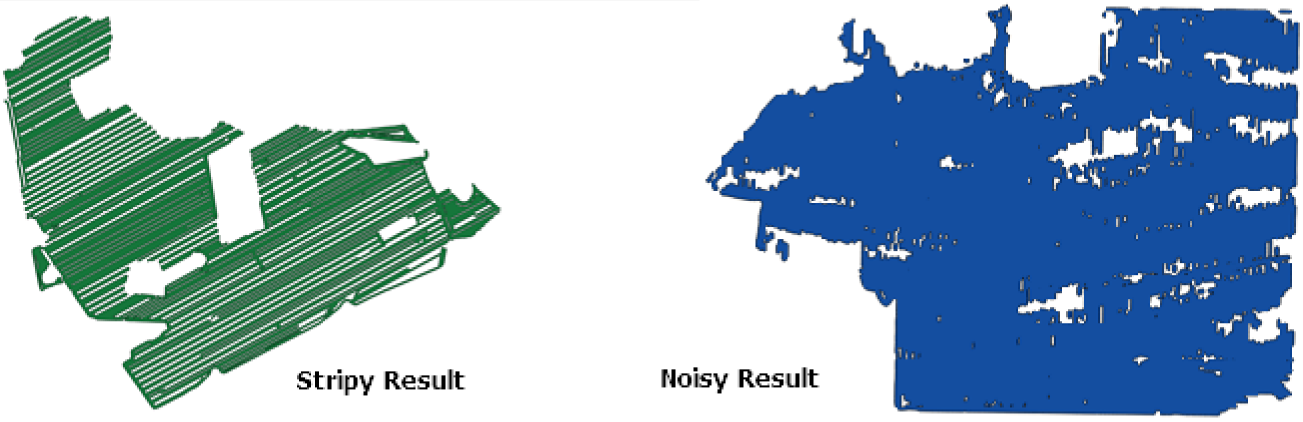
Thin distance (m)	0.00 to 100.00 Default is 1 Use 0 to omit	Any points spaced at less than the minimum distance apart will be removed.
Aggregate distance (m)	0.00 to 100.00 Default is 25	The maximum distance between points used to separate strings of connected points into individual lines. Typically this is slightly larger than the row/swath width.
Buffer distance (m)	0.00 to 100.00 Default is 10	A distance in meters used to buffer the lines to create overlapping polygons. Typically this is half the row/swath width.
Shrink distance (m)	0.00 to 100.00 Default is 3	A distance in meters used to shrink the overlapping polygons after dissolving. Typically this is slightly less than the buffer distance.
Polygon file	Derived from layer name	The output filename for the polygon Shapefile.
Projected coordinate system		The output projected coordinate system of the Shapefile.
Auto detect WGS84 UTM zone	If Auto detect is checked the following rules will apply: - Will try to match the input if it is a projected coordinate system - If the inputs are in Geographic's (lat/long) it will calculate the relevant WGS84 UTM Zone Note: If in Australia then MGA GDA 1994 zones, will be used.	

Notes

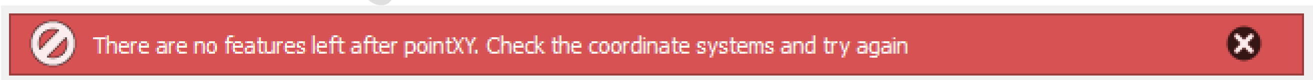
- The following notification occurs when a delimited text file contains invalid characters in the column name. A copy of the file will be made in the PAT temporary folder containing corrected column names as specified in the PAT log message and to file. For more information on the location of the saved log file and temporary folder see the Technical Notes section.



- A warning is triggered when the resulting polygon is considered stripy or noisy. This can usually be corrected by increasing the buffer and shrink distances.



- The following error is caused when the wrong coordinate system is applied to the input source file or layer. Thinning and/or clipping will result all points being removed leaving no points for further processing



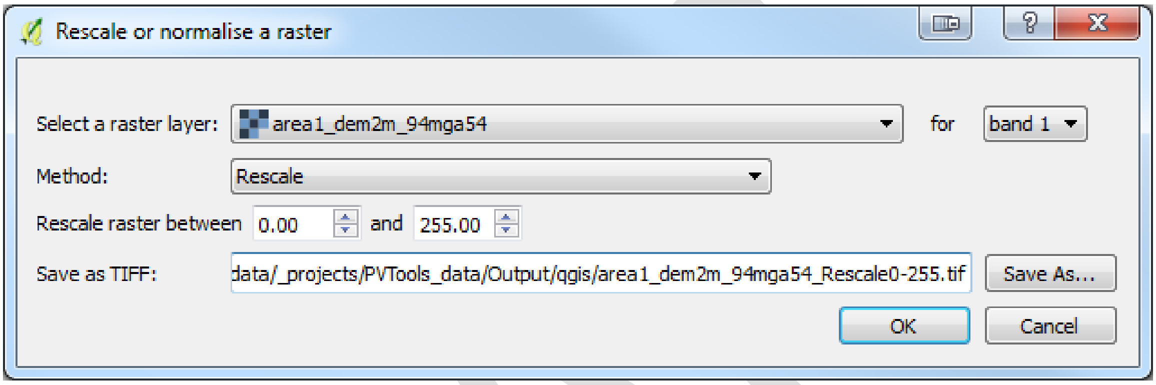
2.6 Rescale or Normalise a Raster

Summary

This tool rescales or normalises a raster and output to a new GeoTIFF file. Existing nodata values will be ignored in any calculation.

- Rescale will adjust the raster between the specified values (e.g. output values all in the range 0 to 1)
- Normalise will adjust the raster to a mean of zero and standard deviation of one

Dialog



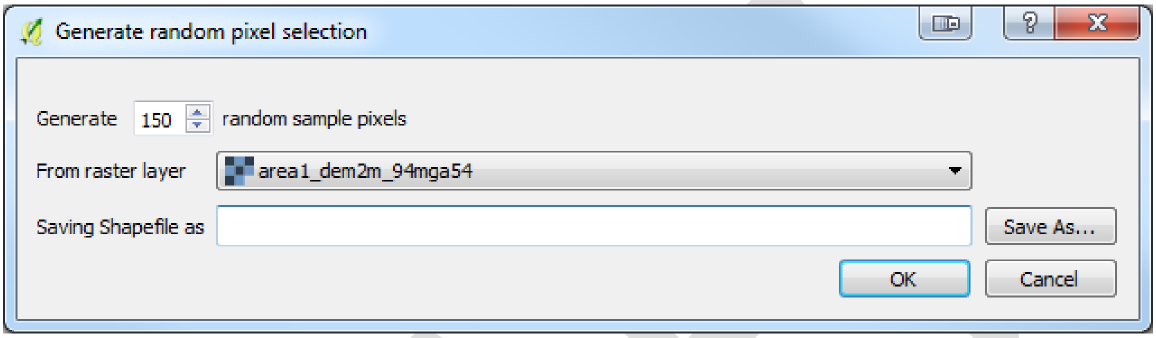
Rescale or normalise a raster		
Select a raster layer for band X	Default is band 1	The raster layer and band to rescale or normalise
Method	Default is rescale	Options: • **Rescale** – adjust values to a fixed range • **Normalise** – adjust values to a mean of zero and a standard deviation of one
Rescale between (when selected)	Default 0 to 255	The range of values used with rescaling
Save as Shapefile	Default will be derived from the input layer name	The output Shapefile to be created.

2.7 Generate Random Pixel Selection

Summary

This tool is used to select randomly distributed pixel locations from an existing raster and save to a point Shapefile. Pixels will be selected from areas inside the raster extent which contain valid data. The resulting points will be located in the centre of the chosen pixel and the output shapefile will contain columns representing the X and Y coordinates.

Dialog



Generate random pixel selection		
Generate random sample pixels	Default is band 1	The number of pixels to randomly select
Select a raster layer		The raster to use as the base for selecting pixels. NoData pixels will be exempt from selection.
Save as Shapefile	Default will be derived from the input layer name	The output Shapefile to be created.

2.8 Extract Pixel Statistics for Points

Summary

Extract pixel statistics for points is used to extract pixel statistics from multiple rasters using a pre-defined set of points. Statistics are calculated on pixel values within a square neighbourhood and extracted to a CSV file.

Applying a neighbourhood filter to rasters is useful for removing (smoothing) small anomalies introduced from instrument inaccuracies or on-the-go movement. The neighbourhood consists of a centre pixel and a number of pixels forming a square around the central pixel as shown in Figure 3.

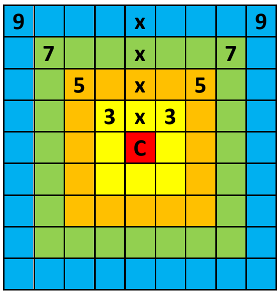


Figure 3. A representation of the 3x3, 5x5, 7x7, 9x9 neighbourhood size around a central pixel (C) as is used when calculating filtered statistics.

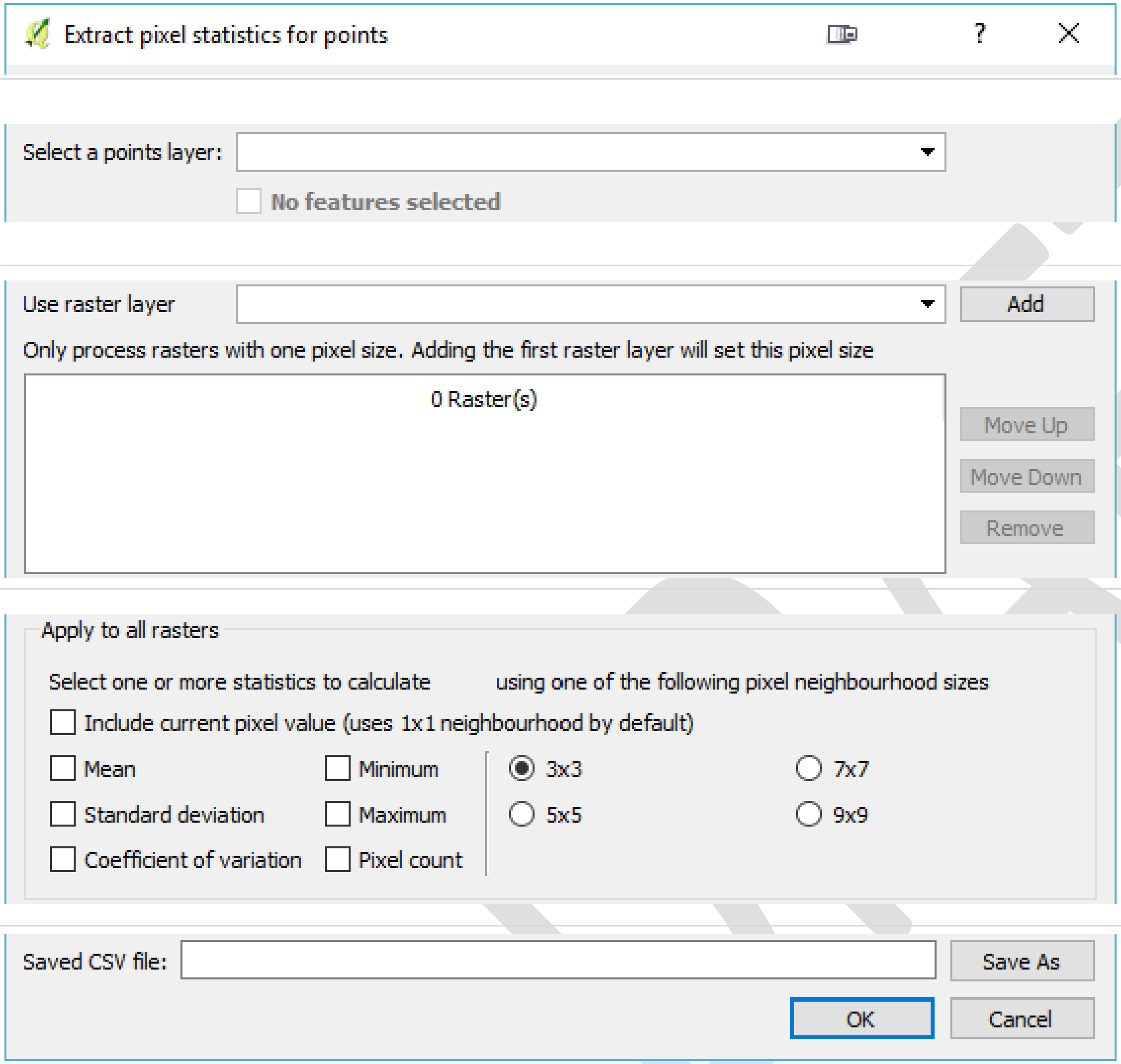
For example, a mean statistic on a 3x3 neighbourhood on 2 m pixels, will calculate the mean of the central pixel (red) and the surrounding 3x3 area of 8 pixels (yellow) equating to 36 m^2 on ground.

Pixels designated nodata will be excluded from the statistical calculation, however, a central nodata pixel may be assigned a value if at least one pixel in the neighbourhood has a valid value.

Currently the statistical methods supported by this tool are; mean, standard deviation, co-efficient of variation (CV), minimum, maximum and a count of pixels contributing to the statistical calculation.

The output values are saved to a CSV data file. Column names for each raster and statistic combination are explained below.

Dialog



Select point layer		A point layer in QGIS used to extract pixel statistics values.
Use selected features	Default is unchecked	If **checked**, extract pixel values only for the selected points. If **unchecked**, all the points will be used
Use raster layer		The raster layer to extract values from. Only raster layers of the same pixel size can be analysed at a time and this is set by the first raster layer added. The *Add, Delete, Move Up, Move Down,* buttons can be used to manage the list of rasters. The order of rasters is retained in the output CSV file with separate columns for each raster and statistic combination.
Calculate pixel neighbourhood statistics		Select the required statistical methods for each raster in the list. **Current pixel** just extracts the pixel value and/or **Statistics** to be calculated using the set neighbourhood size The output column naming format is explained below
Neighbourhood size (pixels)	Default is 3x3	The size of the neighbourhood footprint to use while calculating statistics.
Save CSV file	Derived from layer name	The name and path of the output CSV file containing the final data points.

File and Column Naming Conventions

- <> denotes an existing element or input
- non-alphanumeric characters are removed with the exception of hyphens (-) and underscores (_).

Output Filenames:

CSV filename	<*QGIS points layer name*>_pixelvals.csv

Column Names:

NAMING RULE	EXAMPLE	EXPLANATION
<*statistic*><*size*>_<*raster file*>	mean3x3_swblock_YldMassDry_PRED	The column containing values from the mean 3x3 neighbourhood filter for the raster swblock_YldMassDry_PRED.tif.
	pixel_swblock_2009YldMassDry_PRED	The column containing the pixel values for the raster swblock_2009YldMassDry_PRED
	cv5x5_seblock_2014YldMassDry_PRED	The column containing values for coefficient of variation (CV) 5x5 neighbourhood filter for the raster seblock_2014YldMassDry_PRED.tif
	pixelcount7x7_swblock_2024YldMassDry_PRED	Column containing values representing the count of pixels used for statistical calculations with a 7x7 neighbourhood filter for the raster seblock_2014YldMassDry_PRED.tif

2.9 Calculate Image Indices for Blocks

Summary

Calculate Image Indices for Blocks is used to calculate indices for a multi band image and processed to align the output to the extent and pixel size of an on-the-fly generated block grid. Indices currently supported are normalised difference vegetation index (NDVI); plant cell density index (PCD); green normalised difference vegetation index (GNDVI); chlorophyll red-edge index (CHLRE); and normalised difference red-edge index (NDRE).

Each band is mapped to a spectral band e.g. Red, Red-edge, Near Infrared and is then used to calculate relevant image indices. If a non-vine mask is present in an existing band of the image it can be used to remove non-vine signals prior to the resampling and alignment to the block grid. This will ensure that spectral signatures relating to ground cover are excluded from the resulting image outputs. This non-vine masking is not relevant for cereal crops.

An optional block boundary polygon layer, and a column containing the block name or ID, can be used to separate the resulting images into individual blocks. By default if no column is specified, then all polygons are assumed to be from the one block and will be processed accordingly. If no block boundary layer is specified, then a single polygon outlining the image (excluding no data) will be used.

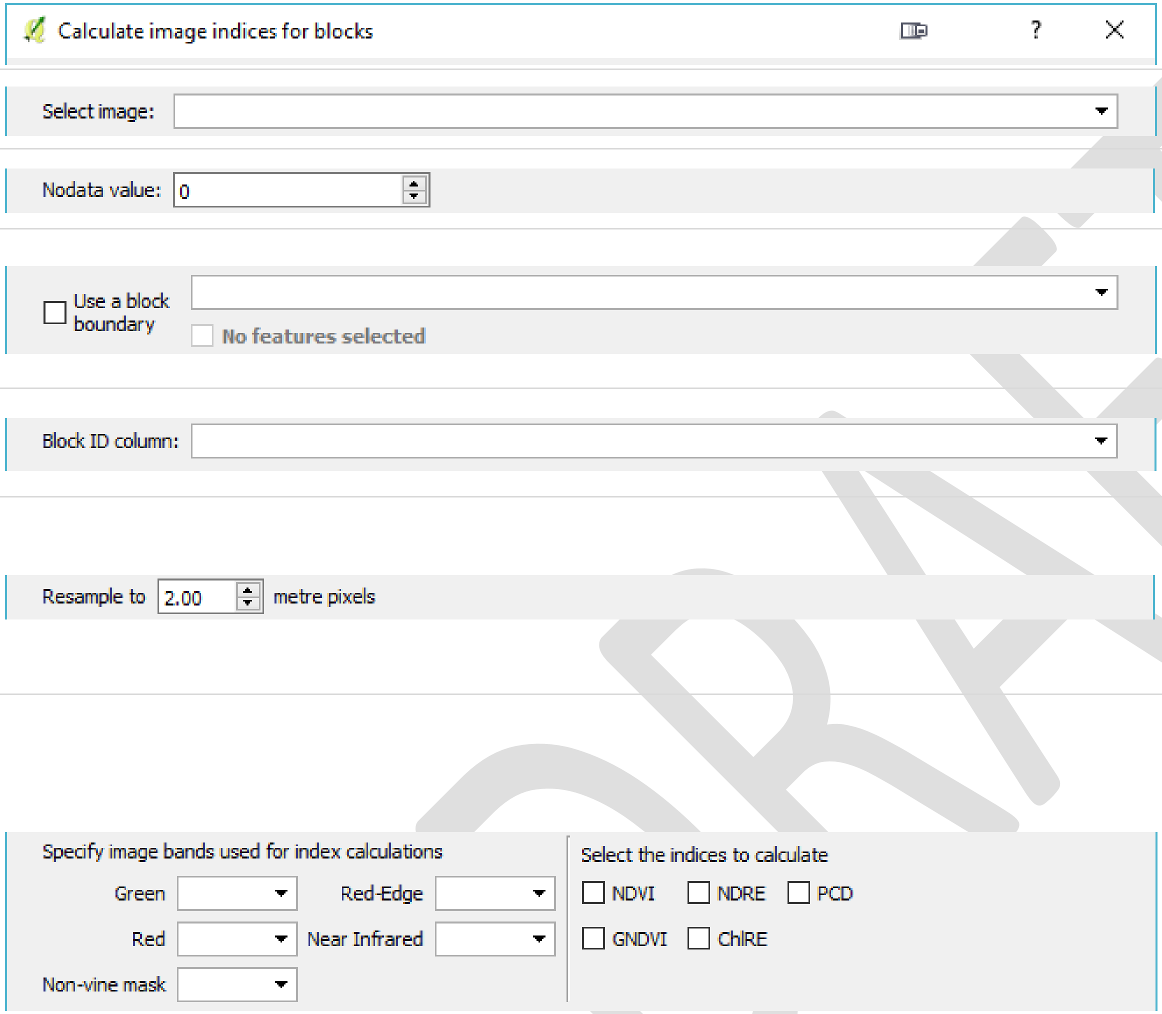
Steps to calculate and aligning the image this tool uses are as follows:

- Reprojects outputs to the specified projected coordinate system
- Calculate image indices based on mapped bands.
- Dissolves polygons by the block id column and loops through blocks and
    - Clips the band to the block extent
    - Creates the block grid on-the-fly for the specified pixel size.
    - Resamples to match the block grid using an averaging interpolation method
    - Apply an averaging smoothing filter across image
- Saves a single band TIFF for each block and index combination.

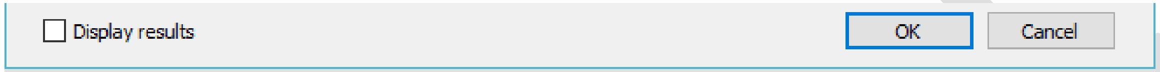
Table 3 the list of supported indices

Normalized Difference Vegetation Index (NDVI)	$\mathrm{NDVI} = \frac{(NIR - Red)}{(NIR + Red)}$
Green Normalized Difference Vegetation Index (GNDVI)	$\mathrm{GNDVI} = \frac{(NIR - Green)}{(NIR + Green)}$
Normalised Difference Red-Edge Index (NDRE)	$\mathrm{NDRE} = \frac{(NIR - Red\,Edge)}{(NIR + Red\,Edge)}$
Plant Cell Density Index (PCD)	$\mathrm{PCD} = \frac{NIR}{Red}$
Chlorophyll Red Edge Index (ChlRE) (Gitelson 2004; Gitelson *et al.* 2005)	$\mathrm{Chl}_{red\,edge} = \left(\frac{NIR}{Red\,Edge}\right) - 1$

Dialog



Select Image	The image layer containing the appropriate bands required for calculate indices.	
Nodata value	Default from image.	Can be used to specify a different no data value.
Use a block boundary	**Default is unchecked**	A layer in QGIS containing polygon(s) representing blocks.
Use selected features	**Default is unchecked**	If **checked**, only the selected polygons will be used.
Block ID column	A column containing the block id or name. This will be used treat multiple polygons with the same block id or name as one.	
Resample pixel size (m)	0.00m to 6 km **Default is 2 m**	The pixel size to apply to the raster outputs. This is expressed in meters. Recommended Values: Viticulture: 2 m Sugar: 2 m Broadacre grains: 5 m
Specify image bands used for index calculations	Mapping of band numbers to band types. The mapped bands will enable/disable indices based on individual index requirements. For most images Green is band 2 Red is band 3 Near Infrared is band 4 Non-vine mask is a band where pixels <u>not</u> containing vine signals are set to nodata	
Select the indices to calculate	The indices to calculate. If an index is disabled (greyed out) the bands it requires haven't been mapped. For index acronym and equation, see table above.	

	Projected coordinate system	The projected coordinate system to apply to the output files. By default it will calculate the relevant coordinate system from the input image or block boundary's coordinate system and extent coordinate system. Note: If in Australia then MGA GDA 1994 zones, will be used.	
	Output folder	The folder to save output TIFF files. A folder based on the input image name will be created and all TIFF files will be saved here. See table below for *File Naming Conventions* used for output files.	
	Display results	**Default is unchecked**	If checked all resulting TIFF files will be loaded into QGIS.

File Naming Conventions

- <> denotes an existing element or input
- non-alphanumeric characters are removed from strings with the exception of hyphens (-) and underscores (_).

Filenames:

NAMING RULE	EXAMPLE	EXPLANATION
Output Folder:		
*<**output_folder**>\<**image_name**>*	C:\data\vineyard\area1_rgbi_jan_50cm_84sutm54_tif	A new folder based on the image name is created in the output folder and all created images are saved here. In this example the image **area1_rgbi_jan_50cm_84sutm54.tif** is used to create a new folder called **area1_rgbi_jan_50cm_84sutm54_tif**.
Image Names:		
*<**block_id**>_<**index**>_<**pixel_size**>.tif*	B1_NDVI_2m.tif	The TIFF file resampled to **2m** pixels for the Normalised Difference Vegetation Index (**NDVI**) created for block id/name of **B1**.
	PCD_250cm.tif	The TIFF file resampled **250cm** pixels for the Plant Cell Density (**PCD**) Index created **without** specifying a block id column.

2.10 Resample Image Band for Blocks

Summary

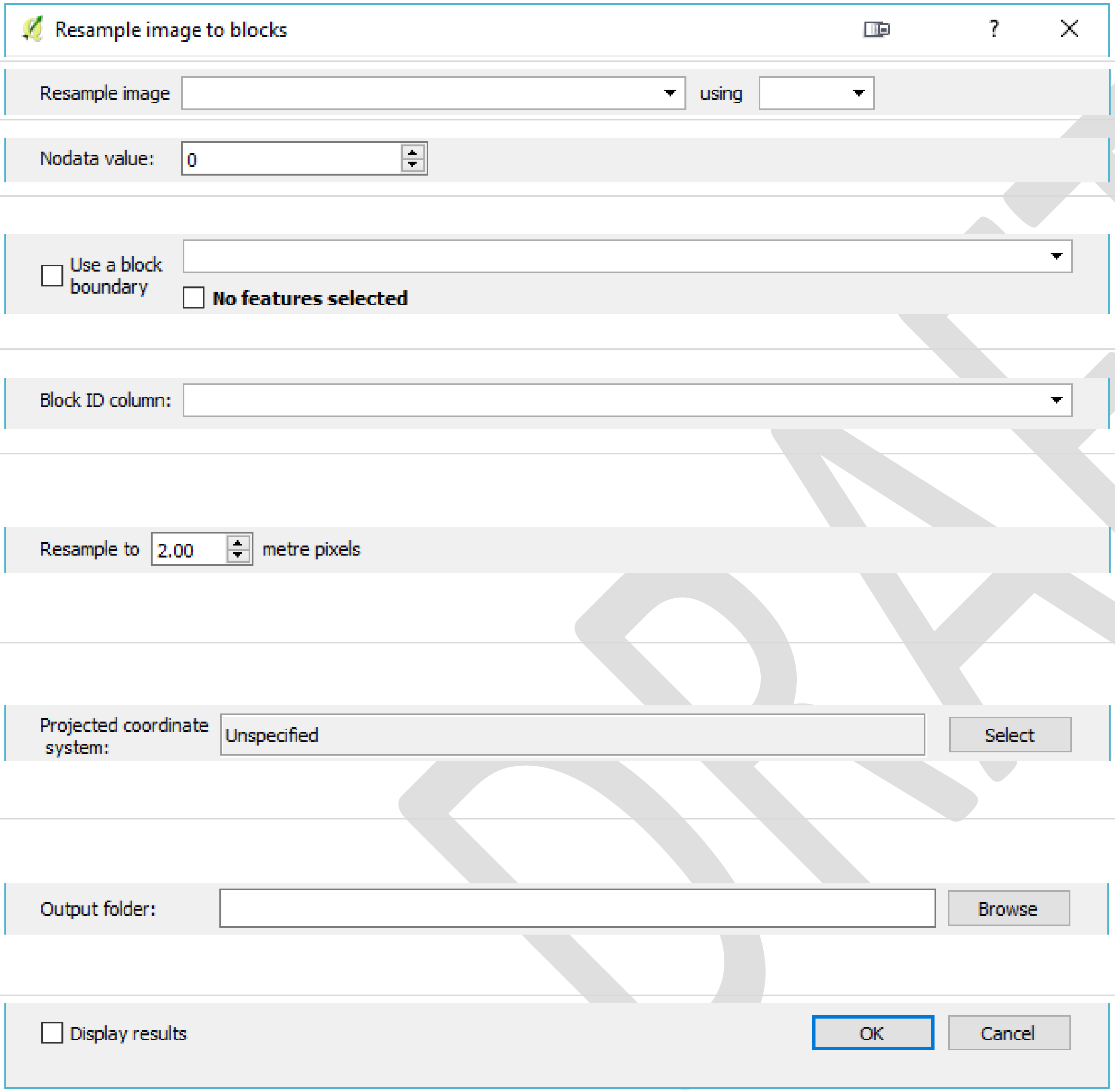
Resample Image Band for Blocks is used to resample, align and smooth an existing band of an image to match a block grid.

An optional block boundary polygon layer, and a column containing the block name or ID, can be used to separate the resulting images into individual blocks. By default if no column is specified, then all polygons are assumed to be from the one block and will be processed accordingly. If no block boundary layer is specified, then a single polygon outlining the input image will be used.

This tool:

- Reprojects the input image band to the specified projected coordinate system
- Dissolves polygons by the block id column and loops through blocks and
    - Clips the band to the block extent
    - Creates the block grid on-the-fly for the specified pixel size.
    - Resamples to match the block grid using an averaging interpolation method
    - Apply an averaging smoothing filter across image
- Saves a single band TIFF for each block.

Dialog



Select Image	The image layer containing the band to resample.	
Nodata value	Default from image.	Can be used to specify a different no data value.
Use a block boundary	**Default is unchecked**	A layer in QGIS containing polygon(s) representing blocks.
Use selected features	**Default is unchecked**	If **checked**, only the selected polygons will be used.
Block ID column	A column containing the block id or name. This will be used treat multiple polygons with the same block id or name as one.	
Resample pixel size (m)	0.00m to 6 km **Default is 2 m**	The pixel size to apply to the raster outputs. This is expressed in meters. Recommended Values: Viticulture: 2 m Sugar: 2 m Broadacre grains: 5 m
Projected coordinate system	The projected coordinate system to apply to the output files. By default it will calculate the relevant coordinate system from the input image or block boundary's coordinate system and extent coordinate system. Note: If in Australia then MGA GDA 1994 zones, will be used.	
Output folder	The folder to save output TIFF files. A folder based on the input image name will be created and all TIFF files will be saved here. See table below for *File Naming Conventions* used for output files.	
Display results	**Default is unchecked**	If checked all resulting TIFF files will be loaded into QGIS.

File Naming Conventions

- <> denotes an existing element or input
- non-alphanumeric characters are removed from strings with the exception of hyphens (-) and underscores (_).

Filenames:

NAMING RULE	EXAMPLE	EXPLANATION
Output Folder:		
<***output_folder***>\<***image_name***>	C:\data\vineyard\area1_rgbi_jan_50cm_84sutm54_tif	A new folder based on the image name is created in the output folder and all created images are saved here. In this example the image **area1_rgbi_jan_50cm_84sutm54.tif** is used to create a new folder called **area1_rgbi_jan_50cm_84sutm54_tif**.
Image Names:		
<***block_id***>_<***Band***>_<***pixel_size***>*.tif*	B1_**Band6**_2m.tif	The TIFF file where **Band 6** is resampled to **2m** for block id/name of **B1**.
	Band7_250cm.tif	The TIFF file where **Band 7** is resampled **250cm** pixels **without** specifying a block id column.

2.11 Create Zones with *k*-means Clusters

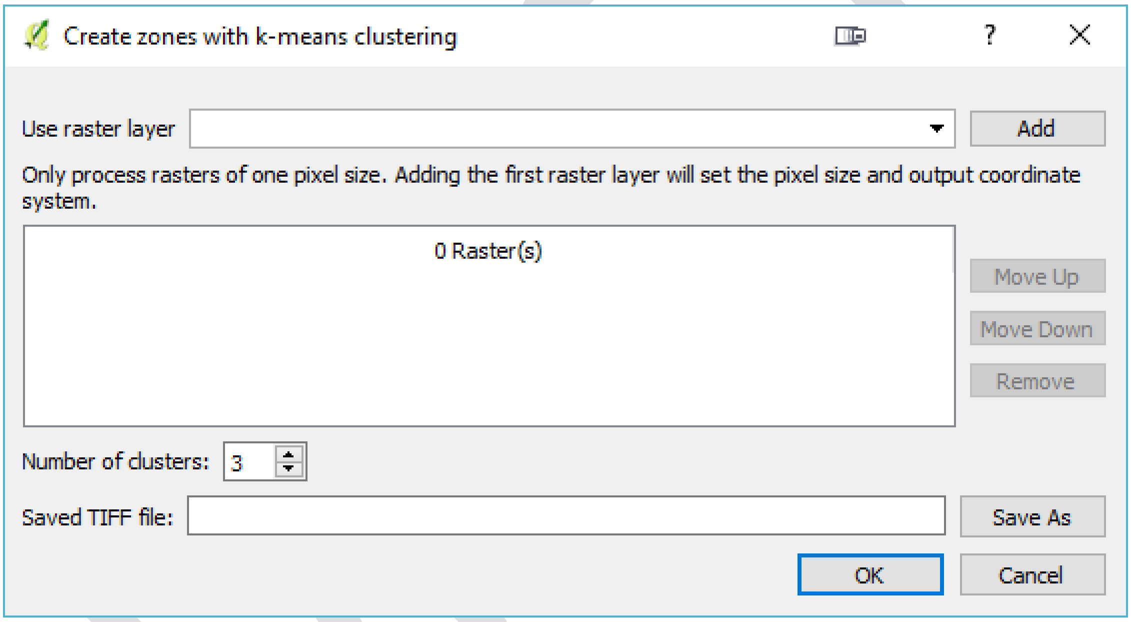
Summary

This tool allows zones to be created by combining multiple rasters together and perform *k*-means clustering to create clusters of similarity by minimising variability within clusters while maximising variability between clusters. If significant differences between clusters are observed then the clustered results can be used as potential management zones.

Raster files with the same single pixel size, and coordinate systems are used as inputs and the common area of overlap will be used to generate an output tiff containing the clustered result.

On completion of the *k*-means clustering the mean and standard deviation for each zone/cluster and source raster combination will be calculated and written to a CSV File alongside the output TIFF file as well as being displayed in PAT's log messages panel.

Dialog



Create zones with *k*-means clustering		
Use raster layer:	The raster layer to extract values from. Only raster layers of the same pixel size can be analysed at a time. The first raster layer added sets both the pixel size and the output coordinate system. The *Add, Delete, Move Up, Move Down,* buttons can be used to manage and order the list of rasters. The order of rasters is retained in the output CSV file with separate columns for each raster and statistic combination.	
Number of clusters:	Default is 3	The number of clusters/zones to create.
Save TIFF file	The name and path of the output TIFF file representing the zones. In addition, a statistics CSV file will be written to disk along side the TIFF, and results printed to PAT's log messages panel..	

File and Column Naming Conventions

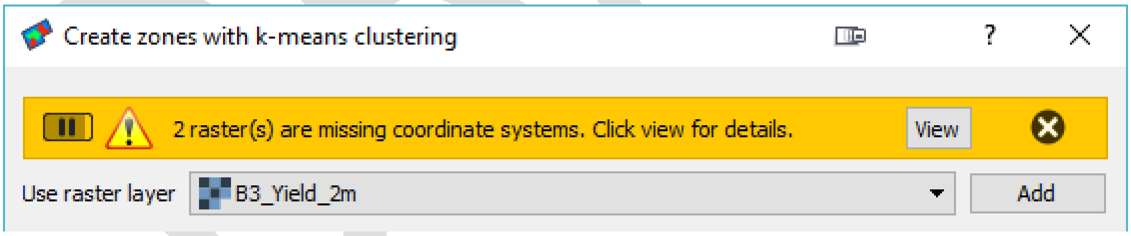
- <> denotes an existing element or input
- non-alphanumeric characters are removed from strings with the exception of hyphens (-) and underscores (_).

FILENAMES:		
Output TIFF		
	Naming Rule:	k-means_<*n_clusters*>*clusters*_<*n_rasters*>*rasters*_<*pixel_size*>*.tif*
	Example:	k-means_**3**clusters_**5**rasters_**2m**.tif
	Description:	A 2m pixel TIFF file for **3** k-means clusters using 5 input rasters
Output Statistics CSV		**<** output TIFF name**>** where **.tif** is replaced by **_statistics.csv**

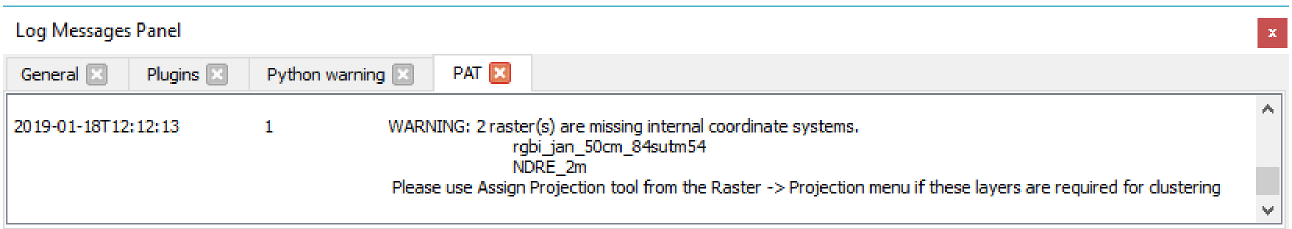
CSV COLUMN NAMES:	
Naming Rule:	**<*raster_file*> _<*statistic*>**
Example:	swblock_2024YldMassDry_PRED_**std**
Description:	The **standard deviation** value for swblock_2024YldMassDry_PRED.tif for the corresponding cluster/zone.

Notes

- To successfully use this tool, all input raster files <u>must</u> contain the coordinate system internal to the file. When a file without a coordinate system is loaded into QGIS an external coordinate system will be applied based on your QGIS settings. These files cannot be used by this tool. The user will be notified of this when launching the tool as follows.



Clicking on ***view*** will open the PAT Log Messages Panel and provide a list of those images. Users can then use the *Assign Projection* Tool from the *Raster -> Projection* menu to assign an internal coordinate system to the files. If the *Assign Projection* tool.



2.12 Settings

Summary

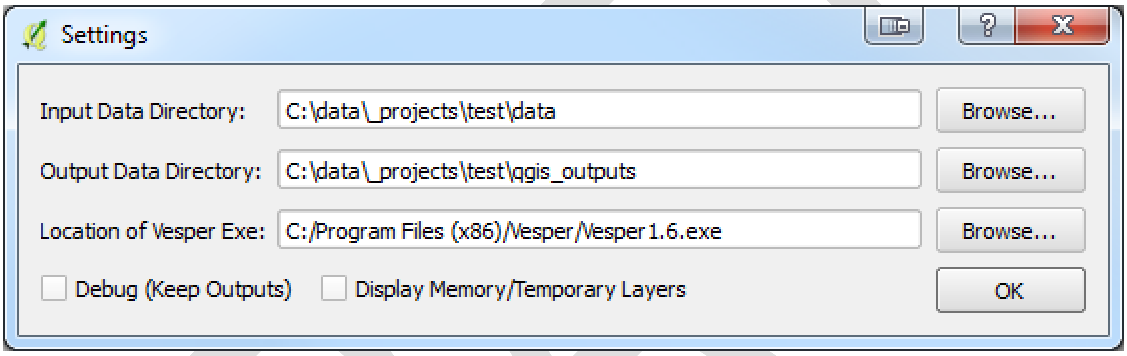
This tool is used to display and edit PAT settings.

The input and output data directories set here will be used to set the default paths by the *browse for file/folder* functionality for all tools. Each tool will store and access its own values after first time use.

Checking the ***Debug (keep outputs)*** box will save intermediate files created while processing data to file. It should be noted that this will slow down the time taken to run tools, but can be a useful diagnostic tool.

The ***Display Memory/Temporary Layers*** checkbox can be used to add the intermediate files to QGIS along with any in-memory or virtual layers which are used but not saved to disk.

Dialog



Input Data Directory	A folder containing input data.*
Output Data Directory	This is the coordinate system of the VESPER results.*
Location of VESPER Exe	Set the location of the VESPER executable. If this is not found or specified, VESPER cannot be run, but relevant VESPER input files can still be created.
Debug (Keep Outputs)	When checked, various intermediate files will be written to disk to assist with error/debugging analysis, however this will slow down processing.
Display Memory/Temporary Layers	If checked, any files written to disk, or created in memory will be loaded into QGIS into a grouped layer labelled DEBUG and can be used for error/debugging analysis.

* By default this will be the PrecisionAg sub-folder in the user's home directory. To quickly navigate here type *%homepath%/PrecisionAg* in the address bar of Windows Explorer.

3 Technical Notes

- PAT makes use of the CSIRO developed pyPrecAg Python module which is an open source Python package containing a range of specialised analysis functions.

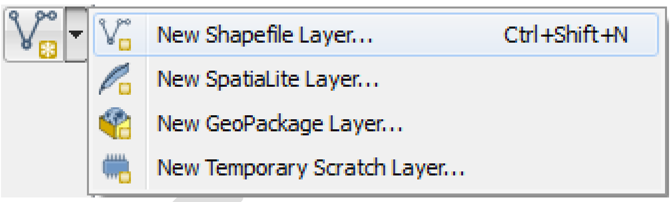
- All intermediate files created while processing are located in the PrecisionAg folder of the user's temporary folder. To quickly navigate to the temporary folder, type %temp%/PrecisionAg in the address bar of windows explorer. This folder is deleted when QGIS exits.

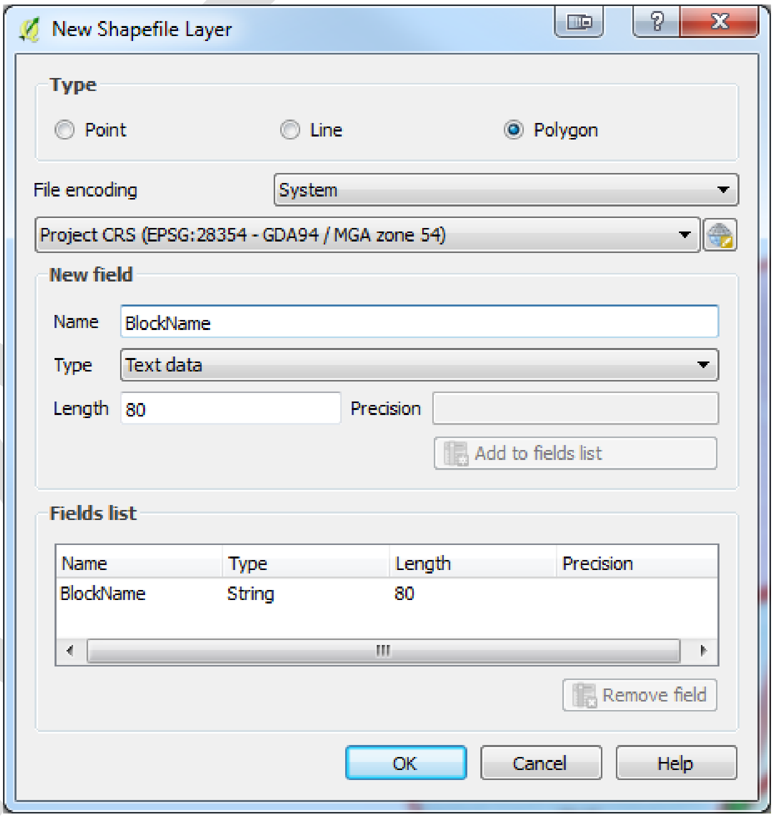
- All progress, messages and errors are displayed in the PAT tab of the Log Panel as shown in Figure 2 and is saved to a log file located in the PrecisionAg folder of the user's temporary folder. A list of important paths including the location of temp and the user's plugin folder.

- A Users QGIS Plugin folder can be found by typing %homepath%/.qgis2/python/plugins into the address bar of Windows Explorer.

4 QGIS How-To's

4.1 Create a block boundary polygon from a CSV of GPS collected points

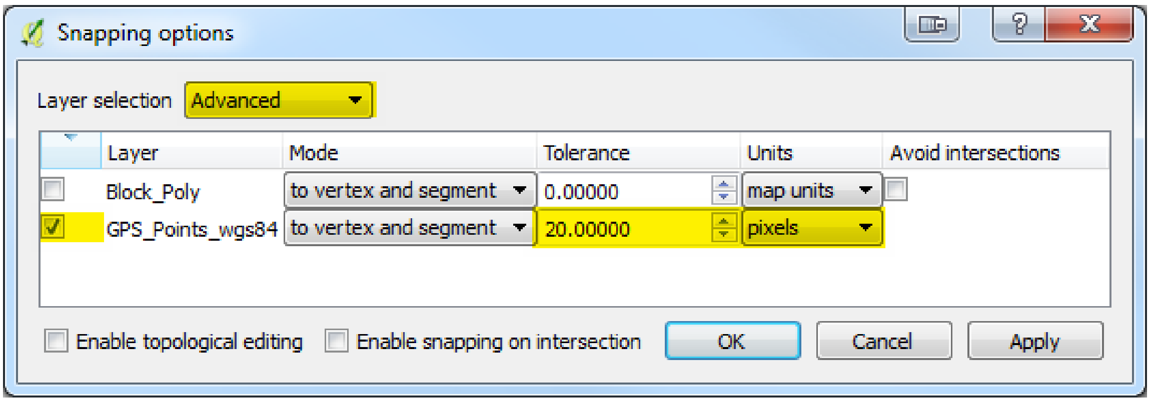




1. Using the ***New Shapefile Layer*** tool from the ***manage layers toolbar*** *(or Layer menu -> Create Layer -> New Shapefile Layer*) create a new polygon shapefile adding the relevant coordinate system and attribute fields you require. Clicking OK will prompt you for the location to save the shapefile.
2. Set a style and labelling to the polygon layer. A hatching polygon fill works well for editing.
3. Launch the ***Add Delimited Text Layer*** tool from the ***manage layers toolbar*** *(or Layer menu-> Add Layer -> Add Delimited Text Layer)* and load your GPS CSV file as a layer into QGIS. 

   Hint: Your coordinate system is probably WGS 84
4. If required, load other vector or raster data, like imagery, which can be used as reference.

5. **Setup your snapping environment**.
   a. Open ***snapping*** options (*Settings menu -> Snapping Options*)
   b. Change ***layer selection*** to ***advanced***.
   c. **Tick** the layer containing the **point layer** loaded in step 3.
   d. Change the ***tolerance*** to **20** and set **units to pixels**



6. Select/activate the **polygon** layer in the layers panel and click the ***toggle editing*** icon from the ***digitizing toolbar***.
7. **Add new features** by using the ***add features*** tool from the ***digitizing toolbar***.
8. As you move the mouse close to a point the point will change to show a magenta cross hairs (+), this means the mouse has snapped to this point. Clicking the mouse will add this point as a vertex in the polygon. Continue following around the points to form a polygon. Right-mouse-click to finish a polygon.
9. When you finish a polygon a dialog will open to allow you to enter attributes. Click **OK** to add attributes and finalise polygon.

   Save your edits using the ***save layer edits*** icon on ***digitizing toolbar*** and ***toggle editing*** off when complete.

To add, move or delete a vertex, toggle to node mode using the ***node tool*** . Click the polygon to edit. Nodes/Vertex will appear as red squares.

- **Double click** to **add** new vertex.
- **Single click** to select existing vertex. The square will turn blue. Use the **DEL** key to delete
- **Click** and **drag** a vertex to **move**.

To add a hole (donut) to a polygon use the ***add ring*** tool from the ***advanced digitizing toolbar*** and sketch your polygon as described in step 8.

To delete a hole (donut) in a polygon use the ***delete ring*** tool from the ***advanced digitizing toolbar*** and click in the hole.

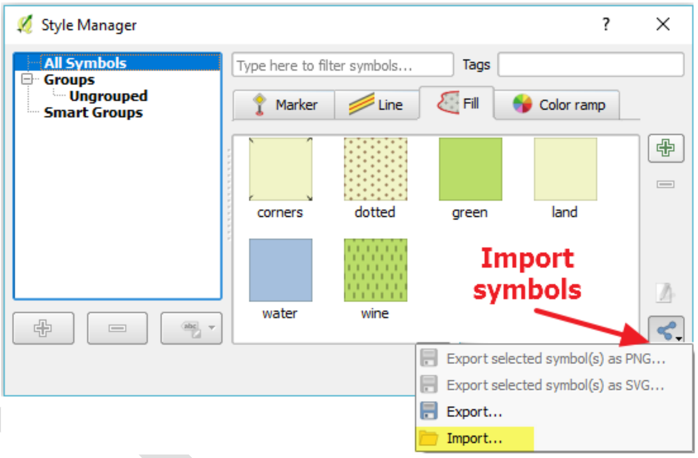
To split a polygon use the ***split features*** tool from the ***advanced digitizing toolbar*** and sketch the path to split. Multiple polygons will be created having the same attribution.

Useful editing shortcut keys.

Add new feature	Ctrl+.	**Zoom in**	Scroll wheel or	Ctrl ++
Delete last vertex	Del	**Zoom out**	Scroll wheel or	Ctrl +-
Undo	Ctrl+Z	**Zoom full**	Ctrl+Shift+F	
Cancel edit	Escape	**Pan**	Middle mouse or Spacebar (while adding a feature only) Note: spacebar also turns active layer visibility on/off	

4.2 Loading PAT Symbols into QGIS

The PAT plugin includes a pre-defined set of symbols and colour ramps for use with datasets derived while using the plugin.



1. In QGIS, launch the **Style Manager**

   Settings menu -> Style Manager

2. From the lower right corner of the dialog, select ***Import*** dialog

3. Do one of the following

   a. Set ***Import from*** to ***URL specified below*** and enter the following URL and click ***Fetch Symbols.***

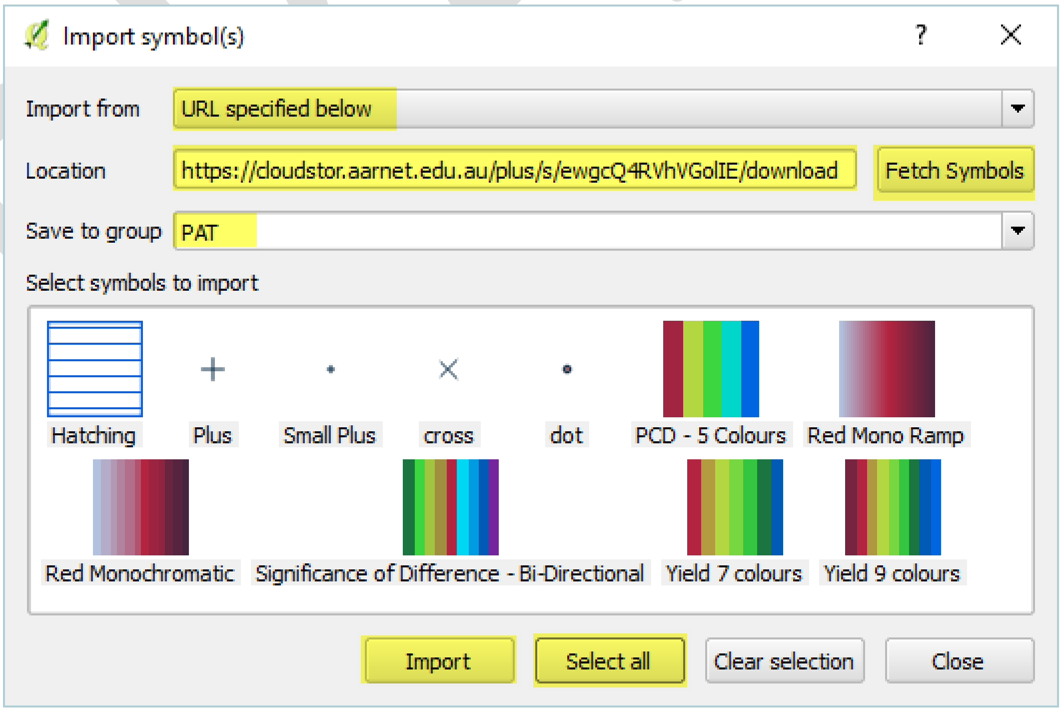
      https://cloudstor.aarnet.edu.au/plus/s/ewgcQ4RVhVGolIE/download

   b. Set ***Import from*** to ***file specified below.*** Browse to the users QGIS plugin folder and find the PAT_symbols.xml file in the PrecisionAg_Plugin folder (see 1.3 Uninstall PAT for help finding this folder).

4. Enter PAT as the ***Save to group.***

5. Select symbols to import or click ***Select all***.

6. Click ***Import***. If symbols with the same name are already loaded, will be notified and given the option to overwrite.



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