Using phosphorus budgets to assess fertiliser use in vegetable cropping in the Sydney basin

E Hollinger [1], PS Cornish[1] and AT Wells[2]

[1] Centre for Farming Systems Research, University of Western Sydney Hawkesbury, NSW
[2] Horticultural Research and Advisory Station, Gosford, NSW Agriculture, NSW

ABSTRACT

This paper explores the use of crop-scale nutrient budgets to assess the sustainability of agricultural production. It uses phosphorus (P) budgets for conventional vegetable cropping in the Sydney basin as an example. Results from monitoring commercial crops and NSW Agriculture's 'vegetable farming systems' experiment indicate that fertiliser P inputs greatly exceeded crop removal and runoff losses of P. Very high fertiliser P inputs (191-472 kg $ha^{-1}yr^{-1}$) resulted in very high soil extractable P concentrations. Between 3 and 34% of P inputs were lost in runoff, which is sufficiently high to have significant offsite ecological impacts. The largest runoff losses of P occurred on a sodic fine sandy loam. Crop removal of P was greater for potatoes than for leafy vegetables. Results from the vegetable systems experiment suggest that commercial use of fertiliser P may be excessive. P inputs of <30 kg yr^{-1}over two years resulted in reduced runoff losses, with no significant impact on yields of capsicum and sweet corn.

Key Words

Phosphorus, soil P, runoff, phosphorus budget, phosphorus balance, crop yield, vegetable farms.

INTRODUCTION

In Australia, movement of phosphorus (P) from agriculture to rivers is a key environmental issue and the relative quantities of P inputs and outputs from farming systems should be indicative of both environmental performance and the efficiency of agricultural production. Nitrogen (N) budgets are used in the European Union (EU) to underpin agro-environmental policy. The EU's Nitrate Directive concerns the concentration of nitrate-N in drinking water. N budgets are used to provide an economic incentive for the adoption of extensive over intensive farming systems. It is based on the premise that intensive, high input systems, have surplus N (inputs exceed outputs) and the size of the surplus indicates potential for leaching of nitrate to groundwater (1, 2).

This paper focuses on P budgets for vegetable cropping in the Sydney basin, where elevated concentrations of soil P have contributed to a decline in water quality (3). The aim of this paper is to determine whether a nutrient budgeting approach assists to identify opportunities to reduce P application rates. As a farm management tool, the use of nutrient budgets is in its infancy. Much work is needed to establish whether a balanced budget is feasible and the consequences of sub-optimal fertilisation.

Accordingly, we have focussed on measuring the major inputs and outputs at the crop scale. These data will assist the development and implementation of Best Practice and guidance for policy makers. Our work combines on-farm research (4) and a vegetable farming systems experiment at NSW Agriculture's research station at Somersby (5).

MATERIALS AND METHODS

On-farm work described in this paper is derived from two years of continuously monitoring a farm on duplex (textural contrast) soil and preliminary data from ongoing monitoring on a sodic fine sandy loam on the floodplain. Our on-farm crop-scale monitoring is continuing on a range of shale-derived duplex soils and alluvial soils. The other major soil type used for vegetable production in the Sydney basin is a sandy yellow earth, which is being fully investigated in the systems experiment (5).

Underway since 1992, the vegetable farming systems experiment involves analysis of five vegetable production systems. The aim is to find ways of growing vegetables that have minimum impact on the environment while remaining economically viable for the long-term. Two vegetable farming systems that differ primarily in their fertiliser inputs are discussed in this paper; 1) a conventional high input system, and 2) a lower input system.

To develop a budget, the major inputs and outputs are quantified. Inputs in our P budget included mineral and organic fertilisers. The major outputs were runoff and crop removal. For more detail on method see Hollinger *et al.* (4) and Wells *et al.* (5). Evidence suggests P losses through leaching on the highly permeable sandy soils at Somersby, were relatively small in relation to the other budget components, and are ignored here. We also have data to suggest some lateral movement of soil solution P above the B horizon on a duplex soil, but here we assume P leaching is not significant on the heavier, less permeable soils.

RESULTS AND DISCUSSION

A total of 24 months of data from on-farm monitoring (July '95-June'97) and 29 months of data from Somersby (April '95-August '97) are summarised in Fig. 1. To enable comparisons, the data have been converted to annual rates.

The type and rates of P inputs varied between years and soils types. The fertiliser P inputs shown in Fig. 1 ranged from 191-472 kg ha $^{-1}$yr^{-1}.

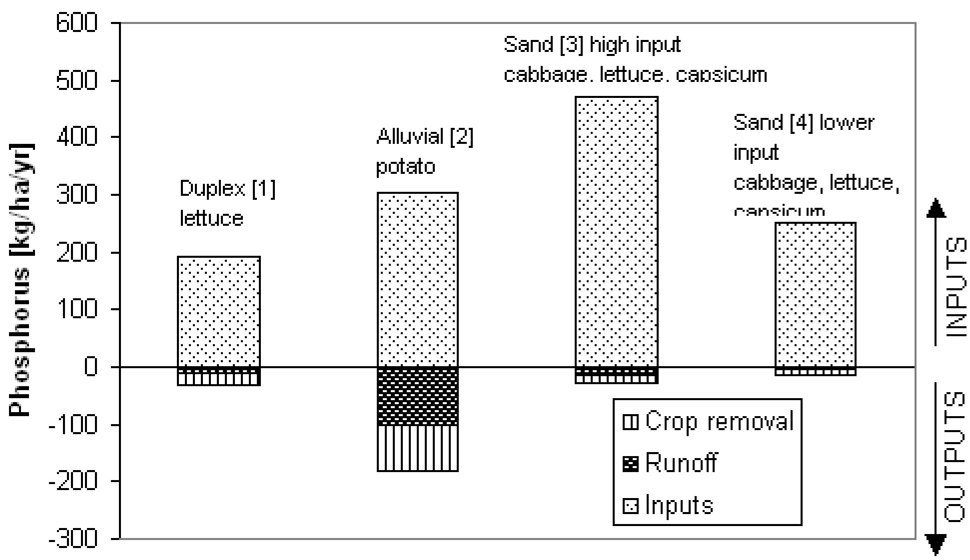

Figure 1. Annual P inputs and outputs on [1] duplex soils growing lettuce, [2] alluvial soils growing potatoes, sandy soils growing cabbage, lettuce and capsicum with [3] high P inputs and [4] moderate P inputs.

Notes: [1] is based on four lettuce crops per year. [2] is based on one crop, multiplied by three (assuming three crops per year). [3] and [4] are for rotations of cabbage, lettuce and capsicum.

With the exception of potatoes, crop removal of P is a very small proportion of fertiliser inputs (3-5%). Crop removal was considerably larger for potatoes than for lettuce, cabbage, and capsicum. Crops that utilise larger amounts of P (eg. Potatoes as suggested by Fig. 1) could be used where soil extractable P is excessively high and may otherwise lead to offsite ecological problems (Fig. 2). In the long-term, P fertiliser rates should be adjusted according to the P removing potential (in the harvested produce) of crop rotations grown on each farm.

While crop P removal varies according to crop type, P inputs are not varied to the same extent. Ongoing monitoring of a wider range of warm and cool season crops on a range of soil types will provide a more complete picture and indicate how crop rotations can be used to utilise a larger proportion of P inputs.

Fig. 1 clearly shows that P inputs far exceed P outputs. Soil P analysis indicates that the bulk of applied P accumulates in the soil, resulting in an increase in extractable P. The concentration of extractable P (Bray) (0-10 cm) on the sandy soils increased from a mean of 87 mg kg^{-1} at the outset of the experiment (previously the site was a citrus orchard) to 361 mg kg^{-1} for the high input system and 203 mg kg^{-1} for the lower input system. On the duplex soil, Bray P (0-10 cm) increased from 174 mg kg^{-1} to 304 mg kg^{-1} within the monitoring period, compared to a concentration of 5 mg kg^{-1} in a nearby native soil. Results from analysis of P in the alluvial soil are not yet available.

It is well known that very high rates of P application are used in vegetable cropping in the Sydney basin (eg. 450 kg P $ha^{-1}yr^{-1}$ (6)), which is made up of poultry manure (≈40-65%), superphosphate and N P K blends (5). There is also strong anecdotal evidence that growers are continuing to apply high rates of P even though extractable soil P concentrations exceed the threshold recommended in best practice guidelines. The best practice guidelines for growing vegetables (7) recommend that soils with >150 mg P kg^{-1} (Bray) require no additional P for at least one year. However these guidelines have no sound scientific basis and it is not known if 150 mg kg^{-1} is too high, too low, or should vary according to soil type and crops grown. It is not known whether current high fertiliser P rates are beneficial for vegetable production in the district, or whether growers persist with high P fertiliser rates as 'insurance'. The P budgets shown in Fig. 1 would suggest that P fertiliser inputs could be reduced to a maintenance application rate (to replace system losses) once extractable soil P reaches a threshold concentration.

Regardless of the reasons for current high P input rates, there is a significant downstream environmental impact. A steady rise in the concentration of soluble P in runoff was measured on the farm situated on the duplex soil (Fig. 2). There was a significant relationship ($p<0.01$) between the soluble P concentration in runoff and time. This was probably linked with an increase in extractable P in soil samples from 174 mg kg^{-1} to 304 mg kg^{-1} over the period. These changes in soil P were due solely to the addition of poultry manure as no superphosphate was applied within the period. Similar soil P/runoff P relationships have been reported widely in recent years. For example, Sharpley (8) reported that soluble and bioavailable P in runoff was linked to Mehlich-3 extractable P content of the soil. He found that P sorption saturation in soil was correlated with soluble P ($r^2 = 0.86$) and bioavailable P ($r^2 = 0.85$) in runoff.

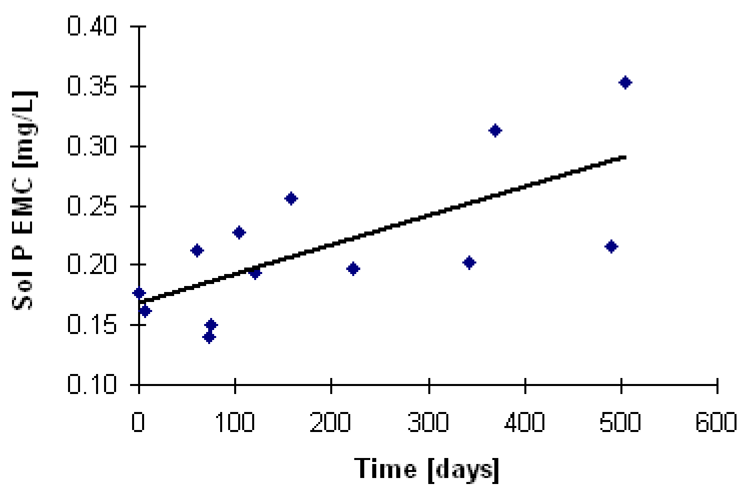

Figure 2. Event mean concentration (EMC) of total soluble P measured in runoff from a vegetable farm on duplex soil.

Although soluble P represents only a small proportion of total P lost in runoff (≈10%) (4, 5), soluble P is immediately available for uptake by algae and therefore causes a more immediate ecological disturbance. The continuing addition of such high rates of fertiliser P is also likely to significantly increase the total soil P pool, as found on the sandy soil at Somersby (5). Therefore, the rate of particulate losses is also expected to increase with time.

Although a reduction in P fertiliser rates is ecologically desirable, is it horticulturally feasible? Trials on capsicum and sweet corn at Somersby showed that P inputs of <30 kg $ha^{-1}yr^{-1}$ over a two year period produced no significant difference in yield compared to conventional high P inputs. Higher sweet corn yields and profitability were achieved with reduced P inputs in combination with reduced tillage after a rye-vetch cover crop. Clearly there is a need to further investigate relationships between soil P tests, P inputs and crop response, and to revise P guidelines for the range of soil types used for vegetable production in the district.

CONCLUSIONS

Quantifying nutrient balances requires reliable farm input/output data as well as reliable techniques for measuring the processes operating in nutrient cycles (eg. runoff). Data collected so far for vegetable cropping in the Sydney basin shows a large imbalance between system inputs and outputs, resulting in ecologically significant P loads to receiving waterways. The degree to which inputs exceed outputs indicates that fertiliser P rates currently used could be greatly reduced for most crops.

Preliminary trials on sandy soils indicate that P inputs can be reduced with no impact on productivity, validating conclusions derived from P budgets. However, work is needed to determine whether this is true for a wider range of crops and soil types. Given that much cropping occurs in soils with initially low fertility, it is also necessary to determine when soil P concentrations are sufficient to reduce fertiliser inputs, and then, whether it is possible to ultimately balance inputs and outputs.

The budgeting approach used here could be used as a model for all forms of agricultural production in Australia, both as a means of broadly assessing environmental sustainability, and to identify possible improvements to farm management.

ACKNOWLEDGEMENTS

The authors wish to thank collaborating farmers. Funding has been provided by NLP, HRDC and LWRDC.

REFERENCES

1. Brouwer, F. 1998. *Nutr. Cycl. Agroeco*. 52, 303-308.

2. Watson, C.A., Atkinson, D. 1999. *Nutr. Cycl. Agroeco*. 53, 259-267.

3. Cornish, P.S., Jones, D., Kuczera, G., Baginska, B., Henderson, L., Jung, R., Riley, K., Wood, R. and Hollinger, E. 1997. Land and water degradation due to agriculture in the Hawkesbury-Nepean. University of Western Sydney, Hawkesbury. Richmond, NSW.

4. Hollinger, E., Cornish, P.S., Baginska, B., Mann, R., Kuczera, G. 2000. *Agric. Wat. Manag.,* In press.

5. Wells, A.T., Chan, K.Y., Cornish, P.S. 2000. *Agric. Ecosys. & Envi.t*, 80 (2000), 47-60.

6. Jinadasa, K.B.P.N., Milham, P.J., Hawkins, C.A., Cornish, P.S., Williams, P.A., Kaldor, C.J., Conroy, J.P. 1997. *J. Environ. Qual.* 26(4), 924-933.

7. NSW Agriculture. 1997. Best Practice Guidelines for Growing Vegetables. NSW Agriculture, Orange.

8. Sharpley, A.N. 1995. *J. Environ. Qual.* 24, 920-926.