MAPPING CANEGRUB DAMAGE FROM HIGH SPATIAL RESOLUTION SATELLITE IMAGERY

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Abstract

CANEGRUBS FEED on the roots of sugarcane plants, reducing plant vigour and yield, and if left untreated within a growing season they have the potential to rapidly increase the impacted area in the following year. For the targeted control of the canegrub, it is essential that the location of the affected areas is identified. However, identifying canegrub damage in the field is difficult due to the often impenetrable nature of sugarcane. Satellite imagery offers a feasible means for achieving this by using the visual characteristics of sprawling, changed leaf colour and exposure of soil in damaged areas. The objective of this research was to use object-based image analysis (OBIA) and high spatial resolution satellite imagery to map canegrub damage. The OBIA mapping approach used in this research was based on four key steps for three selected study sites in Queensland, each covering 50 – 100 km^2 around Mackay, Home Hill and Gordonvale. The steps were: (1) initial segmentation of sugarcane block boundaries based on existing GIS layers provided by the respective Mills and further segmentation of each block into smaller homogenous objects; (2) classification and subsequent omission of fallow/harvested fields, tracks and other non-sugarcane features within the block boundaries; (3) identification of 'potentially' grub-damaged areas within each block with the lowest amounts of green leaves (low Normalised Difference Vegetation Index (NDVI) values) and highest level of image texture; and (4) the further refining of 'potentially' grub damaged areas to 'likely' affected areas based on the absolute difference in the amount of green leaves (NDVI values) and texture between the 'potentially' grub damaged areas and the remaining parts of each block. The initial validation based on field observations of greyback canegrub damage at the time of the satellite image capture in June 2013 yielded overall accuracies between 53–80%. However, this included a number of false positives resulting from sprawling, drainage issues, weed and pig damage. Further research will focus on reducing these false positives as well as investigating the inclusion of additional data layers to increase the predictive accuracies. Such data layers may include distance from damage to tree corridors, distance to neighbouring grub damage and, potentially, soil type, cane variety and treatment information. Analysis of archived imagery may also provide some insight into the historic location and distribution of grub damage, thus assisting with improved understanding of potential risk for the subsequent year. The results of this research will help cane growers to manage and reduce damage caused by canegrubs and increase future yields.

Introduction

The greyback canegrub, *Dermolepida albohirtum* (Waterhouse) (Coleoptera: Scarabaeidae), is the principal pest of sugarcane crops in the area from Mossman in Far North Queensland, to Sarina in the Central District. Previous estimates annual loss of cane production as a result of grub damage is around $10 million (Allsopp *et al.*, 1993; Chandler, 2002). This pest exhibits a one-year lifecycle where adult beetles emerge following the onset of rainfall around October–December, and lay eggs in the soil in December–January.

The larval stage has three instars feeding extensively on the root mass, causing reduced growth, stool tipping and ultimately plant death (Sallam, 2011). By the time damage symptoms are apparent in the field in May–June, it is too late and unfeasible to conduct chemical treatment because of the size of the sugarcane. Therefore, sugarcane growers need to apply chemical treatment well before the commencement of beetle flight (Sallam, 2011). Although it is difficult to predict where greyback cane beetles will lay their eggs, canegrub damage has been identified as a function of the extent of damage sustained in the same field or fields nearby in previous years (Sallam and Lowe, 2012). Hence, knowledge on the spatial location and extent of canegrub damage can facilitate the assessment of where damage is likely to occur the following year and hence where treatment should be applied to prevent the next crop/ratoon from becoming infested.

High spatial resolution satellite imagery collected in May–June when canegrub damage symptoms are most apparent may be used to provide a bird's-eye view of the cane fields and determine the location and extent and canegrub damage. Like the currently adopted strategy of helicopter surveys, the visual assessment of grub damage within a satellite image can be time-consuming and subjective to the interpretation of the surveyor. As such, the development of a semi-automated mapping approach may reduce the time and costs of identifying areas with potential canegrub damage. Research has proven that the most suitable means of high spatial resolution image analysis is an object-based approach, where clusters of pixels forming features, such as a tree, house, or patch of grub-damaged cane field, are analysed instead of individual pixels (Blaschke, 2010).

The objective of object-based image analysis (OBIA) is to develop and apply theory, methods and tools for replicating and improving human interpretation of remotely sensed imagery in an automated manner. OBIA consists of image segmentation, i.e. clustering of pixels into homogenous objects, subsequent classification and modelling based on the characteristics of the objects.

In addition to the statistical characteristics of the objects, OBIA allows the inclusion of additional contextual information properties not available in traditional pixel-based approaches to assist the classification process. Such information may include the area, shape and texture of objects, and location of objects in relation to other objects and land cover classes in the landscape, to name a few (Johansen *et al*., 2010).

With the launch of the first high spatial resolution satellite sensor (Ikonos) in 1999 and the increasing availability of satellite and airborne optical digital high spatial resolution imaging sensors and laser scanners, the need for new techniques suitable for processing and analysing these data sets has become obvious.

Despite the initial foundation for OBIA being laid in the 1970s and 80s (Haralick and Shapiro, 1985; Kettig and Landgrebe, 1976), it was not before the evolution of high spatial resolution digital imagery that a significant need for OBIA was realised. The increasing availability of high spatial resolution digital imagery coincided with the release of the first commercially available object-based image analysis software, eCognition, in 2000 (Benz *et al.*, 2004). An increasing number of peer-reviewed publications on OBIA have been published, especially in the past five years, emphasising the growing community using this technology (Blaschke, 2010).

Hence, the objective of this research was to use OBIA and high spatial resolution satellite imagery to map canegrub damage in three selected areas with known canegrub damage in North Queensland.

Data and methods

Study areas

The three study areas were located around Mackay, Home Hill (Burdekin) and Gordonvale in North Queensland (Figure 1). The selected location of each of the three study areas was based on records of canegrub damage in 2010 from AgriServ and a preliminary survey of farmers by Sugar Research Australia (SRA) during June–July 2011.

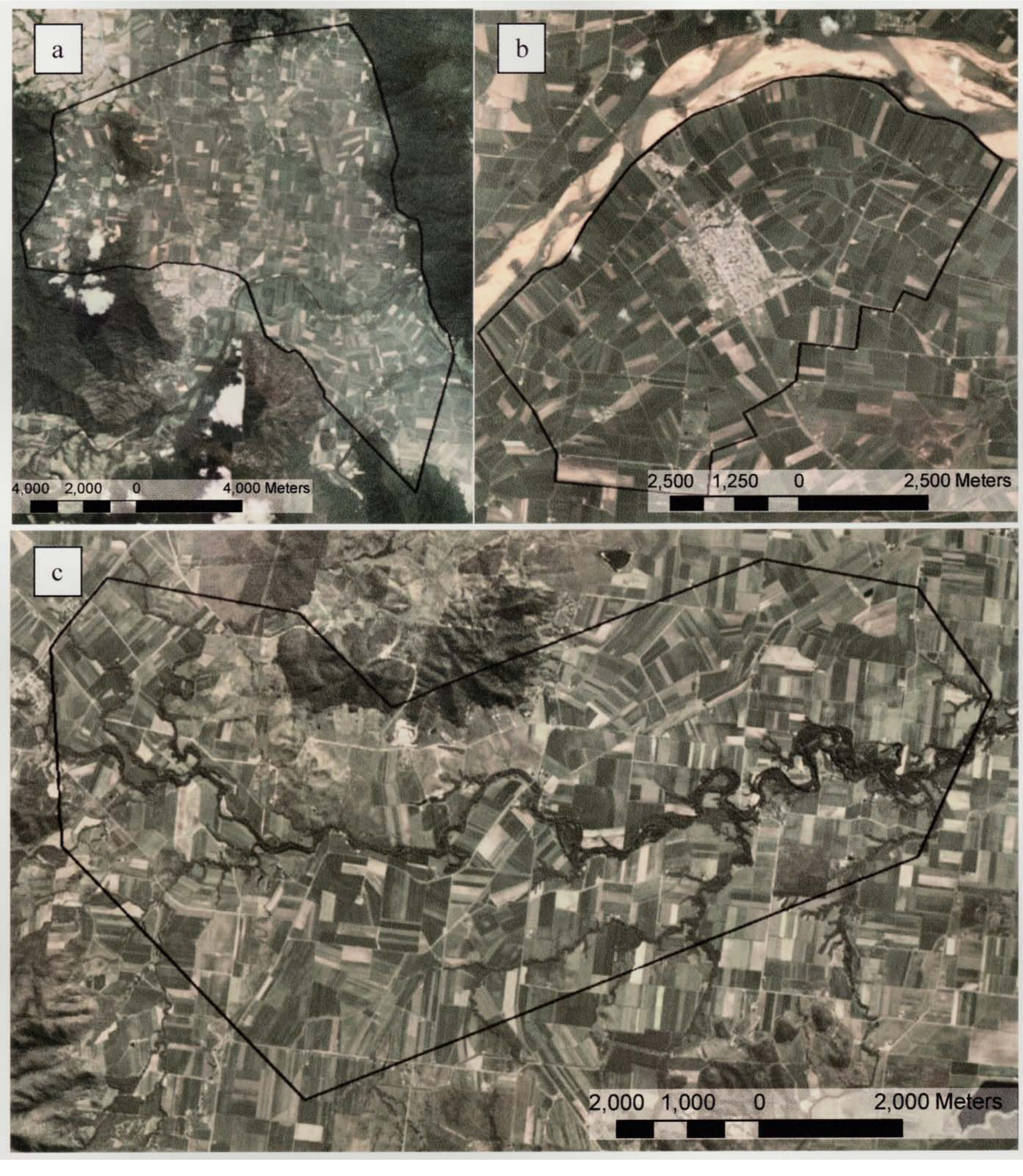

Fig. 1—The three study areas in North Queensland, (a) Gordonvale; (b) Home Hill; and (c) Mackay. The black outlines indicate the areas captured by the GeoEye-1 satellite sensor.

The Gordonvale study area was located 10 km south of Cairns and covered 128 km^2. The Home Hill study area was located 7 km south of Ayr along the southern banks of the Burdekin River and covered 53 km^2. The Mackay study area was located approximately 15 km southwest of Mackay and covered an area of 66 km^2.

Field data

Field data identifying the location of canegrub damage were collected for all three study sites and included (1) positively damaged areas obtained independently of the imagery; and (2) suspected canegrub damaged areas visually identified from the images (prior to image processing and mapping). For observations independent of the imagery, a GPS reading was collected across 47 and 29 field locations at Gordonvale and Mackay, respectively, with the number of grubs per stool counted to confirm the presence of grub damage.

A total of 20 stools were dug out and canegrubs counted at each location (Sallam *et al.*, 2008), and symptoms on roots and stubble were recorded. From the satellite imagery, a large number of sites within each growing area, Mackay (88 locations), Burdekin (81) and Mulgrave (338), suspected of canegrub damage were selected and then ground-truthed for canegrub damage. As most satellite images were collected in May and June 2013, the field assessment took place at a time where many of the canegrubs had gone too deep into the soil for detection. Hence, indirect detection, i.e. identification of damaged roots, was used.

Image data

High spatial resolution satellite imagery was collected by the GeoEye-1 sensor in both May 2013 for all three study sites. The GeoEye-1 images included four multi-spectral bands at 2 m pixels located in the blue, green, red, and near infrared part of the spectrum as well as a panchromatic band with 0.5 m pixels.

All the satellite images were radiometrically corrected to at-sensor reflectance values and orthorectified using the Shuttle Radar Topography Mission (SRTM) smoothed 30 m Digital Elevation Model (DEM). After the orthorectification, the panchromatic band was merged with the multi-spectral bands to pan-sharpen the images to produce colour images with the highest possible spatial resolution of 0.5 m pixels. Finally, the images were geometrically matched to the existing spatial GIS layers of sugarcane block boundaries. These GIS block boundary layers were also used in the OBIA mapping approach.

GEOBIA method

The eCognition Developer 8.9 software was used to develop an approach for mapping of canegrub damage by building up a rule set of conditions based on the pan-sharpened imagery. Initially, the existing GIS layer of block boundaries was used to segment the sugarcane block boundaries (Figure 2b).

Subsequently, all areas with sugarcane within the block boundaries were mapped to exclude fallow and already harvested areas from further analysis (Figure 2c). Then, a fine scale segmentation at a new level was produced to divide each block into smaller homogenous objects (Figure 2d).

As canegrub damage is often manifested by reduced growth, stool tipping and exposure of bare ground, the cane occurring within an object representing ‘canegrub damage’ appeared less green than healthy undamaged cane.

Hence, a vegetation index (Normalised Vegetation Difference Index (NDVI)) based on the red and near infrared bands (Figure 2e) was produced to automatically locate those parts of a block with the lowest 30 quantile of NDVI values.

This threshold was empirically derived. As different blocks have different cane varieties and hence different reflectance properties, the analysis was done at the block level to avoid confusion caused by different cane varieties.

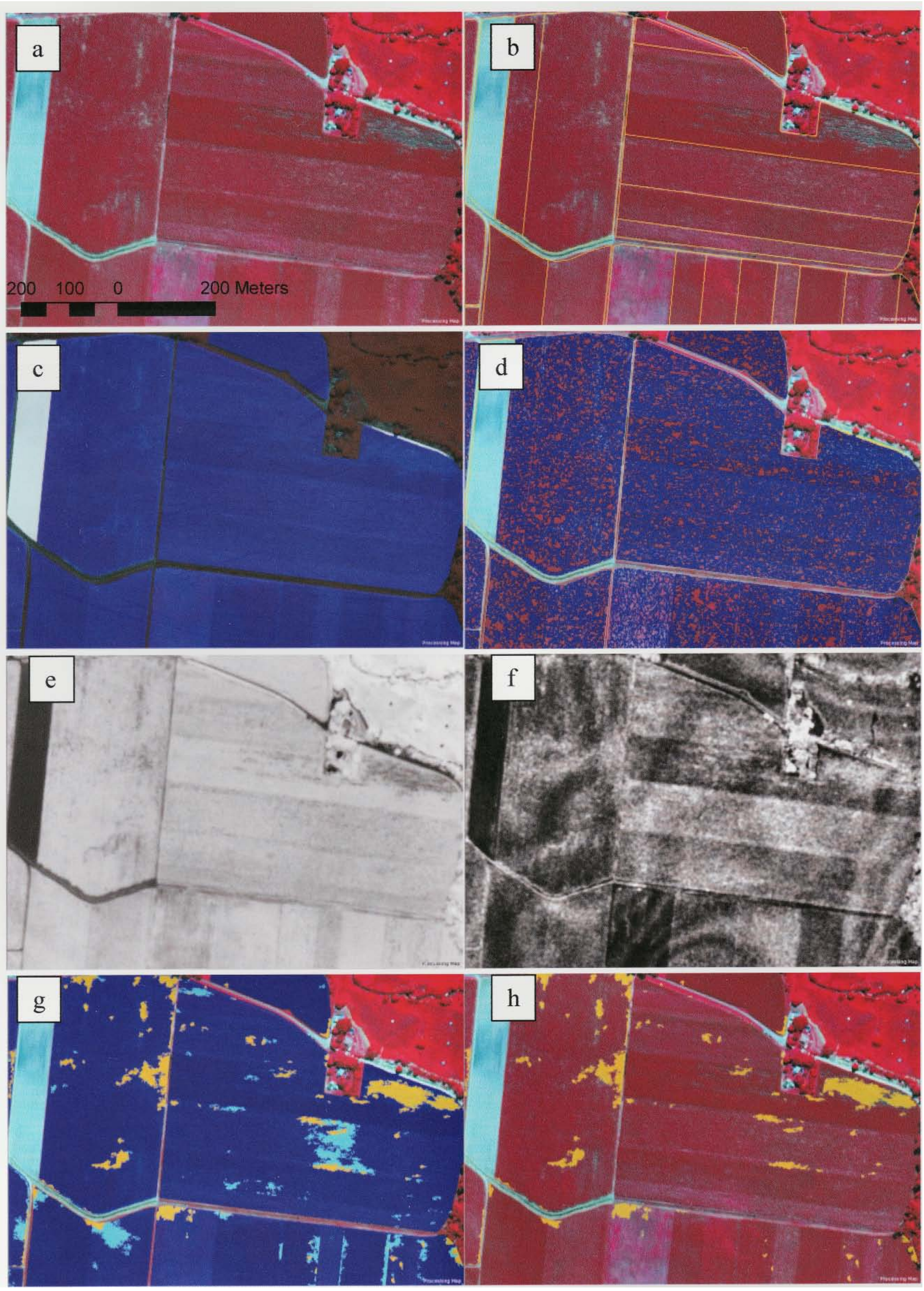

Fig. 2—Processing workflow using object-based image analysis of the satellite imagery: (a) image subset in the Gordonvale area with known grub damage; (b) block boundary segmentation (yellow lines); (c) classification of fallow (white) and cane (blue) fields; (d) fine scale segmentation (blue lines); (e) normalised difference vegetation index; (f) texture image; (g) classification of likely (yellow) and less likely (cyan) grub damage; and (h) classification of likely grub damage (yellow).

As well as having a reduced NDVI value, the damaged areas often displayed a 'rougher' texture than healthy cane. Hence, an edge detection filter was used to identify distinct brightness edges.

To reduce noise, a Gaussian smoothing filter was used to highlight areas with rough texture (Figure 2f). Subsequently, the 70 quantile (30% of highest values) of the smoothed edge layer was used to identify the 30% brightest objects, indicating areas with lots of edges, i.e. rough texture, which can be expected in areas with damaged sugarcane.

This calculation was also done for each individual block to avoid confusion caused by different cane varieties. The 70 quantile (30% of highest values) of the standard deviation of the red layer objects was also used to identify those areas with the roughest texture, potentially representing damaged sugarcane. If these conditions were fulfilled, the objects were considered to be potential grub damage.

As breaks between individual blocks were often included and incorrectly classified as grub damage, these were subsequently excluded, if the objects were elongated, narrow, had smooth edges and had a direction of +/– 5 degrees of the main block direction.

As the potential 'grub damaged' objects only represented those areas with the lowest NDVI values and roughest texture within each block at this stage in the mapping approach, it was considered important to assess the absolute NDVI and texture difference between the potential grub damage objects and the remaining parts of each individual block.

Hence, a number of conditions were specified in the rule set to classify the likelihood of an object representing grub damage based on how different the NDVI and texture values were in relation to the remaining parts of the block (Figure 2g).

For an object to be classified as 'likely' grub damage, absolute differences above a set threshold in both NDVI and texture values were required. Further refinements to the classification was also performed, e.g. by excluding very small objects (< 50 pixels) and, if an object classified as low likelihood grub damage was completely enclosed by likely grub damage objects, the 'low likelihood' objects were reclassified 'likely' (Figure 2h).

Validation

The classified maps were imported into ArcGIS for interpretation and validation purposes. Two types of field data were used for the validation:

(a) the field based observations based on visual interpretation of the satellite imagery;

(b) field based observations of grub damage identified independently of the satellite imagery.

These field based observations were compared to the mapping results and used to calculate the mapping accuracy.

Results and discussion

The developed rule set was found to be transferable between the three study sites, as it was developed based on statistics related to each individual image scene and individual sugarcane blocks within each image scene. Hence, the same processing steps were used for all imagery.

Two examples of the canegrub damage mapping results are provided in Figure 3.

The mapping results were assessed against field observations from locations

(a) identified visually in the satellite imagery prior to producing the mapping results and

(b) identified in the field independent of the satellite imagery.

The field based observations of the Gordonvale area were categorised into light, moderate and heavy grub damage, whereas grub damage was noted as present or absent at the Home Hill and Mackay sites.

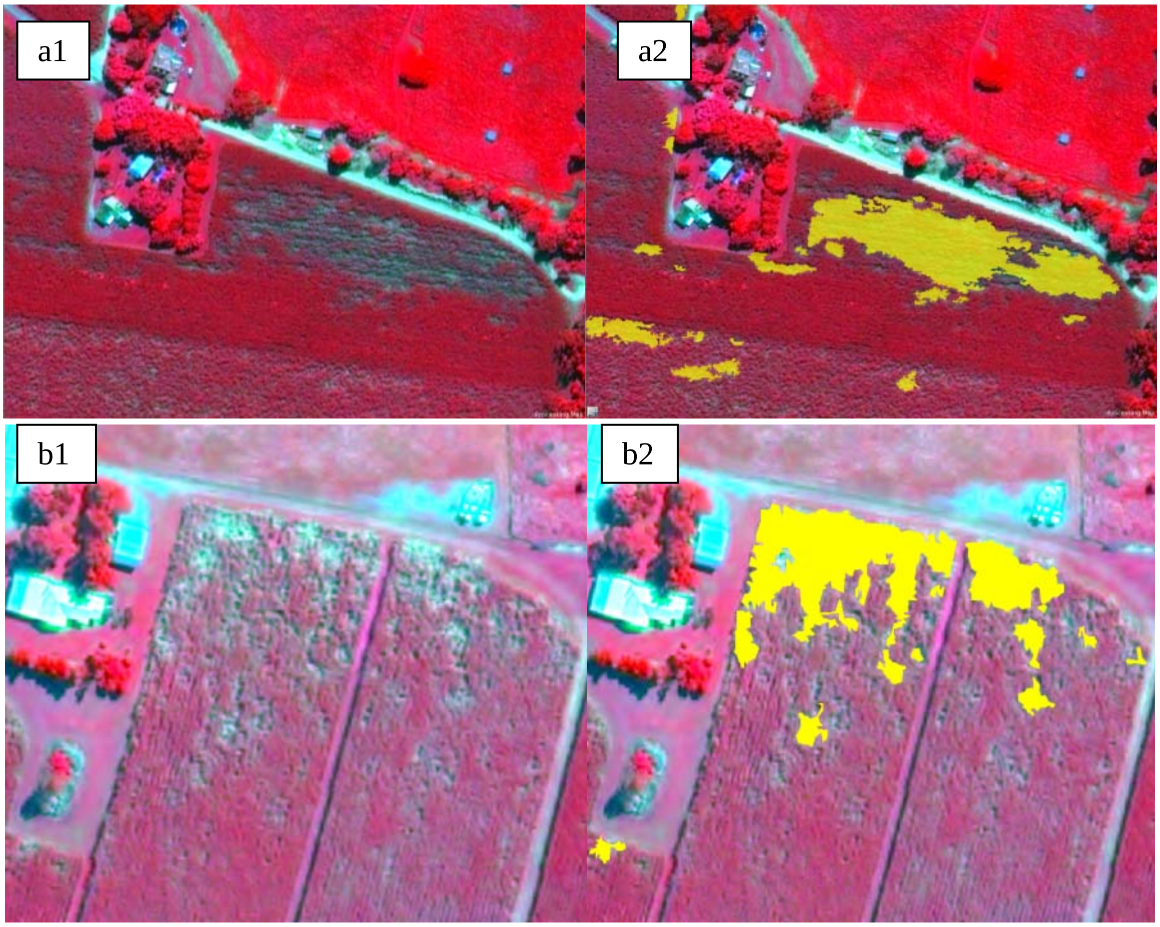

Fig. 3—Two classification examples from (a2) Gordonvale and (b2) Mackay of the mapping results of canegrub damage (yellow). The origial image subsets (a1 and b1) are included to visualise what grub damage look like in the satellite imagery.

Of the Gordonvale sites, between 70% and 80% of the grub damage was correctly mapped using the automated mapping approach in the eCognition software, relative to field-based validation (Table 1).

Of the independently field assessed sites in the Gordonvale study area, the locations with heavy grub damage had the highest mapping accuracy, whereas those locations with light grub damage had the lowest mapping accuracy (Table 2). This is not surprising as the areas with heavy grub damage appeared visually more distinct in the satellite imagery.

Table 1—Accuracy assessment of imaged grub damage at the Gordonvale site, 26 May 2013.

	Light grub damage	Moderate grub damage	Heavy grub damage
Classified correctly	61	26	8
Not classified	20	11	2
% correctly classified	75.3%	70.3%	80%

Table 2—Accuracy assessment of Gordonvale site, 26 May 2013 based on field data independent of image data.

	Light grub damage	Moderate grub damage	Heavy grub damage
Classified correctly	7	10	3
Not classified	16	10	1
% correctly classified	30.4%	50.0%	75%

The mapping results for the Home Hill and Mackay sites appeared with lower mapping accuracies (Tables 3–5). Several false positives, i.e. locations without grub damage but classified with grub damage, occurred. The locations incorrectly classified with grub damage did, in most cases, appear with some level of damage or disturbance caused by the presence of weeds, rat and pig damage, sprawling or water inundation. Therefore, the mapping results may be used to alert growers to where damage of various kinds is present. As damage cause a reduction in yield, it can be assumed that growers would be interested in inspecting any kind of damage occurring on their property before a subsequent treatment strategy is decided upon and applied.

Table 3—Accuracy assessment of imaged grub damage at the Home Hill site, 26 May 2013.

	Grub damage	No grub damage
Classified correctly	18	14
Not classified	16	22
% correctly classified	52.9%	38.9%

Table 4—Accuracy assessment of imaged grub damage at the Mackay site, 26 May 2013.

	Grub damage	No grub damage
Classified correctly	35	8
Not classified	17	10
% correctly classified	67.3%	44.4%

Table 5—Accuracy assessment of Mackay site, 26 May 2013 based on field data independent of image data.

	Grub damage	No grub damage
Classified correctly	16	0
Not classified	15	0
% correctly classified	51.6%	0

Further work in 2014 will focus on improving the eCognition rule set based on the image interpretation results and validation. It is anticipated that mapped grub damage will be assigned a probability of actually being grub damage based on additional information to be included in the mapping approach:

- distance to cluster/corridor of trees (requiring all trees to be mapped)
- soil type
- distance to neighbouring mapped grub damage
- grub damage history based on mapped time-series (currently including 2–3 years of imagery)
- years since last treatment.

The occurrence of grub damage in individual cane varieties will also be assessed. It is envisaged that this additional information will be used to produce risk maps indicating where grub damage is likely to occur the following year. This may provide useful information for cane growers for preventing or at least reducing the occurrence of future grub damage and hence increase future yields.

Conclusions

This research provides an automated canegrub damage mapping approach using high spatial resolution satellite imagery and the eCognition mapping software. The initial satellite image based mapping results appear with mapping accuracies between 53–80%.

Based on research to be conducted in 2014, it is expected that a refined mapping approach, yielding higher mapping accuracies, will be produced. The results of this research will help cane growers to manage and reduce damage caused by canegrubs and increase future yields.

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