PAT: Accessible tools for precision agriculture data analysis

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Abstract
PAT – Precision Agriculture Tools is a 'plugin' for QGIS, a free and open-source desktop geographic information system. PAT provides a suite of tools for processing and analysing precision agriculture (PA) datasets. The need for accessible and easy to use PA data processing tools has been demonstrated by survey data showing that whilst many growers have access to PA data, such as through yield monitors, a relatively small proportion of growers use these data in making management decisions. The PAT plugin is the culmination of many years of PA tool development, and includes tools for basic data preparation and map generation, as well as powerful tools for analysis of on-farm trials and experiments.

Key Words
Precision Agriculture, Spatial Analysis, Kriging

Introduction
There has been widespread adoption of spatially referenced sensor-based data collection technology such as yield monitoring, high resolution soil survey and increased availability of various forms of airborne and satellite imagery. This technology potentially provides growers with large amounts of useful spatial datasets that could be of value in their enterprises. However, a recent survey of grain growers (Bramley and Ouzman, 2018) found that of the growers who have access to a yield monitor, only 50% process the data collected into yield maps. Of growers who have generated 5-7 years of yield maps, 38% of growers have not used yield maps to assist with management decisions. The failure to utilise these spatial datasets occurs despite the existence of protocols and methods for PA in research papers (e.g. Bramley and Williams, 2001; Bramley and Hamilton, 2004; Taylor et al., 2007; Panten and Bramley, 2011; Lawes and Bramley, 2012), commercial GIS software, online web services and of organisations such as Society of Precision Agriculture Australia (www.spaa.com.au). Whilst many of these protocols derive from work undertaken in the viticulture wine sector, PA involves generic processes and thus, PAT is highly applicable to broadacre agriculture.

PAT – Precision Agriculture Tools plugin (Ratcliff, Gobbett and Bramley, 2019a) leverages these techniques and makes a suite of tools available within the Quantum Geographic Information System (QGIS; QGIS Development Team, 2018), an easy-to-use free and open source GIS package. PAT aims to be accessible to a wide range of users such as growers and consultants across any agricultural industry.

Description
PAT contains tools for both data preparation and analysis. The core PAT functions are also available in a Python library called pyprecag (Ratcliff et al., 2019b) which enables programmers to build the PAT capabilities into their own software. However, the expectation is that most users will access PAT via the QGIS front-end where the tools are made available through drop-down menus and toolbars (Figure 1).

Functionality
PAT can be used to generate maps from on-the-go data, such as from yield monitors, EM38 soil surveys and other sensors such as crop canopy sensors, with tools for various data cleaning steps also available (Table 1). The analysis tools (Table 2) enable users to standardise maps for easy comparison, create vegetation index maps from remotely sensed reflectance data such as Normalised Difference Vegetation Index (NDVI), and extract values from these maps at known locations. Further tools are available to combine and analyse these maps.

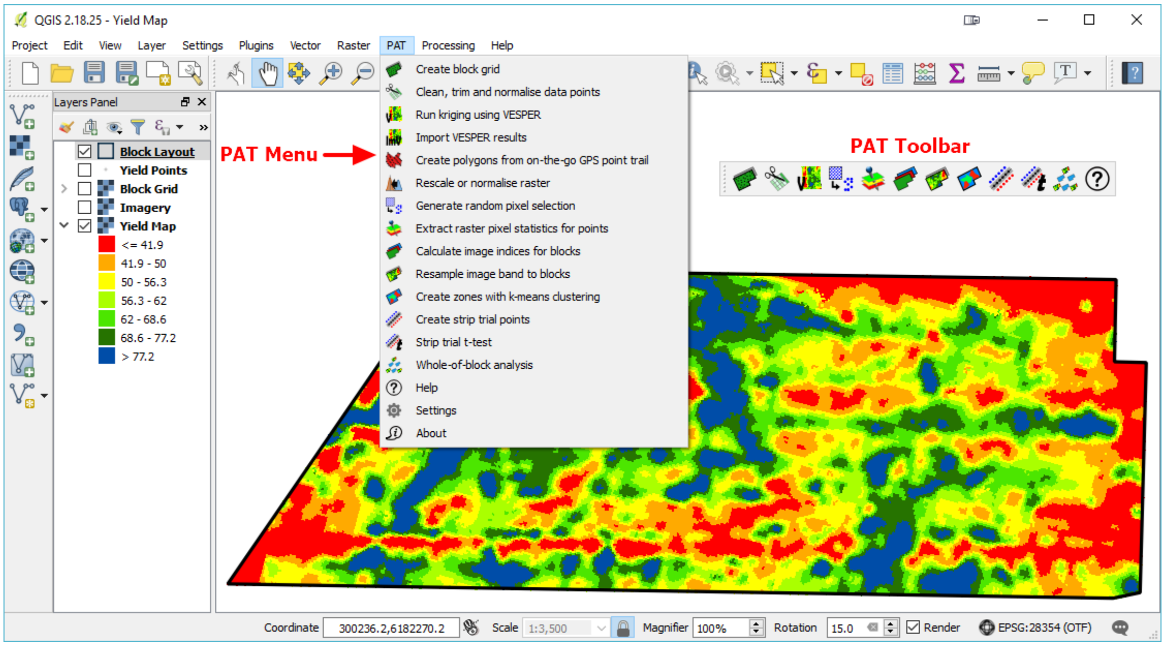

Figure 1 PAT plugin from within QGIS and a yield map produced using the PAT workflow

PAT implements the workflow for yield map generation, as described in a viticultural context by Bramley and Williams (2001), and shown in Figure 2. This is similar to the more grains-orientated method of Taylor et al. (2007) and may also be used to generate maps derived from other sensor data collected 'on-the-go' at high spatial density - such as high resolution soil survey (e.g. EM38) data. PAT links to VESPER (Minasny et al., 2005) for map interpolation using kriging. Each tool's functionality is further described in Tables 1 and 2.

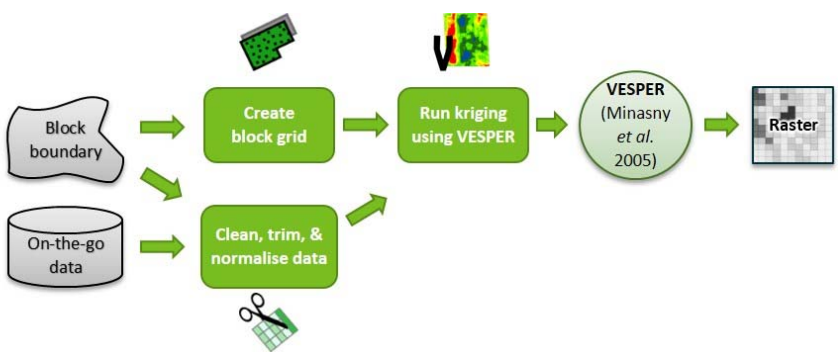

Figure 2 Workflow required to generate a map from high density on-the-go sensor data using PAT

Table 1 PAT tools for processing of on-the-go data

PAT Tool		Description
	Block grid	Basing maps on a common block grid allows comparison of multiple years of data from the same field and different types of data layers. This tool generates a block grid from polygon boundary features such as a field boundary.
	Clean, trim and normalise points	Preparing raw data from yield monitors or on-the-go sensors involves applying clipping, cleaning and filtering rules before the data is ready for interpolation onto the common block grid.
	Prepare for kriging and run VESPER	Prepare and run VESPER which generates interpolated (kriged) raster maps from prepared data.
	Create rasters from VESPER results	Convert VESPER outputs to raster TIF format for display and subsequent analysis.

Analysis tools available in PAT (Table 2) enable maps created using the workflow shown in Figure 2 and other acquired data, like aerial imagery, to be combined and analysed to create additional data and maps for analysis to assist with management decisions. For example, the *create zones with k-means clustering tool* can be used to create potential management zones by combing a number of different datasets. An example of this analysis is shown in Figure 3. On-farm experimentation is supported by the Strip trial and Whole-of-block experiment analysis tools.

Table 2 A selection of PAT analysis tools.

PAT Tool	Description
Rescale or normalise a raster	Convert rasters to a common scale, to enable equally weighted comparisons between years or layers e.g. rescale or standardise a raster to between 0 – 1, or normalising to a mean of 0 and standard deviation of 1.
Extract pixel statistics for points	Extract pixel statistics from multiple rasters using a square neighbourhood around a set of point locations. This extracted data can be used to analyse relationships between different datasets.
Calculate image indices for blocks	Resample and smooth imagery to a larger pixel size, such as that of the common block grid, as well as calculate indices such as NDVI from raw images.
Create zones with *k*-means clustering	Use *k*-means clustering to identify zones from multiple years of data, and/or additional layers such as EM38 maps as described in Bramley and Hamilton (2005) and Taylor et al. (2007) to create potential management zones.
Strip trial *t* test	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).
Create strip trial points	Create points inside a strip trial and generate offset ‘control’ points at a distance away from the strip to use in the Strip trial *t* test tool.
Whole-of-block analysis	Analyse whole-of-block experiments where 2 or 3 treatments are applied across a block or paddock (Panten and Bramley, 2011). This approach can demonstrate whether and where the effects of the treatments are significant.

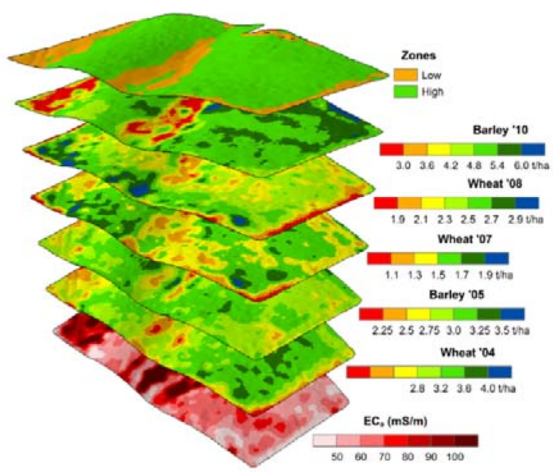

Figure 3 The PAT *k*-means clustering tool enables identification of potential management zones such as in this example from a 96 ha paddock on the Eyre Peninsula.

The suite of tools included in PAT therefore covers the PA analysis spectrum, from raw data cleaning through to generating analytical outputs that facilitate field and farm-scale decision-making. Combined with grower-implemented experimental methods such as strip trials and whole-of-block experimentation (e.g. Bramley et al., 2013), the PAT tools are a powerful enabler for growers and their consultants to undertake site-specific tailored trials to inform paddock-scale management decisions.

Access

PAT – Precision Agriculture Tools plugin for QGIS can be installed into QGIS for Windows version 2.18.21-26 by following the instructions found at https://github.com/CSIRO-Precision-Agriculture/PAT_QGIS_Plugin. Currently PAT does not support QGIS 3.x. For programmers, the pyprecag Python library is available to users from PyPi – a public repository of Python libraries.

In due course, new and enhanced tools will be added to PAT including: automatic colour scheme assignment for maps; map generation for low spatial density point data collected through hand sampling (e.g. disease incidence or severity, biomass measures); and a tool for the analysis of multiple years of yield or imagery to indicate consistency of performance through time.

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