ADAPTATION OF OPTICAL SENSORS TO DETECT URINE AND DUNG PATCHES IN DAIRY PASTURE

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Abstract:
Fertilising urine patches on dairy farms leads to luxury levels of nitrogen being present which increases the risk of leaching as well as reducing the nutrient use efficiency of the fertiliser. A system called Smart-N™ has been developed that applies liquid nitrogen to pasture but avoids application to the urine and dung patches. The system uses four Trimble WeedSeeker® optical sensors to detect the existence of urine and dung patches and control the spray unit.

The WeedSeeker® technology was originally designed to sense weeds in a fallow field and activate the application of herbicide, in this pasture application the technology has been adapted to sense grass patches that are “greener” than surrounding pasture. This precision fertiliser application will help in reducing excessive application, produce more even pasture growth while reducing overall fertiliser application as well as reducing nitrogen leaching as the majority of N leached from pasture is already coming from urine patches.

The only physical modification required to test the setup included using a relay to reverse solenoid operation (open until sensing a patch). In order to log the data for analysis, a data acquisition systems was built that interpreted a 12 volt spike as “patch present” and sent the result to a field computer. The logging software on the field computer was setup to log GPS location along with WeedSeeker® data.

The initial research had two phases: First, a trial was set up to look at pasture response over time after fertilization, which is intended to be a patch simulation. Second; was a paddock scale trial which manually logging urine and dung patches with an RTKDGPS system and comparing these with the Smart-N™ results. Preliminary results indicate that sensor calibration is key to the success of the system.

Introduction:
Urine patches are a major source of agricultural pollution therefore if we could avoid adding extra nitrogen in the form of fertiliser directly to the urine spot this would have a number of benefits. Some of these benefits would include reduced luxury availability of nitrogen as well as increased nitrogen use efficiency.

While it is widely accepted that these urine and dung patches are a major source of agricultural pollution, there are still questions remaining over the nitrogen loading from cows, the density of urine spots, the distribution of these spots and their longevity. Broadcasting fertiliser does not have the ability to discriminate or avoid fertiliser treatment to a urine spot, therefore it is inevitable that a more site-specific sensor-based nitrogen application system is required to apply fertiliser only to the areas of the paddock that need the nitrogen and not the urine and dung patches where high concentrations already exist.

WeedSeeker is a highly sensitive optical sensor used in a commercial sense for detecting weeds using different wavelengths of light to enable it to differentiate between the target and non-target. This sensor coupled with its fast reading time and small window of view, enables this to be a very site-specific tool for targeting scattered weed infestations. All of these features that make it a robust automatic spot spraying tool also enables it to, with a little fine tuning, detect the difference in reflectance between a urine and or dung patch and areas of pasture that have not been affected by urine or dung patches.

Materials & Method:
A series of nitrogen rates were applied to pasture, the trial layout used a randomised design. Figure 1 gives the trial design with each shading indicating a different liquid nitrogen application rate. The application rates are as follows: White = 0 kg N ha^{-1}, Light Grey = 600 kg N ha^{-1},Medium Grey = 1200 kg N ha^{-1} & Dark Grey = 1800 kg N ha^{-1}

Trial Procedure
A Trimble AgGPS FmX system was use in conjunction with an RTKDGPS setup to collect GPS data, which was recorded on an X20 computer with a custom logging program. The WeedSeeker sensors are calibrated over a “buffer” strip where the “greenness” is low, but even and representative of an area that has had no nitrogen applied. After calibration the system is tested by driving down the plots to be sensed and adjusting the sensitivity setting if needed. This is a subjective decision and is altered in order to ensure the sensors are able to “see” differences. Once set, a new logging file was setup for each linear set of plots, which are driven at a constant speed of 5 kph.

As this trial was setup to use destructive measurements techniques (i.e. clipping a grass sample for analysis), plots were assigned a cutting day, which represents the time passed since all plots were mowed. For example, a “day 0” plot would have been clipped on the day of mowing and a “day 5” plot would have been clipped five days after mowing. Samples were taken on days 0, 3, 5, 7, 9, 11, 13, and 15. On each sampling day, all plots not previously subjected to destructive measurements were scanned with the WeedSeeker setup. Plate meter readings were also taken for each plot (before clipping) in order to draw correlations between sensor response and a commonly accepted method for measuring pasture height. Grass clippings were collected in approximately 200g samples. Care was taken to collect samples no closer than 4 cm to the ground. Samples were immediately transferred to a cool environment to reduce respiration and transported to AgResearch in Lincoln within 48 hours of clipping. The laboratory at AgResearch analyzed the samples for nitrogen content, which was the focus of this study.

The major component of the paddock scale trial consisted of comparing patch density (patches per hectare) from manual patch sensing with sensor patch density. The comparison was done by simply counting the total number of sensed patches in a defined area. This approach was used in two separate paddocks.

The trial was completed using liquid applied nitrogen using Teejet SJ3 nozzles, 10mm of irrigation followed N application to try and prevent burning. Biomass, N content and sensor detection readings taken every 2 days (starting day 3)

Day 7		Day 9	Day 5		Day 3	Day 0		Day 15	Day 11		Day 13
1		17	33		49	65		81	97		113
2		18	34		50	66		82	98		114
3		19	35		51	67		83	99		115
4		20	36		52	68		84	100		116
5		21	37		53	69		85	101		117
6		22	38		54	70		86	102		118
7		23	39		55	71		87	103		119
8		24	40		56	72		88	104		120
9		25	41		57	73		89	105		121
10		26	42		58	74		90	106		122
11		27	43		59	75		91	107		123
12		28	44		60	76		92	108		124
13		29	45		61	77		93	109		125
14		30	46		62	78		94	110		126
15		31	47		63	79		95	111		127
16		32	48		64	80		96	112		128

Trial Colour Key	
0 kg N/ha $^{-1}$	
600 kg N ha^{-1}	
1200 kg N ha^{-1}	
1800 kg N ha^{-1}	

Figure 1 Nitrogen trial, plot layout.

Data Logging

The logging application was built with National Instruments LabVIEW 2009 due to ease of use and available libraries to quickly access multiple serial ports. Logging spatial data from GPS units within LabVIEW is straight forward and entails collecting the entire GPS data string, which is then filtered to record only directly relevant information such as the longitude and latitude. Logging the WeedSeeker data was much more involved as the signals could come in at any time (various frequencies). This was dealt with by storing incoming data at the serial port until it could be read at the same frequency as the GPS data. Generally, GPS data was collected at 5 Hz in order to allow for five or six readings per plot at a speed of 5 kph. After WeedSeeker data was retrieved from the serial port, the data string was read to identify a sensor number and an "ON" or "OFF" signal indicated a change in sprayer status. These signals were counted and written to the log file along with GPS data and a timestamp. Pertinent operational data is reported on screen including total sprayer on/off cycles and a position map. Corruption in the data stream from a loss of GPS signal or an improper serial port selection is also possible. Due to there being many different types of GPS systems and various applications of the system, multiple logging frequencies can be selected through menu choice to overcome these issues.

Data Processing

There were a number of steps involved in data processing. After data collection, files are double checked for any corruption. All data must also be spatially corrected as the sensors are approximately 1.95 m behind the GPS antenna and between 0.90 and 1.80 m off to the side (depending on the sensor number). As this process is dependent on the direction of travel of the bike, the processing is done using an iterative approach in a spreadsheet application. Spatially correcting data in this study was quite important due to the precise nature of analysis. These corrections will be implemented "on the fly" once offset algorithms are completed.

Data Analysis

The primary program used for data analysis was ESRI ArcMap 9.3. After each set of data is collected on the plot scale trial, readings in a plot are evaluated for status (whether the sprayer is on or off). This approach allows for comparison between treatments. For example, if there are five measurements in a plot and three of the five are when the sensor senses a spot, 60% of the readings are of a spot, which can be compared to maybe 20% from another treatment.

Results:

Plate meter readings show an increase in measured height for all treatments. The high application rates of liquid Nitrogen used caused tissue burning of the pasture, resulting in slower growth rate than expected from the higher treatments (1200 & 1800 kg N ha^{-1}) compared to the 600 kg N ha^{-1} treatment in particular. Overall the 0 kg N ha^{-1} treatment maintained the lowest plate meter reading (measured in height) of all the treatments, as expected.

The growth rates derived from Figure 2, were very similar for all treatments, part of the reason being, that the higher rates of N application caused burning of the pasture, which retarded growth beyond the 600 kg N ha^{-1} level.

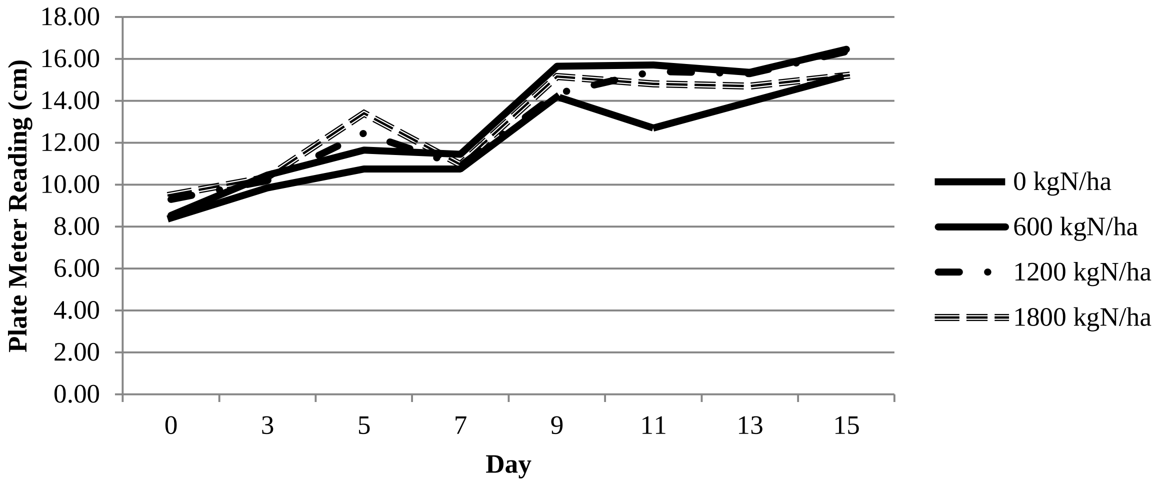

Figure 2. Plate Meter Results for first experimental period.

Biomass N Results:

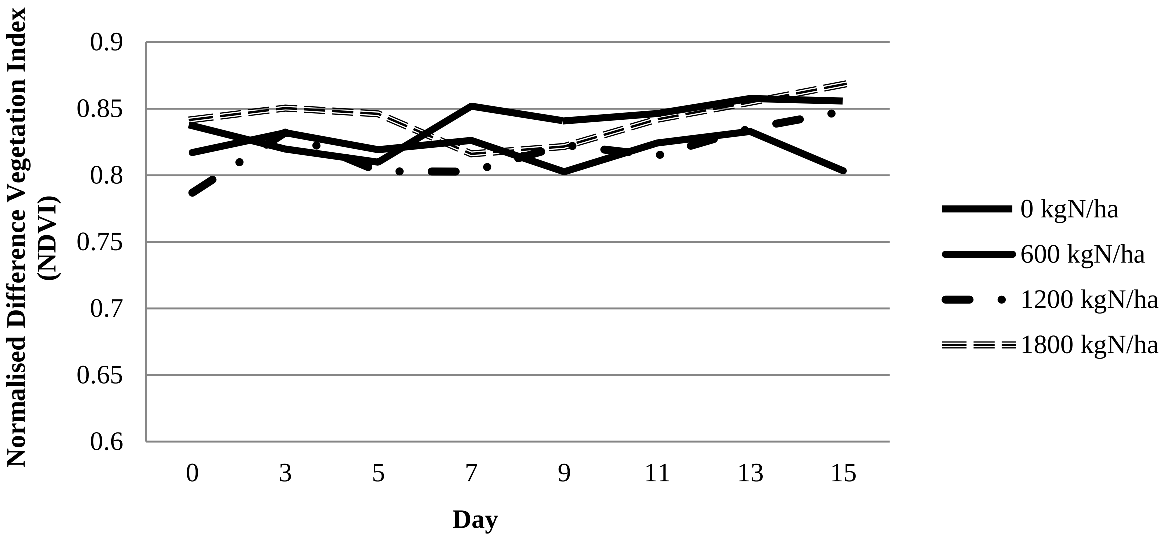

Figure 3. Handheld Greenseeker readings.

Handheld GreenSeeker readings were taken on Day 6 only for all treatment areas. Day 0, 3 & 5 plots have had plate meter readings taken as well as biomass cuts on the measurement days previous to Day 6. Therefore you would expect their NDVI readings to be lower than that of the plots still to have cuts taken. Plot NDVI readings were quite varied and show the variation from completing these trials in the field on a working dairy farm. However the average readings from those plots with cuts not collected prior to Day 6 (Day 7, 9, 11, 13 & 15 plots) were 0.85, 0.82, 0.82 & 0.84 for 0, 600, 1200 & 1800 kg N ha^{-1} treatments respectively. These results show that the 0 kg N ha^{-1} treatments had the greatest NDVI reading, compared to all other treatments. This was observed visually with the biomass from the 0 kg N ha^{-1} treatment being shorter and as green at this measurement time compared to the other treatments. The 600 kg N ha^{-1} treatment had the largest biomass cuts but showed the lowest NDVI, indicating low biomass or low chlorophyll levels. This apparent contradicted could be explained by the tissue burning resulting from the very high rates of nitrogen used.

Smart-N Results:

Some of the 600 kg N ha^{-1} treatments were detected by Day 3, while all treatments were detected by Day 5. Burning of the 1200 and 1800 kg N ha^{-1} treatments remained an issue for sensor detection throughout the trial period.

Early Field Trials:

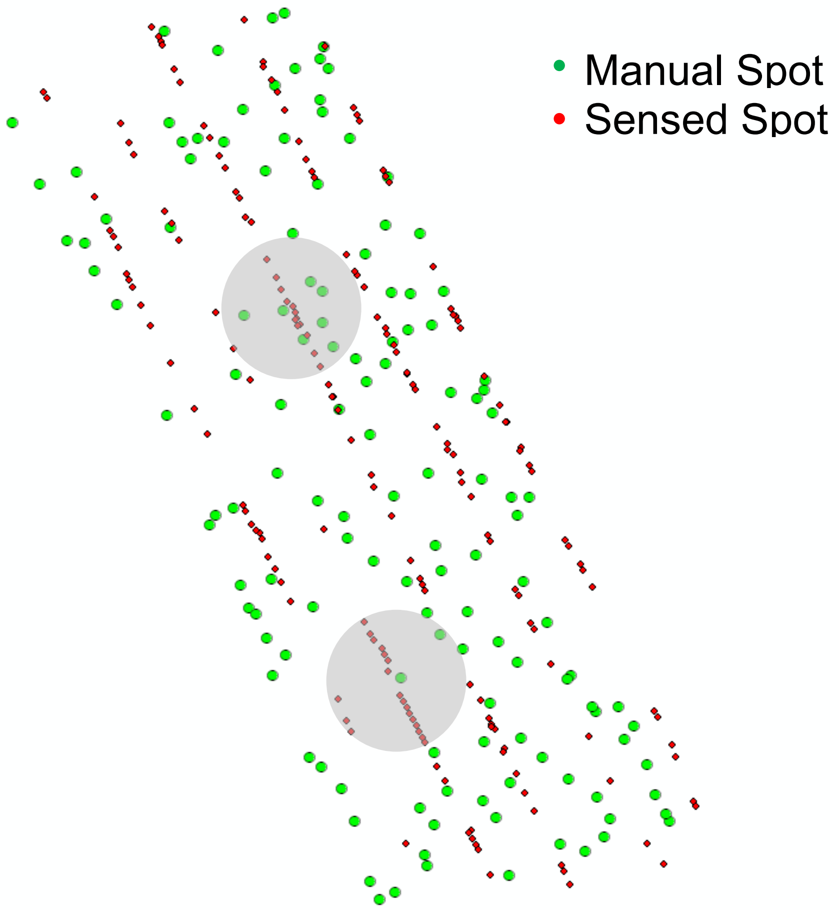

Figure 4. Urine patch detection in the field.

Urine spots in the field site were manually detected and recorded using an RTKDGPS to give precise location. (Marked in green), in Figure 4. The red points mark positions where the Smart N system was triggered. The large grey circles indicate water troughs. Both the manual and sensed method indicated that fertilizing was not necessary in these areas. It must also be noted that the red 'sensed' spots have not been processed for sensor offset and are located on the lines that were driven through this area. The sensitivity of units clearly has an effect on the number of urine patch detections, there will also be some random variation in term of the number of urine patches passing under each sensor.

Table 1. Urine patch detection by Smart-N sensors.

Manual	**(Total a+b+c)**	**Spot Severity High (a)**	**Spot severity Medium (b)**	**Spot severity Low (c)**
Number detected	125	1	21	103
Number detected per ha.	719	10	210	1028
Machine	Sensitivity setting 8			
	Unit 1	**Unit 2**	**Unit 3**	**Unit 4**
Number detected	171	179	138	6
Number detected per ha.	1707	1786	1377	60
Machine	Sensitivity setting 6			
Number detected	72	20	313	126
Number detected per ha.	719	200	3124	1257

During manual sensing the spots located were ranked in terms of their severity to assist with sensitivity settings for the Smart-N sensing system. During sensing events the sensors were only calibrated to what the operator objectively determined to be the optimum sensitivity for all sensors. Sensitivity 8 had an average of 1233 spots ha^{-1} while sensitivity 6 had an average of 1325. However, all sensors varied quite markedly in reading values between the two different sensitivities. This just further emphasises the need for even and repeatable calibration of the sensors.

Conclusions:

- Early trials have proved that the optical sensors can be used to detect urine spots and the spray technology will deliver (or cut off delivery of) the product to the correct spot in the paddock.
- Successful calibration is highly important to the successful and efficient operation of the Smart-N for spraying liquid N in between urine and dung patches!
- The dynamics of urine spots in terms of their longevity and effect needs to be better understood. This will be linked to further work calibrating the sensors for different conditions and periods of the growing season.
- Further trial work is required to work out the environmental impact of this technology
- During the trial work both in plots and in the field environment we noticed Sensor 4 was most easily calibrated for the level of accuracy and sensitivity that were required for the trial work. This further highlights that not all sensors are factory calibrated as evenly as needed for this situation and is a future area for research and development.

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