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PAT - Precision Agriculture Tools Plugin for QGIS

User Manual

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Wine Australia

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Enquiries

Contact PAT@csiro.au for queries about the tools described in this manual.

Contents

PAT - Precision Agriculture Tools

The Precision Agriculture Tools (PAT) plugin is a suite of open source tools developed by CSIRO for Precision Agriculture (PA) data analysis. The tools run within Quantum Geographic Information System (QGIS) version 2.18 (QGIS Development Team 2017), 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 PA data through an established workflow developed for constructing maps using on-the-go data (e.g. from yield monitors or EM38 soil 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). It also includes tools for analysis of remotely sensed imagery and some on farm experiments and for clustering map layers to create potential management zones. Over time more tools and 'how-to' instructions will be added to expand the functionality and usefulness for both practical and research purposes.

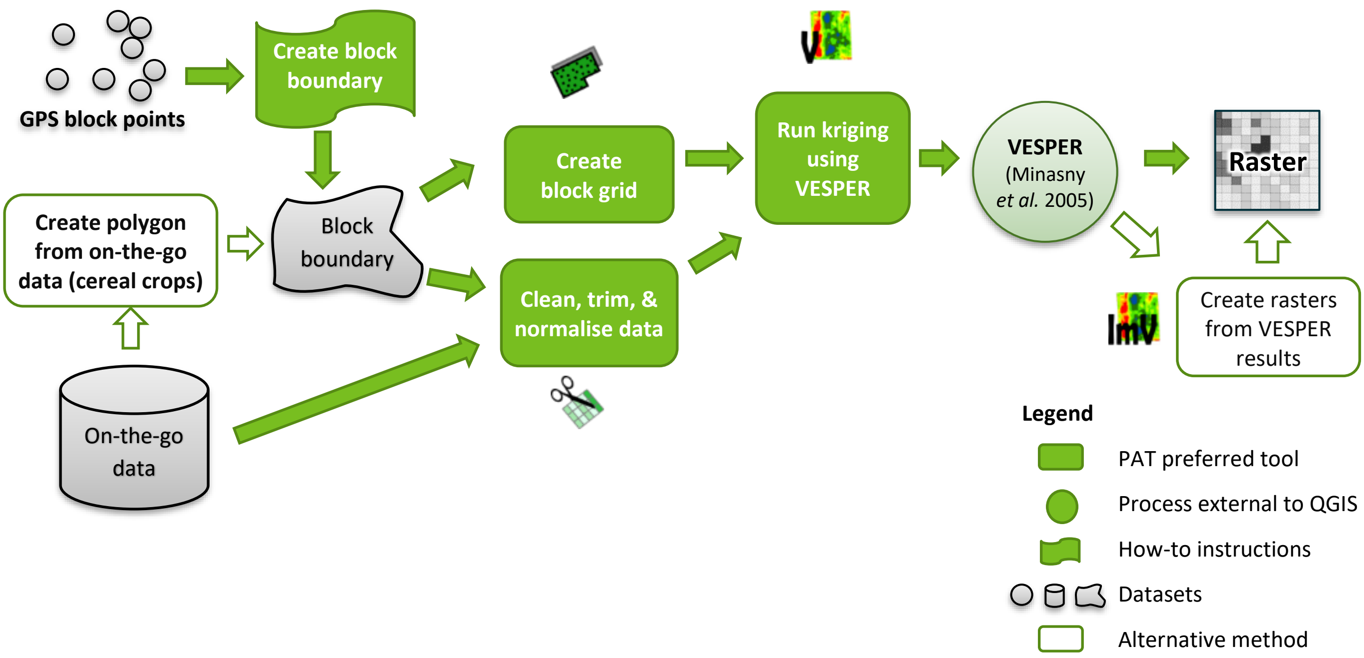


Figure 1 The basic map production workflow used in PAT and some of the existing tools available for processing high density on-the-go data.

Table 1 Brief description of tools available in PAT

	PAT TOOLS	DESCRIPTION
	Create Block Grid	Convert polygon features (e.g. a block boundary – see page 57) to • a TIFF 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 TIFF 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 - see page 57 for instructions on creating a boundary from a set of surveyed data points).
	Rescale or Normalise a Raster	Create rasters by • rescaling (standardising) values between a fixed range (i.e. 0-1, or 0-255); or • 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	Clip imagery to one or more blocks and resample to a different pixel size.
	Create Zones with k-means Cluster	Create zones with *k*-means clustering.
	Create Strip Trial Points	Tool for analysing simple strip-based trials. It generates pairs of points from a central line within a strip and with 'a pair' offset at a distance outset the strip. These points can be used for the comparison of performance along and adjacent to a strip trial (such as an N-rich strip) using the Lawes and Bramley (2012) moving window t-test tool.
	Run Strip Trial *t*-test Analysis	The comparison of performance of a treatment, such as different fertiliser rates, along and adjacent to a strip trial (such as an N-rich strip) using the moving window t test as described in Lawes and Bramley (2012).
	Whole-of-block Analysis	Analyse whole-of-block experiments where 2 or 3 treatments are applied across a block or paddock.
	Persistor	Summarise the patterns of yield across a block over a number of years relative to a target, as described by Bramley and Hamilton (2005).
	Apply Raster Symbology	Apply predefined symbology to a displayed raster.
	Settings	User settings for PAT. 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.

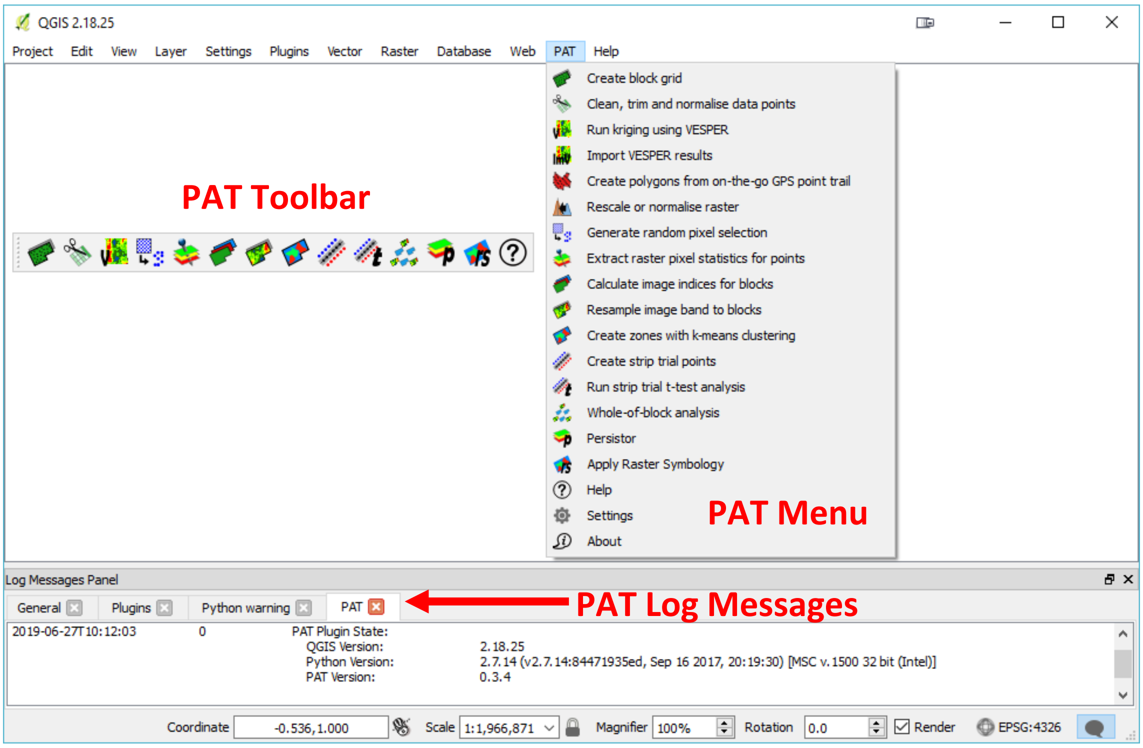


Figure 2 PAT toolbar, menu and log messages panel within QGIS.

1 Installing, Upgrading and Uninstalling

1.1 License

The PAT plugin for QGIS is free to download and use under a GPL V3 Open Source license. PAT license details can also be found in the ***About*** tool under PAT menu. The companion Python library 'pyprecag' (Ratcliff *et al.* 2019) is also freely available and is released under the CSIRO Open Source Software License Agreement (variation of the BSD / MIT License). All source code and license files are available from https://github.com/CSIRO-Precision-Agriculture.

1.2 Requirements

VESPER: To use the ***Run Kriging Using VESPER*** tool requires installation of VESPER (note: only available for Microsoft Windows operating systems). VESPER is a kriging (map interpolation) program (Minasny *et al.* 2005). It 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.

R 3.5.1+: The R statistical language (R Core Team 2018) is required to carry out the analytical processing for the *Whole-of-block Analysis* (Section 2.14). R is **not** distributed with this plugin. If ***Whole-of-block analysis*** is required, then you must download and install R in addition to QGIS. The minimum R version suitable for this is v3.5.1 Configuring QGIS to use R section on page 10.

QGIS LTR 2.18.21-26: Download and install the QGIS standalone long-term release (versions 2.18.21 to 2.18.26). **Note that the PAT tools do not currently work with QGIS version 3 or later.**

QGIS 2.18.26 can be downloaded directly using these links.

32bit : http://download.osgeo.org/qgis/win64/QGIS-OSGeo4W-2.18.26-1-Setup-x86.exe
64bit: http://download.osgeo.org/qgis/win64/QGIS-OSGeo4W-2.18.26-1-Setup-x86_64.exe

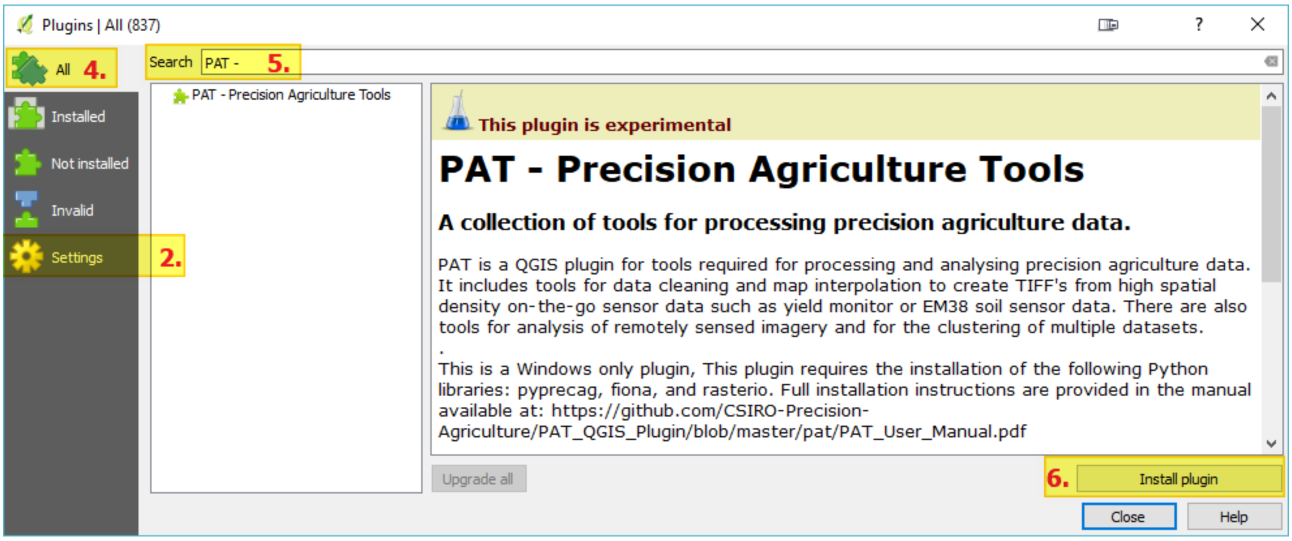
Additional Python Packages: QGIS includes Python and numerous Python packages. However, PAT requires the following additional packages: ***pyprecag*** (Ratcliff *et al*. 2019), ***Fiona*** (Gilles *et al*. 2011) ***and Rasterio*** (Gilles *et al.* 2013). The ***Fiona*** and ***Rasterio*** packages have been bundled with the PAT plugin and instructions on how to install them are included.

1.3 Installing PAT

1.3.1 Install the PAT - Precision Agriculture Tools Plugin.

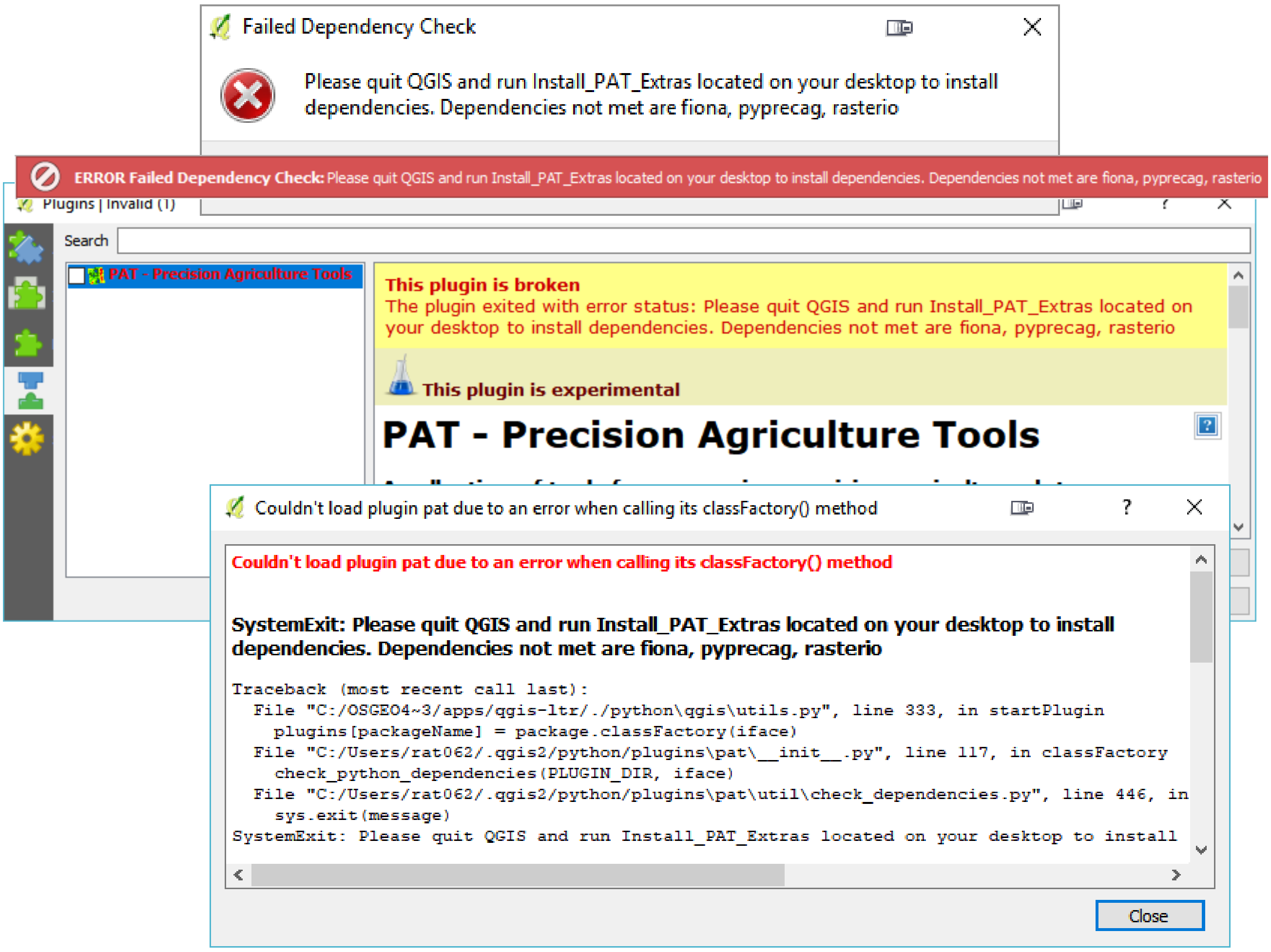
1. In QGIS open the plugin manager.
   Plugins Menu → Manage and Install Plugins
2. Select the ***Settings*** side tab.
3. Select the ***All*** or ***Not installed*** side tab.
4. Search for and select **PAT - Precision Agriculture Tools.**
5. Click ***Install plugin***.

You will receive an ***Failed Dependency Check*** message box and ***Error loading plugin*** messages. This is expected and is resolved by completing the next section titled **Installing or Upgrading PAT Python Dependencies.**

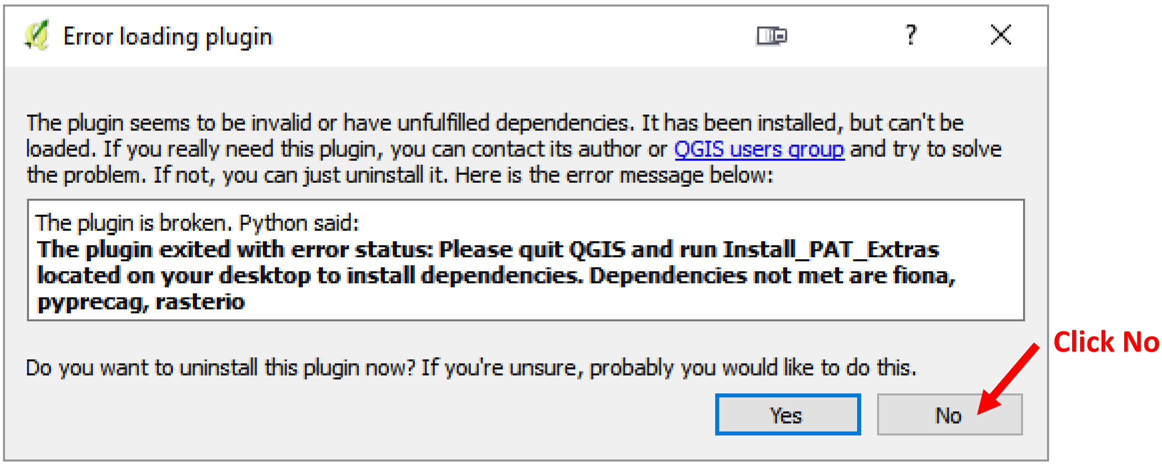


1.3.2 Installing or Upgrading PAT Python Dependencies

While installing or upgrading PAT, a check will be completed to ensure the required Python packages are installed on your system. If any of the images below appear, then this check has failed. <u>This is normal and they may appear multiple times</u>.



If the following message appears click **No.**



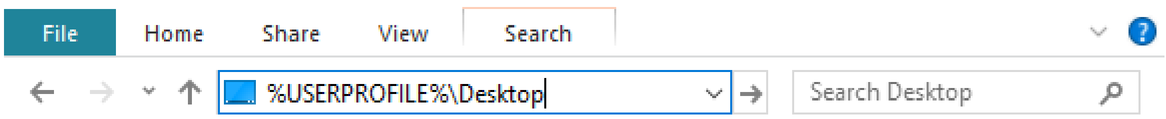
Steps to install dependencies.

1. Close QGIS and go to your windows desktop.
2. A shortcut has been created on your desktop named ***Install_PAT_Extras***. Double click the shortcut to run it.
3. Choose **YES** for the ***Windows Account Control*** and any other messages which may appear.
4. Restart QGIS. The check will run again to ensure the installation occurred correctly.

If the shortcut does not appear on your desktop then try one of the following.

<u>Using the shortcut</u>

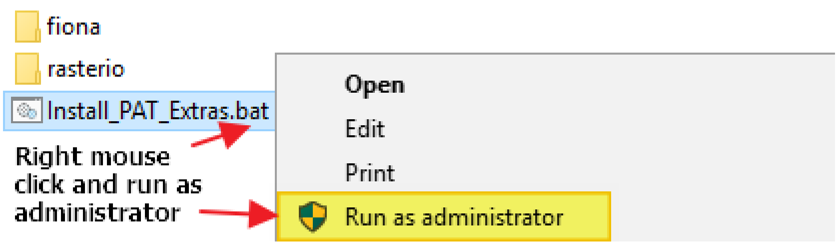
a) Open windows explorer
b) Add **`%USERPROFILE%\Desktop`** and hit enter.



c) Double click the ***Install_PAT_Extras*** file in this folder.
d) Continue from step 3 above

<u>Running batch file as administrator.</u>

a) Follow steps a & b above but enter **`%temp%/python_package`** into the address bar.
b) Right click the ***Install_PAT_Extras.bat*** file and select ***run as administrator.***



c) Continue from step 3 above

If the PAT menu and toolbar are not present, then reinstall and/or check/activate PAT using the plugin manager. QGIS should now contain the PAT menu, toolbar and log panel similar to Figure 2 on page 6. PAT has now been successfully installed.

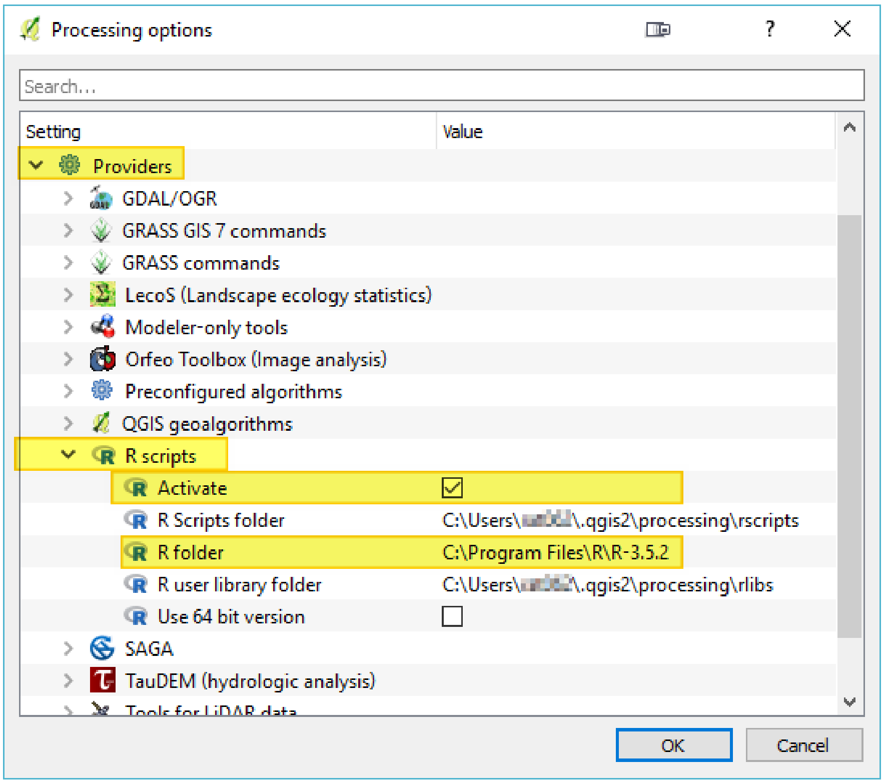
1.3.3 Configuring QGIS to use R

If R is not installed and you launch the ***Whole-of-block analysis tools*** via the menu or toolbar you will a warning message as shown.

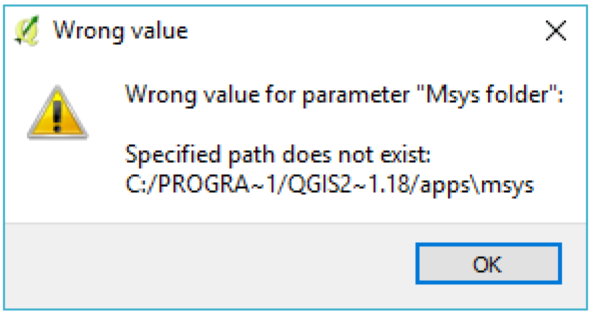
To resolve this, complete the following steps to configure R and QGIS

1. Download R from Windows version can be downloaded from http://r-project.org/ . The minimum R version suitable for this is v3.5.1.
2. Install using all the default options
3. If required, activate the **Processing** plugin in QGIS plugin manager.
    a. In QGIS open the plugin manager.
       Plugins Menu → Manage and Install Plugins
    b. Select the ***Installed*** *section*
    c. Find **Processing** and ensure the adjacent checkbox is ticked.
    d. Close the Plugins dialog.
    This will give you a processing menu and the processing side panel.

4. From the ***Processing*** menu select ***Options***.
    a. Expand ***Providers***
    b. Expand ***R scripts***
    c. Tick on ***Activate***
    d. Ensure that the R installation folder is shown against ***R folder***
    e. Click OK.

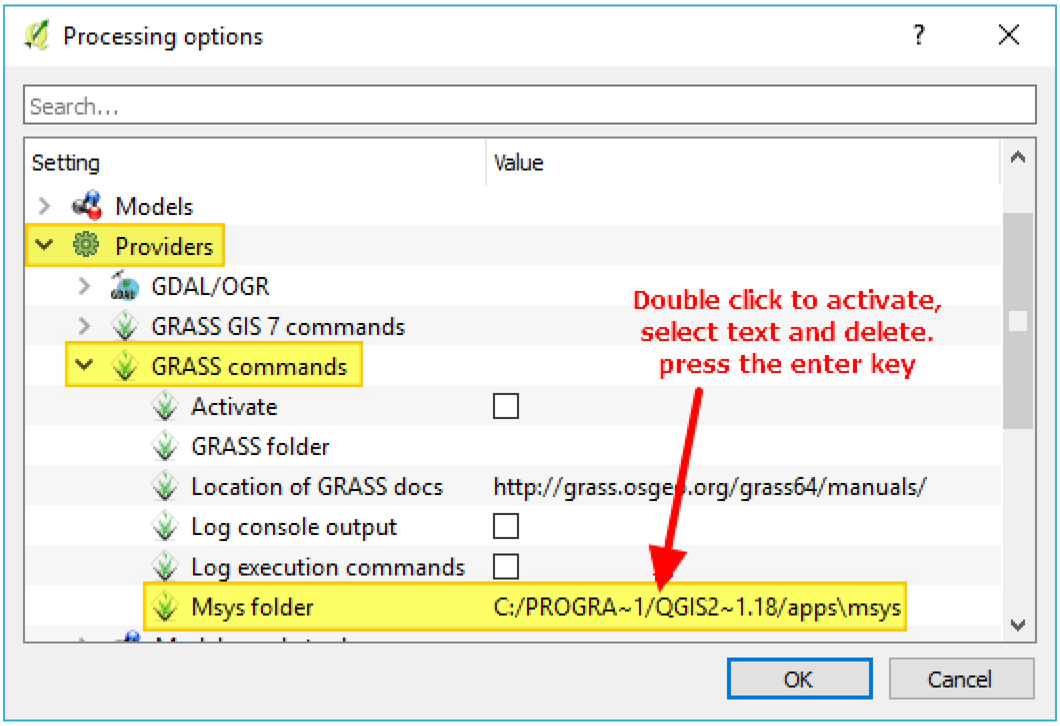


When clicking OK you may get a ***Wrong value*** error message as shown below, and your mouse cursor will remain a circle.



To resolve treat the mouse circle as an arrow and

1. Under ***Providers***, expand ***GRASS commands***
2. Double click the text to the right of Msys folder, select and delete it and press the enter key.



3. Click OK
4. Close and re-open QGIS to reset your mouse cursor.

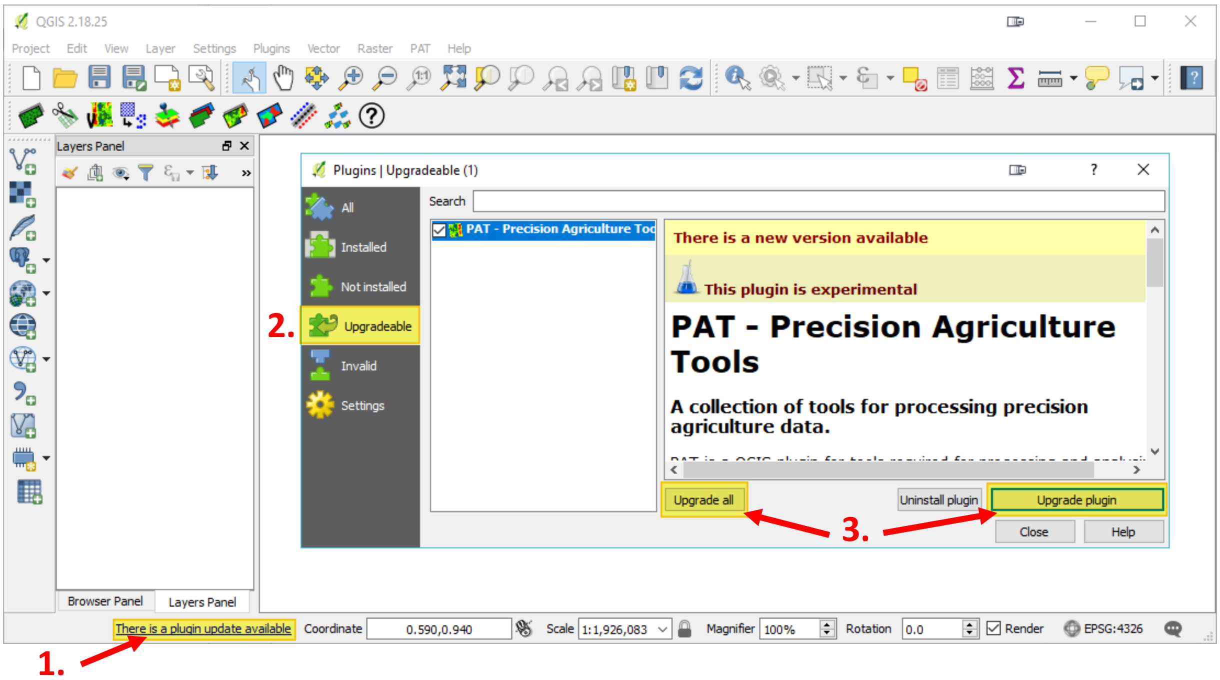
1.4 Update PAT

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. It is recommended that ***Check for Updates*** is checked.

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 selecting the PAT plugin and click ***Upgrade plugin.***

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.

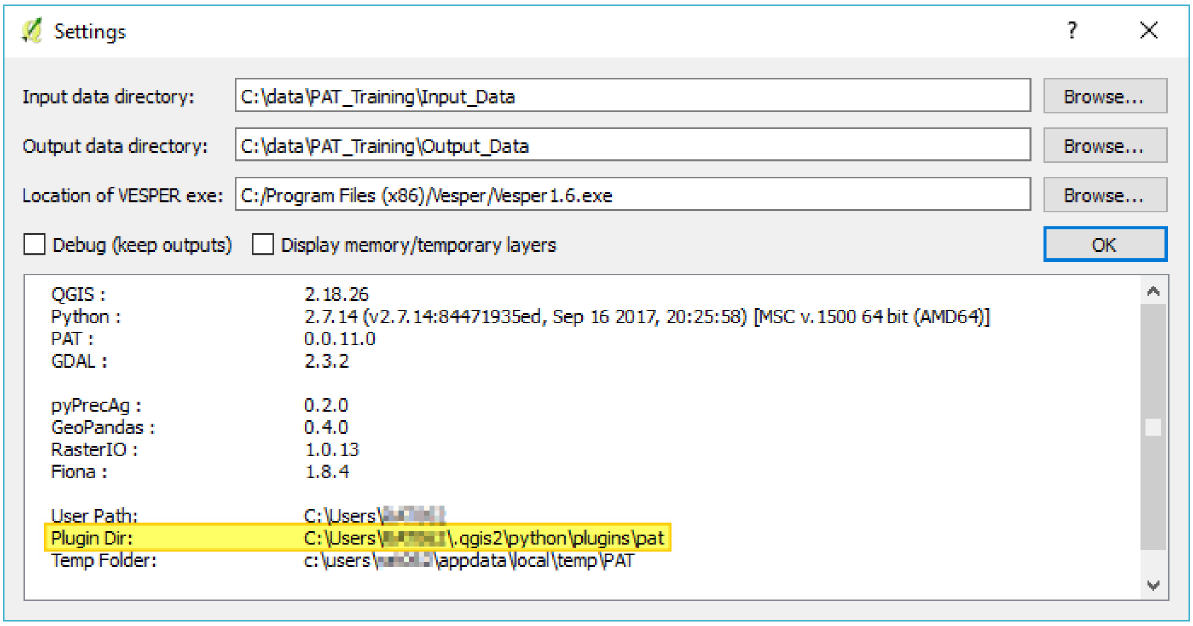


1.5 Uninstall PAT

If you wish to uninstall PAT and its Python dependencies you must first uninstall the Python dependencies, followed by the plugin as instructed below.

1.5.1 Uninstall PAT Python dependencies for all users.

1. Navigate to the current user's PAT installation directory. This folder is listed in as **Plugin Dir** in the ***settings dialog*** as shown highlighted in yellow below.



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 appear.

1.5.2 Uninstall PAT Plugin.

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 1.5.1.1 above.
   b. Delete the entire pat folder.

2 Individual Tools

2.1 Create Block Grid

Summary

This tool converts polygon features such as a block boundary to a raster grid 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 ‘frame’ for the grid. Refer to instructions on page 57 on how to generate a block boundary.

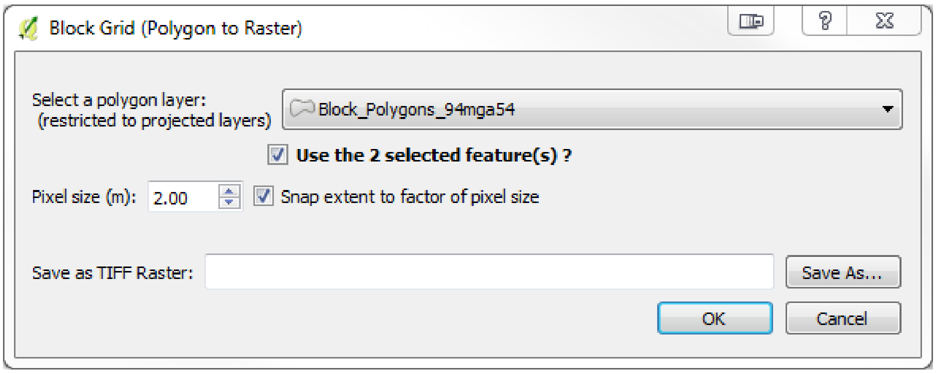
The raster outputs created by the Block Grid tool are:

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

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

If your shapefile layer does not appear in the layer list, then it is probably in a geographic coordinate system. Refer to page 59 for information on why using a projected coordinate system is important, and how to reproject it. A future version of the ***Create Block Grid*** tool will include this conversion when required.

Dialog



Block Grid (Polygon to Raster)		
Select a polygon layer		A layer containing the block boundary 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. Useful in creating a grid for a single field from a boundary layer comprising more than one field.
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 metres. <u>Recommended Values</u>: Viticulture: 2 m Sugar: 2 m Broadacre grains: < 200 ha 2m > 200 ha 10 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 TIFF raster	Default derived from input layer	The output raster TIFF 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 soil survey) containing GPS coordinates recorded as latitude and longitude in decimal degrees, to output point values in a projected coordinate system. The tool also 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. An EPSG number is an international numbering system for coordinate systems (see http://www.epsg.org).
- 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.

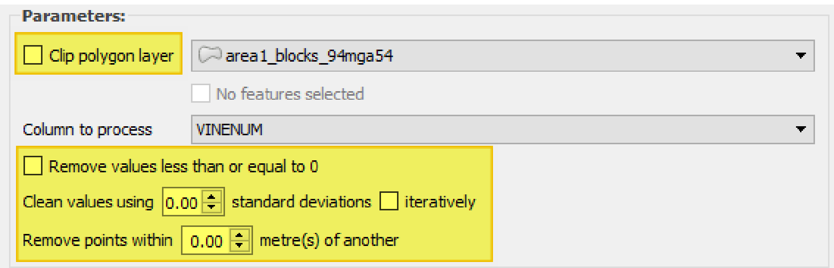
This tool filters data by:

- optionally clipping the data to a Shapefile boundary (i.e. removes points that lie outside the boundary).
- optionally removing values from a given column which are null (missing) or are less than or equal to zero.
- creating a normalised column using a prefix of nrm_ and calculating normalised values for the data such that their mean is zero and standard deviation is 1. The normalised value of column Z is calculated as (Z - mean(col Z))/(s.d.(col Z)) .
- optionally trimming 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. It is recommended that, by default, normalised data are trimmed to +/- 3 standard deviations.
- optionally thinning the data by removing points that are closer together than a set distance. For data that have been georeferenced using a differential GPS, we recommend removing points that are closer than 1 m apart.

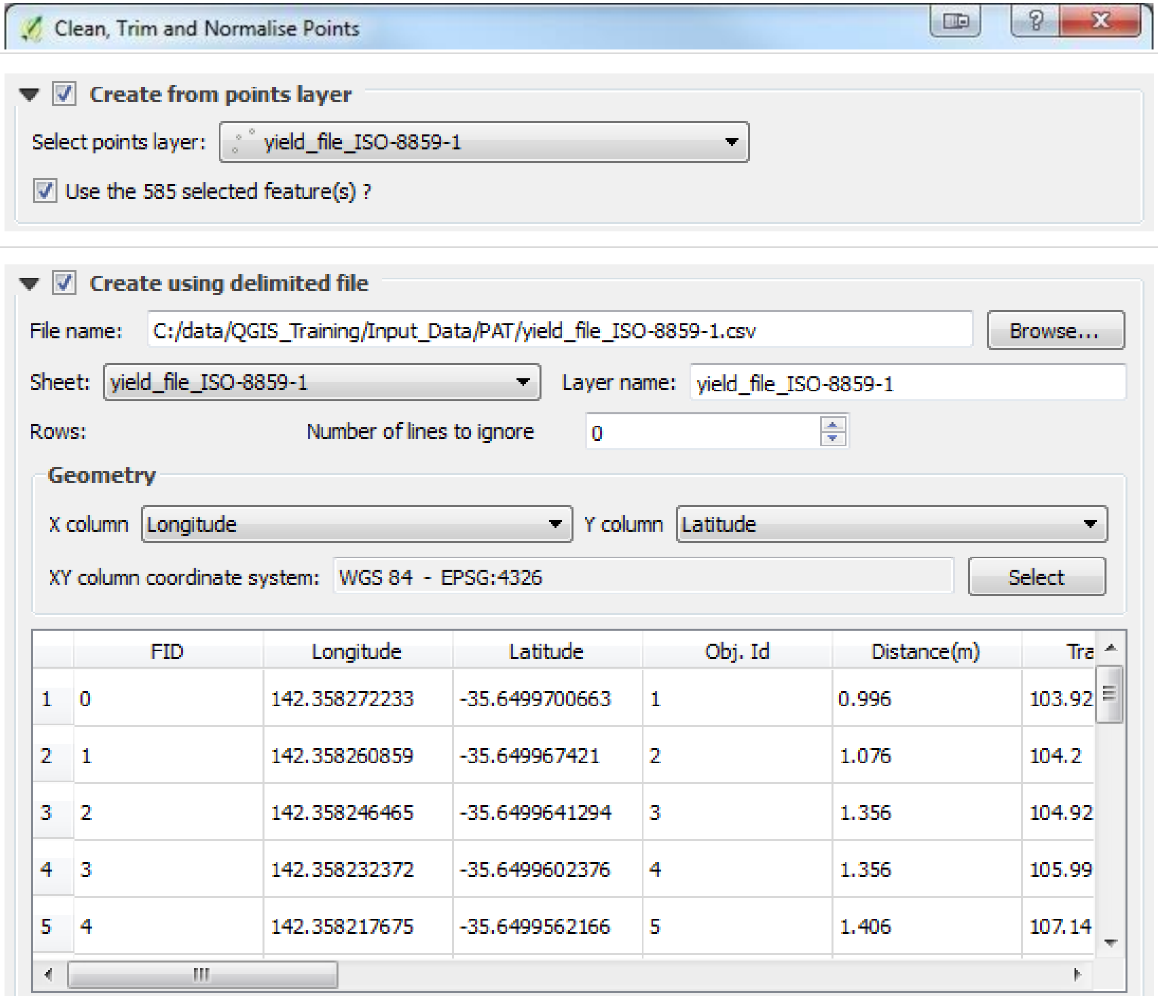
As part of the filtering process, the tool may rename some data columns to adhere to Shapefile column name limitations. The new names are displayed as a PAT log message and written to the log file. For more information on the location of the saved log file and temporary folder refer to the Technical Notes section on page 56.

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.

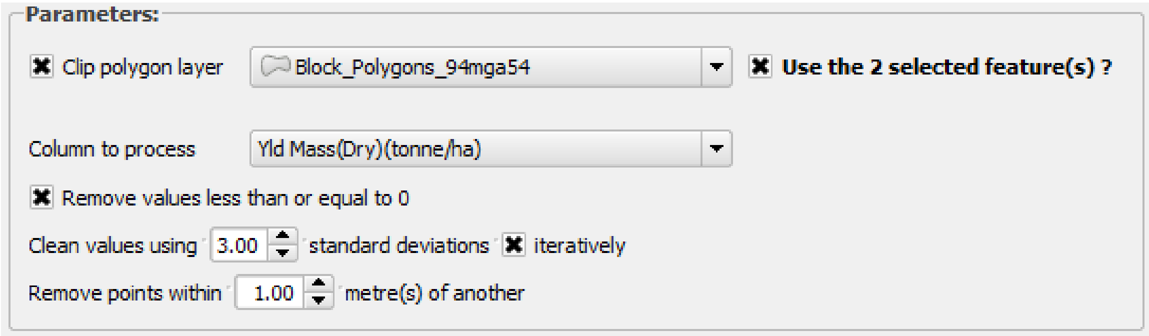
The ***Clean, Trim, Normalise Point Data Tool*** can also be used to reproject csv files containing coordinate columns without the cleaning, trim and normalise functionality by changing the parameters to those highlighted below.

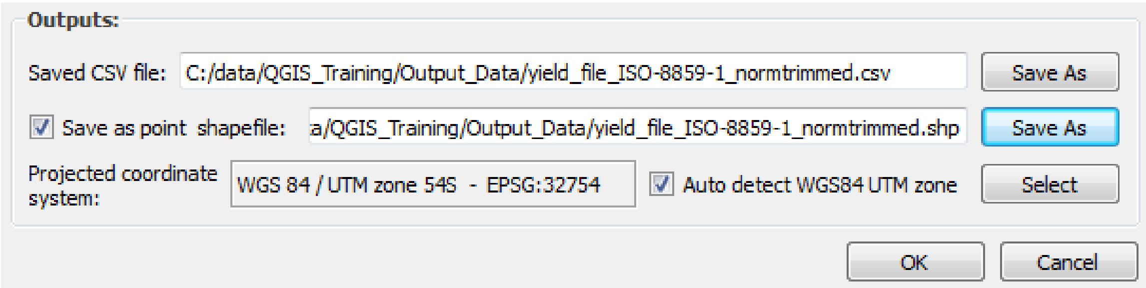


Dialog



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 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**		The columns representing the X and Y coordinates within the input file. By **default** will attempt to match to commonly used column names like X,Y, longitude, latitude; lon, lat etc.
XY columns coordinate system		The coordinate system of the XY Columns. Note: GPS normally records 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.





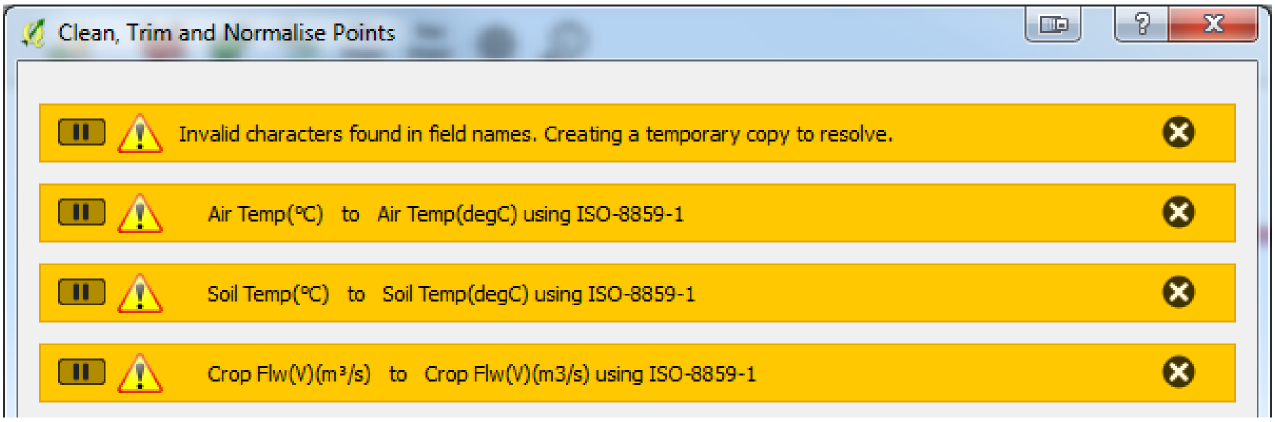
Use selected features	Default is unchecked.	If checked, use the selected features to clip the input points. If unchecked, all the features will be used.
Column to process	The column to normalise, trim and clean.	
Remove values less than or equal to 0	Default is checked.	If checked, rows from the chosen 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: - attempt 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 – see Technical Notes on page 56.	

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 with corrected column names will be made in the PAT temporary folder (location shown in PAT log message). For more information on the location of the saved log file and temporary folder see the Technical Notes section on page 56.



2.3 Run Kriging Using VESPER

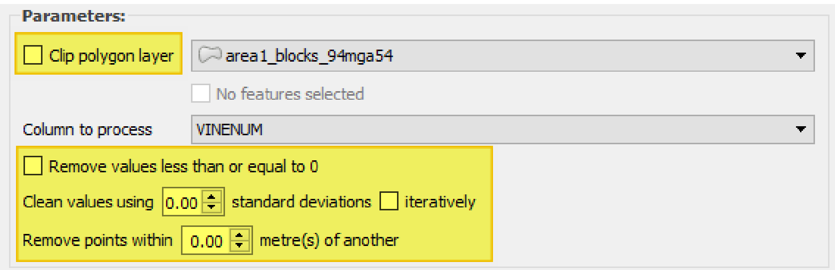
Summary

This tool is used for mapping on-the-go data at high spatial density, such as are collected by a yield monitor or an EM38 soil survey, following established protocols (Bramley and Williams 2001; Taylor et al. 2007; Bramley et al. 2008; Bramley and Jensen 2014) using local block kriging. It 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.

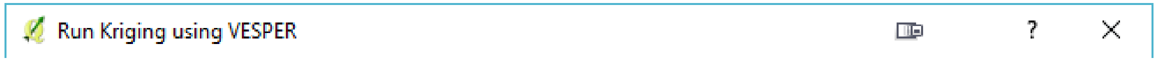
To run VESPER control files from within QGIS, VESPER must already be installed on the PC and configured in the PAT settings (**2.17 Settings** on page 55).

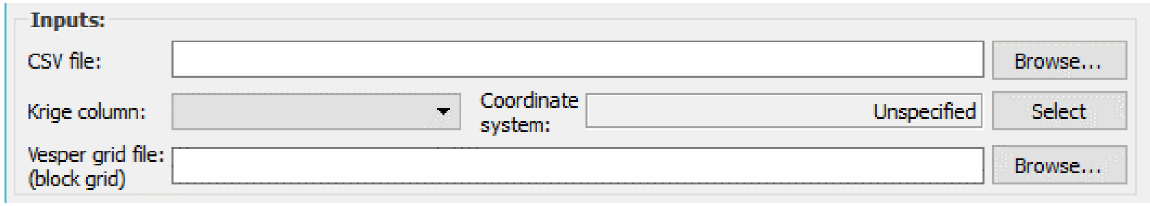
Data validation checks will be completed before running the tool. This aims at ensuring that the input csv file which contains eastings and northings, overlaps with provided VESPER grid text file. If you receive a warning, please check that these two files use the same coordinate system and indeed overlap. If your csv coordinates are in a different coordinate system to the VESPER grid file, the ***Clean, Trim, Normalise Point Data Tool*** can be used to project coordinates <u>without</u> using the cleaning, trim and normalise functionality, by setting the options as shown highlighted below.



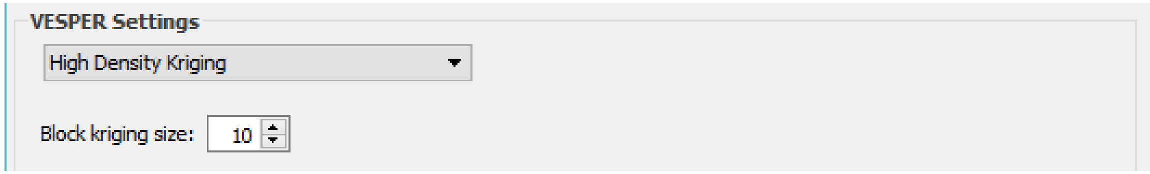
Kriging of data collected at much lower spatial density, such as through hand sampling (e.g. grape bunch number, mid-season cuts of wheat biomass) is also possible in PAT. However, it should be noted that we DO NOT recommend interpolation of maps from 'low density' data when fewer than 100 data points are available (Webster and Oliver, 2007). Experience also suggests that, in vineyards and sugarcane fields, a sample intensity of around 26 points per ha is required, given the typical dimensions of such fields. A lower sample density may suffice for broadacre situations but the 100 point minimum always applies. Note also that this analysis should only be undertaken by users with an understanding of map interpolation using kriging and the generation and role of the variogram in this process (Webster and Oliver, 2007). Detailed instructions on this process can be found in section ***4.4 Kriging 'low density' data in PAT***.

Dialog



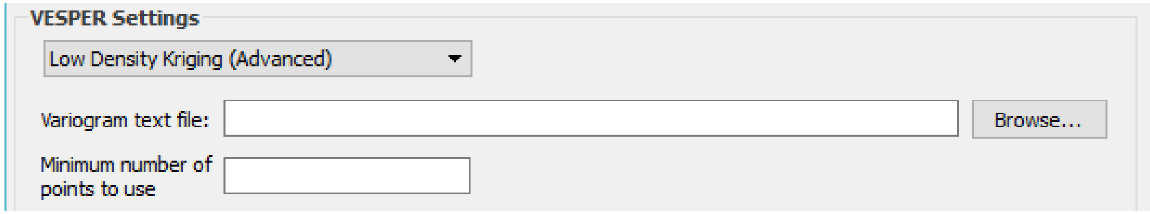


Cleaned and trimmed CSV file	A CSV file containing the data to krige. Use the ***Clean, Trim, Normalise Point*** tool to generate this input or to convert the coordinate system.
Coordinate system for CSV file:	This is the coordinate system of the coordinate columns in the CSV file. By default, the value of the EN_EPSG or ENEPSG column in the input CSV file will be used.
Krige column	The column containing values to krige.
VESPER grid (block grid) file	The VESPER grid file representing the area to be kriged. Use the ***Create Block Grid Tool*** to generate this input.



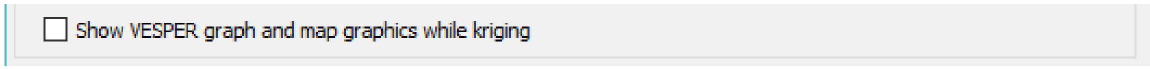
HIGH DENSITY KRIGING

Block kriging size	0 to 1000 Default is 10	The value in metre to set as the block size when using block kriging in VESPER. This value should be approximately 5 times the pixel value. <u>Recommended Values</u>: Viticulture: 10 m Sugar: 10 m Broadacre grains: < 200 ha 30 m > 200 ha 60 m

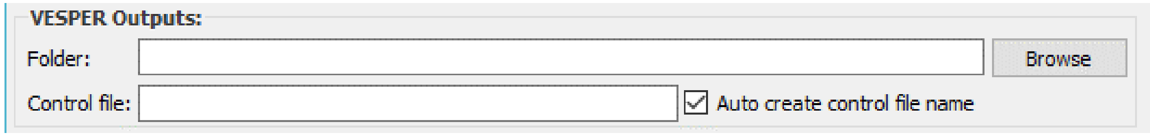


LOW DENSITY KRIGING – FOR ADVANCED USERS ONLY

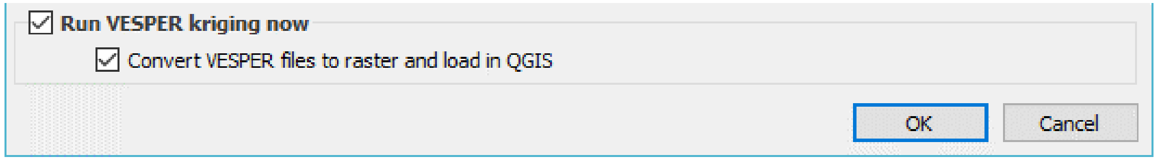
Variogram Text File:	The saved VESPER variogram text file. See ***4.4 Kriging 'low density' data in PAT*** for creation instructions.	
Minimum number of points to use	Default is the number of data rows minus 2	Minimum number of neighbourhood points used for kriging interpolation.



Show VESPER graph and map graphics while kriging	Default is unchecked	Checking this option will display the map and graph while VESPER is running but will increase the processing time.



Folder	The output folder for the VESPER files. A sub-folder called VESPER will be created if required.
Control file	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.



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 TIFF 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	< ***20 characters of CSV file***>_<***low or high density***>_<***krige column***>_control	.txt	**swblock_HighDensity_YldMassDry_control**.txt
VESPER grid file	<***control file***> where control is replaced by vespergrid.	.txt	**swblock_HighDensity_YldMassDry**_vespergrid.txt
VESPER data file	<***control file***> where control is replaced by vesperdata.	.csv	**swblock_HighDensity_YldMassDry**_vesperdata.csv
*Files **created** by VESPER and saved to the VESPER output folder.*			
VESPER Krige file (contains Prediction and SE)	<***control file***> where control is replaced by kriged.	.txt	**swblock_HighDensity_YldMassDry**_kriged.txt
VESPER parameter file	<***control file***> where control is replaced by parameter.	.txt	**swblock_HighDensity_YldMassDry**_parameter.txt
VESPER report file	<***control file*** > where control is replaced by report..	.txt	**swblock_HighDensity_YldMassDry**_report.txt
*If **converting VESPER files to raster** is checked or the **Create Rasters from VESPER Results** tool is used.*			
Kriged Prediction TIFF source: VESPER Krige result above	<***control file***> where kriged is replaced by PRED.	.tif	**swblock_HighDensity_YldMassDry**_PRED.tif
Standard Error TIFF source: VESPER Krige result above	<***control file***> where kriged is replaced by SE.	.tif	**swblock_HighDensity_YldMassDry**_SE.tif
Confidence Interval (CI) metadata text file	<***control file***> where control is replaced by CI.	.txt	**swblock_HighDensity_YldMassDry**_CI.txt

2.4 Import VESPER Results

Summary

This tool converts the output files generated by VESPER into raster TIFFs.

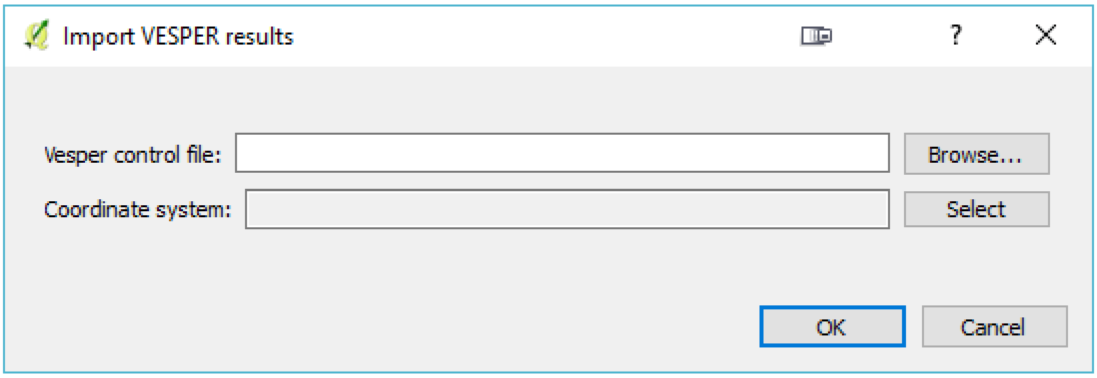
The output filenames will be created using the VESPER control file name as a base and demonstrated in the ***Run Kriging Using VESPER Tool - File Naming Conventions*** section on page 22.

The files created include:

- a TIFF file representing the predicted (kriged) value; these are the values used to generate the resulting map.
- a TIFF file representing the standard error (SE) of the kriging prediction.
- a text file containing the calculated median kriging prediction SE and the 95% confidence interval for the map. This is important information for testing the significance of the difference between different zones when different map layers are clustered to generate potential management zones.

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.

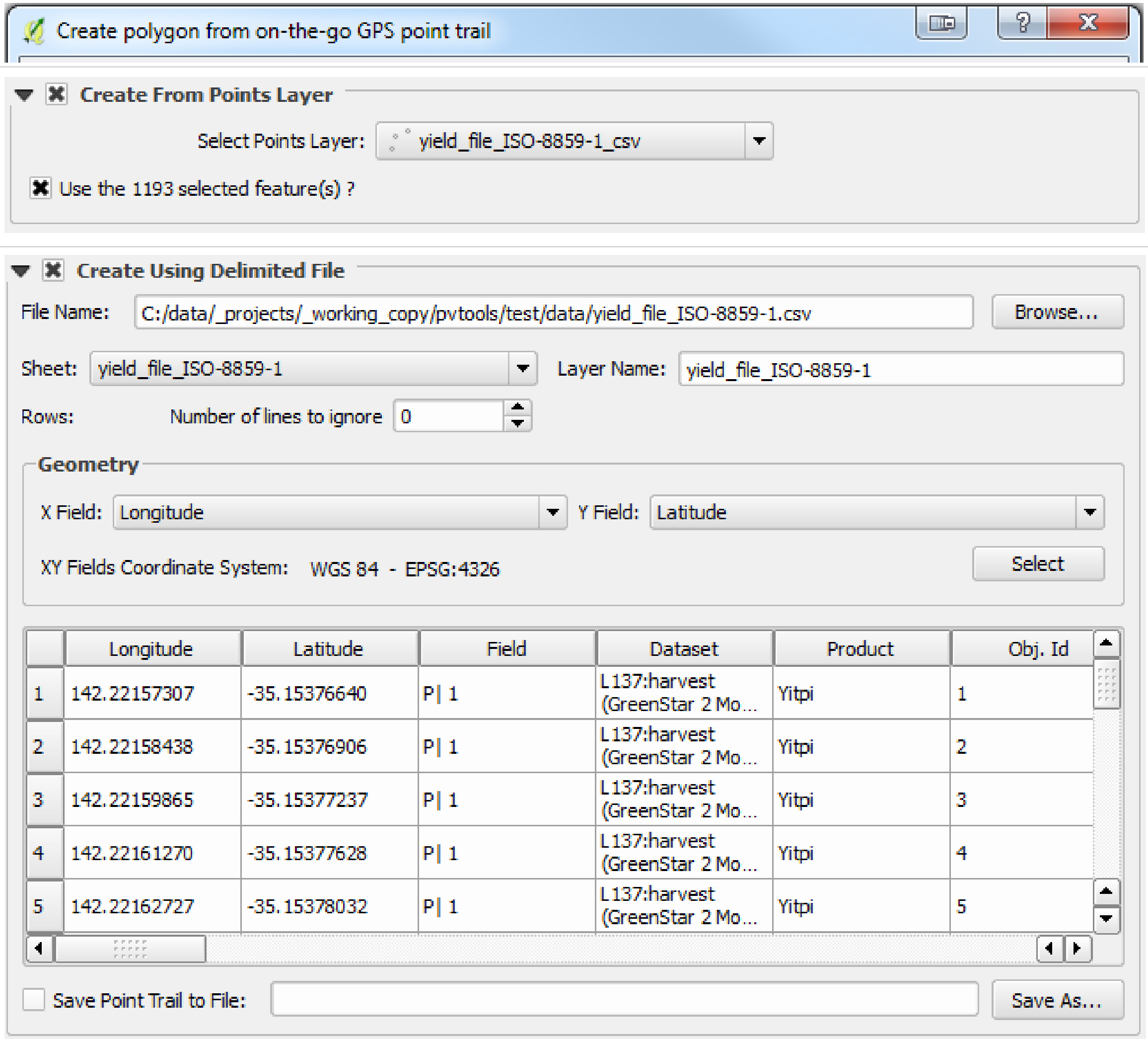
2.5 Create Polygon from On-The-Go GPS Point Trail Data

Summary

Having a block boundary polygon is central to many 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*** on page 57 for instructions on this method). However, if accurate GPS data for the boundary is not available, then a less accurate 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 data). Note that this method is not preferred, but the tool is provided as a 'quick fix' for those wishing to generate maps in the absence of surveyed block or field boundaries.

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 - as would be normal for data collected by an on-the-go sensor such as yield monitor). 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

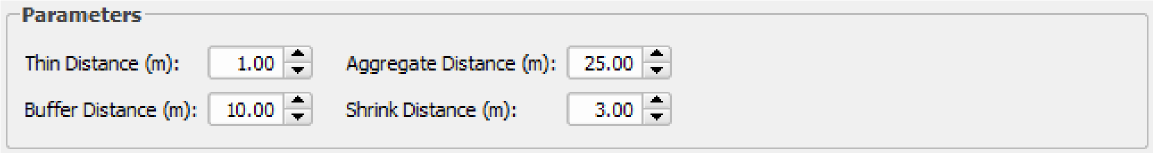


Choose whether to use GPS data currently loaded as a QGIS Points Layer

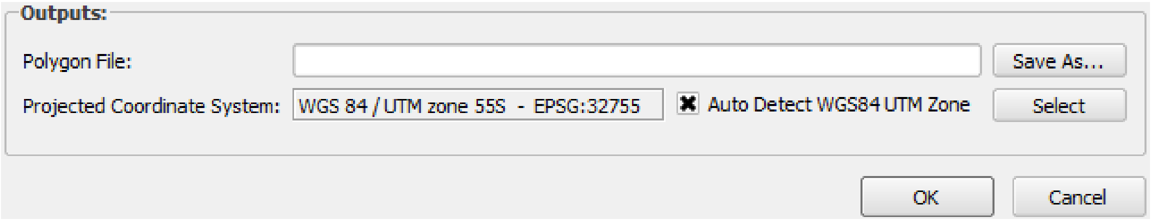
Use selected features	Default is unchecked	If checked, only uses the selected features to generate a polygon. If unchecked, all the features will be used.

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 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**	The columns representing the X and Y coordinates within the input file. By **default** will attempt to match to commonly used column names like X,Y, longitude, latitude; lon, lat etc.	
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.



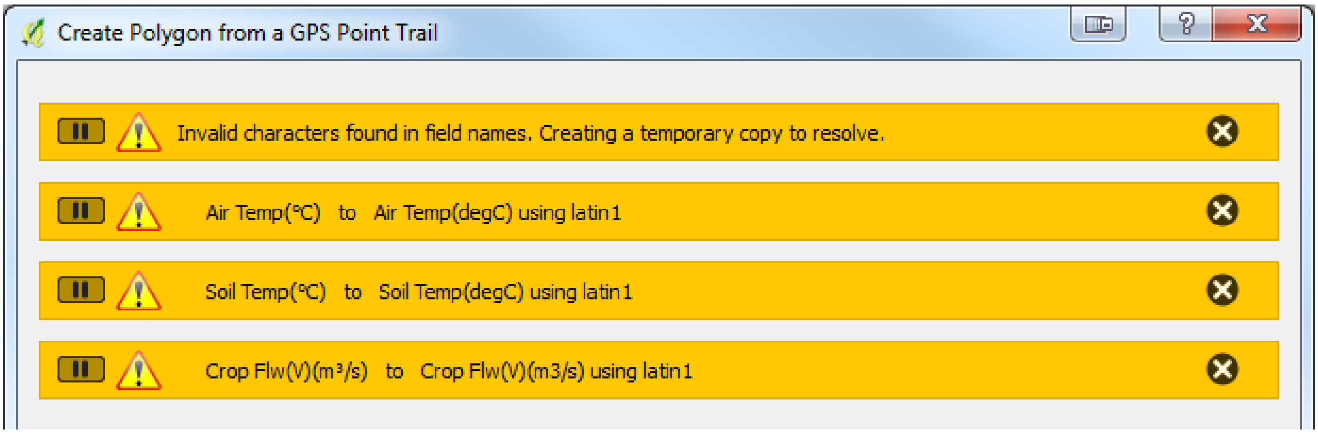
Aggregate distance (m)	0.00 to 100.00 Default is 25	The maximum distance between points used to separate strings of connected points into individual lines. Typically, this is slightly larger than the row/swath width.
Buffer distance (m)	0.00 to 100.00 Default is 10	A distance in metre used to buffer 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 metre used to shrink the overlapping polygons after dissolving. Typically, this is slightly less than the buffer distance.



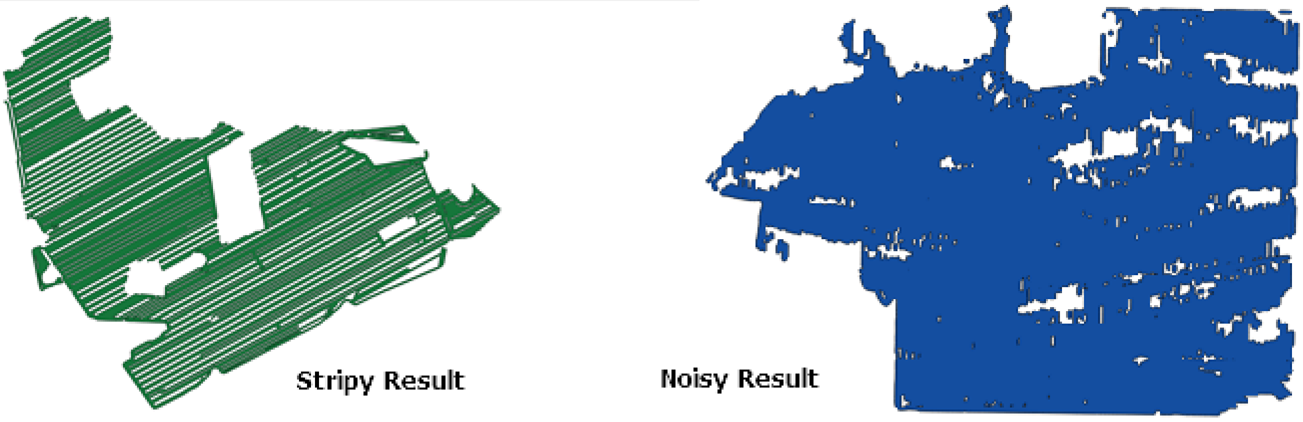
Polygon file	Derived from layer name	The output filename for the polygon Shapefile.
Projected coordinate system	The output projected coordinate system of the Shapefile.	
Auto detect WGS84 UTM zone	If Auto detect is checked the following rules will apply: - attempt to match the input if it is a projected 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 – see Technical Notes on page 56.	

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

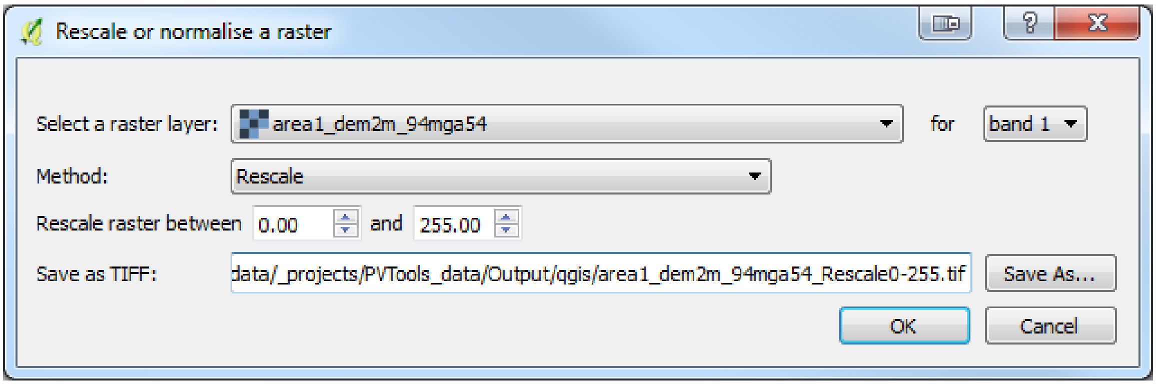
Summary

This tool rescales or normalises a raster and outputs to a new TIFF file. Existing no-data values will be ignored in any calculation.

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

Such re-scaling is useful when you wish to compare several map layers, for example, yield maps for several years.

Dialog



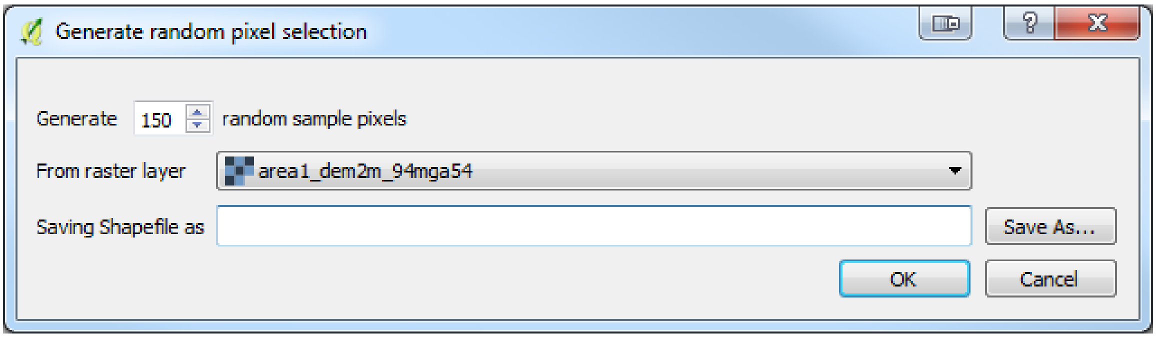
Rescale or normalise a raster		
Select a raster layer for band X	Default is band 1	The raster layer and band to rescale or normalise.
Method	Default is rescale	Options: • **Rescale** – adjust values to a fixed range; or • **Normalise** – adjust values to a mean of zero and a standard deviation of one.
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 them 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. This tool provides the key location input for the ***Extract Pixel Statistics for Points Tool*** described on the following page.

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. No-data 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. These points could be identified using the ***Generate Random Pixel Selection Tool*** described on the previous page. Statistics are calculated on pixel values within a square neighbourhood and extracted to a CSV file. This tool is useful when relationships are being sought between different maps layers – for example, a regression or correlation analysis between yield and soil map data.

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.

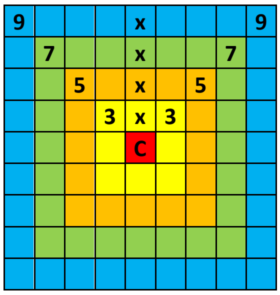


Figure 3. A representation of the 3x3, 5x5, 7x7, 9x9 neighbourhood size around a central pixel (C) as is used when calculating filtered statistics.

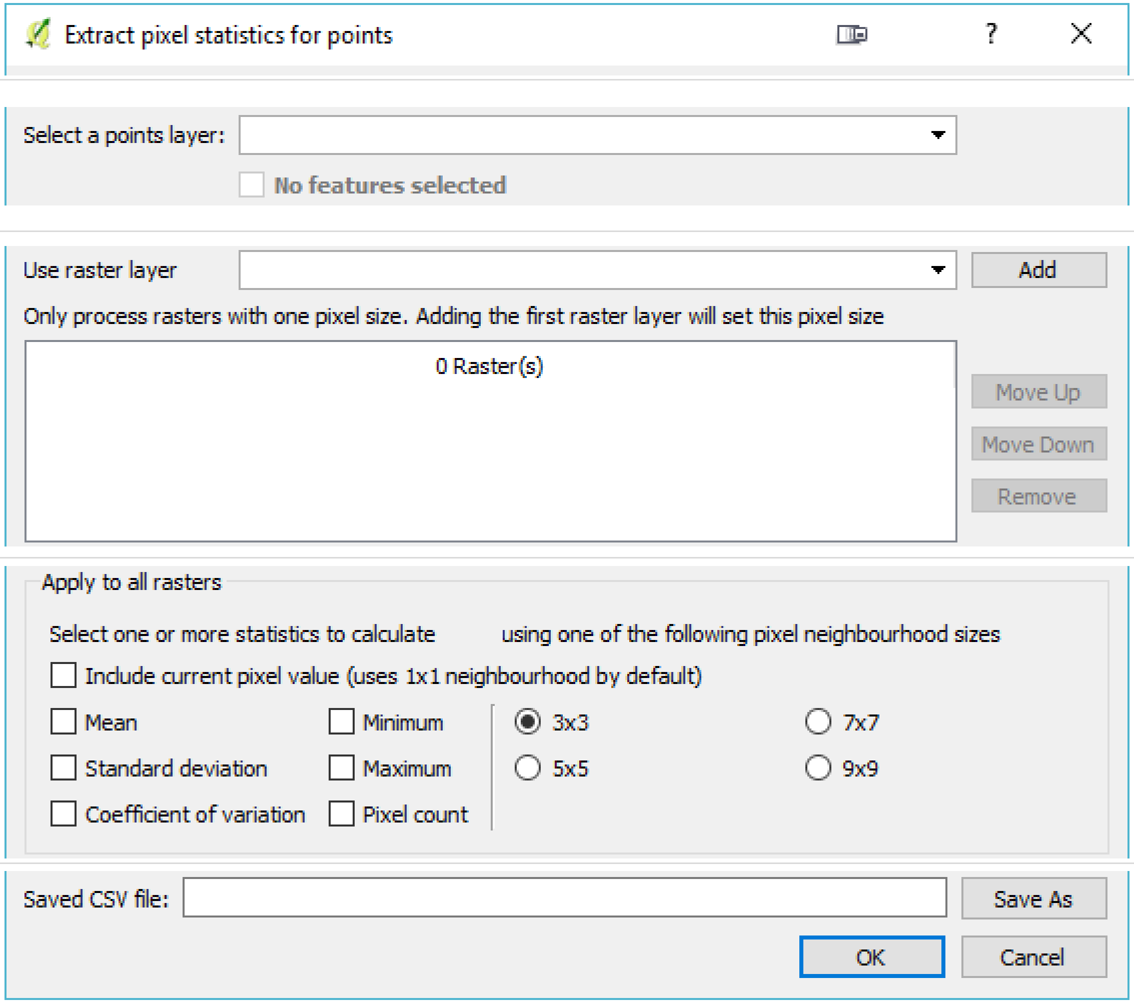
For example, a mean statistic for a 3x3 neighbourhood on 2 m pixels, will calculate the mean of the central pixel (red) and the surrounding 3x3 area of 8 pixels (yellow) equating to 36 m2 on ground.

Pixels designated no-data will be excluded from the statistical calculation. However, a central no-data 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

Many providers of remotely sensed imagery deliver data to clients as multi band files. The Calculate Image Indices for Blocks tool is used to calculate indices for a multi band image and aligns the output to the extent and pixel size of a block grid. Indices currently supported are Normalised Difference Vegetation Index (NDVI); the 'simple ratio' or Plant Cell Density index (PCD); Green Normalised Difference Vegetation Index (GNDVI); Chlorophyll Red-Edge index (CHLRE); and Normalised Difference Red-Edge index (NDRE). Table 3 describes how these indices are calculated.

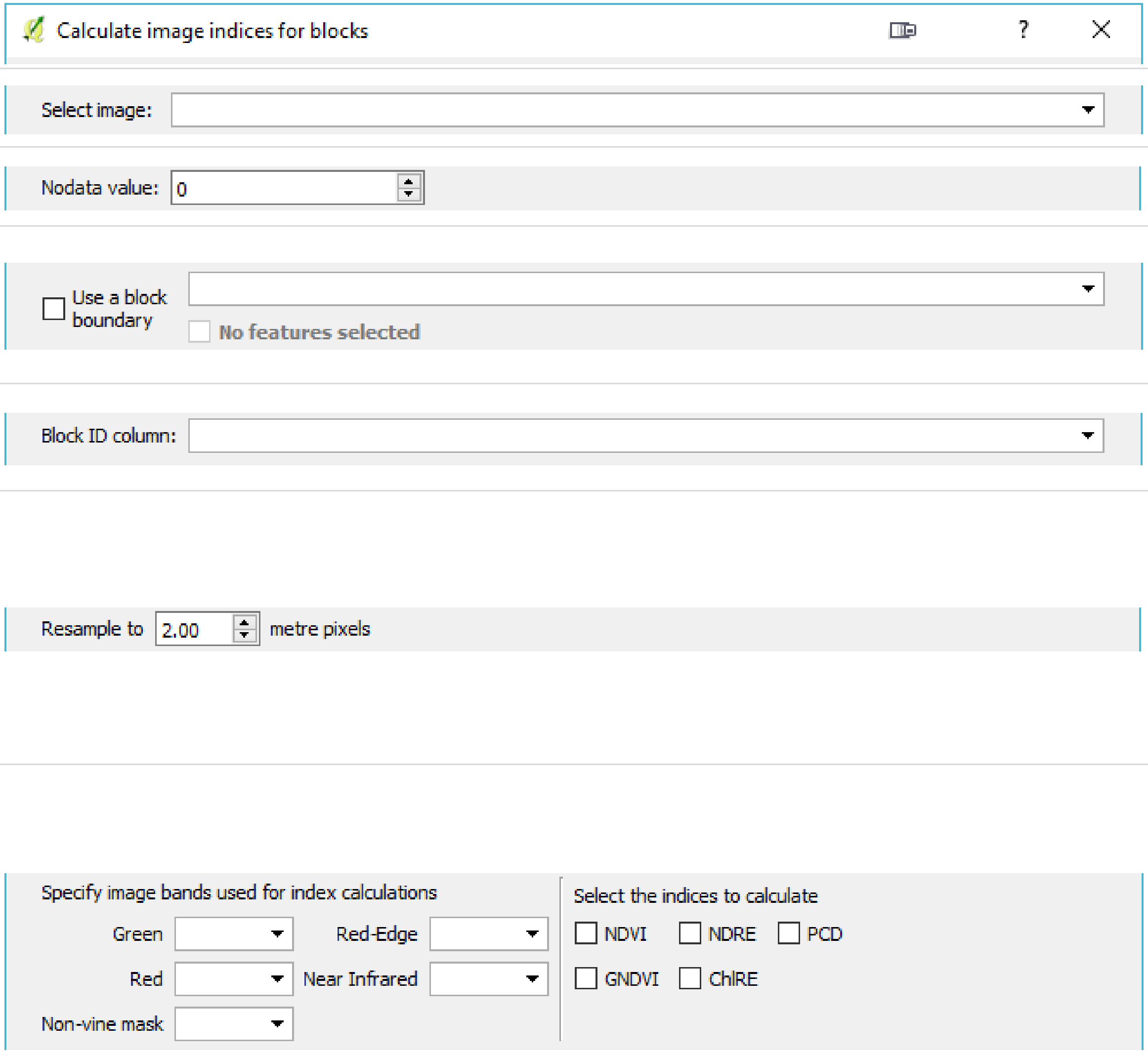
Each band in the image file is mapped to a spectral band e.g. Red, Red-edge, Near Infrared and is then used to calculate relevant image indices. In the case of vineyard data, if a non-vine mask is present in an existing band of the image, it can be used to remove non-vine signals prior to the resampling 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 broadacre 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. The output from this tool will be aligned to a block grid that will be identical to the one created separately using the ***Create Block Grid Tool*** on page 14.

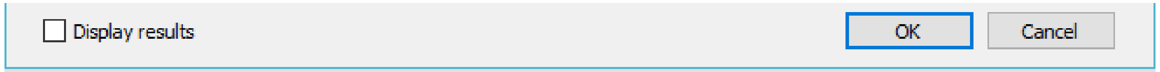
Table 3 The list of supported indices

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

Dialog



Select Image		The image layer containing the appropriate bands required for calculate indices.
No-data 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 metre. Ideally this should match your **Block Grid TIFF** file. <u>Recommended Values</u>: Viticulture: 2 m Sugarcane: 2 m Broadacre grains: < 200 ha 5 m > 200 ha 10 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 no-data. Not required for broadacre data.
Select the indices to calculate		The indices to calculate. If an index is disabled (greyed out) the band it requires hasn'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. Note: If in Australia then MGA GDA 1994 zones, will be used – see Figure 8 on page 59.
	**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**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 **rgbi_jan_50cm_84sutm54.tif** is used to create a new folder called **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

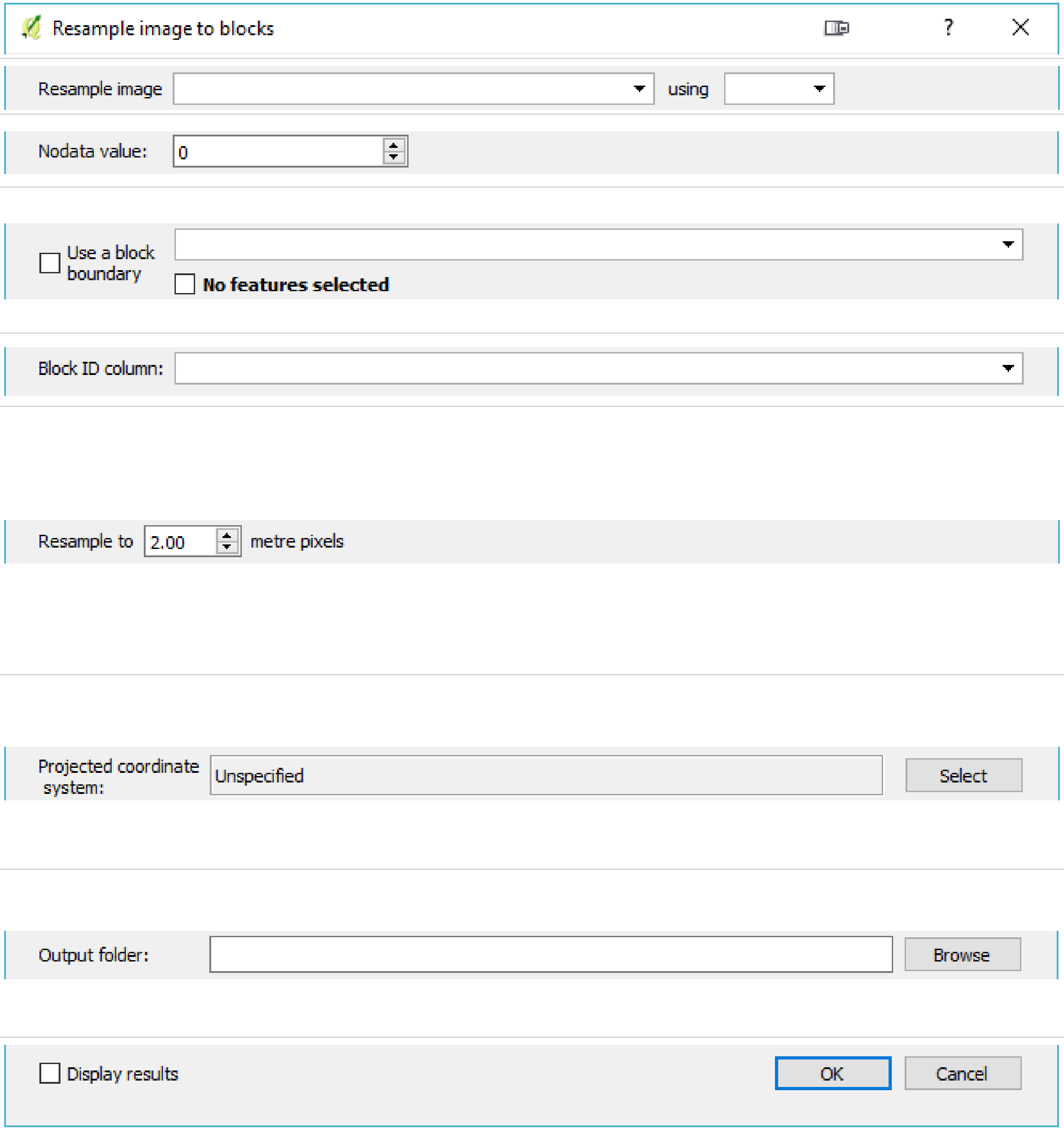
Summary

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.

The output from this tool will be aligned to a block grid that will be identical to the one created separately using the ***Create Block Grid Tool*** on page 14.

Dialog



Select Image	The image layer containing the band to resample.	
No-data 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)	0m to 6 km Default is 2 m	The pixel size to apply to the raster outputs. This is expressed in metre. Ideally this should match your **Block Grid TIFF** file. <u>Recommended Values:</u> Viticulture: 2 m Sugar: 2 m Broadacre grains: < 200 ha 2 m > 200 ha 10 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 – see Figure 8 on page 59.	
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

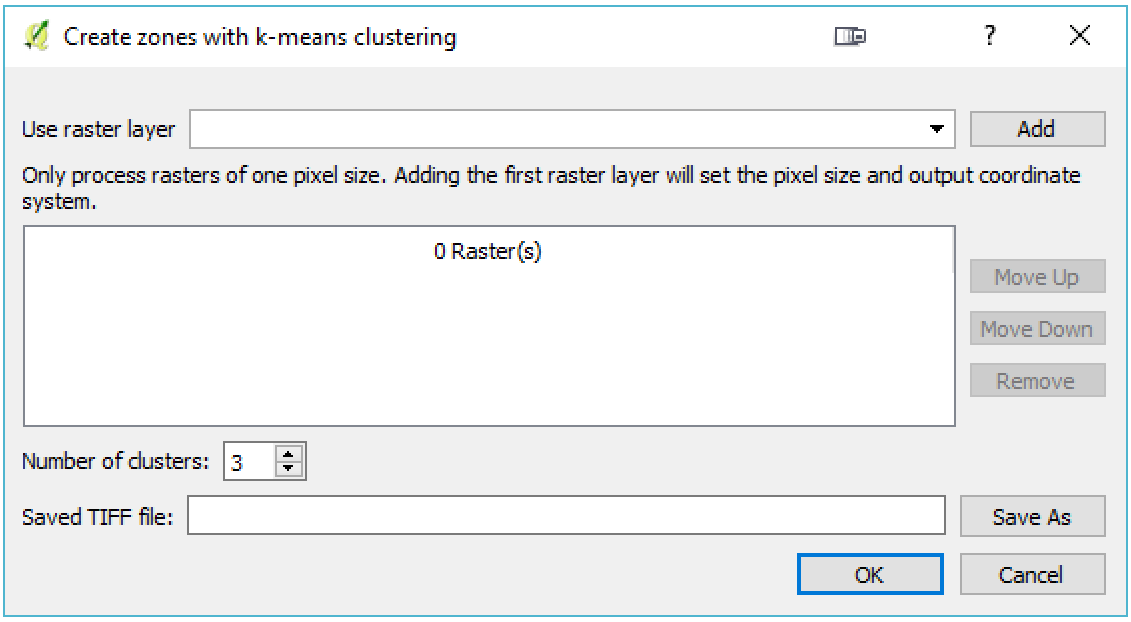
Summary

This tool allows zones to be created by performing k-means clustering on multiple rasters (i.e. map layers) 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 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. Aside from trying 3, it is recommended that users also try 2 clusters. 4, 5 or an even larger number of clusters may also be appropriate.
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 with the TIFF, and results printed to PAT's log messages panel.	

File and Column Naming Conventions

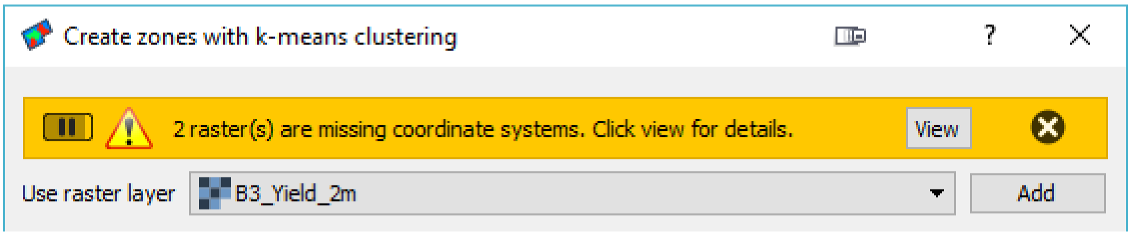
- <> denotes an existing element or input
- non-alphanumeric characters are removed from strings with the exception of hyphens (-) and underscores (_).

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**

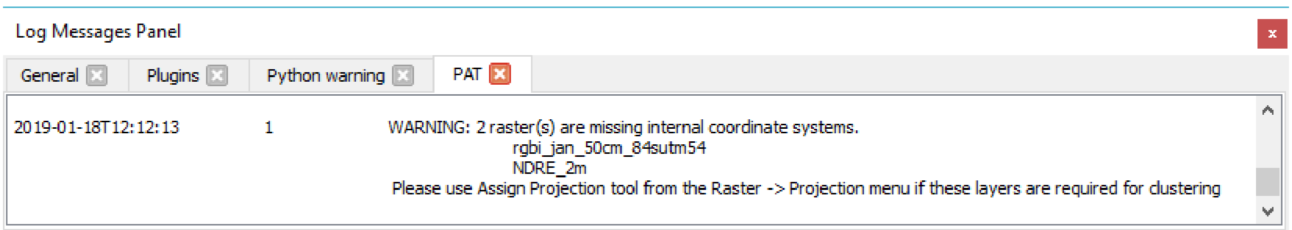
CSV COLUMN NAMES:	
Naming Rule:	**<*raster_file*> _<*statistic*>**
Example:	swblock_2024YldMassDry_PRED_**std**
Description:	The **standard deviation** value for swblock_2024YldMassDry_PRED.tif for the corresponding cluster/zone.

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 the appropriate internal coordinate system to the files. If the *Assign Projection* tool is unavailable activate the GDALTools plugin.



2.12 Create Strip Trial Points

Summary

This tool is used to generate the data needed to conduct the moving window *t*-test method of Lawes and Bramley (2012) and is available in PAT's ***Run Strip Trial t-test Analysis Tool***. It may be useful to users who, for example, have implemented a treatment like an N-rich strip in their cereal paddock, or who want to compare a row of vines that have been pruned differently to the rest of a vineyard.

The tool uses a line representing the centre of a strip trial (or treatment) and creates points along the line spaced using the nominated distance. In addition, two sets of parallel '*control*' points are created at an offset to the strip trial line as shown in Figure 4. This allows the treatment strip data, to be compared to data from the neighbouring (control) area.

The tool creates a number of identifiers to facilitate the analysis: each point has values assigned to new columns headers TrialID, Strip_Name, PointID and DistOnLine. The treatment strip is assigned a unique identifier in the column TrialID and the value of '*Strip*' in the Strip_Name column. Points are created along the line and assigned a unique point identifier in the column PointID. In addition, two sets of control points are placed at the offset distance either side of the strip. The PointID of the control points are paired with the corresponding treatment point. The Strip_Name values of the control points are assigned based on the direction of offset from the original treatment line as shown in Figure 4. Each point is also assigned a value in the column DistOnLine representing the distance in metres of the point from the start of respective line.

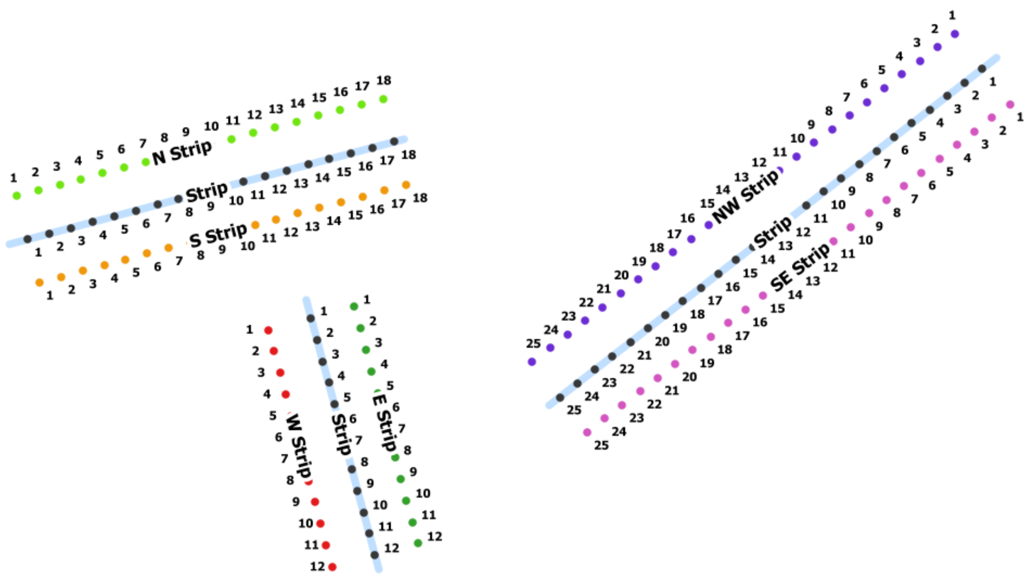
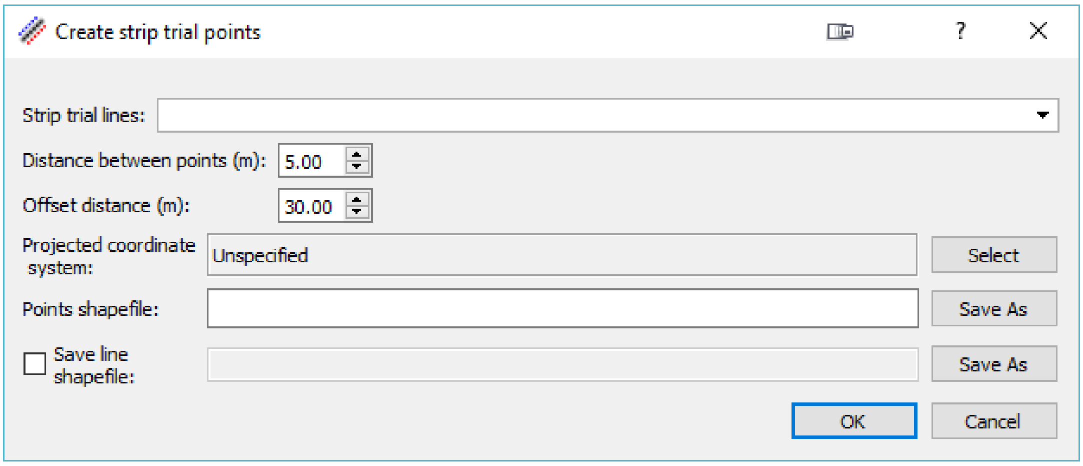


Figure 4 Output from the *Create Strip Trial Points tool*. The blue line represents the treatment strip and the dots indicate the equally spaced treatment and control (i.e. offset) points.

Dialog



Create strip trial points		
Strip trial lines:	The layer containing the strip trial lines.	
Distance between points (m):	1 – 500 m Default is 5m	The distance used to space points along the centre line. In this instance, users are advised to select a value appropriate to their trial rather than accepting the default. If used in conjunction with a strip trial t-test then this distance should be the pixel size of the input rasters used for the t-test. This will result in every pixel in the strip being used for the analysis.
Offset distance (m)	1 – 500m Default is 30m	The distance used to offset the points from the line. If used in conjunction with a strip trial t-test then this should be far enough away from the strip trial to remove the trial's treatment influence. In the case of an N rich strip trial laid down using a boom spray, the offset distance ought to be at least equivalent to the length of the boom.
Projected coordinate system:	The projected coordinate system to apply to the output files. By default it will calculate the relevant coordinate system from input layer's coordinate system. Note: If in Australia then MGA GDA 1994 zones, will be used – see Figure 8 on page 59.	
Points shapefile:	Derived from layer name	The name and path of the output points shapefile.
Save line shapefile:	Default is unchecked. Derived from layer name.	The name and path of the output points shapefile.

Column Naming Conventions

CSV COLUMN NAMES:	
FID	Unique feature identifier for each point.
TrialID	The unique strip trial identifier.
Strip_Name	A name assigned to each line. The treatment will be assigned a value of *'Strip'* while the offset strips will be assigned the cardinal direction of the offset to the treatment as shown in Figure 4.
PointID	The identifier of each point along the centreline, and its paired control points.
DistOnLine	The distance in metres of the point from the start of each line.

2.13 Run Strip Trial *t*-test Analysis

Summary

This tool enables a user to analyse strip trials to determine the effectiveness of treatments. For example, it could be used analyse the difference between an N-Rich strip treatment and the adjacent normally fertilized paddock, or to compare different pruning or spray treatments in a vineyard.

Using points created from the ***Create Strip Trial Points Tool,*** values will be extracted from input rasters and a pairwise moving window *t*-test conducted based on a calculated Response Index (RI) and treatment differences. These are then graphed as described in Lawes and Bramley (2012).

The input rasters include:

- **Strip values raster:** A map produced through following the high density on-the-go sensor mapping workflow (Figure 1) which includes data sourced from the trial strip.
- **Control values raster** (optional): A map produced through following the high density on-the-go sensor mapping workflow after data sourced from the trial strip have been removed. Often this is desirable because, when interpolating a map containing all the data for a 'nitrogen rich' strip, the higher values in the strip may impact the interpolation of adjacent areas. In general, our recommendation would be to make use of a control values raster by re-kriging the original data excluding the data points under the trial strip.
- **Zone raster** (optional): A zone raster can be created using the ***Create Zones with k-means Clusters*** tool. You may want to use this to identify which zone different parts of the experimental strips are located in. Desirably in a field with defined zones the strip would run across these zones.

For each input strip a map image will be produced along with a graph and CSV file, for each strip combination a) Strip vs Control 1, b) Strip vs Control 2, c) Strip vs Average of Control 1 & 2 (Figure 5).

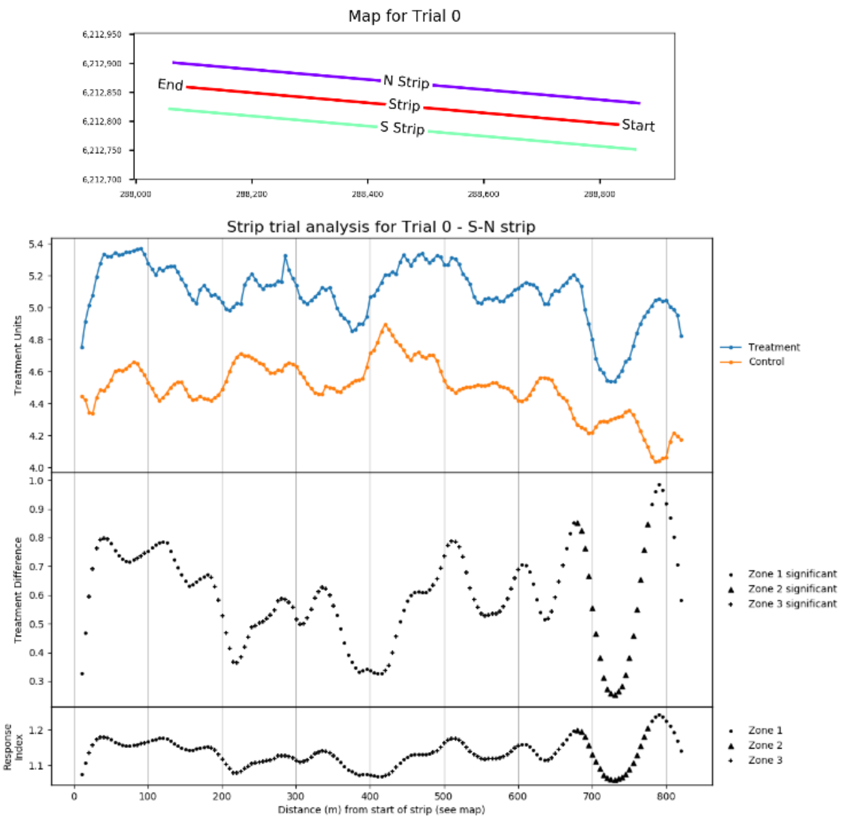
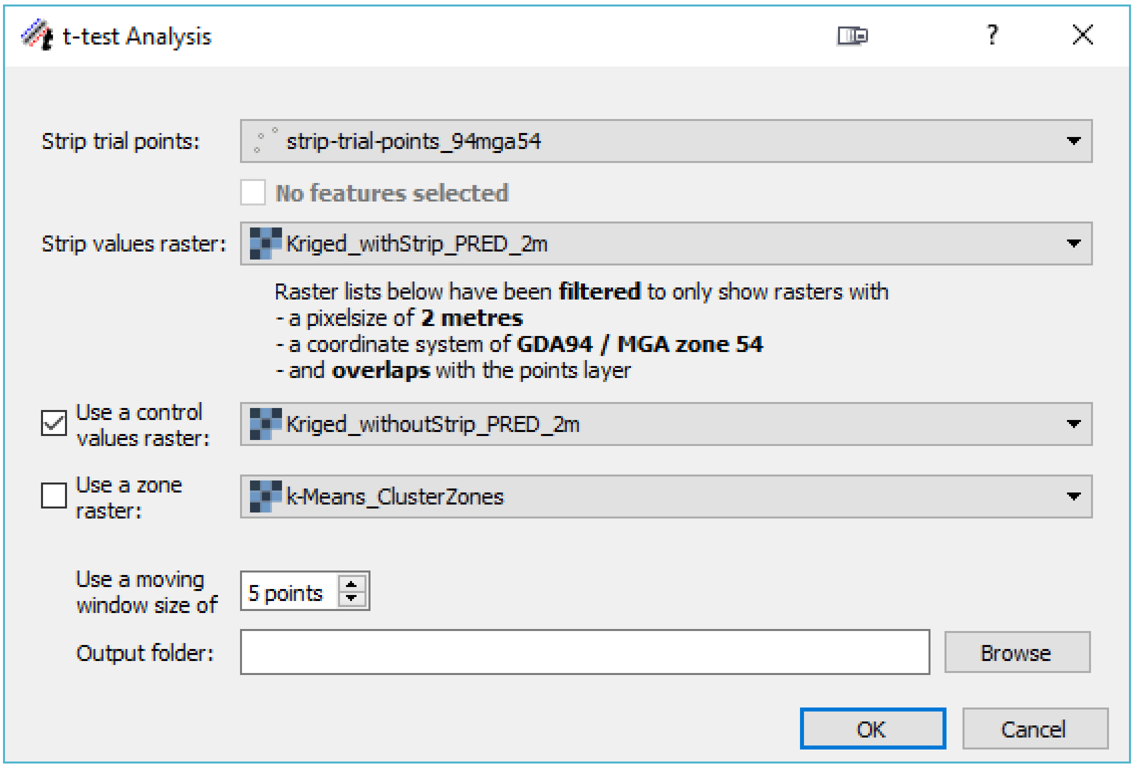


Figure 5 Output graph and map from the *Run Strip Trial t-test analysis tool*.

Dialog



Run Strip Trial *t*-test Analysis		
Strip trial points:		The layer containing the strip trial points. This must be the output from the ***Create Strip Trial Points Tool***.
Strip values raster:		The raster containing values to extract for analysis.
Use a Control values raster:	Default is unchecked	The raster layer created after treatment points have been removed.
Use a Zone raster:	Default is unchecked	The raster containing the zone values. If not provided, a zone of 1 will be applied to the entire strip.
Use a moving window size	Derived from layer name	The name and path of the output points shapefile.
Output folder:		The folder to save output map, graph and CSV files. See table below for used for output files.

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 (_).

TrialID represents the unique strip trial identifier from input points ***TrialID*** attribute.

strip represents the value(s) from input points ***Strip_Name*** attribute. When the analysis uses both control strip points their values will be hyphenated e.g. N-S

FILENAMES:	
Map file:	A map showing the Trial points.
Naming Rule:	*Trial-<**TrialID**>_map.png*
Example:	Trial-**3**_map.png
Description:	The map for the strip with a TrialID of **3.**
Graph files:	The results displayed as graphs.
Naming Rule:	Trial-<***TrialID***>_<***strip***>_graph.png
Example:	**Trial-3_N-strip**_graph.tif
Description:	The graph result for Trial **3** which compares the **N** control strip to the treatment strip.
CSV files:	The csv file used to create the graphs.
Naming Rule:	Trial-<***TrialID***>_<***strip***>.csv
Example:	Trial-**3**_**N-S-strip**.csv
Description:	The csv file containing the Trial **3** results for the comparison of **N-S** control strip to the treatment strip.

CSV COLUMN NAMES:	
TrialID	The unique strip trial identifier from the input *Strip Trial Points*.
PointID	The identifier of each strip trial point from the input *Strip Trial Points*, and the paired control points.
DistOnLine	The distance in metres of the point from the start of the centreline of the treatment strip.
Strip Value	The number extracted from the **Strip value raster**. The units of value will be inherited from the source data (eg NDVI, Yield t/ha).
<strip> Control (if provided)	The number extracted from the **Control values raster.** Applies only when a **Control values raster** is used. The units of value will be inherited from the source data (eg NDVI, Yield t/ha).
Strip Zone (if provided)	The zone identifier extracted from the **Zone raster**. Creates a Zone value of 1 if not specified.
<***strip***>_mean	The mean of the input control strips for each point if both control strip are used.
treat_diff	The difference between the treatment and controls points columns.
av_treat_diff	The average of the column treat_diff using a moving window.
p_value	The t-test p-value calculated using a moving window.
RI	The RI calculated using a moving window: RI = mean of treatment / mean of control

The column names for the output file are dependent on the input scenarios. In the following example, a subset of the column names for the East-West strip trial shown in Figure 4 where a **strip values raster**, **control raster** and **zone raster** were provided as inputs.

CSV COLUMN NAMES:	
Strip Value	The pixel value from the strip value raster for the strip trial points.
N Strip Control **S Strip Control** **- or -** **N Strip Value** **S Strip Value**	The pixel value from the control raster for control line to the north or south of the treatment strip. If a control raster is not provided, then pixel value will come from the strip value raster and the column name will be ***N Strip Value*** or ***S Strip Value***.
Strip Zone	The pixel value from the zone raster for the strip trial. If a zones raster is not provided, then a value of 1 will be assigned.
N Strip Zone **S Strip Zone**	The pixel value from the zone raster for control points to the north or south of the strip trial. If a zones raster is not provided, then a value of 1 will be assigned.
N-S_mean	The average of the control strip points when both of sets of control strips are used in the analysis.

2.14 Whole-of-block Analysis

Summary

Whole-of-block experimentation, also known as spatially distributed experimentation, involves on-farm experiments where treatments are applied in a highly replicated design over an entire block or land management unit, or a large section of it. Given their scale, they are typically laid down using the farmer's normal equipment. These experiments can be thought of as a three-dimensional version of the strip trial, discussed in the previous section ***Create Strip Trial Points.*** Users interested in this experimental approach may wish to read the book chapter by Bramley et al. (2013) and perhaps the references listed in that chapter. In brief, the objective of whole-of-block experimentation is to recognise the possible effect of underlying spatial variability in the field in which the experiment is located, on the crop response to experimental treatments, and so use this variability as an experimental tool to guide decisions about variable rate or targeted management. Whole-of-block experimentation therefore moves away from the classical approach to agronomic experimentation which seeks to identify whether treatment A is better than treatment B and typically uses small plots. Instead, it is recognised that treatments A and B may both deliver benefit, albeit in different parts of the block or field; the whole-of-block approach identifies these different areas.

An example is given in Figure 6. Here, some different vineyard floor management treatments have been evaluated in an experiment aimed at improving the availability of water to the vines. The cereal/legume treatment delivers a significant benefit over the other treatments, but this is expensive and so the vineyard manager would only want to use this in those areas where it is beneficial. The whole-of-block analysis tool enables users to generate maps such as those shown in Figure 6 – maps showing the response to the different treatments over the entire block, and maps indicating the significance of differences between these treatments.

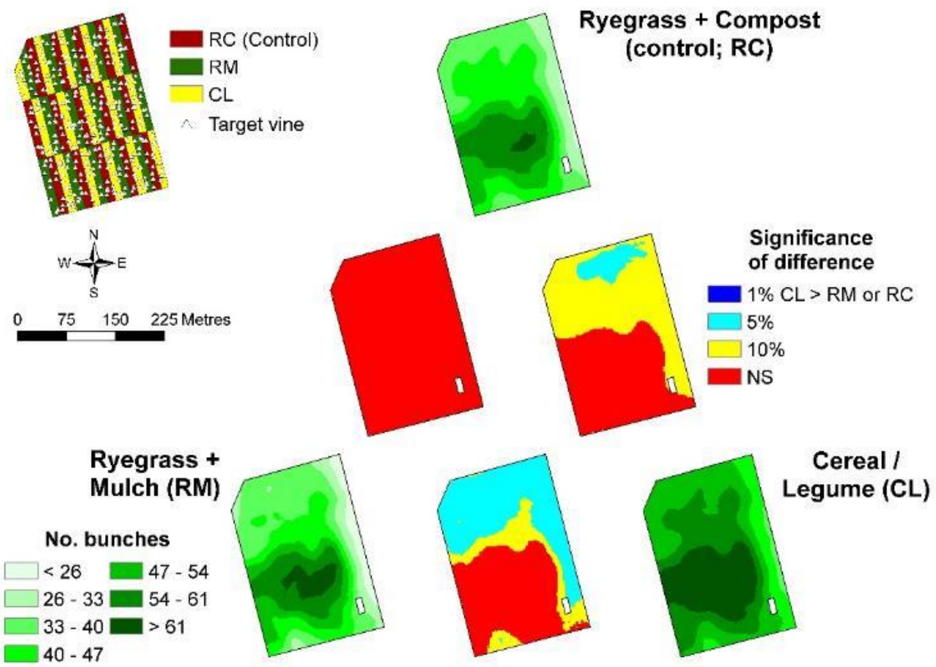


Figure 6 An example of a whole-of-block experiment conducted in a 4.8 ha Clare Valley vineyard. Panten and Bramley (2011) provide further information

The purpose of the ***Whole-of-Block analysis tool*** is to predict treatment responses and their differences over the entire experimentation area as illustrated by Figure 6. Similar to the use of VESPER for kriging, this tool interpolates point data (low or high density) to the area of the entire block. Low density data would typically include up to a few hundred points, perhaps collected through hand sampling, dispersed across a block, whereas high density data includes a few thousand or more points, typically collected using a sensor such as a yield monitor. The tool will handle either two or three treatments, and will identify areas of the block where the treatments are significantly different from each other. To address the technical and computational challenges in this analysis, the tool uses fast and efficient global and local cokriging techniques.

Use of R

This tool is somewhat different from the other PAT tools in that it uses the R statistical language (http://r-project.org/) to carry out the analytical processing. This means that R must be installed on your PC for this to work – see ***Configuring QGIS to use R*** on page 10. The minimum R version suitable for this is v3.5.1.

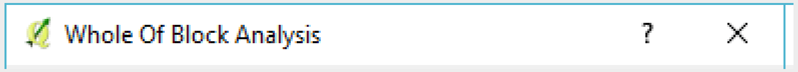
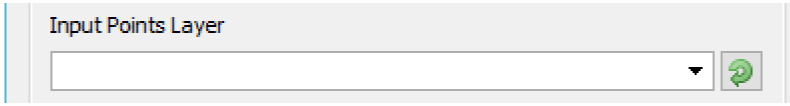
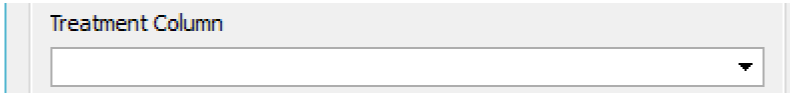
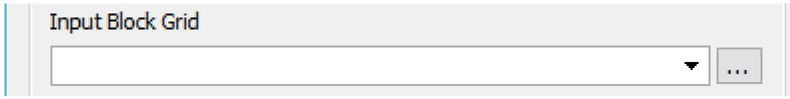
Algorithm for the Local Cokriging System – a brief commentary on the data radius used

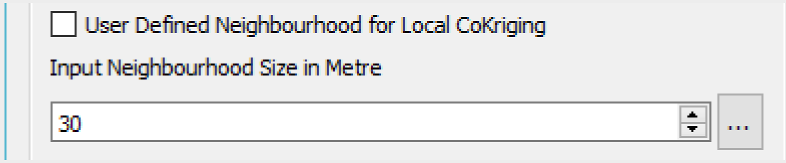
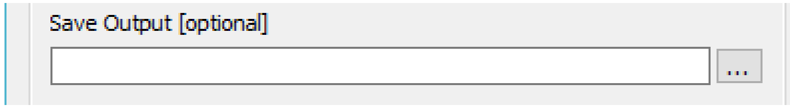
A spatially-varying local co-kriging method is used to balance the trade-off between the computation efficiency and prediction accuracy. We use a neighbourhood radius r(s) to identify neighbours for location s.

For subregions with lower density observations, such as at the corners, or edges of a farm field, the neighbourhood radius required by local cokriging will be relatively bigger to ensure the stability of the estimated cross-variograms and balance the number of observations from different treatments within the neighbourhood.

For high density datasets we will use a relatively small neighbourhood radius, and ensure it will change relatively smoothly across the field. This adaption is achieved by two specific algorithm choices. Firstly, an initial neighbourhood radius is selected automatically based on the observation density and achieving a reasonable balance in the number of observations from different treatments. This neighbourhood radius increases iteratively to include more observations if the current radius is not large enough to meet prediction quality criteria. Secondly, a spatial-varying neighbourhood radius surface is estimated based on neighbourhood radius values from a subset of locations. This exploits the spatial-smoothness of the neighbourhood radius and provides a better default neighbourhood radius from which to optimise.

Dialog

			
	**Input points layer**	A text format data file (CSV format) containing the experimental data that has been loaded into QGIS. The file should be a minimum of four columns containing, the following:	
	**Easting and Northing**	The names of columns in the CSV data file containing the projected Easting and Northing point coordinates	
	**Treatment column**	The name of column in the CSV data file containing the treatment applied at each point. The treatments can be represented by numbers (1,2,3), short characters (“AM”,”BL”,”CS”) or text 10 characters or less **without** spaces like (“Control“,“Mulch”,”Cover_crop”).	
	**Data column**	The name of column in the CSV data file containing the measured treatment response (e.g. Yield) at each point.	
	**Input Block Grid or Prediction Grid**	The grid onto which treatment predictions, differences and standard errors are to be interpolated by the tool. The block grid created by PAT Create Block Grid tool is ideal for this, or it can be a raster (TIF) file with the same coordinate system as the Input Points Layer.	
	**Model**	Default is Global	There are two model options. • Global cokriging (default) is useful for small datasets (a few hundred points) • Local cokriging is useful for moderate or larger datasets (thousands of points), particularly with local heterogeneity. This option initiates a starting radius for localised cokriging and uses an iterative algorithm to optimise the local cross-covariance structure. The cross-variogram is fitted using a Linear Model of Coregionalisation (LMC). The current version of the software defines 20 lag classes, giving 20 points to the cross-variogram. The maximum distance used in this process (i.e. largest lag class) is set as 1/3 of the maximum distance between points in the input dataset.
	**Covariance Model**	Default is Exponential	Exponential (default); users may also select Spherical and Gaussian models

	**User Defined Neighbourhood radius for Local Cokriging**	Default is unchecked Default is 30m or 15 times the pixel size	Only applicable to the Local Cokriging method, and allows a user to define an initial neighbourhood radius. If this option is ticked then user should define the "Input Neighbourhood Size in Metres". The default is 30 m. A suggested starting value can be calculated as 15 times the pixel size of the block grid. However, if "User Defined Neighbourhood for Local Cokriging" is not ticked then the initial neighbourhood radius will be chosen as a function of total number of data points and corresponding number of treatments. This is the recommended starting point for using this tool.
	**Save output**	Folder in which to save the output files. See File Naming Conventions (below) for an explanation of the different output files that will be created in this folder.	

File Naming Conventions

- <> denotes an existing element or input. For example <Data Col> refers to the name of the Data Column selected in the input parameters (above).
- non-alphanumeric characters are removed from strings with the exception of hyphens (-) and underscores (_).

Filenames:

NAMING RULE	EXAMPLE	EXPLANATION
Output file names:		
<Data Col>_dump_file_<Model><Covariance Model>.tif	Bunch_wt_dump_file_GlobalExp_.log	Logged information mainly useful for debugging purposes
<Data Col>_model_parameters_<Model><Covariance Model>.txt	Bunch_wt_model_parameters_GlobalExp_.txt	Summary of parameters used during processing
<Data Col>_list_of_tif_files_<Model><Covariance Model>.txt	Bunch_wt_list_of_tif_files_GlobalExp_.txt	List of TIF files generated as output
<Data Col>_tr_<Tmt1>_<Model><Covariance Model>_.tif	Bunch_wt_tr_KC_GlobalExp_.tif	Treatment inference in "Input Block Grid or Prediction Grid".
<Data Col>_tr_<Tmt1>_var_<Model><Covariance Model>_.tif	Bunch_wt_tr_KC_GlobalExp_.tif	Corresponding variances of the treatments.
<Data Col>_ tr_diff_<Tmt1>_<Tmt2>_<Model><Covariance Model>_.tif	Bunch_wt_p_val_KC_SP_GlobalExp_.tif	Predictions of treatment response differences between treatments
<Data Col>_tr_<Tmt1>_var_<Model><Covariance Model>_.tif	Bunch_wt_tr_KC_var_GlobalExp_.tif	Corresponding covariances of the treatment differences.
<Data Col>_p_val_<Tmt1>_<Tmt2>_<Model><Covariance Model>_.tif	Bunch_wt_p_val_KC_SP_GlobalExp_.tif	p-values of the treatment differences between pairs of treatments.
<Data Col>_z_<Tmt1>_<Tmt2>_<Model><Covariance Model>_.tif	Bunch_wt_z_KC_SP_GlobalExp_.tif	Z-statistics of the treatment differences.

2.15 Persistor

Summary

Persistor is used to summarise the similarities in patterns of variation across a block over a number of years (Bramley and Hamilton 2005). It might be used as an alternative to *k*-means clustering for identifying clusters based on yield, but also enables zones to be assessed in terms of a target level of performance (e.g. mean yield + 10%) and so provides information about how frequently such a target is met.

The "***Target over all years***" method assigns a value to each pixel to indicate the number of instances (in the raster list) in which that pixel was either less than or greater than the mean (+/- a nominated percentage) of that raster.

The "***Target probability***" method builds on the *target over all years* method, in that it includes an upper range (i.e. cells with a given frequency of values that are above the mean +/- a given percentage) and a lower range (i.e. cells with a given frequency of values that are below the mean +/- a given percentage).

The tool assigns a value to each pixel which indicates whether the performance in that pixel over a given proportion of years is:

a) Greater than the mean plus or minus the nominated percentage (value = 1)
b) Less than the mean plus or minus the nominated percentage (value = -1)

The remaining pixels which do not fall into category a) or b) are given a value of 0.

All input grids must overlap and have the same coordinate system and pixel size.

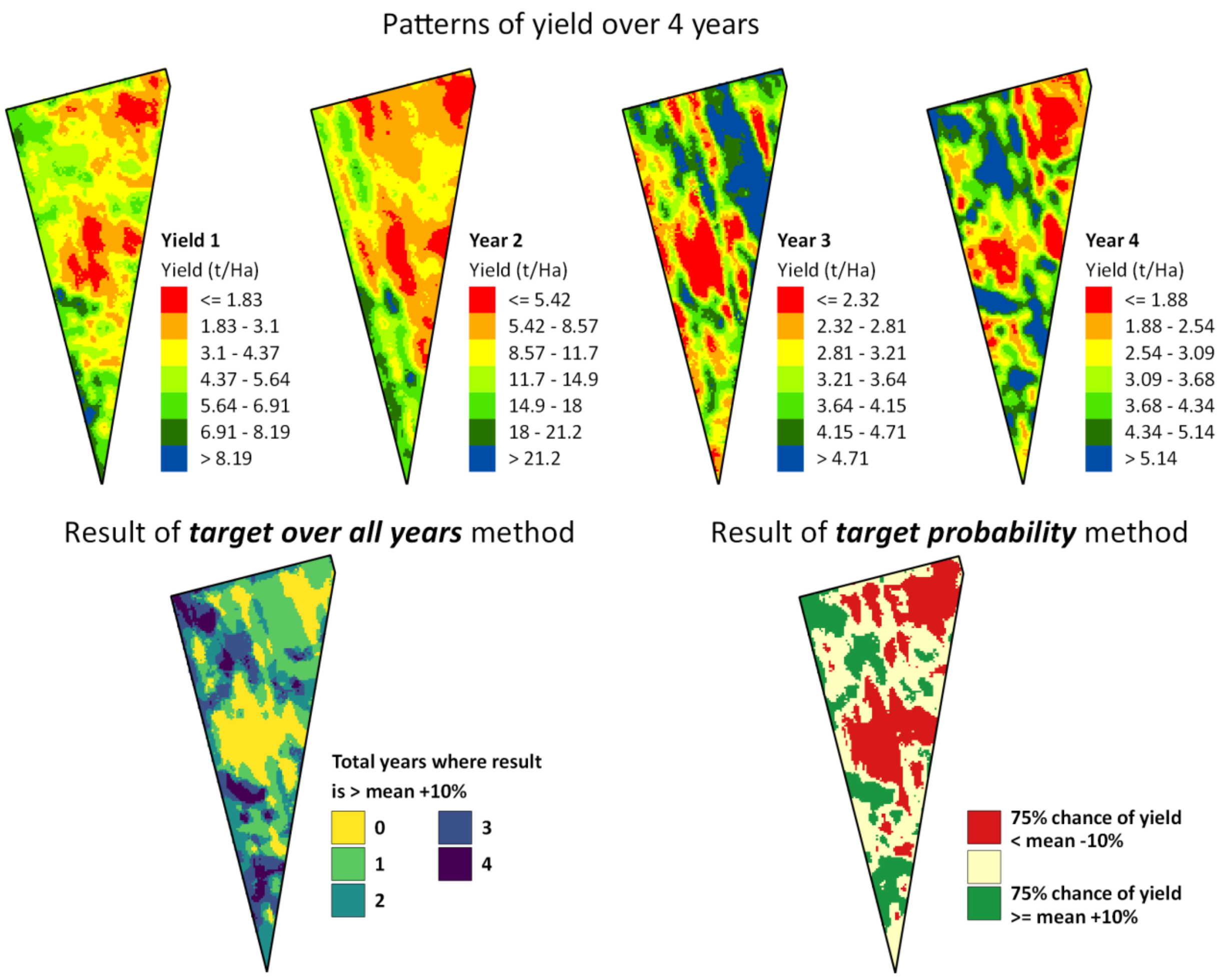
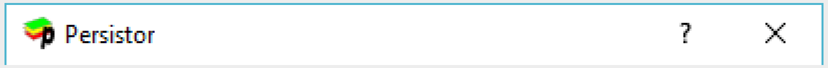
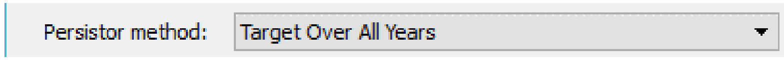


Figure 7 An illustration of the *Persistor Tool* results.

Dialog





Persistor Method:

Default is Target Over All Years

Select the analysis method from:

- **Target Over All Years** –the performance persistence of yield across multiple years.
- **Target Probability** – indicates which pixels meet an upper and a lower limit.

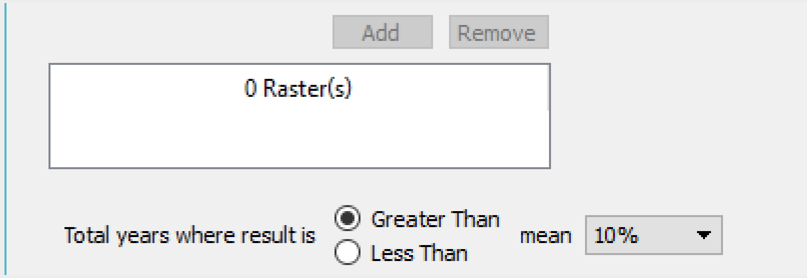
Select a raster layer:

Use *Select Raster Layer* with the *Add* button to add rasters to the list(s) below.

Raster layers will be filtered ensure they have the same pixel size as the first raster layer added to either the upper or lower raster lists. The values for these filters applied will be shown on the dialog.

Target Over All Years

The performance persistence of yield across multiple years.



Raster List

The list of rasters used for the ***Target Over All Years Method.***

Use *Select Raster Layer* with the *Add* button to add rasters to the list. The *Remove* button removes a selected raster from the list.

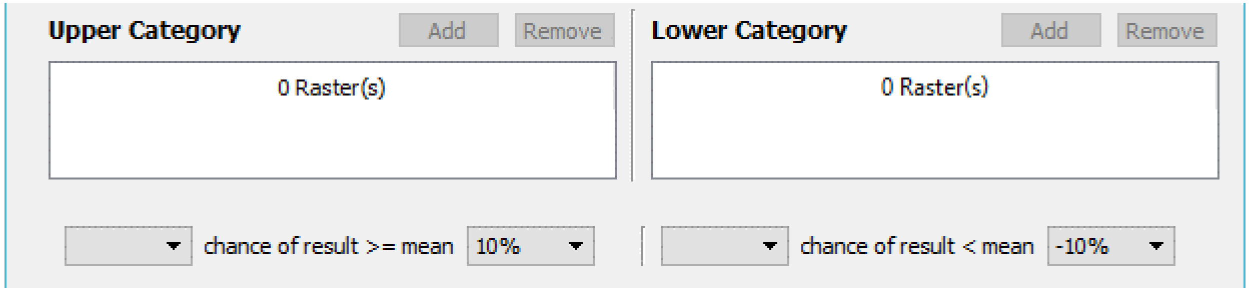
Total years where result is

Default is Greater Than and +10%

Count the years (from the list of rasters) where the pixel value is either **greater than** or **less than** the mean plus or minus the given **percentage** of the raster mean.

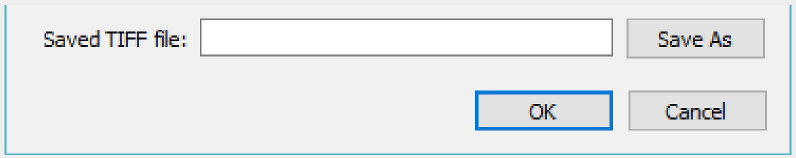
continued on next page……

TARGET PROBABILITY *Indicate which pixels meet an upper and a lower limit.*



Raster Lists Use *Select Raster Layer* with the *Add* button and the *Remove* button to manage the rasters in the upper and lower category lists.

UPPER LIMIT			LOWER LIMIT		
Upper Category Raster List	The list of rasters to apply upper category rules too**.**		**Lower Category Raster List**	The list of rasters to apply upper category rules too.	
Upper Category Settings	Default mean percentage is **+10%**	The **frequency** (as percentage) with which a pixel must exceed the raster mean (plus or minus the given **percentage)** to be included in the upper category. Pixels in this category will be assigned a value of +1.	**Lower Category Settings**	Default mean percentage is **10%**	The **frequency** (as percentage) with which a pixel must fall below the raster mean (plus or minus the given **percentage)** to be included in the lower category. Pixels in this category will be assigned a value of -1.



Saved TIFF file The name and path of the output TIFF file.

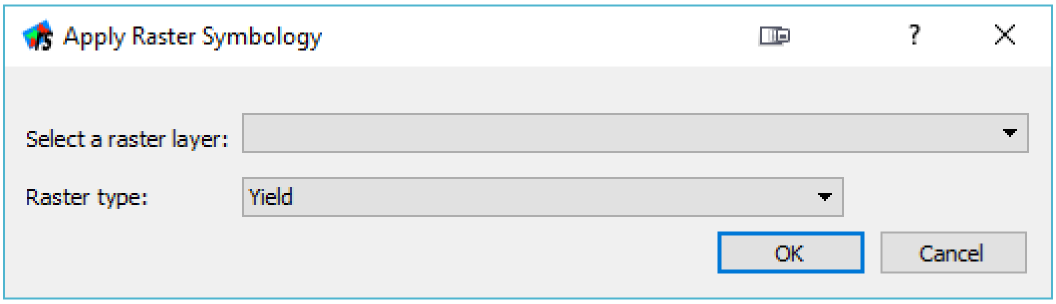
2.16 Apply Raster Symbology

Summary

The ***Apply Raster Symbology Tool*** allows for the quick application of the symbology for the different PAT tool output rasters.

Instructions for installing the PAT symbology can be found in ***4.3 Loading PAT Symbols into QGIS.***

Dialog



Supported raster types	Used by	Colour Ramp
Yield	Run Kriging Using VESPER, Import VESPER Results.	Yield 7 Colours
Image Indices (ie PCD, NDVI)	Calculate Image Indices for Blocks.	Imagery 5 Colours
Zones	Create Zones with k-means Clusters.	Random Colours
Block Grid	Create Block Grid.	Random Colours
Persistor - All Years	Persistor – Target All Years Method.	Viridis
Persistor - Target Probability	Persistor - Target Probability Method.	RdYlGn

2.17 Settings

Summary

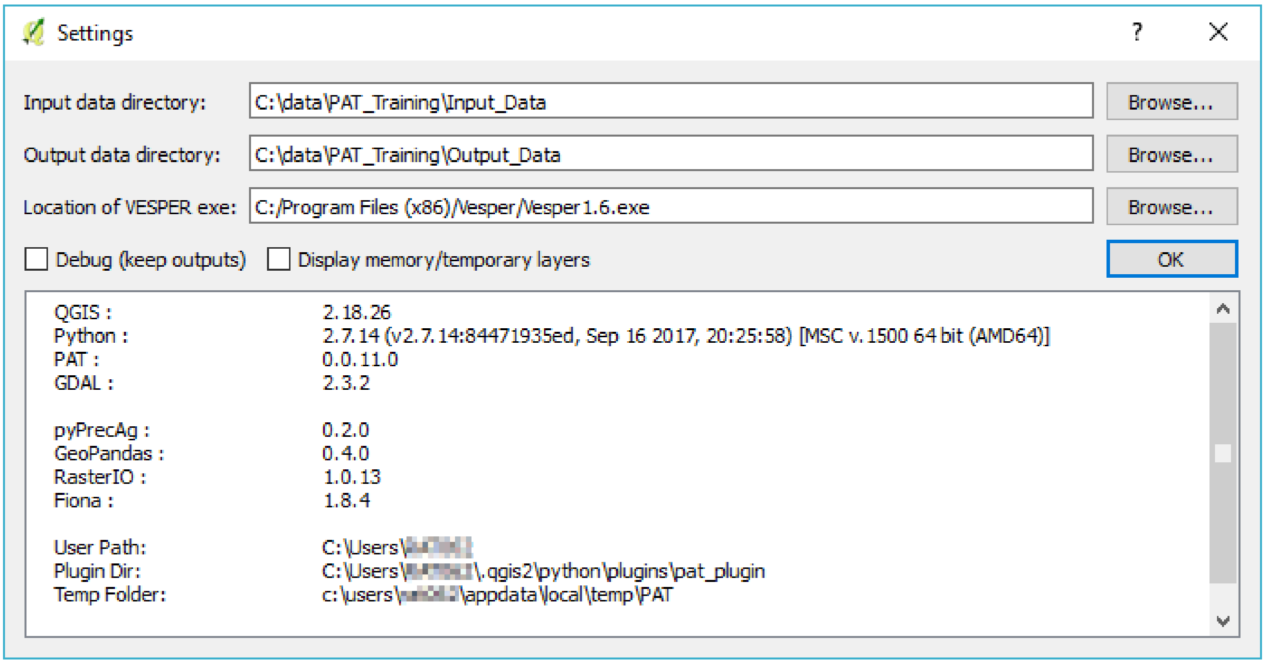
This tool is used to display and edit PAT settings.

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 location of the output file.
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 PAT sub-folder in the user's home directory. To quickly navigate here type *%homepath%/PAT* in the address bar of Windows Explorer.

3 Technical Notes

3.1 General 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 is 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 are 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.

3.2 Manually Install PAT dependencies

The preferred method of installing of installing PAT python dependencies is through the method described in ***1.3.2 Installing or Upgrading PAT Python Dependencies*** as it sets up the correct environment to do so. However, if you have administrator rights to your PC then you may manually step through the process as follows.

1. Open windows explorer and go to
   `%userprofile%/.qgis2/python/plugins/pat/python_packages`
2. Open the OSGeo4W shell as administrator. Install fiona and rasterio, using either the 64bit (amd64) or 32bit (win32) wheel files using

   ```
   python -m pip install <path to wheel file>
   ```
3. Install pyprecag using `python -m pip install pyprecag`
4. Using Windows Explorer, locate

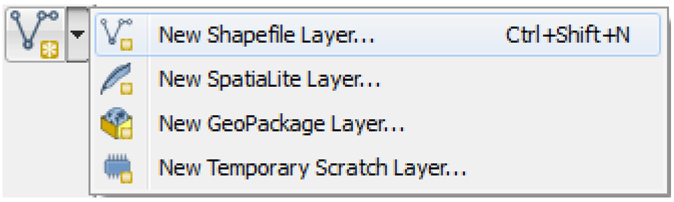
   ```
   C:\Program Files\QGIS 2.18\apps\qgis-ltr\python\PyQt4\uic\widget-plugins\qgis_customwidgets.py
   ```

   and copy it to

   ```
   C:\Program Files\QGIS 2.18\apps\Python27\Lib\site-packages\PyQt4\uic\widget-plugins
   ```
5. Restart QGIS.

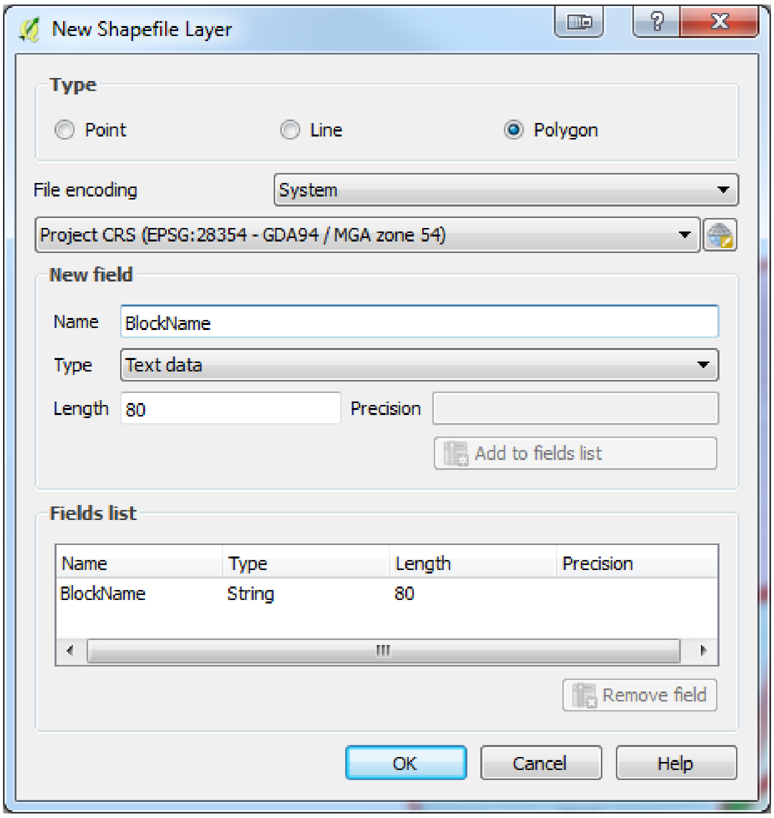
4 How-To’s

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

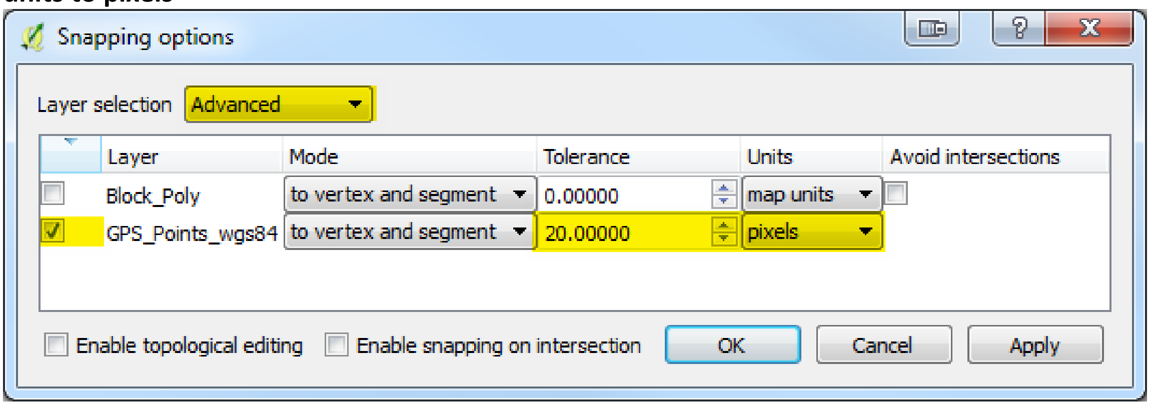


1. Using the ***New Shapefile Layer*** tool from the ***manage layers toolbar*** *(or Layer menu -> Create Layer -> New Shapefile Layer*) create a new polygon shapefile adding the relevant coordinate system* and attribute fields you require. Clicking OK will prompt you for the location to save the shapefile.

More information on coordinate systems can be found at



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**



*More information on selecting a coordinate system can be found on page 59.

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 How to reproject a shapefile and why you need to do this

A projected coordinate system is used to depict the curved earth surface as a flattened surface – as it is when printed on a piece of paper. Currently the block grid tool requires the polygon shapefile to be in a projected coordinate system. However, raw GPS data such as you might have in your yield monitor data file uses a geographic coordinate system most likely with position expressed as decimal degrees or degrees minutes second (such as in Google Maps). These will typically be labelled as latitudes and longitudes.
If your shapefile is in a geographic coordinate system then you will need to reproject it to a projected coordinate system.

Geographic coordinate systems include:
Global: EPSG: 4326, WGS 84
Australian: EPSG: 4283, GDA94

In projected coordinate systems, the Globe/Australia is divided up into zones (see UTM zone map). Map grid of Australia (MGA) zones align closely with the UTM zones, but use the 1994 Geocentric Datum of Australia. Figure 8 shows the position of the MGA zones.

Projected coordinate systems include:
Global: WGS84 / UTM Zone divided in to North and South of the equator
Australian: GDA94 / MGA zones

You need to know the projected coordinate system for your data and which zone it lies in. This projected coordinate system will get used throughout PAT. This is made simpler through the use of EPSG numbers. An EPSG number is an international numbering system for coordinate systems (see http://www.epsg.org)

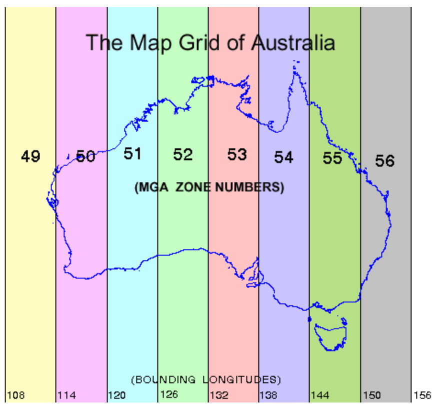
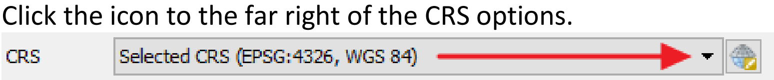


Figure 8 The Map Grid of Australia. (www.environment.gov.au/erin/tools/mga2geo-gda.html).

1. **Determine your projected coordinate system.**
   - Within Australia use GDA 1994 Map grid of Australia (MGA)
     EPSG: 283xx
   - Outside Australia use the WGS84 UTM Zone system.
     North of the Equator - EPSG: 326xx
     South of the Equator - EPSG: 327xx

   Using your EPSG prefix listed replace the xx with your zone. For example Adelaide is an Australian city in zone **54** so projected coordinate system then becomes EPSG: 283**54** GDA94 / MGA zone **54**.

2. **Reproject your shapefile**
   a. In QGIS, select your shapefile and select ***Save as*** from the ***Layer menu.***
   b. In the dialog, browse for a new shapefile and assign a name.
   c. Click the icon to the far right of the CRS options.



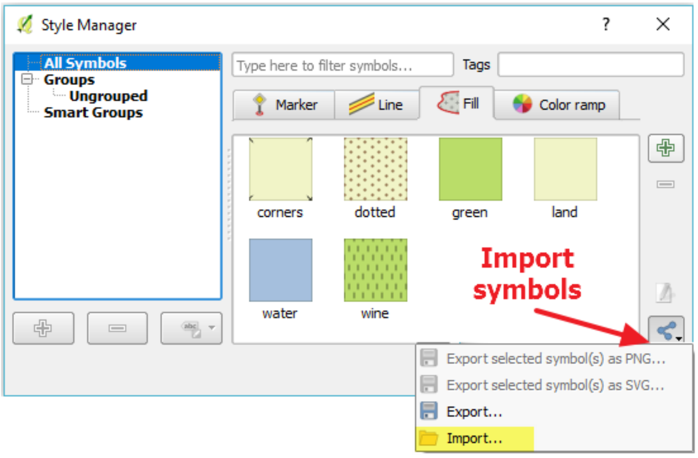
   d. Search for your projected coordinate system. The easiest way is to use the EPSG number from step 1.
   e. Leave all other options as is and click OK

The shapefile will be reprojected and loaded into QGIS and is now ready for use.

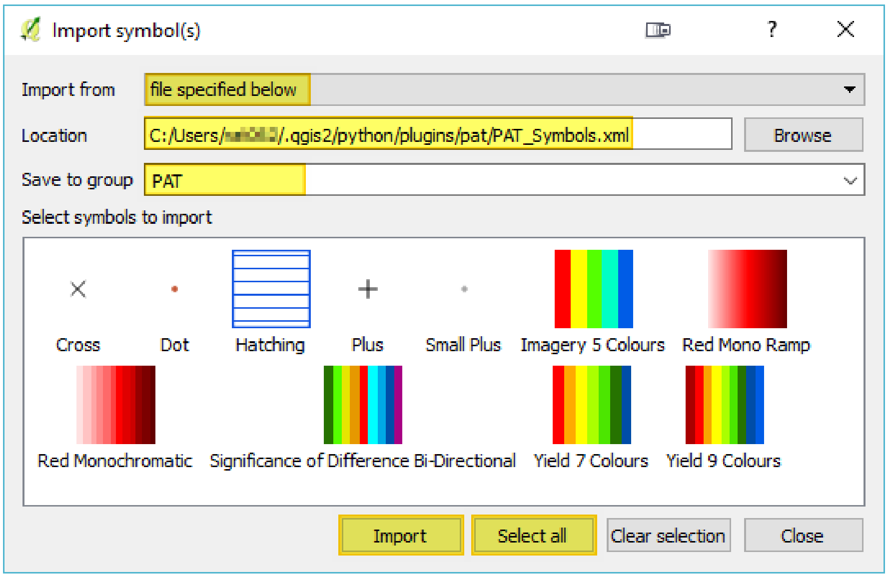
For further information on coordinate systems see
https://docs.qgis.org/2.18/en/docs/gentle_gis_introduction/coordinate_reference_systems.html

4.3 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** from the settings menu.
2. From the lower right corner of the dialog, select ***Import*** dialog.
3. Set ***Import from*** to ***file specified below.*** Browse to the users QGIS plugin folder and find the **PAT_symbols.xml** file in the pat folder (see 1.5 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, you will be notified and given the option to overwrite.



4.4 Kriging ‘low density’ data in PAT

The mapping protocol which forms the ‘backbone’ of the PAT workflow is designed to handle data collected at a high spatial density using an on-the-go sensor – such as a yield monitor, proximal canopy sensor or electromagnetic soil sensor. Sometimes, there will be a need to collect data using hand sampling – for example using biomass cuts in a wheat field, counts of bunch numbers in a vineyard or assessments of disease – and for mapping these. Whereas the interpolation of high density, on-the-go data uses local block kriging, for hand sampled data collected at much lower density, global point kriging is more appropriate. This can be done in VESPER, but requires more user input, not least because the ‘variogram’ which underpins interpolation using kriging, needs to be generated manually and carefully. Additional information on this can be found in the VESPER manual available here with additional information on geostatistics available in books such as Webster and Oliver (2007). These notes are intended to guide the generation of the variogram and other input that PAT needs to run VESPER for low density data sets. Note for this current release of PAT, the procedure requires some use of VESPER independently of PAT.

Important notes

- It is not the intention in these notes to provide training in geostatistics. Users wishing to gain a better understanding of this topic should consult appropriate texts such as Webster and Oliver (2007). However, in general, we do not recommend that PAT users engage in low data density map interpolation unless they have acquired some prior understanding of map interpolation using kriging.
- It should also be noted that we DO NOT recommend interpolation of maps from ‘low density’ data when fewer than 100 data points are available (Webster and Oliver, 2007).
- Experience with work in vineyards (3-10 ha) suggests that a sample density of 26 samples or data points per hectare leads to satisfactory maps but a general rule of thumb is that higher data densities give better maps.

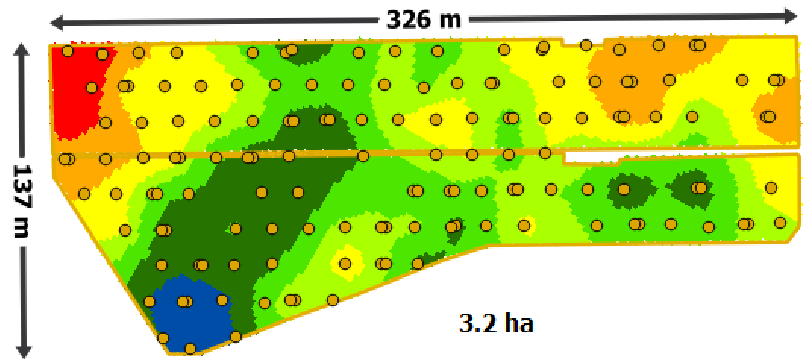


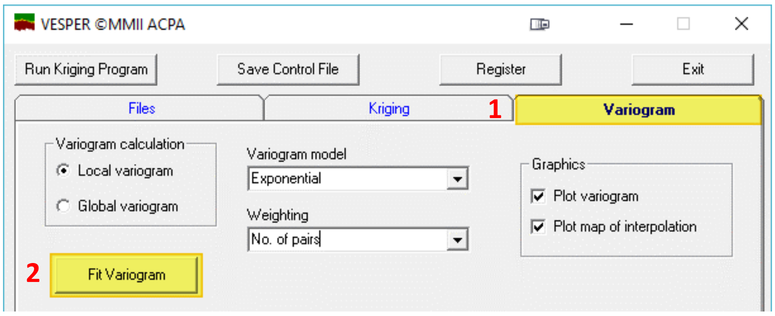
Figure 9 A map showing the data points used for the low data density kriging of 140 measures of grape berry weight in a 3.2 ha vineyard along with the final kriged result. This is the example used for the variogram fitting below.

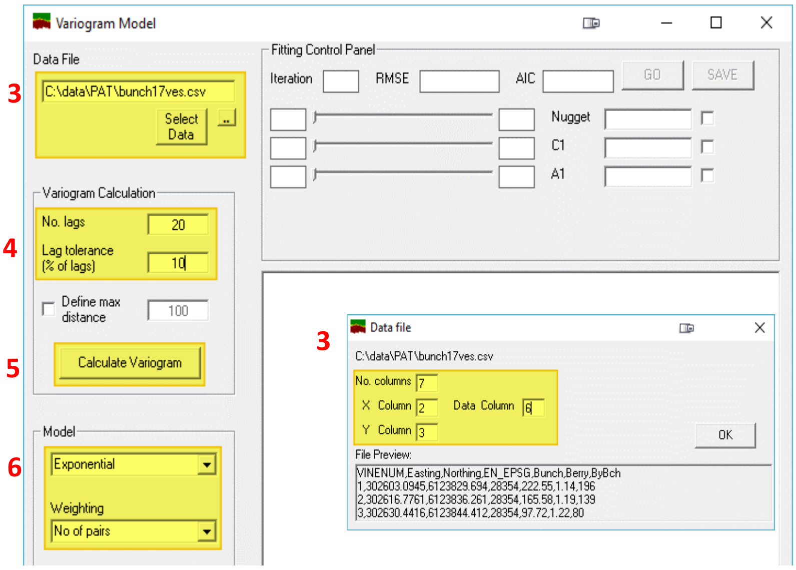
Requirements

- A **CSV file** containing separate columns for each of X coordinates (e.g. Easting), Y coordinates (e.g. Northing) and the data value(s) to be mapped.
- A **VESPER grid file** created using the ***Create Block Grid Tool***
- The coordinate system for both the **CSV file** and **VESPER grid file**. Both these files should have the same coordinate. The ***Clean, Trim, Normalise Point Data Tool*** can be used change the coordinate system of the CSV file to match the VESPER grid file described in 2.2.
- **VESPER:** ***Run Kriging Using VESPER*** tool requires installation of VESPER (see section 1.3.2)

Setup the Variogram

1. Open **VESPER** independently of PAT and QGIS (i.e. as a stand-alone application).
2. In the Variogram tab, click *Fit Variogram*.
3. Browse to your csv file and in the **Data files** dialog that will appear, select the columns representing your X, Y and data value. For this example the X (Easting) is in column 2, Y (Northing) column 3 and data value (Berry) column 6.
4. Change the Variogram computation to
   a. ***Number of Lags*** to **20**
   b. ***Lag tolerance (%)*** to **10**
5. Ensure the ***Variogram Model*** is **Exponential** and ***Weighting*** is **No. of pairs.**
6. Click **Calculate Variogram** to calculate and display the variogram.

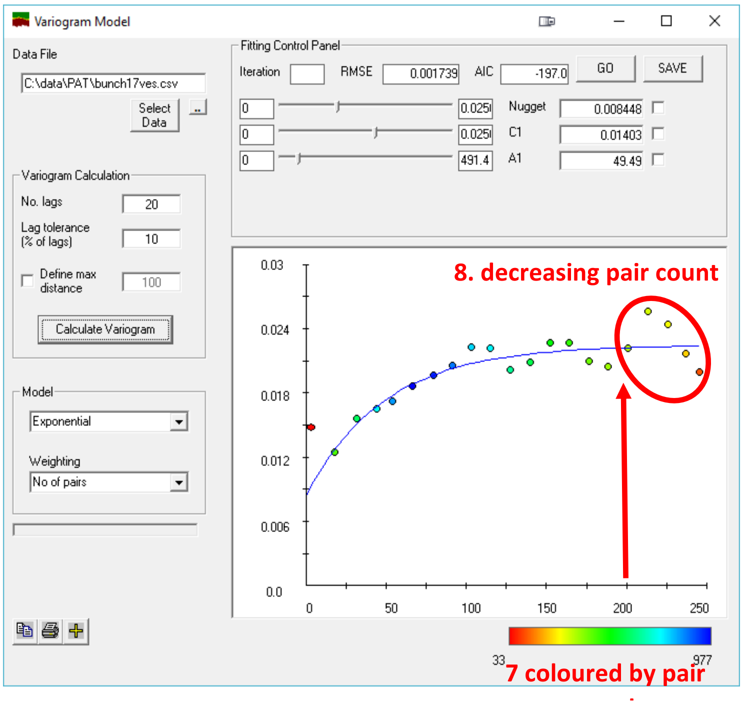




The Variogram

A variogram is a function which describes the variation in a dataset as a function of the distance between the points which comprise that dataset. It is key to the kriging process because the weights used to interpolate a map surface from sample data is a function of the distance between nearby data points and the location of the points for which map values are being interpolated. These weights derive from the variogram. Both Webster and Oliver (2007) and the VESPER Manual (Minasny et al., 2005) provide further information

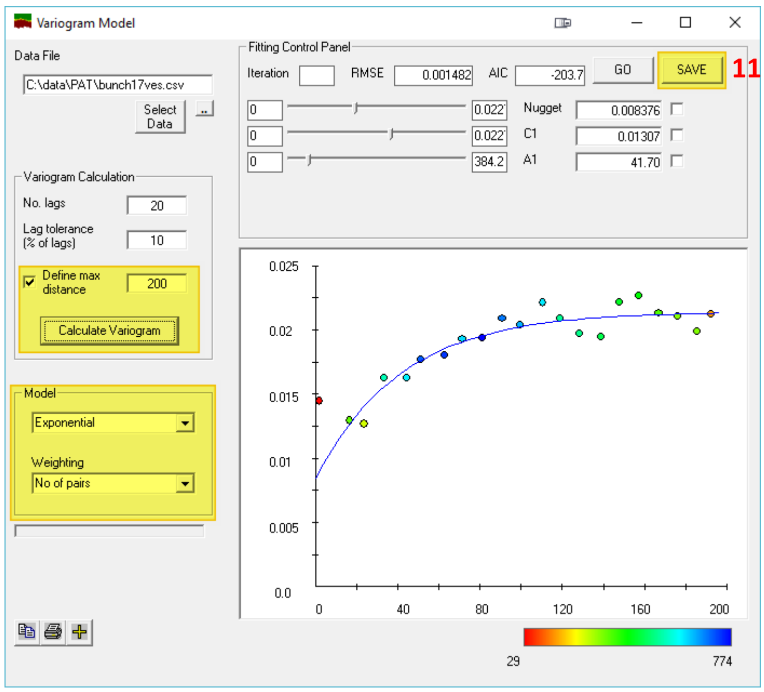
7. The colour coding in the variogram plot relates to the number of pairs of samples that have been used (or are available) to calculate the 'semivariance' of samples separated by each lag (i.e. distance) class.



8. In this example, it can be seen that beyond a distance of about 200 m, the number of pairs of points drops off. Because these points are at large lags, and the important part of the variogram is the sloping part at shorter lags, it can often be useful to set the maximum distance. The distance will vary between datasets.

   When a maximum distance is set, it should reflect the drop-in pairs of points and should also be larger than the apparent range of spatial dependence (see Webster and Oliver, 2007 for further discussion of the form of the variogram), and also needs to be sensible in relation to the size of the field being considered. For example, if your vineyard being mapped is a 1 ha square of 100 m side, one would generally expect the maximum distance to be less than 100 m.

9. For <u>this</u> dataset, tick the Define max distance and enter 200 m, then click Calculate Variogram to update the variogram.

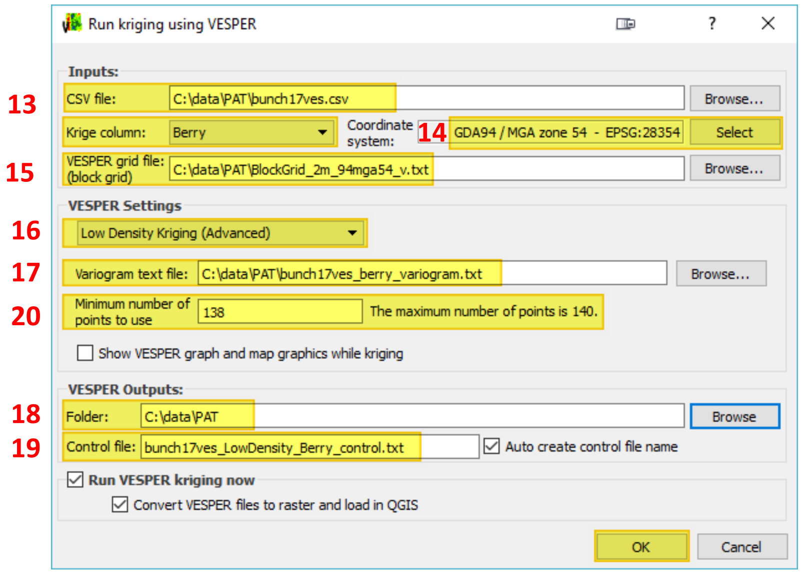


10. To this point, the default settings of an Exponential variogram model have been used with a weighting for the fitting of the curve dependent on the No of pairs. Often, a curve which describes the data a little better might be obtained by selecting a different model and/or using a different weighting method. In general, and with the exception of advanced users, we would recommend that the variogram model selection is confined to either Exponential (the default) or Spherical and that the Weighting used is either No of pairs or No_pairs/st_dev. Further information on settings is available in the VESPER Manual (Minasny et al., 2005).

11. Once satisfied with the fitted variogram, click ***Save*** to save variogram parameters to file. It is useful if the output has the same prefix as the CSV file with the name of the data column you used in step 3 and variogram is added to the end (e.g bunch17ves_berry_variogram.txt). This is the input variogram file for the low density kriging option in ***Run Kriging Using VESPER Tool.***

Run Kriging using PAT

12. Close VESPER, launch QGIS and the open then dialog for ***Run Kriging Using VESPER Tool*** from the PAT toolbar or menu. Further details on this dialog can be found section 2.3. The Low Density Kriging implementation is as described below.



13. Select the <u>same</u> ***CSV file*** and ***Krige*** (data) ***column*** used in step 3

14. The ***coordinate system*** will be automatically determined if a column (*EPSG* or *ENEPSG*) exists in the CSV file. If this does not exist then you will be required to set it prior to continuing.

    If your CSV file needs reprojecting, the you can use the ***Clean, Trim, Normalise Point Data Tool*** using the settings described in 2.2.

15. Browse to the ***VESPER grid file***.

    At this point a dataset overlap check will be completed if you have provided the CSV and VESPER grid file where it is assumed that these two files have the same coordinates system. If this fails you will be warned as shown. No overlap will cause VESPER kriging to fail.

16. Choose the ***Low Density Kriging (Advanced)*** method**.**

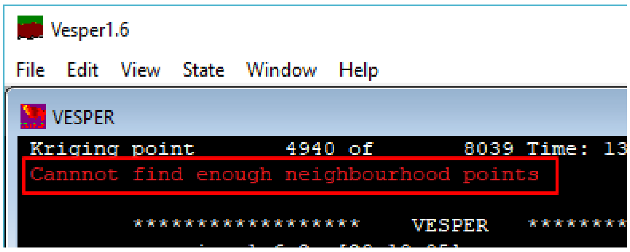
17. Browse for the ***variogram text*** file saved in step 11.

18. Specify the ***output folder*** to store the VESPER files and results in. A sub-folder called VESPER will be automatically created if it does not already exist.

19. If required change the default ***control file name***. This is saved into the **folder** from step 18.

20. Use the default (total point count minus 2) ***minimum number of points to use*** during VESPER kriging.

    In some cases, this will cause a *Cannot find enough neighbourhood points* error in VESPER and create an empty output. If this occurs re-run the kriging by repeating steps 13-21 and decrease the ***minimum number of points to use*** by one and try again . You may have to re-try multiple times to find the right value.



21. Click OK and the control file will be created and added to the VESPER queue. When the VESPER processing is completed, the resulting kriged text file will be converted to a TIF and loaded into QGIS.

5 Contributors

The following individuals have contributed the production of PAT and the underpinning pyprecag Python package, through coding, configuration and expertise in PA, and in the case of the Whole-of-block analysis tool, the development of statistical methodology.

Core Project Team: **Christina Ratcliff** (lead developer), **Rob Bramley** (project leader) and **David Gobbett** (technical lead)

Whole-of-block analysis tool: **Shuvo Bakar**, **Warren Jin** and **Brent Henderson**

pyprecag packaging and publishing: **Andrew Spiers**, **Adrian D'Alessandro, David Benn** and **Daniel Collins**

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