Fertiliser evenness – losses and costs: A study on the economic benefits of uniform applications of fertiliser

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Abstract

Over two million tonnes of fertiliser are applied to New Zealand pastures and crops annually and there is an increasing desire by farmers to ensure that the best possible economic return is gained from this investment. Spreading distribution measurements undertaken by Lincoln Ventures Ltd (LVL) have identified large variations in the evenness of fertiliser application by spreading machines which could lead to a failure to achieve optimum potential in some crop yields and to significant associated economic losses. To quantify these losses, a study was undertaken to calculate the effect of uneven fertiliser application on crop yield. From LVL's spreader database, spread patterns from many machines were categorised by spread pattern type and by coefficient of variation (CV). These patterns were then used to calculate yield losses when they were combined with the response data from five representative cropping and pastoral situations. Nitrogen fertiliser on ryegrass seed crops shows significant production losses at a spread pattern CV between 30% and 40%. For P and S on pasture, the cumulative effect of uneven spreading accrues, until there is significant economic loss occurring by year 3 for both the Waikato dairy and Southland sheep and beef systems at CV values between 30% and 40%. For nitrogen on pasture, significant loss in a dairy system occurs at a CV of approximately 40% whereas for a sheep and beef system it is at a CV of 50%, where the financial return from nitrogen application has been calculated at the average gross revenue of the farming system. The conclusion of this study is that the current Spreadmark standards are a satisfactory basis for defining the evenness requirements of fertiliser applications in most circumstances. On the basis of Spreadmark testing to date, more than 50% of the national commercial spreading fleet fails to meet the standard for nitrogenous fertilisers and 40% fails to meet the standard for phosphatic fertilisers.

Keywords: aerial spreading, crop response, economic loss, fertiliser, ground spreading, striping, uneven application, uneven spreading, yield loss

Introduction

Over two million tonnes of fertiliser are applied to New Zealand pastures and crops annually. Most is applied on the basis that the application rate per hectare will maintain sufficient nutrients to maximise growth or production consistent with availability of moisture and light. In calculating the application rate required, it has been assumed that the specific application rate is applied evenly to each part of the area. Distribution testing of over 325 commercial ground spread machines by Lincoln Ventures Ltd within the last 4½ years shows that the assumption of even spreading is incorrect.

Variability in the uniformity of fertiliser distribution from machines presented for Spreadmark certification (Horrell 1995) ranges from 10% to 80% coefficient of variation (CV). Locally made spreaders usually have poor performance because of design deficiencies and the failure of manufacturers to calibrate the machines. Well-designed European machines often give poor performance because of the lack of calibration with local fertilisers.

The loss of potential yield due to uneven fertiliser application has been well understood by European researchers for many years and the unevenness of nitrogen (N) on crops has been quantified by Prummel & Datema (1962), Holmes (1968) and Richards (1985). The economic impact of uneven aerial spreading of phosphate fertiliser on New Zealand pasture was modelled by Chiao & Gillingham (1989) who concluded that the cost of uneven spreading was greatest when soil fertility levels were low.

Method

Crop and pasture response data

Models for the response of ryegrass for seed production to N fertiliser were derived from experimental results from an irrigated site at Lincoln (Rolston *et al.* 1994) but scaled to an industry average yield of 1450 kg/ha. The Outlook model (Metherell *et al.* 1997) was modified to produce a response curve for the scenarios involving pasture response to phosphate (P) and sulphur (S) fertiliser, while a prototype pasture N response model (Metherell 1996) was recalibrated to produce the pasture N response function.

The pasture N response curve (Figure 1) was derived from single cut, small plot, mowing trials with many N fertiliser rates (O'Connor 1982) and from dairy farmlets with approximately 0, 200 and 400 kg N/ha/year (Penno *et al.* 1996), assuming eight applications per year. It is included here as an example of the equations and response curves used.

Three scenarios were simulated using a modified version of the Outlook P & S model (Metherell *et al.* 1997). Two were for groundspread superphosphate, the first for a Waikato dairy farm (1050 kg milk solids/ha, Olsen P 25, organic S 10), and the second for a Southland sheep and beef farm (15 stock units/ha, Olsen P 18, organic S 10). The third was for aerial application of superphosphate on a Hawke's Bay hill country sheep and beef farm (11 stock units/ha, Olsen P 10, organic S 5). The model was run with annual applications of fertiliser with rates of application varying between 0 and 100 kg P/ha. It was assumed that an identical spread pattern was repeated each year. Predicted dry matter production at Years 1, 3 and 5 was recorded and the results used for the economic analysis.

Figure 1 Pasture response to N fertiliser.

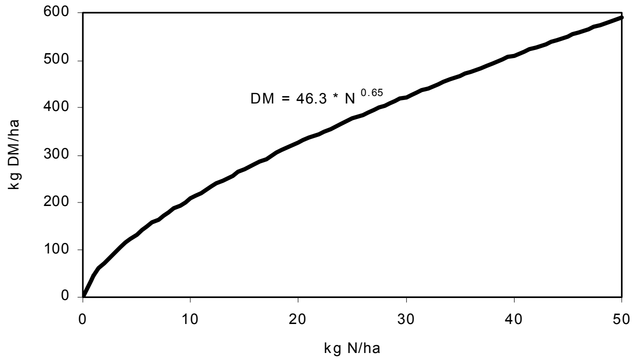


Figure 2 Example of Type 1 spread pattern (CV 40%). Bars show single pass pattern, continuous line shows overlapped pattern, dashed vertical lines indicate bout width of spreader.

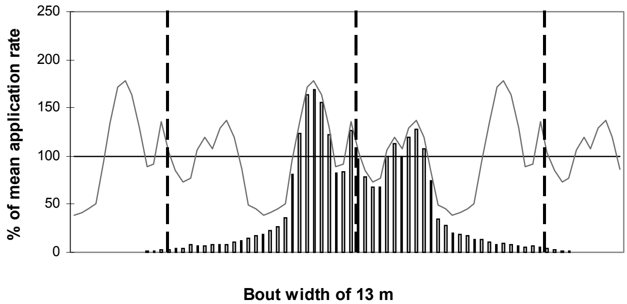
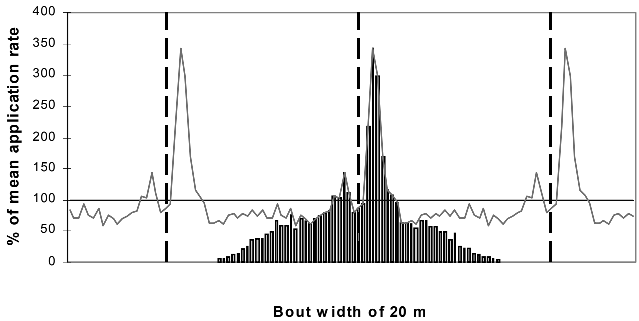


Figure 3 Example of Type 2 spread pattern (CV 40%). Bars show single pass pattern, continuous line shows overlapped pattern, dashed vertical lines indicate bout width of spreader.



Spreader database

A database of spreader performance was built from the first spreader test run made during Spreadmark testing which also gave a measure of current industry practice. Three distinct overlapped pattern types were identified: Type 1 – even departures above and below the mean rate (Figure 2), Type 2 – a sharp spike above the mean rate (Figure 3), Type 3 – a sharp spike below the mean rate (Figure 4). To establish if these differences were significant, the actual run patterns were used to calculate the yield losses rather than a mathematical formula. Patterns were categorised into the three pattern types at CV levels of 10, 20, 30, 40, 50 and 60%. In most cases, three examples were found to fit each category at each CV level.

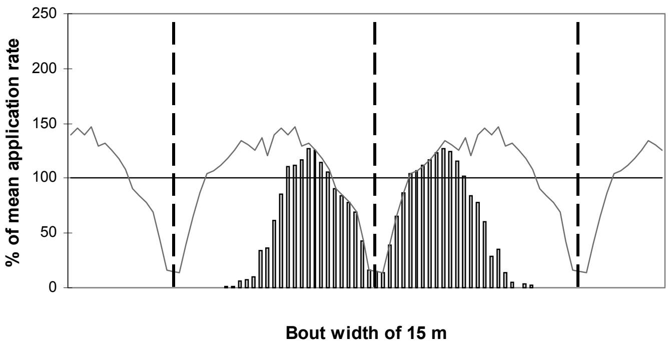
For ground spread superphosphate application to pastures, analysis of the three pattern types showed little difference at lower CV levels, and averaged results for the three pattern types are presented.

For aerial spreading there were insufficient runs in the database to categorise by pattern type and the runs were grouped by CV only, using 10% intervals from 10% to 100%. Also, because of the influence of wind on the actual spread pattern, it is not possible to categorise patterns so readily.

Calculating yield variation

For ground spreaders, the raw data for each spreader pattern consisted of gross fertiliser amounts collected in individual trays (0.5 × 0.5 m trays continuous across the line of travel) for a single pass of the spreader. These data were overlapped at selected bout widths to give the percentage of the mean application rate landing on 0.5 m wide (one tray width) strips along the direction of travel. The corresponding CV was also calculated. Using the crop response data, a computer program was developed to calculate the crop yield resulting from the actual percentage of fertiliser landing on each 0.5 m strip compared with the optimum yield, assuming even application. These yields were then used to calculate crop value.

Figure 4 Example of Type 3 spread pattern (CV 40%). Bars show single pass pattern, continuous line shows overlapped pattern, dashed vertical lines indicate bout width of spreader.



Economic analysis

The yield losses calculated for the three spreader pattern types at the various CV levels were converted to an economic loss by multiplying the yield loss by the gross revenue expected from that crop or farming system (Table 1). These gross revenues were derived from Gross Margins for crops and the Gross Income returns achieved in the MAF Farm Monitoring models for the various livestock system converted to returns/kg DM produced. The significant loss levels were those considered to be significant by most farmers. These were derived in relationship to the profitability and cost structure of the farming systems. They are not significant in a statistical sense. The results are given in Tables 3 and 4.

Table 1 Gross revenue figures for five farming systems.

Farming system	Gross revenue	Significant loss level
Ryegrass seed crop	$1.20/kg seed	$20/ha
Waikato sheep and beef	$0.15/kg pasture DM	$5/ha
Waikato dairy	$0.20/kg pasture DM	$5/ha
Southland sheep and beef	$0.15/kg pasture DM	$5/ha
Hawke's Bay sheep and beef	$0.05/kg pasture DM	$5/ha

Table 2 Yield loss (kg/ha) for a range of six CV levels and five farming scenarios (average for all spread pattern types).

Crop – Fertiliser	CV levels					
	10%	20%	30%	40%	50%	60%
Canterbury ryegrass seed – N	1.4	6.2	16.6	32.2	59.8	89.1
Waikato pasture – N	1.3	5.7	12.6	21.5	38.2	54.5
Waikato pasture – P&S *	1.6	7.0	22.7	51.1	117.1	277.0
Southland pasture – P&S *	2.9	11.1	26.4	45.0	70.2	100.3
Hawke's Bay pasture – P&S *	6.3	28.3	57.7	110.4	170.6	239.1

* Results for year 3 only

Results and discussion

Table 2 gives examples of ryegrass seed and pasture DM yield losses compared with production from the same rate of fertiliser spread uniformly.

Predicted economic losses from N application to Canterbury ryegrass seed crops, Waikato sheep and beef, and Waikato dairy pasture are shown for each spread pattern type in Table 3. Predicted economic losses from superphosphate applications over five consecutive years on Waikato dairy pasture, Southland sheep and beef pasture, and Hawke's Bay sheep and beef pasture are shown in Table 4.

Economic analysis

The yield and value of the crop and pasture considerably influence the CV levels at which economic losses become significant. Nitrogen on ryegrass seed crops shows significant losses at a CV of between 30% and 40%. Dairy and sheep and beef systems have a significant loss at a CV of approximately 40% and 50% respectively.

Repetitive uneven spreading of phosphate and sulphur could give significant economic losses over a

Table 3 Predicted economic loss ($/ha) from one seed crop and two pasture scenarios using three fertiliser spread patterns types and six variations in the uniformity of groundspread fertiliser distribution (coefficients of variation (CV)).

Scenario	CV	Type 1	Type 2	Type 3
Nitrogen applications on Canterbury ryegrass seed crops	10	1.80	1.58	1.80
	20	6.75	5.35	10.37
	30	16.55	13.13	30.14
	40	37.40	20.28	58.23
	50	66.16	27.12	122.07
	60	-	41.67	172.05
Nitrogen applications on Waikato sheep and beef pasture	10	0.15	0.23	0.19
	20	1.12	0.64	0.81
	30	1.26	1.54	2.86
	40	3.23	2.60	3.83
	50	5.56	3.80	7.85
	60	-	5.42	10.94
Nitrogen applications on Waikato dairy pasture	10	0.20	0.31	0.26
	20	1.49	0.85	1.08
	30	1.67	2.05	3.81
	40	4.31	3.47	5.11
	50	7.42	5.06	10.47
	60	-	7.22	14.58

Note: Shaded area deemed significant loss

Table 4 Predicted economic losses ($/ha/annum) from three pasture scenarios over five consecutive years and a number of variations in the uniformity of fertiliser distribution (coefficients of variation (CV)).

Scenario	CV	Year 1	Year 3	Year 5
Superphosphate on Waikato dairy pasture (groundspread application)	10	0.17	0.31	5.00
	20	0.66	1.41	18.43
	30	1.54	4.54	53.43
	40	2.53	10.31	110.53
	50	3.83	23.41	208.57
	60	4.66	55.53	401.15
Superphosphate on Southland sheep and beef pasture (groundspread application)	10	0.03	0.43	0.83
	20	0.12	1.67	3.23
	30	0.23	3.97	8.20
	40	0.40	6.75	14.72
	50	0.65	10.52	24.91
	60	0.96	15.04	37.70
Superphosphate on Hawke's Bay sheep and beef pasture (aerial application)	10	0.07	0.32	0.38
	20	0.32	1.41	1.77
	30	0.64	2.89	3.42
	40	1.21	5.52	6.57
	50	1.85	8.53	10.04
	60	2.57	11.96	13.10
	70	3.78	18.05	20.65
	80	4.57	22.07	22.06
	90	5.79	28.30	27.11
	100	6.73	33.33	27.56

Note: Shaded area deemed significant loss

3- to 5-year period at a CV >30%. Repetitive spreading occurs where there is a stable spreading contractor/farmer relationship and the same spreader and driver does the same paddocks year after year. Repetitive uneven aerial spreading of phosphate and sulphur could give a loss to hill country farmers at CV values above 40%.

The spread pattern types can occur with any ground spread machine at any time because of driving error (bout width too wide or narrow) and/or spreader set-up, particularly the fertiliser feed point onto the disc. An individual ground spreader could give all three spread pattern types at different times in the same paddock. While the pattern types are of interest from a research point of view, economically they become insignificant if the dollar losses are kept below the threshold levels, nominated in Table 1, by using a low CV.

As would be expected, nitrogen applied to crops and superphosphate applied to pasture gives increasing losses in yield as the unevenness of fertiliser application increases. However, this is not necessarily the case when nitrogen is applied to pasture. The virtually linear response curve (see Figure 1) gives yields that are self-compensating for uneven fertiliser application if other factors are not limiting. Thus a pasture which has a striped growth pattern due to uneven N application may have little yield loss in-spite of the uneven appearance.

The financial return of N application on pasture has been calculated as the average gross revenue of the farming system expressed in dollar return per kilogram of dry matter grown. In most cases N is used as a strategic accelerator of grass growth and therefore can contribute much higher returns than the values assigned in Table 1 and used to calculate the losses given in this paper. In this case, the cost of uneven fertiliser application will be greater than the values shown in Table 3.

While this study has been confined to lost potential yield, there are other forms of loss. Uneven fertiliser applications to seed ryegrass cause variations in maturity and therefore harvest time. Pasture saved for silage may have variable maturity and therefore may not be harvested at optimum feed value. Leaching losses, luxury uptake and loss of efficiency in nutrient usage by the plant, and flow-on effects on stock health, also occur.

Spreadmark certification

The standards set for Certification are:

- Nitrogenous fertilisers – CV <15%
- Non-nitrogenous fertilisers – CV <25%

The calibration testing is usually done indoors under ideal conditions. It is expected that some deterioration of performance from that tested will occur under field conditions due to factors such as changes in mean particle size and differences in particle size distribution from the test product or the effect of wind or slope on the spread pattern. While these factors are beyond the control of the spreading operator, contract-spreading machines need to achieve a standard that will give a satisfactory result regardless of the particular circumstances. The standards were set taking these factors into account, hence the difference between the Spreadmark standard and the CV levels that give significant loss in the tables.

The data on New Zealand contract spreaders show that for nitrogenous fertilisers, using the common industry bout width of 14 m, only 34% of spreaders met the Spreadmark standard before certification and the average CV for spreading is 20.4%. The national spreading fleet is better when spreading superphosphate at the common bout width of 16 m, where 58% meet the standard.

Cost of achieving even fertiliser application

For ground based spreaders, the main cost is calibration of the unit to ensure it is operated with the correct settings and bout width to give even spreading for a particular fertiliser. The calibration can often result in an increase in operating bout width and therefore a reduction in paddock time and cost. Calibration can either be through the Spreadmark scheme for spreading contractors (New Zealand Groundspread Fertilisers' Association members) or type calibration by importers/manufacturers for farmer-operated spreaders. For the Spreadmark scheme, cost of this calibration ranges from 10¢ to 30¢ per hectare. Farmer-operated spreaders could be calibrated by importers/manufacturers for approximately $50 per unit based on sales of 200 units.

For aerial application the costs of achieving lower CVs are greater and often involve fitting a spreading device and/or flying closer tracks. The New Zealand Agricultural Aviation Industry has introduced an "accreditation" scheme for operators which has standards based on those for ground spreading.

Conclusions

The evenness with which fertiliser is required to be spread depends on the fertiliser type, the fertility of the paddock, the crop to which it is being applied and the efficiency of utilisation of that crop. While these factors are beyond the control of the spreading operator, contract-spreading machines need to achieve a standard that will give a satisfactory result regardless of the particular circumstances.

This study shows that the current Spreadmark standards are a satisfactory basis for evenness requirements of fertiliser applications in most circumstances. On the basis of Spreadmark testing to date, more than 50% of the national commercial spreading fleet fails to meet the standard for nitrogenous fertilisers and 40% fails to meet the standard for phosphatic fertilisers.

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