A COMPARISON OF CROP SENSOR SYSTEMS FOR INFORMING FERTILISER PLACEMENT

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Abstract

A number of optical devices have been available to farmers to measure the development of growing crops such as cereals, brassica, maize and ryegrass for seed production. These vehicle mounted sensors are linked to GPS so that the position of the readings is recorded and can be accurately mapped in order to inform variable rate fertiliser or growth regulator application. Estimates of crop biomass are made using optical sensors which operate at discrete wavelengths in the visible and near infrared region of the electromagnetic spectrum. The usually accepted method is to use the Normalised Difference Vegetation Index (NDVI) of the crop and relate that to biomass.

Under the Sustainable Farming Fund Project, Crop Sensing for Improved Nitrogen Use Efficiency, (Project X09/08), three commercial systems which are available to farmers in New Zealand were used and their results compared with cut samples. The systems were; Greenseeker® from Trimble, Crop Circle® from Holland Scientific, and CropSpec® from Topcon. Each sensor uses at least two wavebands, with one in the visible range and the other in the near infrared, the Crop Circle sensor used (Crop Circle 470) had a third channel. Two main questions were considered. What is the level of accuracy of these sensors and, to what extent are the results from one sensor comparable to another system?

The systems were tested in a range of crops on farms in both the North and South Islands over a range of crop growth stages. The systems operate at slightly different wavebands and have different sampling footprints but are intended for the same purpose. The collected data was mapped in a GIS package and the geo-referenced data was analysed to determine the relationships between sensor based estimates of NDVI in the different crops, as the crop development was tracked. The results from the initial season of data collection and analysis are presented from some of the sites measured under the project.

Introduction:

The use of optical instruments is becoming an established part of the management decision making process around N fertilisation for major crops such as corn in the US and wheat in Europe. The three sensors used in this work have the same declared purpose but are slightly different in design and operation. The technical specifications are given in Table 1.

Materials and Methods:

Five properties were used in this trial, with at least one crop being monitored on each farm. The crops monitored were Maize (1 site), Wheat (5 sites) and Ryegrass on the three South Island sites. The crops were scanned at key growth stages for N management using the three sensing systems simultaneously while mounted on farm spray equipment. Two systems (comprising the three sensors) were used, one in the North Island and one for the South Island. One Greenseeker system was the property of AgriOptics will the others were owned by Massey University.

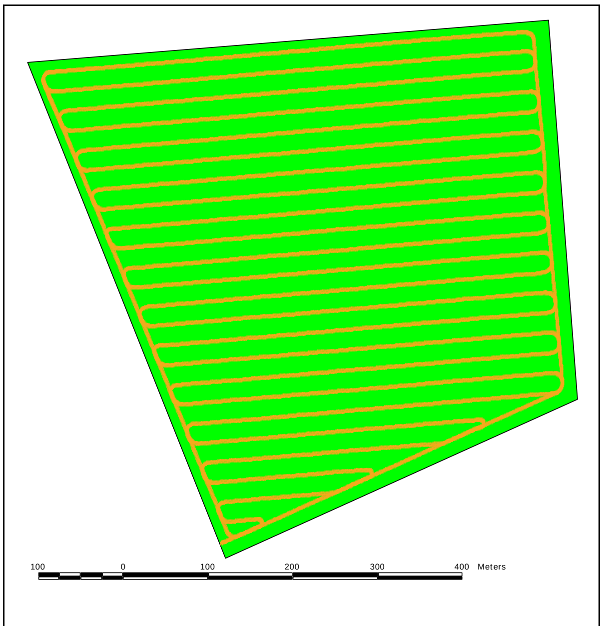
Table 1. Sensor specifications from Pullanagari (2010)

Specifications	**GreenSeeker®**	**CropCircle®**	**CropSpec ®**
Manufacturer	N Tech Indus. Inc.	Holland Scientific	Topcon
Model	RT 200	ACS 470	IP 67
Data logger	RTCommander	GeoSCOUT GLS 400	X 20
Light Source	LED	Modulated polychromatic LED array	Lasers
Power	12 VDC	10 to 17 VDC	10-32 VDC
Operational Wavebands	660/15 (Red) and 770/15 (NIR)	670/20 (Red) and 760/LWP (NIR)	730/10 nm (Red) and 800/10 nm (NIR)
Foot print/ Field of view	5×60 cm	15×57 cm (changes with height)	2-3 meters
Viewing angle	32°	32/6°	45-55°
Operating Height	0.86 meters	0.6-1.2 meters	2-4 meters
Mount	Handheld or Sprayer boom	Handheld or Sprayer boom	Tractor cab

Figure 1. Sensors in use. Cropspec sensors were mounted on the cab of tractor while the Greenseeker and Crop Circle Sensors were mounted on the spray boom as per manufacturer's instructions.

Each sensor system was linked to GPS, in most cases an RTKDGPS was used to give a high level of spatial accuracy. The systems recorded the crop reflectance data independently and GPS information was fed to each system. The process used to compare the performance of the sensors is explained in figure 2. The information was recorded, figure 2a shows a plot of the track used to record an example paddock. A 24m raster grid layer was then used to assign an interpolated grid value from each reading produced from the sensors that fall within that grid, assuming a forward speed of 12km hr^{-1} and a sampling rate of 5 Hz, the interval between points was 0.66 m meaning that 24 m of travel would produce approximately 36 readings from each sensor within each grid cell. Figure 2b illustrates the process, in this case light coloured areas have a lower NDVI, while the darker area have higher NDVI.

The raster grid values from the individual sensors were then used as the basis for comparison as individual points, although the GPS point was the same, the sensors were mounted on a slightly different positions on the boom or tractor for practical purposes. It was decided that as 24m was the minimum management scale, from the 24m tramline and sprayer width, to use that size of grid. The software used was SSToolbox, this software will always form a raster grid in north south orientation and provided the same boundary layer is used for calculation, the grid points will be in the same position within that boundary. This allows individual grid points within the layers of the GIS to be compared as they are geographically co-located.



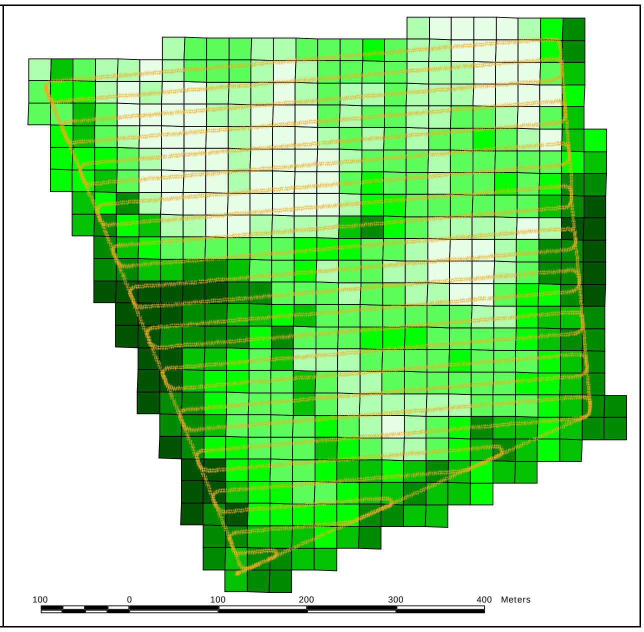


Figure 2a. GPS track of sensing process.

Figure 2b. Values assigned to raster grid sensors readings within each grid cell.

Figure 3 uses the data produced from this approach to compare raster layers produced from each of the sensors. The first thing to note is that the data in figure 3 is presented as standardised figures. (standard deviation of 1). This was completed in Excel and was done to get over the problem of the fact that the sensors produced different numbers. Although this was seen as a better basis for comparison the R^2 of the regressed results would be the same as if raw data was used.

In each paddock three areas were identified as being high, medium and low yielding (in terms of biomass) and 5 cuts were taken from each area of the paddock. This was done to compare the biomass estimate given by the sensors (NDVI) to actual above ground biomass. At the time of publication this data was not available.

The measurement process was repeated a number of times through the growing process, this was not always possible in each crop due to growing condition, for example in maize the crop quickly became too high to travel through with the sprayer unit. An example of the results from wheat, sampled five times between September and December are illustrated in Figure 4.

Results

At the time of publication many of the results had not been collated, however initial results would seem to indicate a reasonable consistency between sensors. Table 2 illustrate two crops, Wheat and Ryegrass taken in the early part of the season (September). Each point within the chart is a raster grid value. Within the wheat crop the Greenseeker and Crop Circle sensors would appear to give similar results. The Greenseeker data is oriented along the x – axis, the relationship with the CropSpec sensor appears slightly noisier with a poorer level of explanation given. The coefficient of determination between Cropcircle and Greenseeker is 0.88, where as the Crop Spec has a coefficient of determination of around 0.59 with the other sensors. The results within early season ryegrass show a similar level of explanation between the Crop Circle and Greenseeker sensors and this time the Crop Spec also has very similar results with a coefficient of determination around 0.80, as opposed to the 0.84 between the Crop Circle and Greenseeker.

The same wheat field was used to compare the performance of the sensors over time and growth stage. Five reading events took place between early September and December. The key growth stages for the intended use of these sensors is the early season and this is where there appeared to be greater consistency between sensors. As the crop grew then the relationship between the sensors appeared to break down slightly.

Figure 5 illustrates a crop of maize which was measured in the same way. In this case the results are represented in map form, again although the NDVI obtained from each sensor is different as observed from the legends in the figure, the relative pattern or distribution of NDVI over the field is very similar.

Conclusions

The purpose of this paper is to report some of the initial results from a Sustainable Farming Fund Project (X09/08) where one of the objectives was to compare the performance of three optical sensors designed for the purpose of estimating crop biomass through the use of an NDVI. These sensors are used to fine tune nitrogen application to a number of crops in situations where variable rate application of fertiliser is possible. Three crop are illustrated, wheat, ryegrass and maize.

Initial result suggest that although the sensors have different sampling footprints and wavelengths of operation, the results when used in the mode of operation tested, did appear to give some consistency between sensors especially in the early growth stages of the crop. As the architecture of the crop develops there is some evidence to suggest that the differences become more apparent. Further work is planned and further analysis of results collected so far will be collated and presented in the projects reporting process.

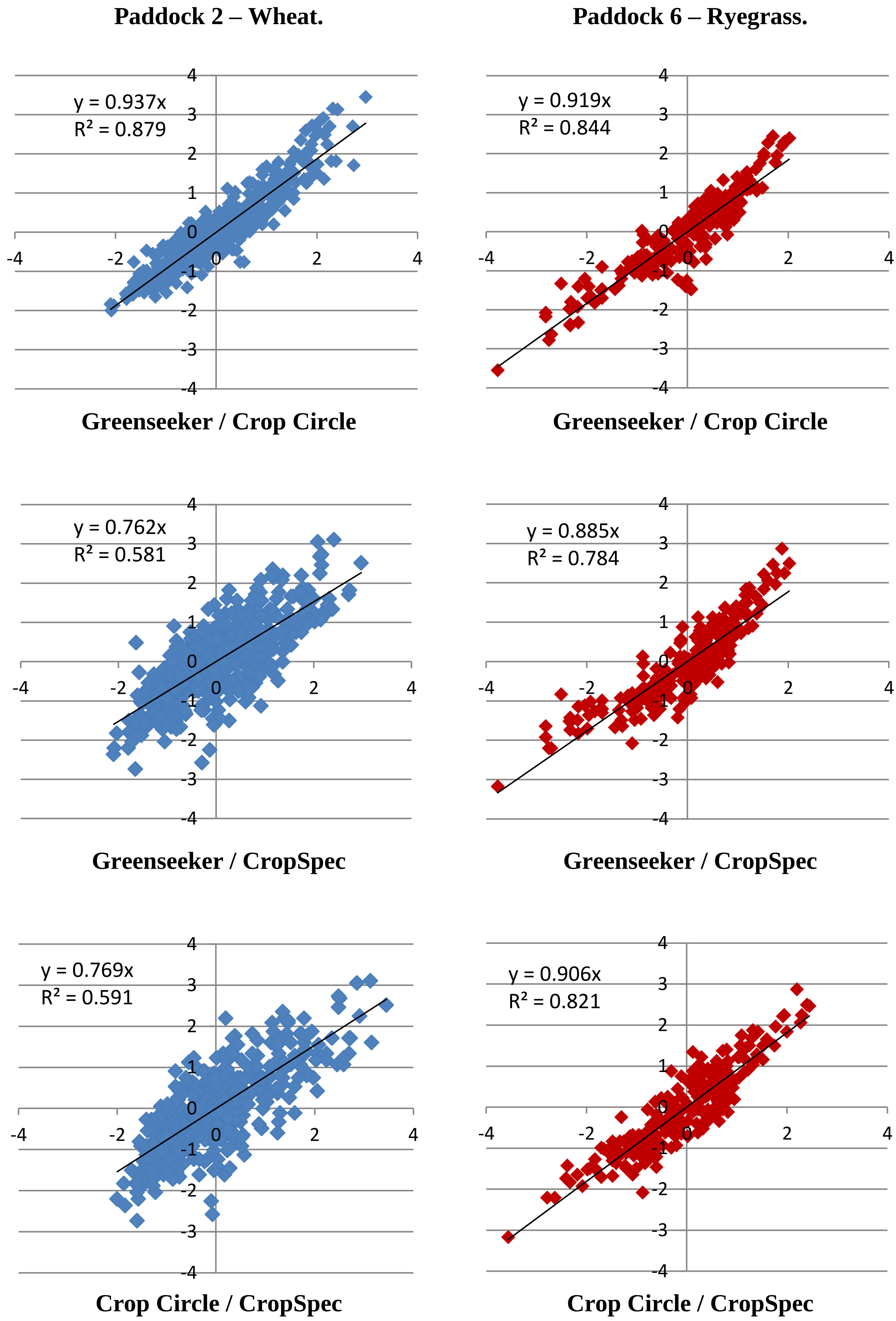


Figure 3. Comparison of sensor performance in Wheat and Ryegrass crops.

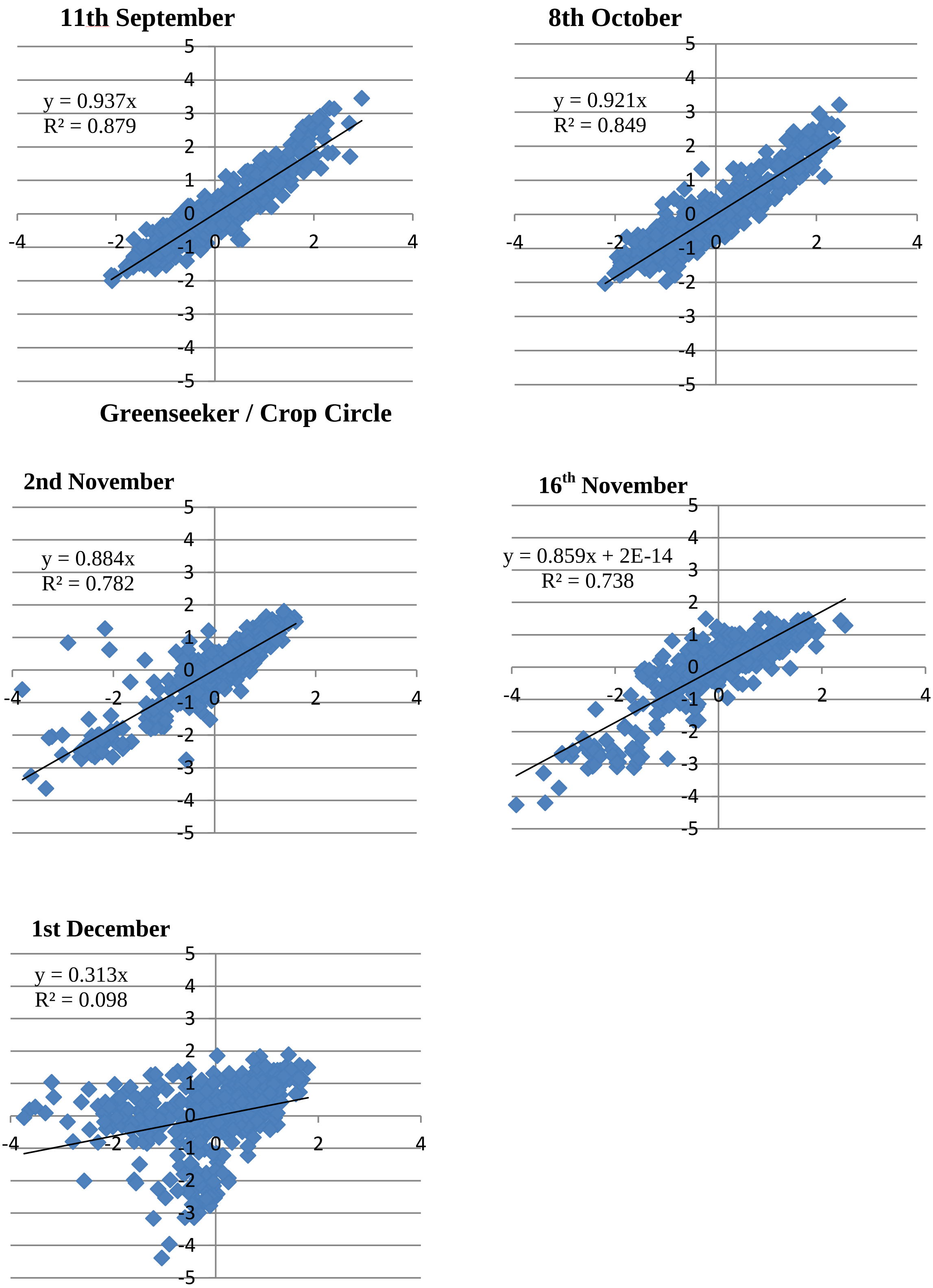


Figure 4. Comparison of Crop Circle and Greenseeker sensors through different growth stages in a wheat crop.

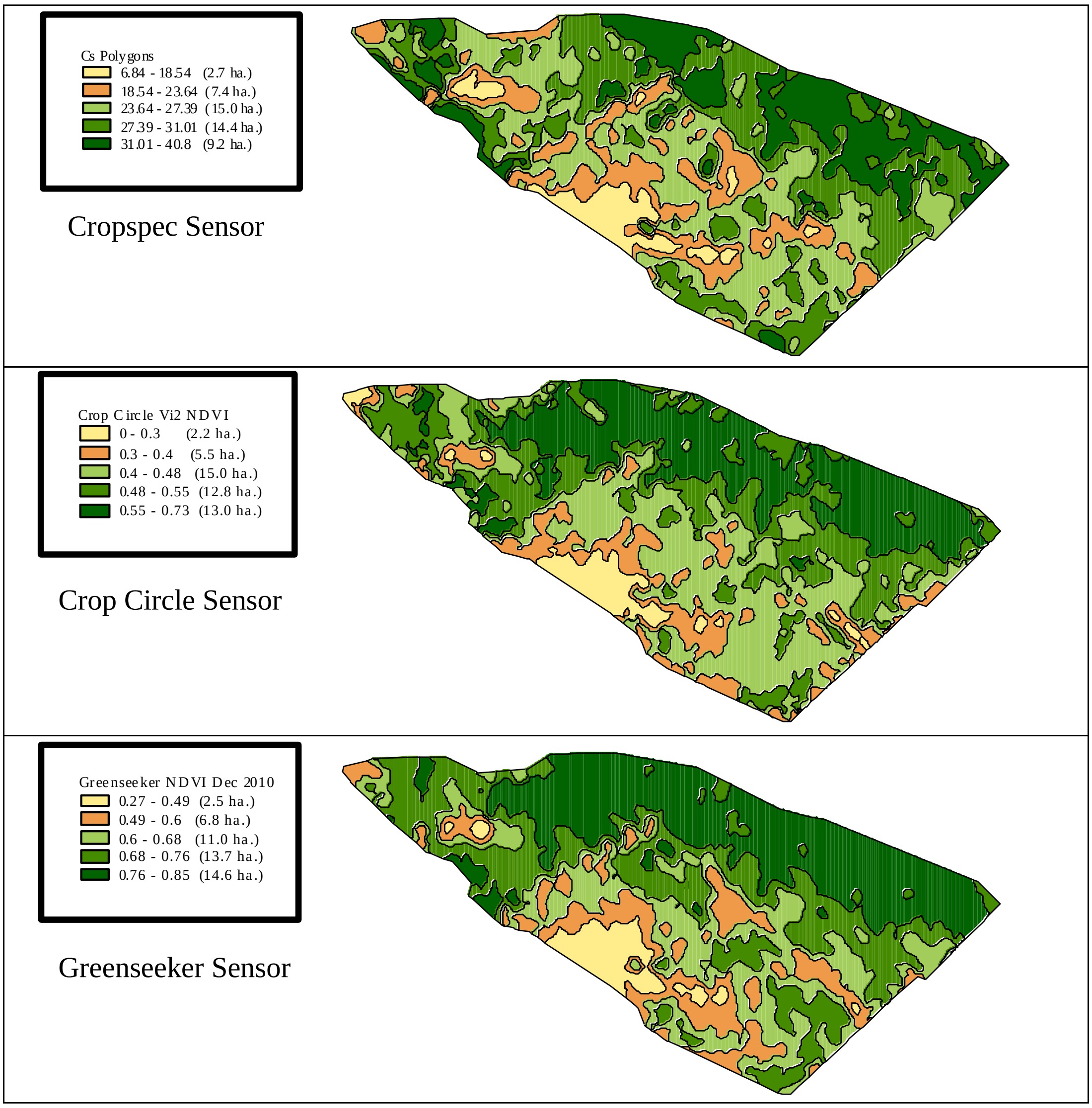


Figure 5. Maps of maize NDVI using the three sensing systems. Sensing completed on December 10th 2010.

References:

Pullanagari, R., Yule, I. (2010) In-field methods of collecting crop reflectance data. In: *Farming's future: Minimising footprints and maximising margins.* (Eds L.D. Currie and C.L. Christensen). Occasional Report No. 23. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. Pp. 429 – 433.