Detection of pasture pests using proximal PA sensors: a preliminary study investigating the relationship between EM38, NDVI, elevation and redheaded cockchafer in the Gippsland region

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Abstract

The redheaded cockchafer (*Adoryphorus couloni)* (Burmeister) (RHC) is an important, native soil-borne pest of improved pastures in South Eastern Australia. The aim of this preliminary investigation was to determine whether commonly used Precision Agriculture (PA) sensors could identify landscape attributes that correlate with RHC population density. Soil apparent electrical conductivity (soil EC_a) measurements were derived from EM38, relative photosynthetically-active biomass via the normalised difference vegetation index (NDVI) derived from an Active Optical Sensor (AOS) and elevation measurements derived from dGPS (differential global positioning system) mapping. Eight paddocks across seven properties in the Gippsland region of Victoria were surveyed using a Geonics EM38, CropCircle™ AOS and a dGPS. Eighteen to twenty sample sites in each paddock were selected based on different zones of soil EC_a, and the RHC (and other cockchafer species) populations were assessed at each of these sites. No RHC were found in East Gippsland confirming that the damage to pasture observed by farmers at this time was caused by a different cockchafer species. Few RHC were found across all sites, probably due to high rainfall, however correlations tended to suggest that RHC were more likely to establish or survive in areas of high elevation and low soil EC_a. On one property RHC were associated with low NDVI values and at one other high NDVI suggesting more complex relationships may exist between AOS data and RHC densities. Threshold-level relationships were apparent between RHC density and elevation and EC_a to suggest that a useful indicator of pest risk could be developed, at least for some areas of Gippsland, however the relationships are complex and need to be investigated further.

Keywords

Redheaded cockchafer, *Adoryphorus couloni,* EM38, CropCircle™, elevation mapping, precision agriculture

Introduction

The redheaded cockchafer (*Adoryphorus couloni)* (Burmeister) (RHC) causes severe damage to pastures of South Eastern Australia, especially in Gippsland, a key dairying region of Victoria (Mickan 2008; Douglas 1972). A survey recently undertaken in Gippsland reported that the cost of pasture renovation, replacement feed and the loss of production caused by the RHC ranged from between \$23,520 - \$212,124 per annum per producer (Mickan 2010). Rath and Pearn (1993) calculated that in Victoria alone over 3 million hectares of agricultural land were subject to damage by the RHC. The situation is made worse by the lack of insecticides registered for use against RHC and the absence of effective cultural controls (Hardy and Tandy 1971). Mickan (2008) suggested that there are some deep rooted plant species such as cocksfoot, lucerne and phalaris which are less susceptible to RHC damage when compared with perennial ryegrass, however the benefits of planting these species to prevent RHC damage has not been thoroughly explored.

Biological information surrounding RHC is limited and action thresholds published have been highly variable (Rath and Pearn 1993; Hardy and Tandy 1971). The RHC has a two year life cycle but, due to overlapping generations, damage can be observed each year, typically in late summer and autumn (Mickan 2008). Damage is often noticed as large patches of overturned pasture as a result of cattle or machinery tearing up grasses with weakened roots or birds foraging on the larvae (Douglas 1972). Given the apparent connection between the incidence of RHC and soil condition and above-ground pasture biomass, the aim of this study was to conduct a preliminary investigation to determine whether there is any evidence of a relationship between RHC population densities and soil apparent electrical conductivity (soil EC_a) derived from EM38, the normalised difference vegetation index (NDVI) derived from an Active Optical Sensor (AOS) or elevation measurements from dGPS (differential global positioning system) mapping. If a relationship between any of these measurements and RHC populations was to be observed, proximal Precision Agriculture (PA) tools could be potentially used to develop a landscape risk assessment to predict where RHC infestations are most likely to occur for targeted pest control measures. A similar project was undertaken to improve early detection methods for the root-feeding insect, grape phylloxera, in vineyards (Bruce *et al*. 2011).

Materials and methods

Study sites

Seven properties were selected across the Gippsland region in Victoria and an electromagnetic induction (EMI) survey and a NDVI survey were conducted simultaneously in either December 2010 or January 2011. There were three properties in West Gippsland: WG1 (-38.1539,145.72), WG2 (-38.1472,145.741) and WG3 (-38.0616,145.7401), two in South Gippsland: SG1 (-38.8264,146.227) and SG2 (-38.8113,146.2059) and two in East Gippsland; EG1 (-37.7439,148.460) and EG2 (-37.7219,148.4471). The properties were selected because they have reportedly suffered severe damage from RHC for a prolonged period. Commercial dairying is the sole enterprise of each property with the exception of WG3 which runs beef cattle and sheep. Each property had predominantly perennial ryegrass pastures.

EMI measurements

A Geonics™ EM38-RT (Geonics Ontario, Canada) sensor was used for the EMI survey in horizontal dipole mode ($EC_{a\text{-}H}$). The EMI surveys were undertaken in December 2010 and January 2011 whilst the soil moisture profile was full due to recent heavy rainfall. Soil EC_a measurements were logged along with dGPS coordinates using a Trimble TSCe Ranger Field Computer coupled to a 1Hz Trimble ProXRS dGPS receiver. The paddocks were traversed on ≈25 m transects after the EM38 had been zeroed and nulled as per the manufacturer's protocol. The data obtained were interpolated onto a 10 m grid and kriged (block size 10 m) using the software package, Vesper.

NDVI measurements

A Holland Scientific™ CropCircle ACS210, an AOS, was used for the NDVI survey to obtain a sense of the pasture biomass at the time of the survey (December 2010 and January 2011) by collecting the spectral reflectance values of the pasture in the paddock. The CropCircle™ was mounted to the all terrain vehicle at ≈ 90 cm above the ground and logged simultaneously with the EM38 instrument. NDVI was calculated by the CropCircle™ from raw Near Infrared (NIR) (830 nm) and Red (650 nm) reflectance values (NDVI = (NIR - Red) / (NIR + Red); Rouse *et al.* 1974) and interpolated the data onto a 10 m grid using Vesper.

Elevation

A digital elevation map was produced using the dGPS data which were simultaneously acquired during the Crop Circle™ and EM38 surveys. A geographical information system, ArcMap, was used to create this map at a 10 m resolution.

Ground survey

Twenty sites were selected in each paddock using ESAP software which created three zones based on the soil EC_a recorded in the December 2010/January 2011 surveys. A dGPS was used to locate each site in the paddock. At each site a 25 cm x 25 cm quadrant was used to delineate a section of the pasture and a shovel was used to overturn the soil to a depth of ≈ 10 cm. The soil was thoroughly sorted at the sampling site and anything resembling a RHC life-stage was removed from the soil and stored in labelled jars of 70% ethanol. Insect specimens were then taken back to the laboratory for identification of species and stage using morphological characteristics. Each property was surveyed for RHC in both February and April, with the exception of WG2 which was surveyed only in April. The same sampling and identification protocol was used on each occasion**.**

Data analysis

The relationships between RHC larval counts, soil electrical conductivity, NDVI and elevation values were explored using scatter plots in the statistical program JMP. Scatterplots are a useful visual exploratory technique that enables the examination of the relationships that may exist between the variables.

Results and discussion

Of the seven properties surveyed, third instar RHC larvae were only found on the two properties in South Gippsland. Remnants of adult RHC were found on properties in both South and West Gippsland but no evidence of RHC populations was found in East Gippsland confirming that the damage observed by farmers in this area at this time was due to another cockchafer pest species. Overall, RHC populations were low and this was thought to be due to numerous large rain events which caused flooding on each of the properties. Remnants of several adult RHC were found whilst digging for larvae on all properties except those in East Gippsland.

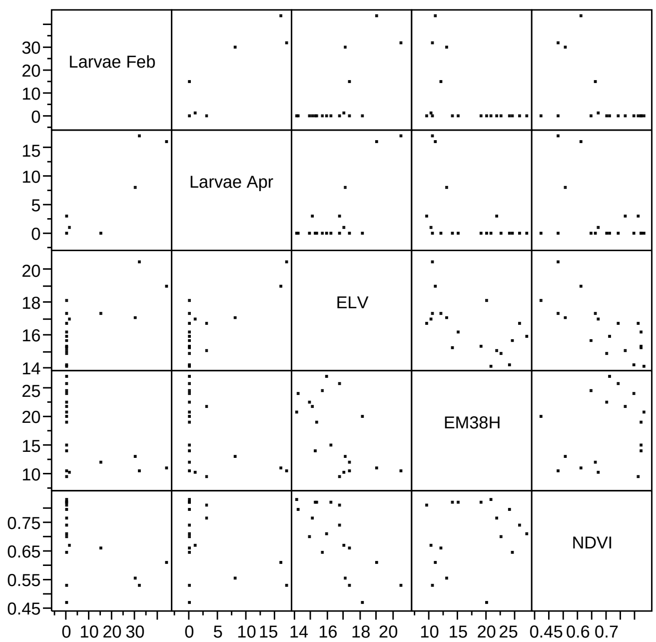

Figure 1. Correlation plot between third instar RHC larvae number, elevation (m), apparent soil electrical conductivity (EC_{a-H}; mS m^{-1}) and NDVI at SG1.

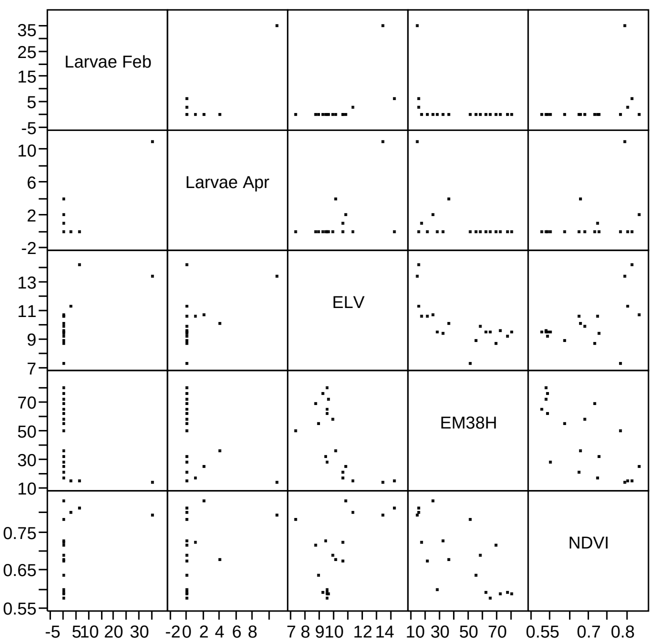

Figure 2. Correlation plot between third instar RHC larvae number, elevation (m), apparent soil electrical conductivity (EC_{a-H}; mS m^{-1}) and NDVI at SG2.

Figure 1 displays the relationships between RHC larval counts per sample in both February and April and survey deduced values for elevation (m), apparent soil electrical conductivity (mS m^{-1}) and NDVI on SG1. The general trend observed is that populations of RHC are found at higher elevations, which is possibly due to these areas having better drainage leading to shorter periods of waterlogging. It also appears that low EC_a is favoured by RHC with larvae found where EC_a is lower than 15 mS m^{-1}. However, a value below this does not guarantee the presence of RHC larvae, instead appearing to be the threshold level for RHC larvae to occur. In Victoria, RHC have been found to favour acidic sandy or sandy-loam soils over clay (Douglas 1972) and as apparent soil electrical conductivity is influenced by soil texture (Padhi and Misra 2011), EM38 surveys may be able to predict more susceptible areas of the paddock. Soil EC_a is influenced by a number of factors including soil texture, presence of ions and the water content of the soil (Padhi and Misra 2011). Correlations with lower soil EC_a suggests the soils favoured by RHC larvae are perhaps lighter in texture and/or have a lower water content.

Figure 2 displays the relationships between RHC larvae populations in both February and April and survey values for elevation (m), apparent soil electrical conductivity (mS m^{-1}) and NDVI on SG2. Similarly to SG1, RHC populations had the strongest relationship with elevation (m) measurements. Higher populations of RHC larvae were found in high elevation areas and low EC_a which was also what was found on SG1. However, on this property, non-zero counts of RHC larvae were found only for NDVI readings above 0.62.

There is some evidence that areas with an abundance of pasture biomass during spring when RHC are laying their eggs lead to higher infestations being observed in the following year (Mickan 2008). This would allow an AOS to assist in predicting areas susceptible to RHC attack.

Conclusion

A relationship between values obtained from Crop Circle™, EM38 and dGPS surveys and RHC population densities in areas of Gippsland, Victoria appeared to exist where RHC larvae were present. For some paddocks there appeared to be certain ranges of preferred NDVI and EM38H values but this relationship appears complex and paddock dependent, needing further exploration. It is likely that due to unusually high summer rainfall in the Gippsland area, RHC numbers did not reflect a 'normal' year with larval densities much lower than expected. Continued observations over additional seasons will assist in understanding such trends. Higher larval densities were observed in areas with lower EC_a values and at higher elevations on both South Gippsland properties. However, it appears that the relationship between RHC larvae and NDVI is more complex. For one property high NDVI appeared to favour RHC but for the other lower NDVIs were found to have higher larval densities.

Further research will involve finding properties with a history of severe RHC infestation and more than one paddock will be sampled on such properties. The spatial distribution of the RHC will be explored so sub-sampling of the paddock is more effective in understanding the existence of any relationships between RHC population densities and sensor data, including vertical soil EC_a. In future trials, the selection of sample sites will involve zoning up the paddock based on elevation, soil EC_a and NDVI measurements as opposed to just soil EC_a measurements as this may also help in understanding the link between RHC and each set of sensor data.

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