SUBSTITUTION OF FERTILISER WITH POULTRY MANURE: IS THIS ECONOMICALLY VIABLE?

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Abstract

Rapid expansion of the KwaZulu-Natal poultry industry has resulted in poultry manure and litter production that in certain areas exceeds the potential for use in crop production. If land application exceeds crop requirements, manure production may result in environmental damage. In this study, potential manure surpluses in intensive poultry producing KwaZulu-Natal areas were quantified. The costs of transferring such surpluses to manure-deficient areas were compared with the economic value of poultry manure as fertiliser. Estimates of potential arable land and pasture for spreading manure took both dairy and feedlot manure production into account. Use of manure surpluses by transfer was found to be economically viable. Public policy actions are needed, however, to promote such transfer.

1. INTRODUCTION

Rapid growth and spatial concentration of poultry production in South Africa has led to increasing concerns about the disposal of poultry litter and manure. Manure here refers to the mixture of poultry excreta, any bedding material and waste feed that is collected from poultry production units. Manure in most poultry producing areas, including South Africa, is often disposed of by applying it as fertiliser to nearby arable land or pastures. Poultry is produced in spatially concentrated areas to minimise feed and poultry transportation costs. This concentration of poultry production may result in high ratios of poultry manure to available nearby arable land, and manure may be applied at higher rates than required by crops. Unused nutrients in poultry manure represent an economic loss to poultry producers and society at large.

Manure transfer from surplus areas, where manure production exceeds potential use on arable land and pastures, to deficit areas may be an effective nutrient-management strategy. Manure transfer to deficit areas results in the substitution of these surplus nutrients for commercial fertiliser nutrients. As a result, less total nutrients are applied to arable land in the surplus areas, and there is less potential for nutrient leaching and runoff. In addition, much of the nitrogen (N) content of poultry manure is in the stable organic form,

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which is converted to inorganic plant available N over several years (Bitzer & Sims, 1988; Keeney, 1982). This slow release may reduce N leaching losses if N release occurs during periods of crop needs. To achieve these benefits, the timing of manure applications and the quantity applied per application must match crop needs (Mkhabela, 2002). Disposal of manure on cropping areas at these rates may require manure transfer to deficit areas.

If the economic benefits of manure transfer from surplus to deficit areas are less than the costs, then regulations that require such transfers will lead to higher costs and reduced competitiveness of poultry production unless the public sector subsidises the disposal. The purpose of this research was to determine if the fertiliser value of poultry manure is adequate to offset costs of disposal when transferred from surplus to deficit areas. The costs of providing the services needed to use manure for fertiliser and the economic value of manure as fertiliser were estimated. Cost and benefit estimates were applied to KwaZulu-Natal to determine if all or a portion of poultry manure surpluses could be disposed of economically.

2. RESEARCH METHODS

2.1 The value of manure as fertiliser

The fertiliser value of poultry manure was estimated based on its N, phosphorus (P), and potassium (K) content. Table 1 shows the average nutrient contents in broiler and layer manure, reported on an as is basis. The fertiliser value of manure was estimated on selected crops by first determining the recommended amount of commercial fertiliser required for the crop. Potential availability of applied N, which is the least stable applied nutrient, was estimated. The required poultry manure required application to match the potential availability of N from commercial fertiliser was then calculated. An economic value was imputed to poultry manure equivalent to the savings in commercial fertiliser cost obtained by using poultry manure.

Table 1: Nutrient analysis of broiler and layer litter*

Nutrient	Broiler Manure	Layer Litter
Number of samples	60	179
Moisture content (%)	63.0	50.0
Nitrogen (kg t^{-1})		
Organic	22.0	22.5
Inorganic	7.0	8.0
Phosphorus (kg t^{-1})	12.9	9.6
Potassium (kg t^{-1})	12.5	11.3

Note: *Nutrient analyses are reported on wet basis and are based on samples submitted to the Plant, Manure and Compost Testing Laboratory at the Soil Fertility and Analytical Section, Cedara.

The crops selected for evaluation of manure fertilizer value have the highest potential for manure use in KwaZulu-Natal based on their requirements for external N applications. Table 2 shows recommendations for N, P, and K applications to each crop. Crop N recommendations were based on soil productivity group, including texture, bio-resource unit and crop management (Manson *et al*, 2000). P and K recommendations were based on provincial average soil test values for P and K by crop (Roberts & Smeda, 2001).

Table 2: Recommended nutrient applications and estimated manure applications and values for representative crops

Crop	Recommended Nutrient Application			Poultry Manure	
	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})	Application (t ha^{-1})	Value (R t^{-1})
Maize silage	120	12	56	5.0	243.30
Maize grain	120	10	56	5.0	221.00
Potatoes	140	20	70	5.0	243.10
Pasture	56	15	28	2.0	314.20

Losses of applied inorganic N occur due to ammonia volatilisation, leaching, and denitrification (Scharf & Alley, 1988). Ammonia volatilisation is a problem when fertiliser containing urea is surface applied. It has been estimated that an average of 25% of N that is applied as urea is volatilised (Scharf & Alley, 1988). Surface-applied N fertilisers in KwaZulu-Natal often contain 50% urea (Brockert, 2002) which would imply an average volatilisation loss of 12% to 13% of applied N. Studies that controlled for background leaching from no N treatments have found that leaching losses ranged from 3% to 10% of applied inorganic N (Scharf & Alley, 1988). Based on these findings, the estimated potential availability of applied inorganic N in commercial fertiliser is 80%. The crop will not take up all potentially available N in the first year. From 10% to 40% of applied N may be immobilised into soil organic matter (Kundler, 1970) and mineralised slowly (Brady, 1974).

Poultry manure application required to match potential availability of N from the application of commercial fertiliser was calculated based on 30 kg of total N per ton of manure of which 7.5 kg is inorganic and 22.5 kg is organic. These figures are the averages for broiler manure and layer litter in Table 1. Seventy-five percent of inorganic N is potentially available assuming that the manure is incorporated into the soil immediately after application (Givens, undated). Of the organic N, 50%, 12%, 5%, 2%, and 2% are mineralised (converted to inorganic plant-available N) in years one to five, respectively, after incorporation (Keeney, 1982). The total amount (kg) of N potentially available to the crop per tonne of manure is as follows:

$$0.75 \times 7.5\ \%\ (0.5\%\ 0.12\%\ 0.05\%\ 0.02\%\ 0.02\%) \times 22.5 \ \text{э}\ 21.6 \qquad (1)$$

where 7.5 and 22.5 represent kg of inorganic and organic N, respectively. These figures assume that manure is applied to the site for at least 5 years for mineralisation of organic N to occur.

Table 3 shows calculations of the manure application rate and imputed manure value on a representative hectare of maize silage. When commercial fertiliser is used, 120 kg of commercial N are applied, of which 96 kg are potentially available to the crop after deducting leaching and volatilisation losses. Based on the average P content of broiler manure and layer litter, 11.3 kg t^{-1}, and the average K content, 11.9 kg t^{-1}, a total of 53 kg of P and 56 kg of K are applied. Total fertiliser costs including application are R1143.50 ha^{-1}. If residual N is available from previous manure application, then 5 t of manure must be applied to match the 99 kg N uptake from commercial fertiliser. The applied manure contains 53 kg P, of which the crop needs 12 kg, and 53 kg K. Fertiliser cost savings from manure use total R1143.50 ha^{-1} or approximately R229 t^{-1}.

A carrying charge could be deducted from the value of the manure to account for the cost of waiting for mineralisation of organic N into inorganic plant-available form (Lee *et al*, 1980). The value of manure would be reduced by about R4.40 t^{-1} at 8% interest. Consistency would require that one also account for lags in plant uptake of commercial fertiliser N due to immobilisation. Thus, due to uncertainty about the amount of immobilised inorganic N, a carrying charge is not deducted from either fertiliser or manure values.

Manure application rates vary from 2 to 5 T (Table 2). Imputed values vary from about R220 t^{-1} for maize grain to more than R310 t^{-1} for pasture. Higher values are obtained on pasture because the potassium and phosphorus contents of applied manure more closely match their recommended application rates. Consequently, more manure nutrients contribute to a reduction in commercial fertiliser costs, resulting in a higher imputed value per ton of manure.

If manure applications were limited to the amount required to meet the crop's P requirement, then applications would be lower and imputed values higher than shown in Table 2. For example, a 1 ton manure application to maize silage would meet the 10 kg P requirement. The manure would have to be supplemented with 90 kg of commercial N and 40 kg of commercial K at a total cost of R784.70, including application. This cost represents a savings of R358.80 ha^{-1} or R326.20 t^{-1} of manure applied.

Table 3: Estimated value of poultry manure applied to maize silage based on commercial fertilizer savings per hectare

	Plant Nutrient Source	
	Commercial Fertiliser	**Poultry Manure**
	kg ha^{-1}	
Poultry manure applied (t ha^{-1})	0	5
Commercial N applied	120	0
Potential availability of applied commercial N	96	0
N applied in manure	0	150
Potential availability of applied manure N	0	109
Total potentially available applied N	96	109
Commercial P applied	12	0
P applied in manure	0	53
Total P applied	12	53
Commercial K applied	56	0
K applied in manure	0	56
Total K applied	56	56
	R	
Commercial N cost @ R5.30 kg^{-1}	636	0
Commercial P cost @ R12.10 kg^{-1}	145.20	0
Commercial K cost @ R4.20 kg^{-1}	235.20	0
	R ha^{-1}	
Commercial fertiliser application cost (R ha^{-1})	111.20	0
Total commercial fertiliser cost (R ha^{-1})	1143.50	0
Value of manure (R t^{-1})	-	243.30

3. COSTS OF POULTRY MANURE TRANSFER

Transfer costs per unit of manure depend on the amount of manure the poultry production firm handles. As the amount of manure handled increases, the firm has to seek customers located further from the source of manure production, and delivery costs increase. If the amount of manure to be handled is known, the costs incurred by the firm can be determined assuming the firm tries to minimise the costs of manure handling, TC. The firm's objective is as follows:

$$\text{Minimise TC} = 3^{M}_{\ i=1}\ 3^{N}_{\ j=1}\ C_{ij}\ X_{ij} \qquad (2)$$

subject to:

$$3^{M}_{i=1}\ X_{ij} = X_i \text{ for } i = 1, 2, \ldots m \qquad (3)$$

$$3^{M}_{\ i=1}\ a_{ij}X_{ij}\ \#\ X_j \text{ for } j = 1, 2, \ldots n \qquad (4)$$

where C_{ij} equals the per ton cost of making manure from the i^{th} area available for fertiliser use in the j^{th} deficit area; m is the number of manure surplus areas; n is the number of manure deficit areas; X_{ij} represents the amount of manure transferred from surplus area i to deficit area j; X_i is the amount of manure available for export from surplus area i; X_j is the amount of N required from external applications by crops in deficit area j; and a_{ij} is the amount of N taken up by the crop per ton of applied manure. Equation 2 states that the firm seeks to minimise its total costs of transferring a fixed amount of manure. Equation e requires the firm to transfer all surplus manure from surplus to deficit areas. Equation 4 states that no area can receive more manure than it has potential to use for N on arable land and/or pasture.

Table 4 shows the estimated handling costs per ton that would be incurred in obtaining and applying manure for fertiliser.

Table 4: Estimated costs incurred in obtaining and applying poultry manure for fertiliser

Item	**Cost (R t^{-1})**
Removal	17.35
Assembly	5.50
Storage	10.00
Testing	25.00
Loading	3.50
Application	20.25
Brokerage	5.50
Total	**87.10**

These estimates assume that a firm would receive manure free in exchange for removing it from the poultry house, which is a common practice in KwaZulu-Natal. The firm would assemble the manure at a central location, store it for up to 6 months, test it for nutrient content, load it onto trucks, and deliver it to the crop field. A brokerage fee is included to account for overhead costs the firm would incur in identifying customers and coordinating pickup and delivery of manure (Weaver & Souder, 1990). The total cost, R87.10, does not include delivery costs, which vary depending on the distance the manure is hauled.

In order to estimate manure surpluses and the costs of transferring surpluses to deficit areas, KwaZulu-Natal poultry and crop production in 1999 (Kars *et al*, 1999) were analysed. Manure production by area was estimated based on the number of broiler and layer chickens produced (Kars *et al*, 1999). Potential manure applications on arable land and pastures were estimated based on harvested crop and pasture area, recommended external N application rates to crops and pasture, and the N content of manure. The following per hectare N application rates were used: 110 kg for grass hay, 90 kg for grass silage, 56 kg for grass pasture, and 100 to 140 for maize silage and maize grain depending on estimated area yield potential and targeted yield (Manson *et al*, 2000). The potential arable land for spreading manure was reduced to reflect the availability of 16.1 kg of plant recoverable N/yr/dairy cow produced in the area (Bosch & Napit, 1991).

The potential of adjacent areas to use manure from surplus areas for fertiliser was determined by calculating the requirement of harvested arable land within the area for external N applications. The amount of N available from locally produced poultry manure and cattle manure was deducted from this requirement. The remainder represented the potential N requirement that could be satisfied by importing manure from surplus areas. The cost per ton of shipping manure was R87.10, plus the delivery charge of 70c km^{-1} (Smith-Bailey, personal communication, 2002).

4. RESULTS

Three scenarios were developed. In the first scenario, all arable land and pastures were available for spreading poultry manure and/or cattle manure (dairy and feedlot cattle) in both surplus and deficit areas. In the second scenario, no pastureland was available for spreading poultry manure and/or cattle manure in surplus or deficit areas. This scenario was included because few farmers in the study area spread commercial fertiliser on pasture; therefore it is unlikely that they would be willing to pay to apply manure to pasture in place of commercial fertiliser. In scenario three, only half of the harvested arable land was available for spreading poultry manure and/or cattle manure in surplus and deficit areas.

With scenario one, one area had over 26,000 T of surplus poultry manure that could be transported to an adjacent area over a distance of 44 km, at a cost of R60.00 T^{-1} or a total cost of R1,560,000. The cost per T was below the lowest value in Table 2, indicating the entire surplus could be delivered at a potential profit. In scenario two, it was estimated that two areas had an estimated poultry manure surplus totalling over 81,000 T. The entire surplus could be transported to two deficit areas at a cost of slightly more than R4.8 million. The weighted average hauling distance was 43 km and average cost was R60.00 T^{-1}. The average cost of hauling manure from a surplus to a deficit area was R60.00 T^{-1}, R161.00 less than the lowest fertiliser value, R221.00, reported in Table 2, indicating that the entire surplus could be profitably transported to deficit areas. In scenario three, five KwaZulu-Natal areas had estimated surpluses totalling over 50,000 T. If haulage would be made to 9 deficit areas the total costs would be slightly over R3 million or about R60.00 T^{-1}.

Preserving manure N content during handling and storage is essential to the economic feasibility of manure transport. With hauling costs fixed at 70 cents/T-km, it was observed that a reduction in N content to 27.5 kg T^{-1} would not affect the percentage of surplus delivered. However, further reductions to 25 and 22.5 kg T^{-1} reduced the proportion of surplus delivered to 51% and 32% respectively. Increases in transportation costs would adversely affect the feasibility of manure transport. With N content fixed at 30 kg T^{-1}, a 25% increase in hauling costs from 70 to 86 cents/T-km would reduce the proportion of surplus delivered to 86%. When costs double to R1.40 T-km, only 24% of the surplus could be profitably transported.

5. SUMMARY AND CONCLUSIONS

Export of poultry manure from surplus to deficit areas for use as fertiliser was found to be economically viable in KwaZulu-Natal. The estimated fertiliser value of manure exceeded the costs of obtaining, storing, delivering, and applying manure to crops. Such transfers would result in substitution of poultry manure for commercial fertiliser nutrients. Less total nutrients would be applied to arable land, thereby reducing the potential for nutrient leaching and runoff into groundwater and surface water. This would also result in a more efficient use of available nutrients thus a more balanced and sustainable system. However, large-scale transfers of poultry manure currently are not happening. In fact, accumulation of manure surpluses in poultry-producing areas, such as the Camperdown/Hammersdale district, threatens further growth of the industry there.

It is apparent that few farmers are making use of poultry manure as an alternative or complimentary resource to inorganic fertiliser. Reasons for this under-utilisation of this alternative are unclear but could include the lack of information on the fertiliser value of poultry manure (Sims, 1987) and other costs that were not considered in this study. Education programmes targeted at showing farmers the economic value of poultry manure used as fertiliser could stimulate more use of poultry manure. Research should be conducted on ways to manage poultry manure more effectively as a crop N, P and K source. Mineralisation rates of organic N in poultry manure may be slowed by cold, dry soil conditions (Bitzer & Sims, 1988; Sims, 1986) thus affecting yields (Sims, 1987). Research should be conducted to prevent such yield losses, perhaps by plant tissue testing combined with supplemental side dressing of commercial fertiliser. Research would benefit water quality and enhance efficient use of resources by reducing potential N losses caused by over-application of poultry manure and/or commercial N.

In light of the information gaps that exist in the knowledge of the value of poultry manure as an alternative to fertiliser and the concomitant under-utilisation of this abundant resource, further research is recommended.

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