A REVIEW OF TECHNOLOGIES FOR IMPROVED FERTILISER APPLICATION ACCURACY

Miles Grafton[(1)] , Ian Yule [(1)] and Bryan Rendle[(2)]

[(1)] *New Zealand Centre for Precision Agriculture, Massey University.*
[(2)] *Ravensdown Fertiliser Co-operative Ltd.*

Abstract
This paper compares the technologies used in ground-spread application and the cost versus benefits difference expressed as an estimate of financial return in terms of pasture response for systems in common use.

From previous work, sources of error due to inaccurate driving, causing poor positioning of the vehicle, inaccurate repositioning post vehicle starts and stops, and the inability to control flow with variable vehicle speed have all been identified as contributing to "in-field" error. As a result of driver error being identified as a significant contributing factor, many operators have installed GPS guidance assistance to their vehicles to improve accuracy. Unless differential correction is used to improve the positioning to within 0.2 m then there may be little benefit from GPS as potential positioning errors (± 8m) are about equal to the standard deviation in spread pattern. The model developed to measure in-field CV is therefore not applicable, as it requires accurate measurement of application tracks so that spread patterns can be accurately combined to spatially model the application rate.

Through further economic modelling it is suggested that using differential correction, automated flow control and automatic shut off to prevent multiple application provide economic benefits greater than the cost of application on high fertility dairy farm situations which respond in line with the Ball and Field (1982) nitrogen response curve.

Introduction
The use of "Global Positioning Systems" to assist guidance of agricultural vehicles isn't new. There has been some uptake of this technology by ground-spread applicators especially those that have tried to improve the accuracy of their spread and have undertaken NZ Spreadmark Certification ®.

Spreadmark® Certification is a quality assurance scheme operated and controlled by the Fertiliser Quality Council an organisation run by NZ Federated Farmers. The Fertiliser Quality Council also controls the Fertmark® brand which audits and assures the quality of fertilisers sold by its members. The council is funded by levies mainly supplied by the major fertiliser manufactures with contributions from other members which include lime millers, ground spread and aerial applicators that have joined the accreditation schemes.

Spreadmark certification is based on the results of a transverse spreading test method requiring the spreading truck to pass over a continuous row of 60 0.5m x 0.5m trays at a typical application speed with a typical application rate. The spreader must be certified for 3 fertilisers (or two fertilisers and lime) with the application bout width being calculated from the transverse test so that the coefficient of variation (CV ,*which is the standard deviation / mean*) is no more than 15% for Nitrogen fertilisers or 25% for fertilisers containing no nitrogen, at a bout width greater than 12 metres. Figures 1 and 2 illustrate the information produced from the test. Figure 1 indicates the mass of material in each tray, from which the overlap pattern is calculated. In this case it is a round and round pattern. Figure 2 shows the effect of changing the bout width on the spread CV. The fertiliser in the trays is weighed after each pass.

Jones *et al*, (2008) found that the "Spreadmark" single pass test method is comparable with other international testing methods such as ISO, but is inferior to the Australian ACCU method which requires multiple passes. Where multiple passes over the trays occur there is an averaging effect, compared to the increased likelihood of variation with a single pass test.

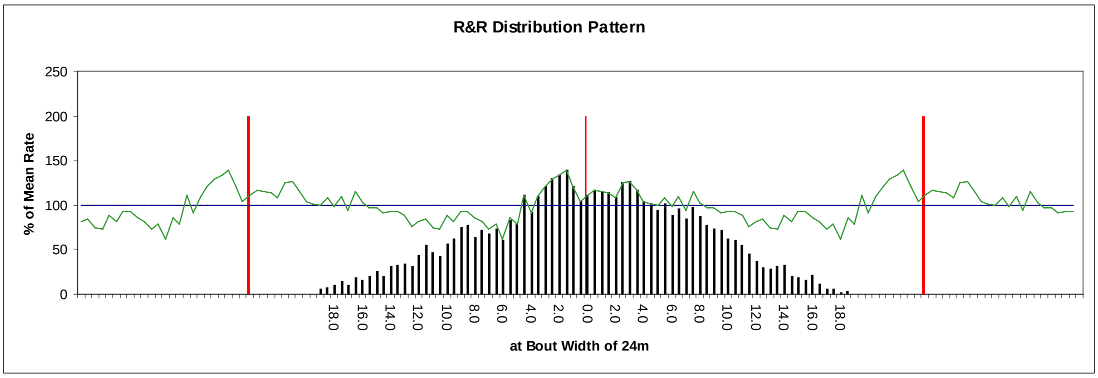

Figure 1: A spread pattern from a truck spreading urea at a rate of 130kgha^{-1}. Courtesy Spreading Canterbury Ltd., prepared by R. Horrell

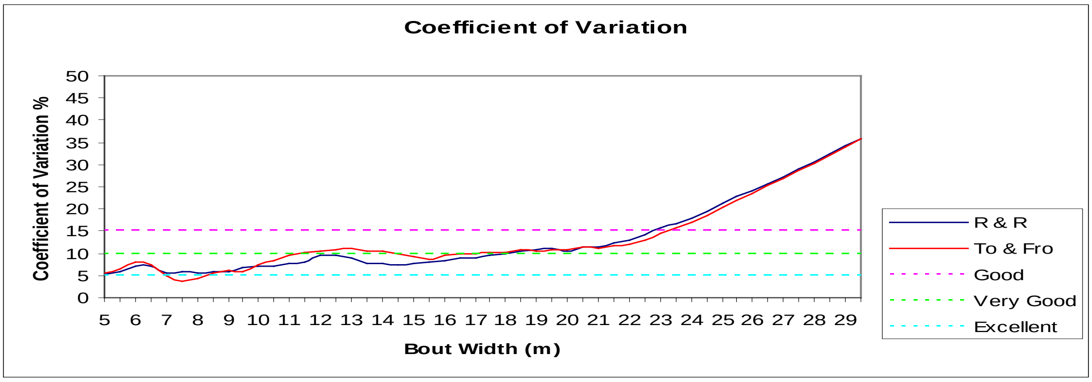

Figure 2: Coefficient of variation versus bout width from Figure 1; shows CV of 15% at bout width of 24m. Courtesy Spreading Canterbury Ltd., prepared by R. Horrell

In practise spreaders endeavour to apply fertiliser in a single pass, but certifying spreaders at low application rates is difficult as large particles in distant trays distort the tests (Jones, *et al*, 2008). It is probably for this reason that fertiliser spreading tests are undertaken at higher application rates than the actual application mean. Given that a Spreadmark certified bout width is only certified to within 30% of the actual application rate over the trays, then it is likely that due to the higher application rate used in the test a considerable amount of fertiliser is spread outside the certified bout width on the certificate. It is a weakness of the scheme that the Spreadmark certificate shows the products tested and the certified bout widths, but not the rate range they are certified for. The introduction of a multiple pass method; or the introduction of alternate testing methods such as the CEMIB system, described by Piron *et al*, (2010) which calculates the complete spreader footprint, for certifying fertilisers typically spread at low application rates may need to be considered in the future. This would require considerable capital expenditure to set up. It should be noted that these facilities have resulted in considerable development of spreading machinery in Europe allowing design changes to be thoroughly and accurately tested, resulting in better financial outcomes for farmers and reducing adverse environmental impacts.

A single pass CV does not represent the variation in spread in the field, it represents the limit in spread variation accuracy obtainable if the spreader is driven at the exact bout width and only considers parallel spreading. Overlaps at starts and stops, the effect of irregular shaped paddocks as well as perimeter effects are not considered. It also represents measurements on a flat plane. Although much spreading is undertaken on hillsides, the most productive valuable farmland is on the flat. Hillsides are still obtaining the overall correct rate when automated flow control systems such as Ravtrak are used, although the variation in coverage will be greater than that achieved on the flat through distortion of the spread pattern.

A method of obtaining the spread CV achieved within a paddock has been developed (Lawrence and Yule, 2007a). This method involves taking an appropriate spread pattern (footprint), which is modelled around the track of a spreading vehicle and where the patterns overlap a cumulative spread is obtained.

Method

Lawrence (2007) established the in-field CV of 37% urea spread by truck using a GPS with a differential correction on 107 paddocks ranging in shape and between 1 and 4 hectares in size. This was achieved when spreading at the correct track spacing which gave a CV of less than 15% over the single row of trays at certification. For this exercise the spreading trucks were fitted with automatic flow control to ensure delivery of the correct rate. However, the technology had not been extended to stop and start control to eliminate multiple applications over the same area.

Lawrence and Yule (2007a and b) developed a method of modelling in-field CV and in addition built a spread pattern footprint model which they used to find optimal delivery strategies to reduce spread variability. They concluded starting and stopping application in an optimum position at the beginning and end of each run could reduce the application CV dramatically. When modelled on a regular 3.48 ha paddock the CV was reduced by 13.5% from 38.5% to 25%. As the CV over the trays was 15% then the other 10% of variance must be due to paddock shape, size and driving accuracy, e.g. not sticking to the virtual road when a console is available. Some variance is inevitable at paddock edges or in irregular shapes where a spread pattern overlap does not occur.

For this exercise the method developed by Lawrence and Yule (2007a) for estimating in-field CV is applied to urea ground-spread by a Spreadmark certified spreading truck; spread at 100 $kgha^{-1}$ modelled from a pattern certified at 130 $kgha^{-1}$ at a bout width of 24m. Where spread patterns overlapped the gross rate achieved was added at the standard deviation of the spread pattern, which was 8.5m at 1, 2 and 3 deviations, see Figures 1 and 2. The spread pattern was modelled in ArcGis 9.3.1 with geostatistical methods applied to model the in-field CV, see Figures, 3, 4 and 5. In contrast to Lawrence and Yule (2007) large uniform shaped paddocks were tested.

The truck applied the fertiliser using Ravtrak® guidance which uses a differential corrected GPS signal and the driver is guided by a route map provided by a Topcon X20 console. This system features automated rate control which adjusts the flow with changes in vehicle speed and also has automatic switch off which turns the spread off when the truck over runs an area which has already been spread. Differential correction allows the computer control systems managing the spread to operate within 0.2m of the truck position, whereas without the differential correction accuracy is within 8m. Given that a signal without differential correction is accurate only to approximately 33% of the bout width; which is almost a standard deviation, measuring the in-field CV without differential correction using the method developed by (Lawrence and Yule, 2007) is not recommended and in the authors' opinion would not be valid, see Figure 6b. Here spatial distortion and swath pattern overlay are clearly visible, the model would assume multiple application in these regions, which may or may not be the case.

Figure 3a: Ravtrak customer printout

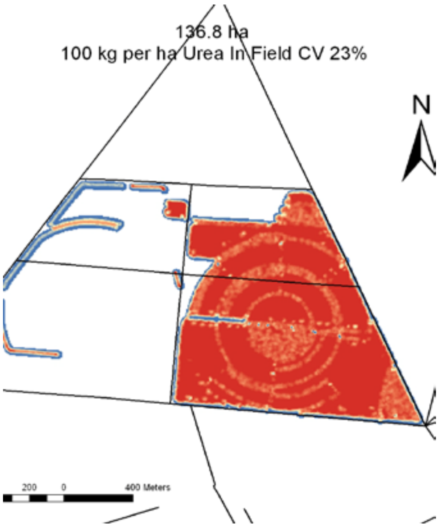

Figure 3b: 136.8 ha in-field CV 23%

Figure 4a: Ravtrak customer printout

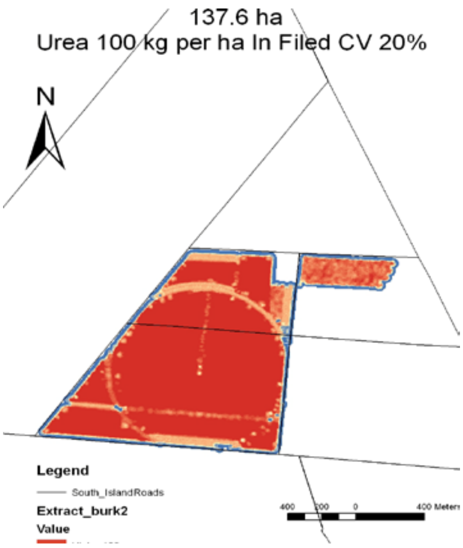

Figure 4b: 137.6 ha in-field CV 20%

Figure 5a: Ravtrak customer printout

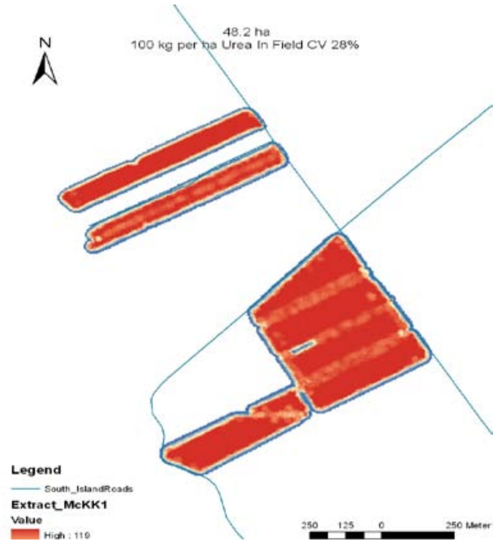

Figure 5b: 48.2 ha in-field CV 28%

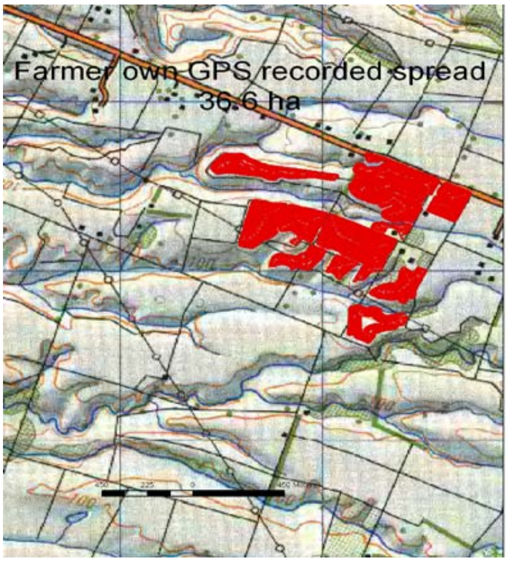

Figure 6a: Farmer's own spread 36.6 ha

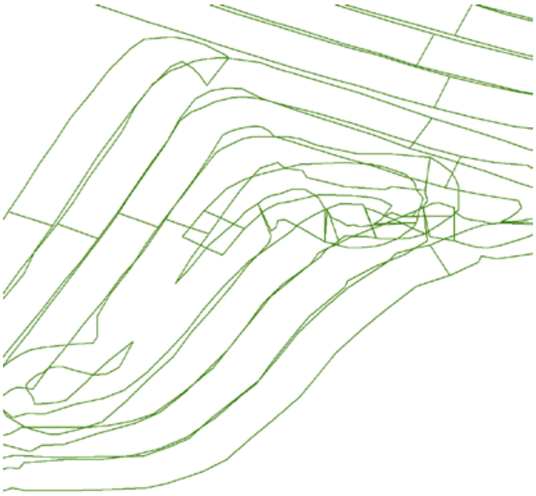

Figure 6b: Figure 6a enlarged showing displacement

Discussion

Lawrence and Yule (2007a) developed an equation based upon Horrell *et al*, (1999) valuation of dry matter at NZ\$0.20 per kg, for economic loss per hectare versus CV of spread, see equation 1. This was calculated using a nitrogen response curve developed by Ball and Field (1982), delivered by urea (46% N) on optimal fertility dairy farms at 80 kg urea ha^{-1}.

$$y = 286.78x^3 - 49.374x^2 + 5.4683x \qquad (1)$$

Current valuation based upon dairy farm conversion ratios value a kilogram of dry matter at NZ\$0.43 based on a pay out of \$6.50 per kg of milk solids (DPO) and a conversion ratio of 15 - 1 (CR), the same as that assumed by Lawrence and Yule allows us to calculate the loss in today's terms. This conversion ratio is well within the range of 7.7 – 25 kg dry matter per kilogram of milk solids found on New Zealand dairy farms (Anon, 2010).

In addition Lawrence and Yule (2007a) calculated, as a result of the exponential nature of the equation, that at CV greater than 30% then the economic loss is significant. The improvement in CV using automated shut off and flow control combined with differential correction is between 9% and 17%, being the difference between 37% CV achieved in 2005 and the range between 20% and 28%, found in 2010. The economic loss at various CV's is described along with the economic benefit from achieving a reduction in CV from the base level of a CV of 37%; where no automatic switch off was used, see Table 1.

Table 1: Economic loss and improvement with change in CV

CV	Economic loss ($)ha^{-1}	Economic Improvement ($)ha^{-1} 2005 - 2010
37	**21.06**	**-**
28	**8.51**	**12.55**
23	**4.60**	**16.46**
20	**3.04**	**18.02**

In all instances measured in Figures 3 to 5, the economic improvement in spread is greater than the average cost of ground spreading urea which is about $11 ha^{-1}.

Yule and Grafton (2010) calculated various sources of variation to in-field CV and the work contained in this paper allows these sources to be more accurately measured. This is achieved by comparing the results obtained in this work with those achieved prior to the introduction of computer controlled flow application and "Start Stop" control, see Table 2.

Table 2 Sources of variability and mitigation strategies for in-field CV.

Source of Variability	Mitigation available	Effect of the Technology on reducing the field CV
Track spacings being inaccurate driven	Guide the spreader with GPS (+- 8 meters)	*Nil*
Track spacings being inaccurate driven	Guide the spreader with GPS corrected signal (+-0.2 meters)	9 – 17%
Variability in application rate when the spreader speed varies	Flow value control linked to spreader speed.	10%
Inaccurate vehicle repositioning post the vehicle stopping and recommencing	Vehicle repositioning GPS with corrected signal	10%
Small irregular shaped paddocks	Remove fences to form large regular shaped paddocks	8%
Application rates outside the certified 30% tolerance	Certify spreaders at a range of application rates as per the Australian test methods	*Unknown*
Variability in fertiliser particles (provided the variability does not exceed >15% <0.5 mm and the product is stored properly	Increase the cost of domestically manufactured fertiliser significantly to enable the product to be dried and cooled	5%

Conclusion

The use of differential correction to GPS guidance, combined with automated flow control and automatic shut off to prevent multiple application has been shown to improve the response from nitrogen application by more than the application cost in all situations with an in-field CV less than 30% for urea application at 80 kg ha^{-1}. The application rate used in the CV calculations for this paper of 100 kg urea ha^{-1} is assumed to be close enough for the equation to remain valid.

Therefore, the use of differential correction and flow control is advisable; especially as accurate measurements of in-field CV is not possible without differential correction. The economic benefits achieved by flow control and automatic shut off are greater than the application cost. It should be noted that this analysis assumes that the performance of the Start Stop control is perfect, which may not be the case as it is impossible to match spread patterns which are converging at a 90^{o} angle for example. Not withstanding this point this work suggests that not using these systems incurs an application cost and an economic loss which is likely to be greater than this cost from reduced nitrogen response.

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