Managing diseases using Precision Agriculture

Summary

Precision Agriculture (PA) techniques were used to improve soilborne disease management. Inoculum levels were often found to differ between PA management zones. Satellite imagery or ground-based data (yield, electrical conductivity (ECa), and elevation) were best for defining disease risk zones. Differences in inoculum level between zones were frequently associated with differences in root damage and plant growth, but were only sometimes associated with yield differences. Methods were devised to define disease risk zones using soil sampling. A prototype decision framework model for Cereal Cyst Nematode (CCN) was developed as a template for other diseases. AccuCore soil sampling tools were developed and are commercially available.

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Conclusions
A series of conclusions has arisen from this research:

1. Soilborne disease inoculum levels often vary significantly between PA zones for all diseases studied.
2. Zones based on satellite imagery Normalised Digitalised Vegetation Indices (NDVI) and ground-based data (eg yield, ECa and elevation) provide the most accurate definition of disease risk zones, and both have gained acceptance from growers for general PA use. The best zone type for defining disease risk zones for any given disease in any given paddock is very difficult to predict.
3. Managing diseases using risk zones has economic potential and adoption will increase as more growers adopt GPS-guidance systems and then look for extra variable rate technology (VRT) uses for the equipment.
4. High inoculum levels in zones are very often associated with greater root damage and plant growth, but yield losses are only observed in some cases. Inoculum x zone x yield effects are more easily observed for take-all and crown rot than for rhizoctonia. The relationship between rhizoctonia inoculum level and yield loss is very complex and unpredictable with our current knowledge.
5. Soil tests need to be repeated annually for each zone due to the dynamic instability of disease inoculum levels.
6. Yield damage per unit of inoculum sometimes varies between zones, but an enormous amount of research would be needed before attempts could be made to predict this. In the absence of this predictive knowledge it is best to assume uniform effect across zones.
7. AccuCore soil sampling tools are useful and effective, but the high cost of production of the collection stand in Australia has almost certainly limited sales and adoption.
8. The prototype CCN decision framework model has successfully captured Australia’s first template for soilborne disease management incorporating PA zones. The model warrants further development, and should be considered as a template example for modelling other diseases.
9. Limited field observations strongly suggest that beneficial organisms associated with disease suppression are also strongly influenced by PA zones. This knowledge may have important implications for commercial use of soil inoculants.

Recommendations
The major recommendations arising from this project are:

1. The methods developed by this project be promoted to growers, consultants and researchers as best-practice for soilborne disease management. Specifically, best practice should be to:
   a. Test soil for disease inoculum in each zone prior to each crop using AccuCore or similar tools, and following prescribed sampling protocols.
   b. Assess the economic risk for each zone, considering inoculum level, yield potential and size of each zone.
   c. Choose strategies to manage the level of risk calculated, using crop choice, VRT disease treatments, and possibly re-allocation of crop inputs (e.g. nitrogen (N), phosphorus (P)) between zones.
2. Consider further research in key areas to capture further important benefits.
Outcomes
This project has equipped growers, consultants and researchers with knowledge, methods and tools to define disease risk zones within paddocks. These methods can be used in a number of ways to reduce the economic impact of soilborne diseases, and to use crop inputs more efficiently. Knowledge of the disease risk and yield potential in each zone will improve risk management by guiding decisions on crop choice and input (eg N, P) allocation between zones. This will increase yield and improve input use efficiency. Disease risk zones may also be used to allocate variable rate treatments (VRT) such as seed dressings to only zones where it is economically viable. Judicious targeted pesticide use has potentially both economic and environmental benefits. Growers can target soil sample positions within zones to collect a single, more representative sample for the whole paddock. Sampling of poor-yielding zones can also determine whether low yields are caused by disease.

The project has accelerated the adoption and hence earlier capture of the economic benefits by giving experience to farmers, consultants and researchers through project collaboration. It has been demonstrated that there is potential for economic gains from using disease risk zones, and that sometimes yield losses can be predicted. It has also been demonstrated that customised and expensive zone models are not necessary to produce disease risk zones. The CCN decision framework model has the potential to be a template for future models for other diseases, and with further development should become a valuable field tool for management of CCN. It is the first decision framework tool in Australia to model disease within zones. The project has also observed that beneficial organisms can exhibit differences in behaviour between PA zones. Little research was possible on this area, but future research into zonal behaviour of beneficial organisms may be very important, especially for commercial inoculants.

Potential environmental benefits may come from targeted seed dressing/pesticide applications that treat only the zones where they are needed. Use of disease risk zones in input allocation decisions may also have environmental benefits by matching fertiliser (eg N and P) inputs to crop growth potential. The project outcomes will contribute to adoption of GPS-based equipment. Use of this equipment is often associated with reports from growers of social benefit outcomes such as reducing the stress and effort of certain tasks (eg spraying, reaping), and more flexible use of available farm labour.

Achievements/Benefits

Overview
Project DAS00035 has successfully developed practical techniques to define disease risk zones within paddocks, and provided experience of the techniques to a wide range of researchers, consultants and growers through collaboration and extension. Research knowledge, commercial sampling tools and a prototype decision framework tool for CCN have also contributed to improved disease management strategies.

Background
Soilborne diseases can cause major yield losses, and their management often drives crop rotations. The large yield increases in the past 10 to 20 years have been underpinned by use of rotations to manage soilborne diseases, especially cereal cyst nematode (CCN) and take-all. Historically, management has been based on estimating the average risk for the paddock, and applying strategies uniformly to the paddock, often using non-host crops resistant varieties. Variable rate farming systems could allow the use of treatments that may have previously been considered too expensive or impractical for use over the whole paddock, such as seed fungicides, especially if targeted at high yielding areas with a significant disease risk.

Recent developments in DNA-based assays used in new decision support services such as Predicta B, enable grain producers to determine inoculum levels of a broad range of soilborne diseases prior to seeding. Research on PA zones showed that many attributes (eg soil pH and P level) differed significantly between zones. Results from GRDC/SARDI project DAS311, using PredictaB tests, suggested that this was also the case for soilborne disease inoculum.

Issues addressed by Project DAS00035

Project DAS00035 further exploited this finding to improve management of soilborne diseases using spatial information. Issues addressed by the project included:

a. How frequently do differences occur between zones?

b. Which spatial data layers best define disease risk in zones?
Research and results

a) How frequently do differences occur between zones?

Inoculum levels differed significantly between zones in 55% of disease x zone cases. It is clear from this research that zonal differences in disease risk are common. Disease inoculum levels were measured in zones of 20 paddocks, using sampling methodologies developed in GRDC/SARDI project DAS311. Zones were constructed using a range of spatial paddock data including satellite imagery (Normalised Difference Vegetation Index- NDVI), yield, ECa (from EM38), and elevation. Soilborne diseases studied included rhizoctonia, CCN, take-all, crown rot, common root rot and *Pratylenchus* spp.

b) Which spatial data layers best define disease risk in zones?

“Satellite” zones (based on NDVI) and “ground-based” zones (using yield, ECa and elevation) gave the best results. They are also currently the most commonly-used commercial zoning systems. These systems performed better over-all than any other zone constructs tested, although most zones defined disease risk to a greater or lesser extent. They performed equally well for CCN, rhizoctonia and take-all. Data layer sets were collected over 13 study paddocks to determine which spatial data layers were most useful for defining disease risk zones.

Spatial layers included satellite imagery (NDVI), yield, ECa (EM38), elevation, slope, Yara N-sensor data, aerial photography, plant cell density (PCD), biomass-yield gap data, and gamma radiometric data. These data sets were analysed using a correlation matrix to select layers for inclusion in multiple linear regression, then candidate layers were combined using a clustering techniques to create zones. Satellite zones performed better for crown rot, but ground-based zones performed better for common root rot and *Pratylenchus* spp. Customised zones (tuned to specific diseases) generally did not perform well enough to warrant use. “Bio” zones (yield, aerial photography, biomass, PCD) and “Geo” zones (elevation, slope, ECa, gamma radiometrics) performed well in some instances, but overall were not as reliable as some other types. The research showed that it was very difficult to predict which zone system would be best for any particular situation, so it is suggested that either satellite (NDVI) or ground-based (yield, ECa, elevation) zones should be used, depending on availability and price. Given current knowledge it seems unlikely that growers benefit from using a zone system designed specifically for one disease or another.

c) Do differences between zones translate to differences in plant damage?

In most cases higher levels of disease inoculum in zones caused higher levels of disease on roots. There were cases of yield differences associated with different inoculum levels between zones, however in most cases this relationship was weak or confounded.

This finding supports the idea that soilborne disease is only a primary yield driver in some zones. There was also some evidence of different levels of beneficial soil organisms occurring between zones. Measured disease inoculum levels need to be converted to risk of yield loss to help growers optimise agronomic decisions. This relationship is often complex, with seasonal conditions playing an important role. Field research using small plots, fumigated plots and header yield data was designed to measure the effects of differential inoculum levels on plant growth within zones. Experiments were conducted in eight paddocks, targeting take-all, crown rot, and rhizoctonia. The amount of damage per unit of disease inoculum varied across zones in some instances, but not in others. The interactions associated with it appear very complex, so it is suggested that end-users assume that disease inoculum will be equally damaging in each zone for a given level. As an example, at a Crystal Brook site crown rot inoculum before sowing was low in one zone, and high in two others. Wheat yield was reduced by 25% in the two high zones, and harvest index was also reduced from 35% to 31%. In another paddock at Pinery during the 2006 drought, high rhizoctonia levels reduced wheat yield in one zone (loam flats), but not zones comprising sand hills or slopes.

d) How can the spatial information be used to improve management?

This project has identified that Precision Agriculture (PA) management zones can be used to manage soilborne diseases in four ways:

c. Do differences between zones translate to differences in plant damage?

d. How can the spatial information be used to improve management?

e. Developing outputs to assist with adoption.
1. Stratified random sampling. Most soil sampling protocols currently use a zig-zag transect pattern across a paddock, without regard to patterns of spatial variability. PA management zones allow consideration of the size and distribution of variability when choosing sampling points to ensure that each zone is proportionally represented in the composite soil sample.

2. Diagnosis of low-yielding zones. Targeted soil samples can be taken from low yielding zones to confirm or eliminate soilborne disease as a cause.

3. Risk management. Analysis of PA management zones often shows that one zone is expected to produce higher yields than the others. It is therefore more significant if this zone is affected by soilborne diseases than would be the case if an inherently low-yielding zone were affected. Growers who do not wish to test each zone for disease inoculum may decide instead to test only the higher-yielding zones to offset the higher risk of crop failure in these zones. Inputs (e.g., nitrogen) may also be re-allocated between zones based on knowledge of disease risk and yield potential.

4. Variable Rate Technology. It is feasible to vary inputs at the zone level to manage soilborne diseases. For example, a grower may choose to use a seed dressing which reduces the impact of take-all by sowing treated seed only in a high-yielding zone at risk from take-all. Judicious targeted pesticide use has potentially both economic and environmental benefits.

e) Developing outputs to assist with adoption

Integration of the research results has produced the following guidelines that growers and advisers can adopt to improve management of soilborne diseases:

1. Construct PA zones using satellite or ground-sensed layers and test the soil in each zone.
2. Assume that damage per unit of disease inoculum will be equally damaging across zones.
3. Assess disease risk in each zone taking into account yield potential and zone area (ha).
4. Design management strategies (e.g., VRT fertilisers, seed treatments, sowing rates etc) which manage the level of disease risk in each zone.

As confidence grows in variable rate farming systems, growers have the opportunity to use treatments targeted at high-risk zones to control specific diseases to enable more profitable crops to be grown more frequently. Accucore soil sampling tools have been developed and are now commercially available to assist with determining disease risk in zones.

A prototype computer-based decision framework model for cereal cyst nematode (CCN) has been completed by the South Australian Research and Development Institute (SARDI) and Applied Economic Solutions Pty Ltd (Mr Mike Krause). The prototype model is designed to be used by researchers and practitioners to experiment with the effects of an array of variables that affect CCN population dynamics and crop losses within PA zones. An open framework has been designed to allow researchers and future developers to change and add knowledge to the model. A feature is the inclusion of “amplification settings” which gives developers the ability to easily change the relative importance of variables, including “switching off” variables with uncertain effect. The architecture of the model was designed based on findings from a literature search and meetings with researchers involved with CCN. The model is only intended to be a prototype at this stage. Construction of the model has identified a number of “research gaps” and future use and refinement will no doubt identify further gaps. It is hoped that in the future the CCN model will be refined and available for growers, and that it may also serve as a template for other disease models.

Other research

This project pioneered soilborne disease management using PA and it revealed an area with excellent potential for improving grower profitability and reducing financial risk. A number of new R&D opportunities have been identified by the project:

Large-scale VRT experiments.

It would be valuable to combine the methods and knowledge generated by this research with the practical knowledge of VRT PA growers to manage disease problems in selected paddocks. A practical collaboration between researchers and VRT growers would demonstrate the practical use of the methods, and identify potential barriers to further adoption. The experiments would compare whole paddock management with VRT zone management. An example might be VRT seed dressing for take-all management.

Decision Framework development.
Further work would develop formal decision framework material. Methods and research findings from DAS00035 would be integrated with economic data and current yield loss knowledge. The material would provide consultants and growers with methods for assessing management options under varying PA zone scenarios.

CCN data under no-till systems.

The CCN prototype model evaluates potential impacts of CCN in zones over several seasons. Future development to prepare the model for field deployment will require multiplication rate and yield loss data from contemporary no-till systems. There is strong research evidence from the 1980s that tillage affects CCN damage, but there is a paucity of relevant data to validate the model.

Rhizoctonia inoculum level x yield loss.

Rhizoctonia continues to be a damaging disease of cereals in Australia. Fumigation research in zones of several paddocks has highlighted the unpredictable relationship between rhizoctonia inoculum levels and yield loss. Strong zone effects are evident, but the mechanisms are poorly understood from the relatively small data set generated. The benefits from understanding this relationship are potentially very large. Even if no direct VRT treatments are available in the short-term, reallocation of inputs (e.g., N, P) and adjustment of seeding rate and depth of disturbance at sowing may result in increased profitability. It is likely that a major research effort would be required to identify the major drivers in the relationship; perhaps the proposed major initiative on rhizoctonia.

Evaluation of more efficient yield loss experimental methods.

Research involving small plots and fumigated plots from 2003 to 2005 was time-consuming and expensive. In 2006 new methods were designed to increase the efficiency of spatial inoculum x yield loss research. Disease risk zones were defined and zone inoculum levels determined by soil sampling. Soil and plant samples were taken from experimental points (10m radius), and header yield data files were kriged around each point. The drought conditions of 2006 prevented collection of good data. It may be valuable to further evaluate this method in better seasons to more efficiently define yield loss risks.

Beneficial organisms and PA zones.

A spin-off discovery from this project was that beneficial organisms associated with disease suppression appear to be heavily influenced by PA zones. The same soil attributes that influence the spatial distribution of diseases can also act on beneficial organisms. Research targeted at the spatial distribution of beneficial organisms may have major implications for the successful deployment of commercial soil inoculants.

**Intellectual property summary**

The AccuCore soil sampler is the only output from this project subject to an agreement. A confidentiality agreement was signed in 2002 and an agreement allowing Spurr Soil Probes to manufacture and sell the AccuCore sampler was signed in 2003.

**Additional information**


Additional information is provided as attachments to this project:

- Attachment 1 DAS00035 pamphlet
- Attachment 2 DAS00035