CSIRO

Measurement and treatment of phosphorus and carbon subsoil movement

Project UAD10

Economic Analysis

October 1999

J.C.R. Varcoe, D.J. Chittleborough
and J.W. Cox

CSIRO Land and Water, Adelaide
Technical Report 37/99, October 1999

THE UNIVERSITY OF ADELAIDE

Land & Water Resources
Research & Development Corporation

CSIRO LAND and WATER

CSIRO

CSIRO LAND and WATER

Measurement and treatment of phosphorus and carbon subsoil movement

Project UAD10

Economic Analysis

October 1999

J.C.R. Varcoe, D.J. Chittleborough and J.W. Cox

THE UNIVERSITY OF ADELAIDE

Land & Water Resources
Research & Development Corporation

CSIRO Land and Water, Adelaide
Technical Report 37/99, October 1999

Economic Analysis of Gypsum Usage

Clearly there are advantages in reducing the DOC content of the water coming off agricultural land, particularly that entering drinking water storages. Because of the complicated nature of DOC in the water purification process it is difficult to estimate a dollar value of reducing DOC input into surface and drinking water supplies. It may well be that the expense of spreading gypsum on a catchment scale far outways current treatment methods. If the amendment of certain soils with gypsum proves of agricultural benefit to land users the cost could be more easily absorbed. Such benefits may prove the use of gypsum to be economical, without even considering the beneficial environmental effects that it can have.

The economic analysis presented is thus centred on the benefit to the land user, which is the essential control on the economic viability of using gypsum to reduce the organic (and possibly P) input from agricultural land.

At present gypsum's primary agricultural uses are in alleviating problems associated with dispersive and hard setting soils (particularly sodic soils). The use of gypsum on these soils to increase plant yields is well documented.

More recently, studies have revealed that gypsum usage in acid soils (particularly acid subsoils) can increase plant yields. It appears that gypsum relieves the symptoms of soil acidity, namely Al toxicity and Ca deficiency. Studies have shown that the higher solubility of gypsum over lime allows gypsum to penetrate subsoil horizons much quicker. Thus as a source of Ca to relieve problems associated with soil acidity, gypsum has a more immediate response.

The economic evaluation presented here is based on crop responses to gypsum (in terms of percentage yield increases). Possible sources of variation in this evaluation are:

1. Source quality of gypsum and distance to be transported
2. Application rates
3. Crop responses
4. Crop value.

Dispersive and hard-setting soils

According to Shainberg *et al.* (1989) the economics of gypsum usage on sodic soils are unquestionably positive. On marginally sodic to non-sodic dispersive soils in Western Australia (Jarvis, 1987; Howell 1987 Table 1) gypsum used to improve soil structure has a significant effect on improving grain yields (4-48%). For these studies average yield increases of between 16 and 26% were obtained depending on whether conservative tillage (eg, deep drilling) or conventional tillage methods were used (respectively). On such soils however, the economics of gypsum are uncertain, as the cost depends on both the source of gypsum and the distance that it has to be transported. Another cost to be considered is that of application. This latter factor may be offset by combining the application of fertiliser and gypsum into the one process (as was done at Myponga in this study). This cost may be further reduced if the type of fertiliser used is a by-product gypsum such as phosphogypsum which already contains significant quantities of P. However the economic viability is still highly dependent on the proximity of a plant producing this by-product. The other factor to be considered is the type of crop. Studies (particularly in Brazil, South Africa and the U.S.A.) indicate that many crop types respond well to gypsum, and in general, the higher the value of the crops the greater the economical viability.

The final factor in determining gypsum economics is the rate of gypsum application. Results of these studies clearly indicated that a single application of gypsum at approximately 5 T/ha can continue to have an effect on yields for periods of 2 to 9 years, and perhaps beyond for a annual rainfalls ≈400 mm. Greene and Ford (1985) concluded that gypsum is leached at a rate of 1 T/ha for approximately every 125 to 360 mm rainfall. These results suggest that the effect of gypsum at 5 T/ha would last in the Adelaide Hills (approx. 700 mm pa) from 2 to 5 years. Whereas Howell (1987) states that there is no benefit in applying more than 2.5 T/ha in the first 4 years, higher rates do not harm the soil or crop, and may last longer. It is clear that there is evidence of long term yield increases in response to high levels of gypsum application (5-10 T/ha) but this is an area that still requires further research and confirmation. From the work summarised in Shainberg *et al.* (1989) it is apparent that an application of 5 T/ha continues to have positive effects for 3 to 4 years. For the purposes of this economic analysis a figure of 1 T/ha per annum consumption of gypsum has been selected.

Table 1. Effect of gypsum on grain yield (from Howell 1987 and Jarvis 1987).

Tillage method	No. Years Cropped	Grain Yield (t/ha)		% Response	Source
		No Gypsum	Gypsum		
Direct Drill	9	.90	.96	7	Howell (1987)
Conventional Drill	9	.62	.79	27	Howell (1987)
Direct Drill	2	.75	.78	4	Howell (1987)
Conventional Drill	2	.63	.75	19	Howell (1987)
Direct Drill	2	.95	1.1	16	Howell (1987)
Conventional Drill	2	.86	1.05	22	Howell (1987)
Direct Drill	2	.89	1.07	20	Howell (1987)
Conventional Drill	2	.66	0.91	38	Howell (1987)
Direct Drill	2	2.44	2.26	-7	Howell (1987)
Conventional Drill	2	2.3	2.28	-1	Howell (1987)
Triple disc drill	3	1.35	1.51	12	Jarvis (1987)
Scarifier/TDD	3	1.29	1.47	14	Jarvis (1987)
Direct Drill	3	1.47	1.53	4	Jarvis (1987)
District Practice	3	0.92	1.36	48	Jarvis (1987)

Gypsum @ 5 t/ha for Howell (1987) and 4.7 t/ha for Jarvis (1987)

The return at 3 rates of gypsum has been calculated based on an annual yield increase of 16%, for each year for every tonne of gypsum applied (Table 2). Figure 1 illustrates the difference in returns for lucerne silage and cereal straw; positive returns result more quickly for the higher value crop.

Note that the use of gypsum is not a panacea for arresting soil structure decline, but a valuable interventionist strategy that must be complemented with improved soil management strategies eg. reducing the initial causes of soil structure decline, through excessive tillage, over grazing etc.

Table 2. Yield increases of various amendments over control (no amendment) on crops in different rainfall zones (from McLay *et al.* 1994).

Site	Year	Treatment	Yield Increase (%)	Crop	Rainfall (mm)
Carrabin	1989	Gypsum 1,3,9 T/ha	45	Wheat	285
Carrabin	1989	Gypsum+Lime	77	Wheat	285
Carrabin	1989	Lime 2,4 T/ha	15	Wheat	285
Trayning	1989	3 above treatments	ns	Wheat	320
Carrabin	1990	Gypsum 1T/ha	12	Wheat	355
Carrabin	1990	Gypsum 3,9 T/ha	25	Wheat	355
Carrabin	1990	G+L	12-25	Wheat	355
Carrabin	1990	Lime 2,4 T/ha	15	Wheat	355
Trayning	1990	Gypsum 1T/ha	3	Wheat	344
Trayning	1990	Gypsum 3T/ha	10	Wheat	344
Trayning	1990	Gypsum 9T/ha	14	Wheat	344
Trayning	1990	Lime 2,4 T/ha	12-15%	Wheat	344
Trayning	1990	G+L	12-20	Wheat	344
Carrabin	1991	all amendments	reduced 0 to80	Lupin	350

There are other benefits, but not easily accounted for economically. First the increase in infiltration, and the resulting increase in plant growth will reduce the topsoil loss by erosion. Secondly, and a consequence of the first, increased plant growth, and therefore increased plant uptake should reduce fertiliser loss and reduce nutrient losses in runoff: an advantage to the farmer and the environment alike!

Acid Soils

The economics of gypsum utilisation, to alleviate the symptoms of soil acidity, is more difficult to quantify than for sodic or dispersive soils, as little study has been done looking at yield responses, particularly in Australia. McLay *et al* (1994) found that surface-applied gypsum increased wheat yields by up to 55% in the first 2 seasons in a Western Australian trial. In the same period lime increased yields by only 15%. The longevity of the response to gypsum was significantly affected by application rate, with the effects of 1 T/ha lasting for 1 season. In this study the most significant increases occurred when gypsum and lime were applied together as with the study of McLay and Ritchie (1993). This study also showed that there were significant variations in yields between regions and climates. A pot study by McLay and Ritchie (1995) further emphasised the benefits of gypsum to increase wheat yields in acid soils.

It is difficult to predict a value by which gypsum may increase yields on acid soils because there appears to be significant variation between both soil type and plant species. Furthermore, to calculate the advantages of gypsum usage over lime, particularly in dealing with subsoil acidity, differences in application need to be considered. Because of its solubility, gypsum may be broadcast on the surface and effect the same change in subsoil acidity to a similar extent as lime which has been incorporated at depth by deep tillage. Such deep tillage may cause a loss of productivity as a result of a degradation of soil structure. The high yield responses, particularly those reported McLay *et al* (1994) (Table 2) are almost certainly the result of gypsum improving soil structure in addition to attenuating soil acidity. Quantifying the proportional yield response to the improvement in soil structure and reduction in acidic effects in acid soils as a result of the application of gypsum not possible because of the paucity of studies on gypsum and acids soils.

Economic Evaluation

The economic evaluation of gypsum on dispersive and acid soils is summarised in Table 3a, b, c and d (as well as Figures 1a, b and c). This evaluation is based on an estimated cost of gypsum delivered at $30/T. This value will vary with distance from source, but approximates the value of gypsum in the Adelaide Hills region. The addition cost of $25/ha for spreading of the gypsum is probably a generous estimate of the actual cost in fuel and labour to the farmer.

Table 3a. Costs of gypsum.

Cost Of Gypsum	Application	Total	Spreading	Total	Cost Spread over year number			
Delivered ($)	T/ha	Gypsum	$/ha	$	1	2.5	5	10
30	2.5	75	25	100	100	40	na	na
30	5	150	25	175	175	70	35	na
30	10	300	25	325	325	130	65	32.5

For the purpose of this economic evaluation the expected effective life of gypsum is 1T of gypsum lasts for 1 year, 2T for 2years and so on. This is a figure, which tends to agree with most literature.

Table 3b. Total yield increase over *normal* production of 1T/ha in units of T/ha.

	Total yield improvement T/ha at 16% pa			
T/ha	**1**	**2.5**	**5**	**10**
2.5	0.16	0.4	0.4	0.4
5	0.16	0.4	0.8	0.8
10	0.16	0.4	0.8	1.6

The yield improvement figure of 16% per annum (Table 3b) is the average yield improvement of the two studies by Howell (1987) and Jarvis (1987). Yield increases in this evaluation are based on a modiste normal production of 1 T/ha. Figures 2a and b show returns on 5 T/ha of gypsum over a 5 year period with yield improvements of 10 and 20%, on 3 crops of varying value. As much of the land that lies in Adelaide's reservoir catchments is pasture, yields in this evaluation are based on hay and silage production. The value of this hay and silage were taken from the *Stock Journal* on 18/3/99, and are the minimum prices paid on crops from the Adelaide hills.

Table 3c. Total yield increase.

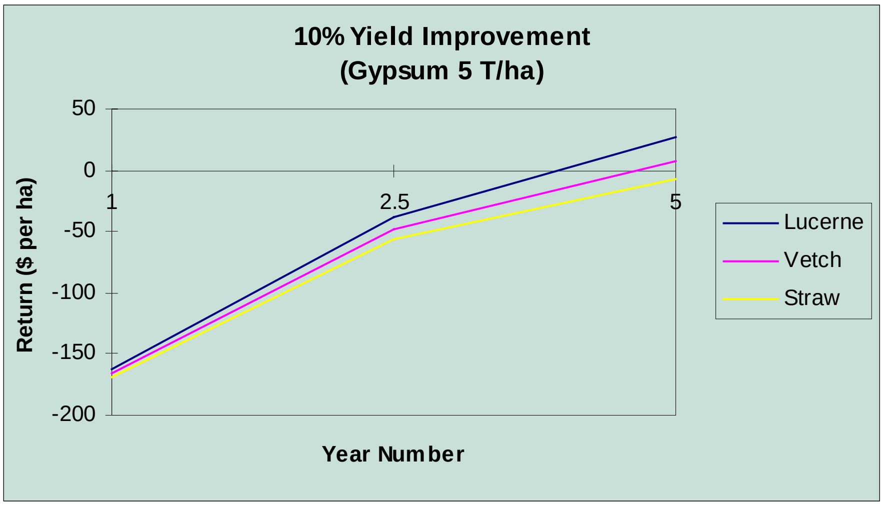
Hay/Silage value in $ per T for Adelaide hills (Stock J. 18/3/99) minimum prices						
Lucerne	**Vetch /oats**	**Medic /clover**	**Oaten hay**	**Cereal Straw**	**Pea straw**	**Ryegrass hay**
125	85	120	90	55	73	85

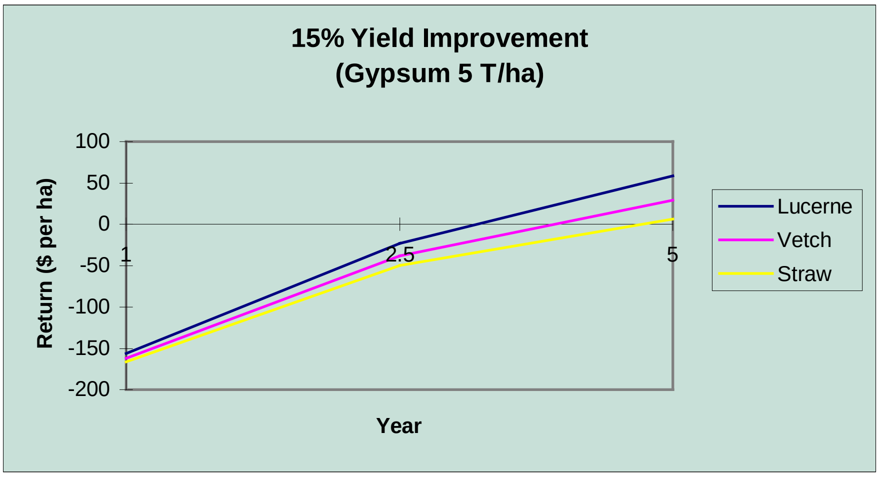
Care has been taken in this evaluation to over estimate costs and underestimate production value, to give a realistic return. Yield improvements however are difficult to estimate, particularly on acid soils, and will vary significantly with soil type.

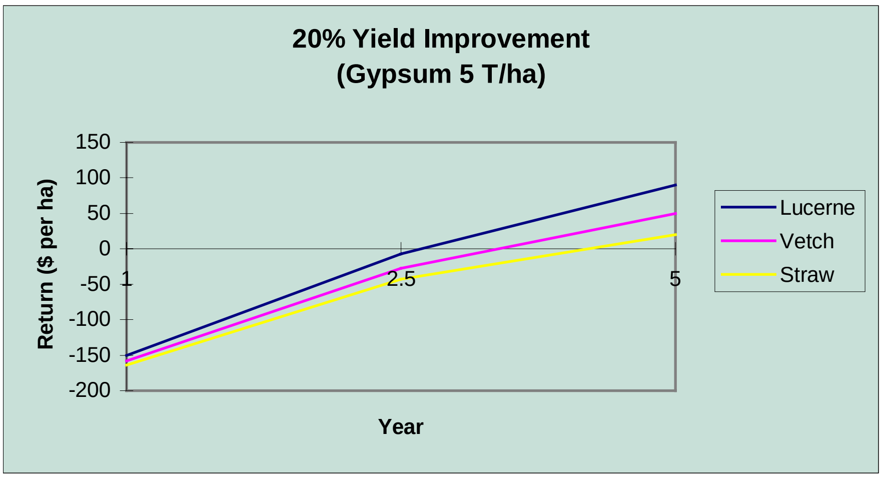
Table 3d. Return on gypsum application in terms of $ per ha.

T gypsum / ha	Year Number 1	2.5	5	10
	Lucerne			
2.5	-80	10	0	0
5	-155	-20	65	0
10	-305	-80	35	167.5
	Vetch/oats			
2.5	-86.4	-6	0	0
5	-161.4	-36	33	0
10	-311.4	-96	3	103.5
	Medic/clover			
2.5	-80.8	8	0	0
5	-155.8	-22	61	0
10	-305.8	-82	31	159.5
	Pea straw			
2.5	-88.32	-10.8	0	0
5	-163.32	-40.8	23.4	0
10	-313.32	-100.8	-6.6	84.3
	Ryegrass hay			
2.5	-86.4	-6	0	0
5	-161.4	-36	33	0
10	-311.4	-96	3	103.5
	Oaten hay			
2.5	-85.6	-4	0	0
5	-160.6	-34	37	0
10	-310.6	-94	7	111.5

Figure 1. Returns per hectare assuming a) 10% yield improvement b) 15% yield improvements and c) 20% yield improvement from applying 5T/ha gypsum.







References

Greene, R. S. B., and Ford, G. W., 1985. The effect of gypsum on cation exchange in two red duplex soils: Australian Journal of Soil Research, **23,** 61-74.

Howell, M., 1987. Gypsum use in the wheatbelt. *Journal of Agriculture, Western Australia* **28**, 40-3.

Jarvis, R., 1988. Tillage systems and soil stability. *Journal of Agriculture, Western Australia* **29,** 54-7.

McLay, C. D. A., and Ritchie, G. S. P., 1993. Effect of gypsum and lime on wheat growth in pots containing an acidic subsoil. *In* 'Plant and Soil Interactions at Low pH' (ed. R.A. Date), p. 747-750. Kluwer Academic Publications, Netherlands.

McLay, C. D. A., and Ritchie, G. S. P. 1995. Effect of gypsum application rate and leaching regime on wheat growth in a highly acidic subsoil: *In* 'Plant and Soil Interactions at Low pH' (ed. R.A. Date) p. 527-530. Kluwer Academic Publications, Netherlands.

McLay, C. D. A., Ritchie, G. S. P., Porter, W. M. 1994. Amelioration of subsurface acidity in sandy soils in low rainfall regions. 2. Changes to soil solution composition following the surface application of gypsum and lime: *Australian Journal of Soil Research*, **32**, 847-65.

Shainberg, I., Sumner, M. E., Miller, W. P. 1989. Use of gypsum on soils: a review: *In* 'Advances in Soil Science' v9 (ed B.A. Stewart), Springer Verlag, New York.

Sumner, M. E. 1993. Gypsum and the World scene. *Advances in Agronomy* **51**, 1-32.