Effects of cultivation on phosphorus exports from irrigated pastures

David Nash, Hayley Castlehouse and Murray Hannah

[A]Future Farming Systems Research Division, Victorian Department of Primary Industries - Ellinbank, 1301 Hazeldean Rd, Ellinbank, Victoria 3821, Australia. Email david.nash@dpi.vic.gov.au

Abstract

Soil, soil water and overland flow were measured on border-check irrigation bays that had received various levels of soil disturbance (i.e. cultivation) aimed at reducing potential P mobilisation from surface soil (0-20 mm) over a four year period.

In general, increasing levels of soil disturbance lowered surface soil Olsen P, Colwell P, Organic P and Calcium Chloride Extractable P although the strength of the relationships diminished with time. Increasing levels of soil disturbance also lowered soil water Dissolved Reactive P (DRP) and Total Dissolved P (TDP). However, these effects did not translate to overland flow. In the first year there was an apparent reduction in overland flow DRP, TDP and Total P with increasing soil disturbance (P=0.041, P=0.012, P=0.025) but that trend dissipated quickly with time (P=0.05). There was no such trend in subsequent years.

These experiments were undertaken on commercial farms. It would appear that while cultivation lessened background or 'systematic' nutrient exports, critical decisions of the land managers such as applications of additional N fertiliser and grazing affected expression of those changes. This study emphasises the need to develop improved management systems rather than simply improved management practices if we are to meaningfully address nutrient exports from pasture based grazing.

Key Words

Runoff, water quality, destratification

Introduction

Excessive phosphorus (P) and nitrogen (N) concentrations in streams draining agricultural catchments and their receiving waters are a world-wide problem. Pasture based grazing is a major landuse in Australia and New Zealand with P exported from these systems contributing to the eutrophication of national assets including the Gippsland Lakes and associated wetlands (Grayson *et al.* 2001). In perennial grasslands surface-applied P amendments, detrital material and wastes from grazing animals can increase P concentrations, lower P adsorptive capacity in surface soils (Dougherty *et al.* 2006) and increase P export potential (Pierson *et al.* 2001). Cultivation is one way of lessening P availability in surface soils (sometimes referred to as P destratification) and therein P exports, although most such studies have been undertaken at the plot scale.

Laser grading (i.e. leveling of pasture soils in preparation for border-check irrigation) is an extreme form of soil disturbance that has been shown to lessen Total Dissolved P (TDP), Total Dissolved N (TDN), Total P (TP) and Total N (TN) exports in wetting-front runoff by 40, 29, 41 and 36% respectively (Nash *et al.* 2007a; Nash *et al.* 2007b). In this study we use a field scale experiment to investigate the effectiveness of a series of lower impact treatments that might be used as part of a pasture renovation program to lower surface soil P and N concentrations and nutrient exports. The specific aims of the study were: (a) to compare management interventions with differing levels of soil disturbance that may decrease P mobilisation and decrease nutrient concentrations in overland flow; and (b) to investigate the longevity of such management interventions and factors that may affect them.

Methods

The experiment commenced in 2003/2004 when 16 irrigation bays (on three farms) in the Macalister Irrigation District (MID) of south eastern Australia were selected and prepared (i.e. covariate soil sampling and irrigation sampling) for testing. A control and five treatments ((i) direct drilling of pasture without spraying with herbicide; (ii) direct drilling following spraying; (iii) spraying followed by aeration and direct drilling; (iv) spraying followed by cultivation to 100 mm and direct drilling; and (v) spraying followed by cultivation to 200 mm and direct drilling) were applied to groups of six bays on each of two farms in 2004/05. The following year an additional three of a group of four bays were treated with the most disruptive treatments (iii, iv and v).

Pasture on the bays contained perennial ryegrass (*Lolium perenne*), white clover (*Trifolium repens*), tall fescue (*Festuca arundinacea* cv. Advance, one bay only) and assorted invasive species including dock

(*Rumex spp.*) and distichum (*Paspalum paspaloides*). The soil type was a Vertic, Grey Sodosol (Natrixeralf). Twice yearly a basal dressing of fertiliser (containing ca. 11, 25, 30 and 15 kg/ha of N, P, K and S, respectively, per application) was applied to the field sites.

Where possible, farms were sampled once in late spring-early summer and once in late summer-early autumn. As fertiliser application and grazing affect runoff nutrient concentrations, sampling occurred at least five weeks after P fertiliser applications and where possible, sampling did not occur less than one week after grazing.

Surface soil samples were recovered a day or two after irrigation when surface water had receded. Fresh faecal deposits were avoided to minimise variability from the potential nutrient source. The soil samples were taken from a 0-20 mm depth at the top of the bays adjacent to the irrigation water inlet and at 50 m intervals thereafter. A minimum of 30 soil cores were extracted using a stainless steel soil probe (25 mm I.D. x 20 mm) and bulked to obtain a composite sample for each bay sampling point. Cores were collected from a transect perpendicular to the check-banks within 2 m of the sampling point. The soil cores were stored (<4^{o}C) in polyurethane bags and transported to the laboratory within 4 hours of collection.

At the laboratory the composite soil samples were thoroughly hand-mixed and bulked prior to preparation for soil and soil water analyses. A single bulked sample, representing the bay in question, was then prepared for soil analyses. Soils were analysed for Olsen P and Colwell P using standard methods (Rayment and Higginson 1992). Organic P was estimated as the additional P released after persulfate digestion of the Colwell P extract and measured using the traditional phosphomolybdenum blue chemistry. Calcium Chloride Extractable P was measured after a 1 hr extraction using a 1:10 ratio of soil to 0.01M $CaCl_2$ solution, followed by filtration through a Whatman (Maidestone, UK) #2 filter paper. Soil water was extracted from a sub-sample of the soil mixture (Toifl *et al.* 2003) on the same day as sample collection and before the soil mixture was dried. Soil water was analysed for EC, pH, Dissolved Reactive P (DRP) and Total Dissolved P (TDP).

Overland flow samples were collected from the irrigation immediately preceding soil sampling. As was the case for soils, overland flow samples were taken at the top of the bay adjacent to the irrigation water inlet and at 50 m intervals thereafter. Overland flow was sampled at the wetting front (i.e. within 2 m of the actual water front). At each sampling location at least 14 columns of water, each *ca.* 70 cm^3, were recovered (Nash *et al.* 2004). Filtered water samples were tested for DRP and TDP (<0.45 μm) and unfiltered samples for Total P (TP) (Lachat Instruments 2009). Dissolved Organic P (DOP) was calculated as the difference between TDP and DRP.

Results

Selected results are presented in Figures 1, 2 and 3. Surface soil (0-20 mm) Olsen P and Colwell P varied between sites, treatments and years. In both cases the lowest Olsen P and Colwell P concentrations were in the 100 and 200 mm cultivation treatments. Soil Organic P did not vary between sites but did vary between treatments and years. Soil Calcium Chloride Extractable P also varied between sites, treatment and years.

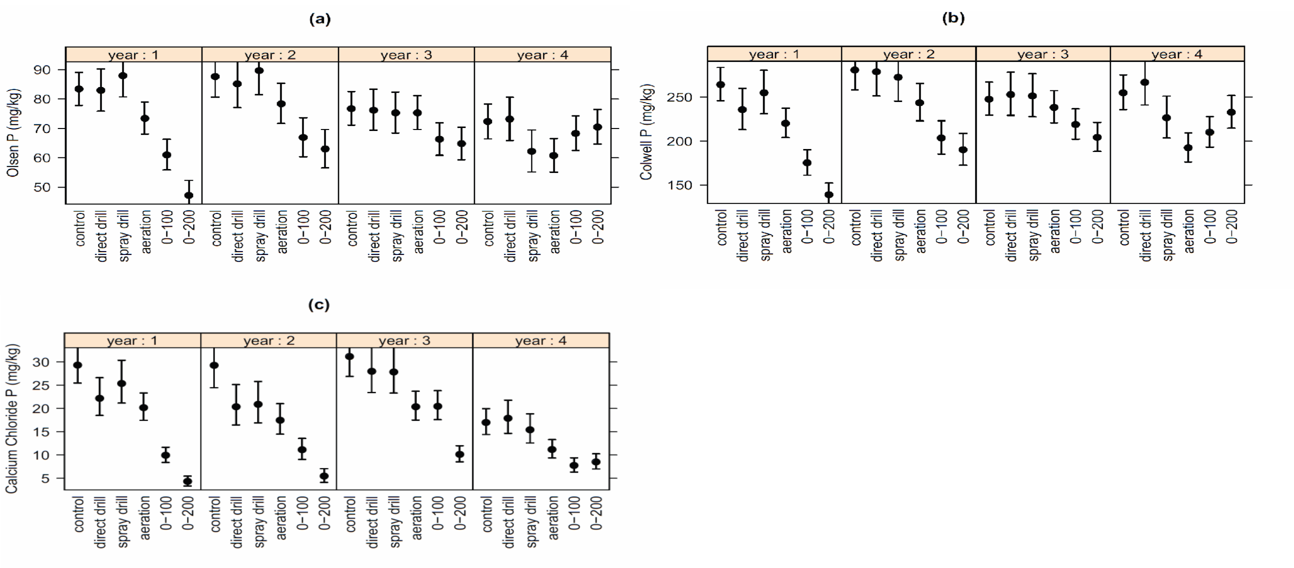

Figure 1. Changes in soil (0-20 mm) (a) Olsen P, (b) Colwell P and (c) Calcium Chloride Extractable P for selected treatments between years.

Soil water analyses were in broad agreement with the soil test results. Soil water DRP varied between sites, between sampling positions in the bay and between treatments, ranging from 3.7 mg P/L for the control to 1.9 mg P/L for the 200 mm cultivation treatment. Soil water TDP was also affected by site, sampling position and treatment. Like soil water DRP, TDP did not vary between years but the effects of treatment did. Soil water DOP (i.e. TDP-DRP) varied with position and treatment.
There were fewer factors affecting the overland flow data compared to either the soil or soil water data. Overland flow DRP was affected by sampling position but unaffected by treatment or year. TDP and TP were also affected by sampling position in the bay.

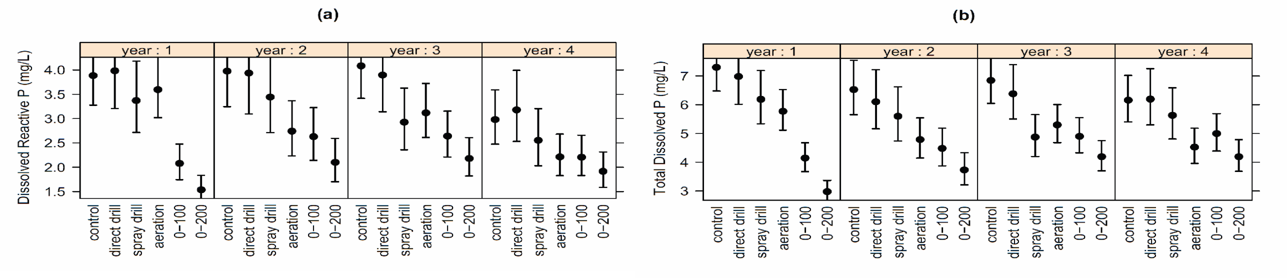

Figure 2. Changes in soil water (0-20 mm) (a) Dissolved Reactive P and (b) Total Dissolved P.

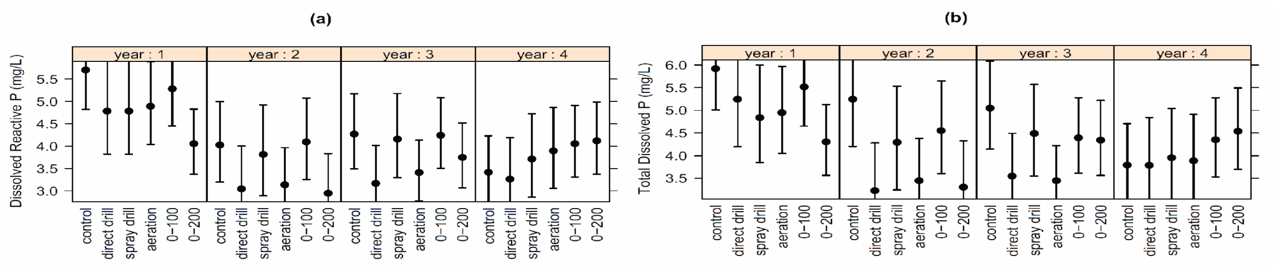

Figure 3. Changes in overland flow (a) Dissolved Reactive P and (b) Total Dissolved P.

Discussion

This study shows that cultivating soil, as commonly would occur during pasture renovation on some Victorian dairy farms, lowers the 'systematic' or 'background' phosphorus export potential. Such cultivation decreased soil Olsen P, Colwell P, Calcium Chloride Extractable P and Organic P as well as soil water DRP and TDP, over the four years of the study. However, this study has also shown that while reduced 'systematic' export potential achieved by cultivation may be important, on commercial farms there are critical decisions, some of which are under management control, that may be equally or more important in determining nutrient exports.
For logistical reasons, even within one farm, grazing could not occur simultaneously across all the bays used for the study and the number of grazing days varied heavily from year to year. It would appear that the variability in the time between grazing and when sampling was undertaken, the between site, between bay and between year variability, the repeated sampling of the same bays and the low degrees of freedom of the overall experiment, resulted in the beneficial effects of cultivation, demonstrated through the soil and water tests, not being expressed in the overland flow results.
These data are from commercial farms operating in a commercial environment. If improved or better management practices do not measurably lessen nutrient exports in commercial systems then it is important it is documented. What this project has shown is that even when we lessen 'systematic' phosphorus export potential through cultivation, critical 'incidents' (i.e. management decisions) can potentially nullify much of those gains. Clearly, we need to develop sustainable farming systems rather than simply improve management practices if we are to address complex issues such as nutrient exports from agriculture.

Acknowledgements

This work was co-funded by the Department of Primary Industries (CMI 100618), GippsDairy and Dairy Australia (DAV12495). The authors would like to acknowledge Jim and Barbara and Brad and Kristie Missen, Tim and Shelley Missen and Graeme and Chris Anderson on whose farms the trial was undertaken, Prof. Aldo Bagnara for his comments on the manuscript, and Dr. Michael Heaven, Dr Nicole Mathers, Ben Webb, Rachel McGee, Lauren Pickering, Ben Rogers, Mitchell Williams, Eric Neville and Mark Watkins for their assistance with the experimental work.

References

Dougherty WJ, Nash DM, Chittleborough DJ, Cox JW, Fleming NK (2006) Stratification, forms and mobility of phosphorus in topsoil of a Chromosol used for dairying. *Australian Journal of Soil Research* **44**, 277-284.

Grayson RB, Tan KS, Western A (2001) Estimation of sediment and nutrient loads into the Gippsland Lakes. CSIRO and University of Melbourne, Final Report No. CEAH 2/01, Melbourne, Australia.

Lachat Instruments (2009) Methods for automated ion analyzers. Hach Company, Loveland, Colorado, USA.

Nash D, Hannah M, Barlow K, Robertson F, Mathers N, Butler C, Horton J (2007a) A comparison of some surface soil phosphorus tests that could be used to assess P export potential. *Australian Journal of Soil Research* **45**, 397-400.

Nash DM, Hannah M, Clemow L, Halliwell D, Webb BJ, Chapman D (2004) A field study of phosphorus mobilisation from commercial fertilisers. *Australian Journal of Soil Research* **42**, 313-320.

Nash DM, Webb B, Hannah M, Adeloju S, Toifl M, Barlow K, Robertson F, Roddick F, Porter N (2007b) Changes in nitrogen and phosphorus concentrations in soil, soil water and surface run-off following grading of irrigation bays used for intensive grazing. *Soil Use and Management* **23**, 374-383.

Pierson ST, Cabrera ML, Evanylo GK, Kuykendall HA, Hoveland CS, McCann MA, West LT (2001) Phosphorus and ammonium concentrations in surface runoff from grasslands fertilized with broiler litter. *Journal of Environmental Quality* **30**, 1784-1789.

Rayment GE, Higginson FR (1992) 'Australian Laboratory Handbook of Soil and Water Chemical Methods.' (Inkata Press: Melbourne, Australia).

Toifl M, Nash D, Roddick F, Porter N (2003) Effect of centrifuge conditions on water and total dissolved phosphorus extraction from rewet and field wet soils. *Australian Journal of Soil Research* **41**, 1533-1542.