ECONOMIC FEASIBILITY OF USING COMPOSTED FEEDLOT MANURE ON DRYLAND MAIZE

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Abstract

The economic feasibility of using composted manure from KwaZulu-Natal midlands feedlots in combination with commercial N in production of dryland grain maize [Zea mays (L.)] was evaluated. Effective disposal of large quantities of manure from large scale feedlots is a concern. Yield data from Cedara experiment station were used to estimate a quadratic production function where maize grain yield is a function of manure and commercial fertiliser N application rates. Four rates of commercial N (0, 50, 100 and 200 kg ha^{-1}) and five rates of composted feedlot manure (0, 5, 10, 20 and 30 t ha^{-1}, as is basis) in a factorial arrangement were applied to dryland maize. The production function estimate was used to determine the combination of composted manure and commercial N, which maximized net returns. The results suggest that a compost application rate of 15 t ha^{-1} with 20 kg ha^{-1} of commercial N would be economically feasible when the price of commercial N, including application charges, is R4.50 kg^{-1} and the price of compost R77.20 t^{-1}. Once the price of compost reaches R95.00 t^{-1} compost use is no longer economically feasible.

1. INTRODUCTION

Recently, increases in soil acidity (decreases in soil pH and increases in soil acid saturation) and decreases in soil organic matter have been attributed to the increase of commercial N fertilizers in crop production (Fey, 2001; Sanchez, 2002). Animal manure is a possible alternative nutrient source in areas where large quantities of it are available. However, raw animal manures as substitute for commercial fertilizers have limitations.

Fresh feedlot manure is primarily water (>80%) with relatively low nutrient content and as a result is bulky thus expensive to transport and handle (Schlegel, 1992; Williams *et al.*, 1994). This encourages high application

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rates on farmland near the manure source, which results in high nitrate levels in the soil, runoff, leachate (Evans *et al.*, 1977; Mathers *et al.*, 1972), odour, and dispersal of viable weed seeds (Mkhabela & Materechera, 2003). Composting manure may reduce these problems, although management to prevent nitrate and potassium leaching at the composting site is important.

Composting raises the dry matter level of manure from about 20 to 80%, resulting in higher nutrient concentration per kilogram of manure (Wiese *et al.*, 1977). This reduces transportation and handling costs. Composted manure (hereafter referred to as manure) has less odour and better physical properties (loose, friable texture with uniform particle size) than fresh manure (Schlegel, 1992). Composting reduces weed seed viability (Wiese *et al.*, 1977; Mkhabela, 2002a). Application of manure also increases soil organic matter. Undoubtedly, the use of cattle manure as an alternative source of plant nutrients has potential benefits, albeit management problems. Farms located long distances from a source of manure, such as a commercial feedlot composting operation, face significant hauling costs to the field. The high volume of manure needed to obtain similar yield results to those provided by commercial fertilizers is another drawback.

Results from yield studies have not shown conclusive positive or negative effects from application of manure compared with fresh or raw manure. Brinton (1985) concluded that no significant difference in maize yields as a result of using manure as opposed to raw manure, even though total N, P, and K were higher in raw manure. Yields were significantly higher for the inorganic N, P, and K treatment than manure, despite application of lower total N, P, and K in the inorganic treatments. Schlegel (1992) concluded that manure alone will increase grain sorghum yield, but larger yield increases occur when a combination of manure and commercial N is used. Schlegel (1992) further reported that, on average, 1 ton of manure and 6 kg of commercial N produced the same yields. None of these studies examined the economic feasibility of using manure as a substitute for commercial N.

Studies of manure use have mainly focussed on the agronomic value of manure as an N source rather than on its economic feasibility. The objective of this study was to evaluate the economic feasibility of using manure as an N source for producing dryland maize.

2. MATERIALS AND METHODS

Yield data and cropping practices are from a study by Mkhabela (2002b) at the Cedara Research Station in Pietermaritzburg, initiated in 1999 and completed in 2001. The purposes of the field study were to examine feedlot

manure as an N and P source for dryland maize and to determine the effects of annual manure and commercial N applications on soil chemical properties and maize yield. The manure was obtained from a commercial manure composting operation. A complete factorial five manure application rates (0, 5, 10, 20 and 30 t dry matter ha^{-1}) and four N fertilizer rates (0, 50, 100, 200 kg ha^{-1}) were arranged in a randomised complete design replicated four times. Plot size was 3.6 by $10m^2$. These were applied to dryland maize on a Hutton form, Lillieburn family (Soil Classification Working Group, 1991). The equivalent classification according to the USDA classification system is a rhodic haplustox (Soil Survey Staff, 1990). Increasing rates of manure or commercial N increased yields, but each partially substituted for the other when combined. Soil test levels of P and K were relatively high, so that responses to manure could be attributed to N-supplying capacity of manure, or to factors other than N, P, and K.

The economic analysis used in this study was based on an estimated production function. The yield results from the 20 combinations of inputs were used to estimate a production function. Once the production function was estimated, it was incorporated into a net return function. The net return function was then used to derive the combination of manure and commercial N that maximized net returns.

Although enterprise budgeting analysis is often used to determine the optimal use of inputs in crop production, it is often constrained by the actual input levels used in the experimental study. Optimum levels of input use may be incorrectly identified because of this constraint. This is important because applications of manure alone, or combinations of manure and commercial N, did not have the same total nitrogen content as any application of commercial N alone. Each ton of manure contained approximately 1.66% N or 16.6 kg N per ton of manure. The standard deviation of ten assays was 0.10%. There were also wide intervals between the application rates. A budgeting analysis using these rates alone provided an inaccurate picture of the profit maximizing combination of inputs. The use of a production function reduces these problems and allows an infinite number of input combinations and resulting yields to be considered in the analysis.

A quadratic production function was estimated. This function form was chosen because it is a conceptually satisfactory representation of yield-input relationships. This quadratic form allows for a positive yield when all or one of the measured inputs (independent variables) are zero. This functional form also allows marginal products from added inputs to increase, decrease, or not change. Thus, the function can demonstrate

increasing total product over a range, a peak output, and decreasing total output over a range. The field data exhibited not only yields increasing at decreasing rate over a range of input combinations but also declining yields at higher rates of commercial N applications. The quadratic form can be estimated easily with a linear transformation of the data using ordinary least squares. Mjelde *et al.* (1991) and Arce-Diaz *et al.* (1993) have used quadratic production functions in their respective studies to estimate yields as a function of several inputs. The function was defined as:

$$Y_i = \$_0 + \$_1 N + \$_2 N^2 + \$_3 C + \$_4 C^2 + \$_5 (N \square C) + \$_6 YR99 + \$_7 YR00 + e \qquad [1]$$

where:

> **Y = yield in t ha^{-1} of maize grain produced,**
> **N = kg ha^{-1} of commercial N,**
> **C = t ha^{-1} of manure,**
> **YR99 = dummy variable for year 1999,**
> **YR00 = dummy variable for year 2000,**
> **e = error term,**
> **$\$$ = parameters to be estimated.**

The model was estimated using ordinary least squares techniques. Dummy variables were included to capture general characteristics that may have caused year-to-year variations in yield (e.g. rainfall and temperature). The base year was 2001. Results are presented in Table 1, and discussed in Section 3.

Table 1: Ordinary least squares regression results of regressing maize grain yield on commercial N, manure, and year with a quadratic functional form.

Variable	Parameter estimate	Standard error	T-Statistic
constant	57.5982	1.0552	54.8243*
N	0.5711	0.0552	10.1057*
N^2	-0.0023	0.0002	-8.4960*
C	7.3216	1.4922	5.1336*
C^2	-0.3087	0.1460	-2.0901*
N × C	-0.0217	0.0051	-4.9866*
Year 1999	12.5200	1.7893	6.8463*
Year 2000	-11.7000	2.3465	-4.9866*
Year 2001 (base year)			
F- Statistic = 48.801			
Adjusted R^2 = 0.8698			

*Indicates coefficients that are statistically significant at the 95% confidence level.

Once the production function was estimated, net returns over variable cost per base hectare were maximized by finding the optimal combination of N

and manure using equation [2], which is the net return function.

$$NR = \{(Y \times P_s) - (N \times P_n) - (C \times P_c) - (Y \times D) - VC\} \times PA + PA \qquad [2]$$

where:

Y = t ha^{-1} of maize grain from the production function in equation [1],
P_s = expected market price of maize grain,
N = kg ha^{-1} of commercial N,
P_n = price of commercial N, R/kg,
C = t ha^{-1} of manure,
P_c = price of manure including application costs, R/t
D = drying cost for maize grain, R/t
VC = all other variable costs per hectare that were not a function of N and C input levels and output level Y,
PA = planted area as a percentage of total base hectare, %.

Table 2: Optimal combinations of commercial N and manure to maximise net returns at various manure prices

Manure price* R t^{-1}	Commercial N kg ha^{-1}	Manure t ha^{-1}	Net return** R ha^{-1}
55.00	80	20	800.00
60.00	90	15	780.00
65.00	100	13	760.00
70.00	103	11	753.00
75.00	106	10	744.00
77.20	109	8	741.00
80.00	110	6	736.60
85.00	112	4	731.90
90.00	114	2	729.70
95.00	118	0	729.60

***Manure price includes delivery. Commercial N price was R4.50 kg^{-1}.**
****Net return over variable cost.**

Equation [1] and [2] were used in an iterative process to determine the combination of N and C that maximized net returns for different N and C prices. For a given set of input prices, the computer algorithm searches for the combination of N and C using resulting yield (Y) from equation [1] that maximizes the net return (NR) using equation [2].

Although application of marginal value concepts found in economic theory can be used to determine the optimal combinations of inputs mathematically, direct numerical methods were employed in this study. The optimiser component of the electronic spreadsheet Quattro Pro version 9.0 was used to iteratively determine the optimal level of manure and

commercial N that maximized net returns.

Net returns over variable cost were used rather than returns over total cost, because fixed costs were assumed to be identical among all manure and commercial N combinations. The manure is generally composted at commercial feedlots and can be applied with delivery equipment. Therefore, additional equipment purchases are not required and fixed costs do not affect the comparative analysis.

Seed and chemical costs were based on the actual rates used in the experiment. Fertilizer costs per unit N for commercial N fertilizer [Urea (46%)] were R1.50 kg^{-1}. Manure costs of R77.50 t^{-1} were based on the actual price charged to farmers in the area by a commercial manure dealer (Paul, 2002, personal communication). Gross returns used in estimating net return were based on the market price for maize grain. The price for maize used was R850.00 t^{-1}.

3. RESULTS AND DISCUSSION

The production function estimation results are presented in Table 1. The coefficients on all variables and the overall explanatory power of the production function were significant. The most economic combination of commercial N and manure was determined from a range of input costs using the net return function and estimated yields from the production function. The price of commercial N was R1.50 kg^{-1} with a R34.00 ha^{-1} application costs, and the price of manure was R77.20 t^{-1}, including application onto the field. Given these prices, the highest net return was provided by using 100 kg N ha^{-1} and 15 t ha^{-1} of manure (Table 2). Figure 1 shows this combination and the amount of manure that is economically feasible to use at various prices and two different commercial N prices.

Transportation charges for manure ranged from a low of R17.00 per ton to a high of R50.00 per ton. Therefore, a range of manure prices, including transportation charges, was examined to determine the optimal combination of inputs at each price level (Table 2). When the manure price was R60.00 per ton (essentially no transportation charge because of close proximity to manure composting operation), 90 kg/ha of commercial N and 15 t/ha of manure maximised net returns. If the cost of manure rose to R95.00 per ton (R60.00 per ton plus R35.00 per ton transportation charge), however, it became uneconomic to use manure. This cost was within the current range of charges in the KwaZulu-Natal Midlands.

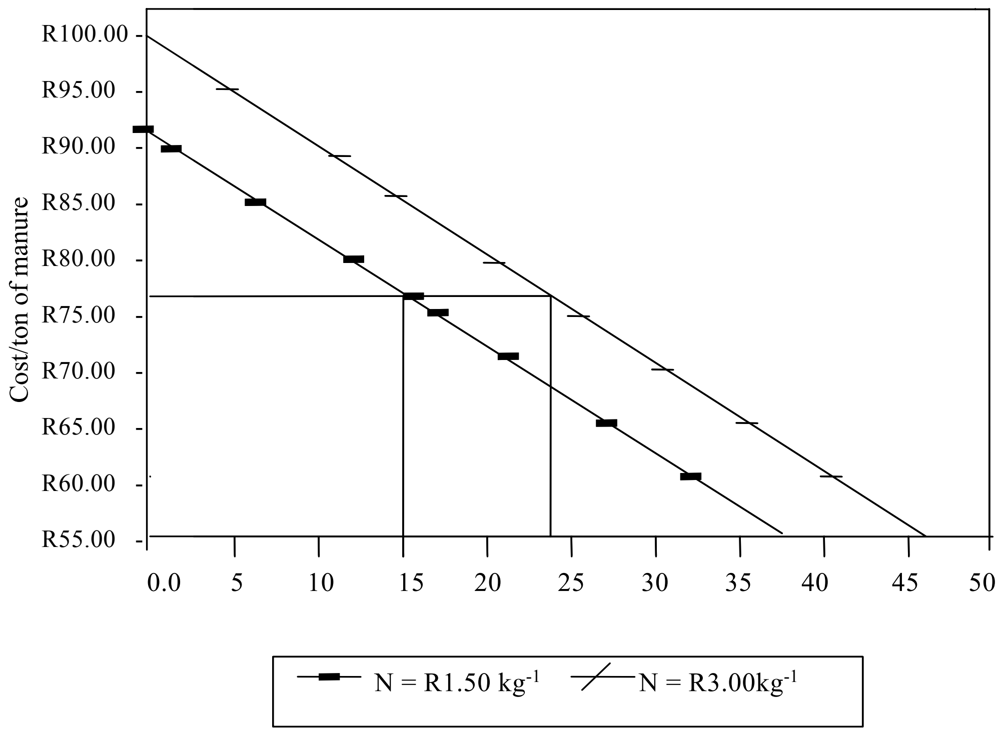

Figure 1: Manure cost and use

The price of commercial N was varied from R4.00 to R9.00 per ton by R0.50 increments, while the price of manure was held constant at R77.20 per ton. The profit-maximising combinations of manure and commercial N over this range of fertiliser prices are presented in Figure 1. The more expensive the commercial N source, the more manure will be used. Commercial N price will have to increase substantially, however, to substantially increase the feasibility of using greater quantities of manure. Given a manure price of R77.20 per ton, the price of commercial N will have to rise from R4.50 per kg to R8.00 per kg to justify an increase in manure use from 15 t/ha to 22 t/ha (Table 3).

Table 3: Optimal combinations of commercial N and manure to maximise net returns at various commercial N prices

Commercial N price R kg^{-1}	Commercial N rate kg ha^{-1}	Manure t ha^{-1}	Net return R ha^{-1}
4.00	110	13	797.60
4.50	100	51	741.00
5.00	90	16	688.10
5.50	80	17	631.00
6.00	70	18	593.70
6.50	60	19	552.20
7.00	50	20	514.40
7.50	40	21	480.40
8.00	30	22	450.20

The profit maximising input combinations from the production function and the net return analysis used a comparatively large amount of commercial N and a small amount of manure. Mkhabela (2002b) reported that N made up 1.66% of the manure and assumed a 43% nutrient availability. If the value of the manure was based only on its N-supplying ability, the cost of N from manure would be R8.40 when the price of manure was R60.00 per ton. Even at this cost of N, the model indicates that the use of some manure is economically feasible. This indicates that yields are probably affected by more than the N content of the manure. Other nutrients and soil-building characteristics could not be valued in this analysis, because the field study design did not isolate the impact of other inputs in manure on yield.

Therefore, manure should ideally be studied as a multiple input rather than an N source alone. Nutrients such as P, K, and micronutrients, as well as organic matter, can affect the value of manure and the economic analysis. According to many studies such as National Research Council (1989) estimates, manure could economically supply approximately 15% of the total N, 9.9% of the total P, and 24.2% of the total K fertiliser requirements of farms in the USA. In 1983 there were approximately three million tons of manure available in South Africa from various feedlots - cattle, broilers and layers, and pigs. The value of this manure calculated in terms of N, P, and K was R29.7 million. This amount was sufficient to meet 13.3%; 9.9% and 27.6% of the country's requirements of N, P, and K, respectively (Bornman *et al.*, 1989). While more recent data are not available, this still illustrates that manure is a potentially important source of P and K, as well as N. The author is not aware of any similar data for micronutrients and organic matter. Phosphorus and K are the two other major nutrients, in addition to N, supplied by manure and often supplemented commercially. It is important to determine if manure can supply these nutrients more economically than commercial fertilisers. Yield data is needed from treatments where P and K were varied by applying increasing amounts of manure on some plots and corresponding inorganic sources on other plots while N content is equivalent or comparable. Economic analysis can then determine the value of each component of manure.

Furthermore, this is important because of the possibility that P and K levels in manure may restrict the amount of manure that can be used depending on soil types. It would also be useful to determine the contribution to yield caused by the organic matter of the manure. Analysis of data from an experimental design that had increasing rates of organic matter from increasing manure applications while at the same time having N, P, and K levels from corresponding inorganic fertiliser applications equivalent is needed. Isolating the impacts that the N, P, and K components of manure have on yield would improve the ability to measure the impact the organic matter has on yield and its value in improving soil tilth and disease suppression. Further measurements of runoff and leaching potential of N from manure compared with commercial sources would be useful in determining the external impacts of and economic feasibility of manure versus commercial N use under environmental restrictions in high rainfall areas and/or irrigated croplands.

Farmers are unlikely to make extensive use of manure unless the content and value of each nutrient component can be established and evaluated against other nutrient sources. Consequently, further field investigations of manure, based on more detailed experimental designs, are needed to conduct a more complete economic evaluation of manure use in commercial agriculture. Both environmental and agronomic benefits of manure use have not been well researched. The ability to determine and control nutrient content of manure is crucial for both environmental and agronomic purposes. Manure application rate recommendation may be conservative to minimise environmental contamination by excess nutrients or excessive to guarantee that crop nutrient requirements are met. Until inexpensive, simpler, quicker, and accurate assays are established, one of these two risk-reducing recommendations may be used, as a result of the existing imperfect information.

Another limitation of this study is that the data used is for only one soil type. Studies conducted on soils of differing chemical, physical and biological properties and productivity would be helpful in order to draw more definitive and general conclusions.

4. SUMMARY

The most economic combinations of commercial N and manure were determined for a range of input costs using a net return function and estimated yields from a production function. The results indicated that some use of manure was economically feasible but was highly dependent upon manure costs. The price of commercial N was initially R4.50 per kg and the price of manure was R76.20 per ton, including the lowest transportation cost. The optimal net return generated by these prices used 100 kg N per ha and 15 tons of manure per ha (Table 2).

Due to varying transportation charges, from a low of about R17.00 per ton to a high of R50.00 per ton, a range of manure prices - including transportation

charges - were used to determine the optimal combination of manure and commercial N. When the manure price was R60.00 per ton (essentially no transportation costs) 90 kg/ha of commercial N and 15 t/ha of manure maximised net returns. If the cost of manure rises to R95.00 per ton (R60.00 plus R35.00 per ton transportation charges), however, no manure will be used.

Further analysis of a manure/manure market is difficult since accurate estimates of supply and demand are not available. Environmental and agronomic research has not conclusively established the on-site and off-site benefits of using manure. Thus, a strong market response has not occurred. In addition, manure should be viewed as a multiple input and not just as an N source. The value of P, K, and organic matter would alter the economically optimal combination of inputs.

REFERENCES

ARCE-DIAZ E, FEATHERSTONE AM, WILLIAMS JR & TANAKA DL (1993). Substitutability of fertilizer and rainfall for erosion in spring wheat production. *Journal of Production Agriculture* 6:72-76.

BORNMAN JJ, RANDWELL JF, VENTER GCH & VOSLOO LB (eds) (1989). *FSSA Fertilizer Handbook*, p 93. The Fertilizer Society of South Africa, PO Box 7438, Hennopsmeer 0046.

BRITON WF (1985). Nitrogen response of maize to fresh and manure. *Biology, Agriculture and Horticulture* 3:55-64.

EVANS SD, GOODRICH PR, MUNTER RC & SMITH RE (1977). Effects of solid and liquid beef manure and liquid hog manure on soil characteristics and on growth, yield and composition of corn. *Journal of Environmental Quality* 6:361-368.

FEY MV (2001). Acid soil degradation in South Africa: A threat to agricultural productivity. *Fertiliser Society of South Africa Journal* 2001:37-41.

MATHERS AC, STEWARD BA, THOMAS JD & BLAIR BJ (1972). *Effects of cattle feedlot manure on crop yields and soil conditions*. Texas Agricultural Experiment Station Technical Report No 11.

MJELDE JW, COTHREN JT, RISTER ME, HONS FM, COFFMAN CG, SHUMWAY CR & LEMON RG (1991). Integrating data from various field

experiments: The case of corn in Texas. *Journal of Production Agriculture* 4:139-147.

MKHABELA TS & MATERECHERA SM (2002). Factors influencing the utilization of cattle and chicken manure for soil fertility management by emergent farmers in the moist Midlands of KwaZulu-Natal Province, South Africa. *Nutrient Cycling in Agroecosystems* 65(2): 151-162.

MKHABELA TS (2002a). Determinants of the utilization of manure by crop farmers in KwaZulu-Natal: A logit analysis. *Agrekon* 41(1): 24-42.

MKHABELA TS (2002b). Improving the efficiency of the utilization of cattle and chicken manure for crop production in KwaZulu-Natal. MSc Thesis, University of North West, Mmabatho, South Africa (unpublished).

NATIONAL RESEARCH COUNCIL (1989). *Alternative agriculture*. National Academy Press, Washington, DC.

SANCHEZ PA (2002). Soil fertility and hunger in Africa. *Science* 295:2019-2020.

SCHLEGEL AJ (1992). Effect of composted manure on soil chemical properties and N utilization by grain sorghum. *Journal of Production Agriculture* 5:153-157.

SOIL SURVEY STAFF (1990). *Keys to soil taxonomy*. SMSS Technical Monograph No 6. Lacksurg, Virginia.

SOIL CLASSIFICATION WORKING GROUP (1991). Soil classification and taxonomic system for South Africa. Men. Agricultural and Natural Resources of South Africa, No 15. Department of Agricultural Development, Pretoria.

WIESE AF, LAVAKE DE, CHENAULT EW & CRUTCHFIELD DA (1977). Effect of composting and temperature on weed seed germination. *Proceedings of Southern Weed Science Society* 30:167.