IMPROVING PHOSPHORUS MANAGEMENT IN INTENSIVE AUSTRALIAN GRAZING SYSTEMS

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Introduction

Australian soils are old and highly weathered and are often characterised by low levels of available soil phosphorus (P). Consequently, P has historically been a critical input into Australian dairy systems in order to achieve economic levels of production. However, excess phosphorus in soils can increase the concentration of P in runoff (Sharpley 1995) and hence the quantities of nutrients exported in surface runoff that may then impact on off-site water quality. In Australia, dairying often occurs in sensitive catchments with a history of water quality problems including those influenced by excessive P. This has focussed the industries efforts to improve P management.

Australian dairying occurs in a diverse range of climates (Figure 1) and on an equally diverse range of soils. For example, dairying occurs in tropical and sub-tropical environments in Queensland where rainfall can be in excess of 2000 mm, in hot dry environments in SE NSW and Northern Victoria where rainfall is <500mm (and irrigation is a critical input), through to cool temperate dairying in Tasmania in diverse rainfall environments. Soils range from highly P sorbing soils of volcanic origin to poorly sorbing sands and freely draining soils with a strong propensity for leaching through to poorly drained soils prone to waterlogging. The broad geographic distribution of farms and diverse characteristics presents challenges to developing BMPs. In this paper we discuss some current issues relating to P management in Australian dairy pasture systems and provide perspectives on nutrient management priorities.

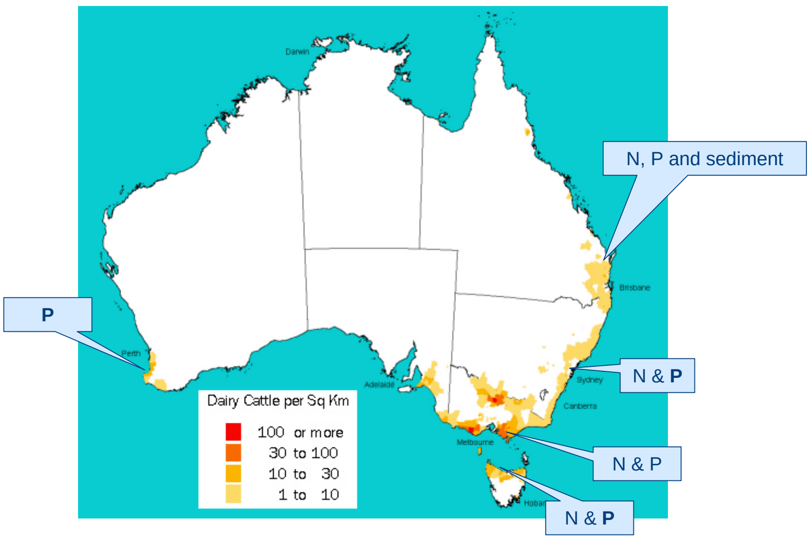

Figure 1. Distribution of dairying in Australia and examples of key water quality issues in catchments where dairying is undertaken.

Phosphorus status of Australian dairy farms

Recent research has revealed that there is a substantial excess of nutrients on Australian dairy farms. In relation to phosphorus (P), the Accounting for Nutrients on Australian Dairy (A4N) farms project (Gourley *et al.* 2012) examined the P balance for 44 dairy farms over a one year period. The median balance was a surplus of 26 kg P/ha/yr, with a range of -7 to 133 kg P/ha/yr. Of the surplus, fertiliser was on average the single biggest contributor at 16 kg P/ha/yr, with bought in feed accounting for 9 kg/ha/yr. Overall phosphorus use efficiency (that % of P brought onto the farm that was removed in produce, predominantly milk) for the 44 dairy farms was 32%. Similar results were found by Lawrie *et al*. (Lawrie *et al.* 2004) and Ovens *et al.* (2008) for other Australian dairy farms. The balance of the P imported onto these dairy farms (68% in the case of the average A4N farm) most likely has accumulated in soils, laneways, effluent and in manure stores.

A large proportion (~80%) of paddocks surveyed in the A4N project were found to have Olsen P concentrations equal to or in excess of the agronomic optimum of 20 mg/kg (0-10 cm) (Gourley *et al*. unpublished). Furthermore, 50% of paddocks had more than twice the agronomic optimum and 20% had 3 or more times the agronomic optimum. These elevated soil P concentrations pose a substantial threat to water quality. Based on the A4N data that suggest that the majority of the P surplus from dairy farms is the result of fertiliser imports, there is a substantial opportunity to reduce P excess and over time reduce soil P levels. Careful soil testing and use of soil P test results will identify those paddocks not requiring further P inputs in fertiliser. These issues are discussed further below.

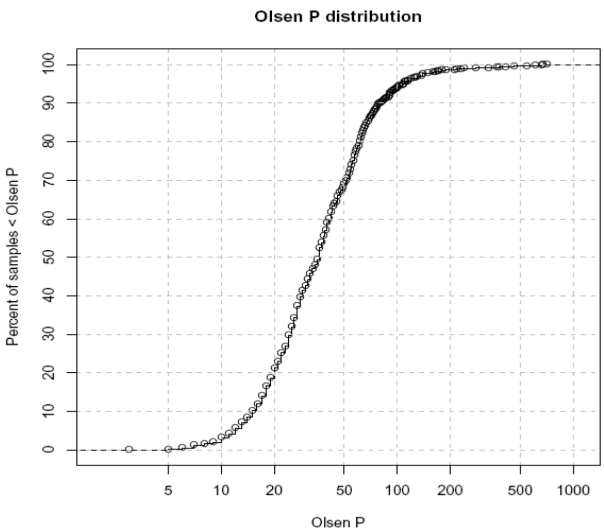

Figure 2. Cumulative probability distribution of Olsen P for grazed dairy pastures (n=1768) from 40 Australian dairy farms (Gourley, unpublished).

Phosphorus distribution and subsequent soil P levels within a farm are highly heterogeneous. Livestock have a major effect on where nutrients are distributed. Preliminary analysis of spatial data from the A4N soil testing program (Gourley *et al*. 2012) reveals that there is a highly significant relationship between paddock distance from dairy and soil Olsen P (Figure 3a). This data suggests that grazing management may be a means of managing the within farm distribution of P. As a first approximation cows excrete nutrients in proportion to the time spent in particular areas of the farm. Cows spend between 40 and 85% of their time in paddocks on Australian dairy farms. The propensity for cows to spend more time in paddocks closer to the dairy shed means that they excrete more P in these areas which contributes to the higher soil P levels closer to the dairy. Grazing strategies to even out the time spent in various paddocks within the farm may provide long term benefits in terms of minimising the uneven distribution of P and the excess accumulation in particular zones of the farm. It may also provide production benefits in terms of higher productivity from some of those currently under-producing areas of the farm more remote from the dairy.

Similar spatial trends can be seen in laneways (Figure 3b). Unpublished research by Dougherty and Hossain show that the surface P loads (defined that quantity of total P in the loose material on laneways) are also strongly related to distance from dairy. The cow movements per unit area (and consequently excretions per unit area) decrease with increasing distance from the dairy as cows leave the laneway and enter paddocks. Those areas closest to the dairy are trafficked more frequently. The ‘structure’ of paddock and laneway complexes also impacts on nutrient loadings. In the case of Farm 1, it had a smaller herd than farm 2 and 2 laneways leading to paddocks whereas Farm 2 had a single laneway, thus the nutrient loadings are much higher on the Laneway system of Farm 2.

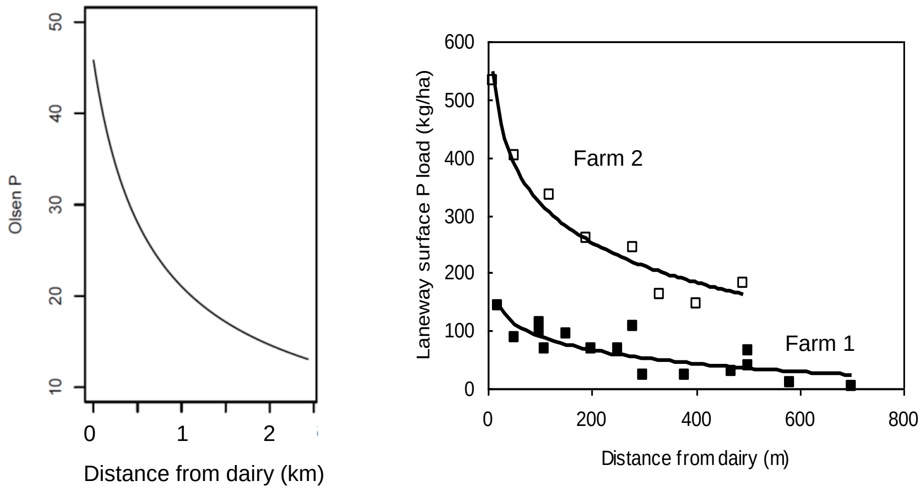

Figure 3. The effect of distance from the dairy milking shed has a highly significant effect on a) the paddock Olsen P value (Gourley unpublished) and b) the load of P on the surface of dairy laneways (Dougherty and Hossain unpublished).

The laneway surface P load is also strongly related to runoff total P concentrations (Figure 4a), much the same as is the case for soils in paddocks. Laneway areas closest to the dairy can generate runoff with P concentrations many times greater than those at the far extent of the laneways. Similar results were observed on several New Zealand dairy farms by Monaghan and Smith (2012). The slope of laneways also has a major impact on the amount of water that runs off them (Figure 4b). Steep laneways generate more runoff per unit input. From a management perspective, the combination of proximity to the dairy and steep slopes represents the greatest risk of nutrient loss from laneways. Flat areas of laneways at the end of laneway systems pose relatively little risk to water quality.

In Australia, laneways have in a number of programs designed to reduce nutrient loss from dairies been targeted as priority areas for remedial works. Runoff from these areas is often perceived as being highly contaminated with P (and other nutrients and pathogens) and indeed monitoring data from recent research NSW confirms that the runoff P generation (that quantity of nutrients mobilised in runoff per unit area per year) is high relative to paddocks used for grazing. Similar relative differences were observed for New Zealand dairy farms (Monaghan and Smith 2012). An interesting result of this research was the relatively low runoff P generation rates for effluent and manure reuse paddocks. Part of the reason proposed for the low generation rates from these areas is that in the systems we studied, these paddocks have low stocking rates and have better physical properties (bulk density and soil resistance measured by penetrometer) and so are less prone to the occurrence of runoff. The runoff P generation rate patterns within the laneways illustrated in Figure 5 do not necessarily decrease with increasing distance from the dairy because of the strong influence of slope discussed previously. For example, on Farm #2, 'laneway middle' is much steeper than 'laneway close' so generates a greater volume of runoff and thus greater runoff P generation.

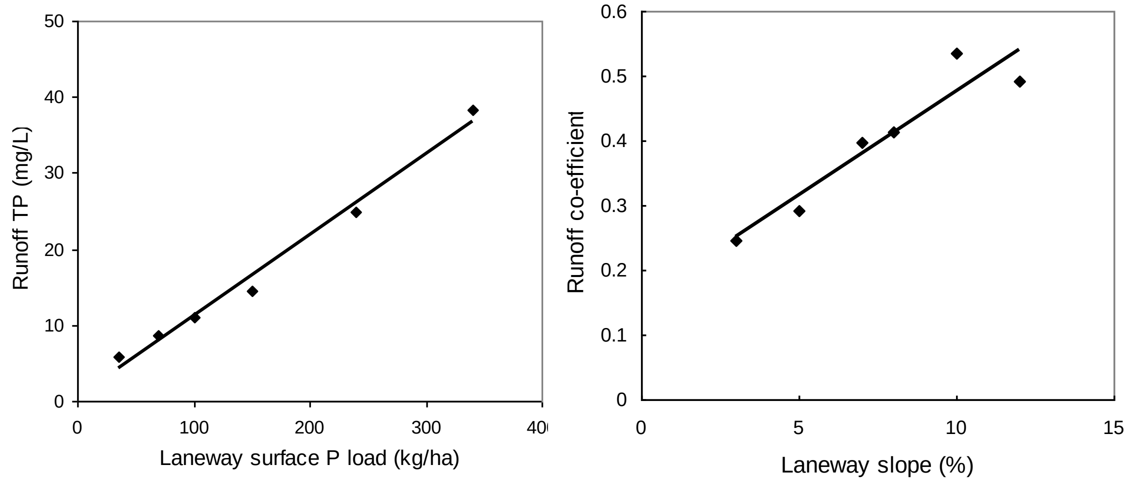

Figure 4. The relationship between a) laneway surface P load and runoff nutrient concentration and b) laneway slope and runoff co-efficient- proportion of rainfall leaving as runoff (Dougherty and Hossain unpublished).

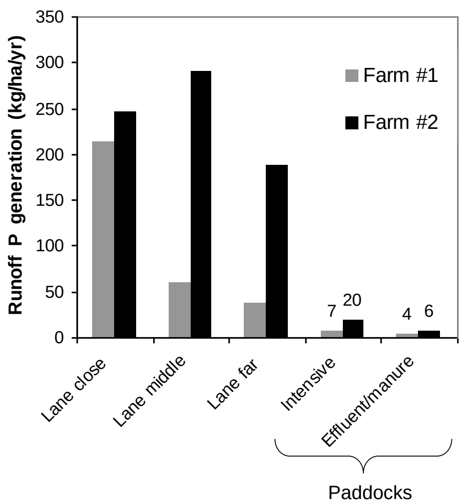

Figure 5. The runoff P generation rates for different areas of two dairy farms near Sydney (Dougherty and Hossain unpublished). 'Intensive' paddocks represent those paddocks used for grazing by the milking herd.

When knowledge of the runoff P generation rates and spatial extent of management zones on farms in combined, we can develop an understanding of the relative importance of their contribution to overall nutrient generation (Figure 6). Despite the relatively large per unit area runoff P generation rates for laneways, their small spatial extent (<1 ha) relative to paddocks on the farms (>100ha) means that their overall contribution to runoff P generation is small. Although we have presented only data for two farms that were intensively monitored for 2 years, further modelling (Dougherty unpublished) for a diverse range of farms shows that similar trends are consistent across farms (data not presented). Thus, although laneways should not be ignored as a source of nutrients, paddocks in fact represent the single biggest source of nutrients being generated in runoff on dairy farms and should thus be the first areas considered for management improvements.

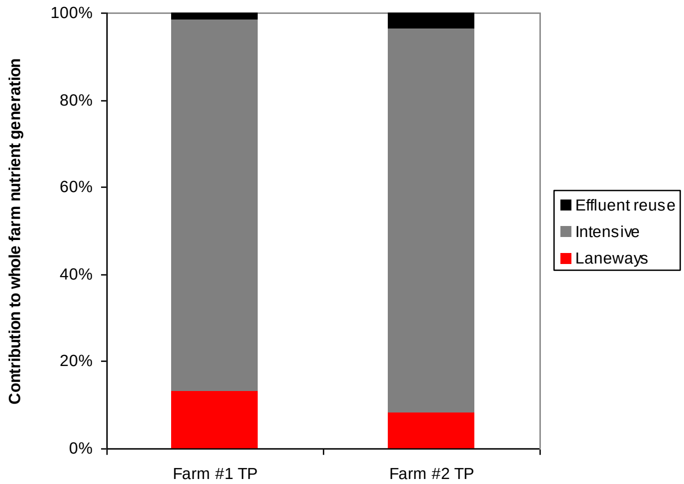

Figure 6. The relative contributions of different management zones to whole farm nutrient runoff P generation (Dougherty and Hossain unpublished).

Reducing P losses from paddocks

With the apparent dominance of paddocks as a source of nutrients attention needs to turn to how to reduce the concentrations of runoff from these paddocks. Given the strong relationship between soil P and runoff P (Dougherty *et al.* 2011; Sharpley 1995), reducing soil P must be a key focus. As previously indicated, there are large proportions of dairy farm paddocks that have far too much soil P.

Anecdotal evidence suggests that farmers are reluctant to with-hold P fertiliser because of uncertainty about the resultant rates of decline in available soil P and the subsequent potential impacts on production. They view the continued use of P fertiliser as a form of insurance. With P expenditure only representing a couple of % of total farm variable costs on the typical farm, the continued use of P fertiliser may represent a cheap form of insurance.

Recent research on a range of soils with diverse P sorption properties and initial soil P levels (Coad *et al.* 2014) shows that the rates of decline in soil P are substantial (Figure 7), but that the declines do not occur so rapidly as to pose a potential threat to production providing that soil testing occurs every 2-3 years to monitor soil P status. Similar conclusions were made by Dodd *et al.* (2012) for New Zealand soils. Coad *et al.* (2014) noted that the withholding of P fertiliser to reduce excess soil P is a no cost strategy that should appeal to farmers.

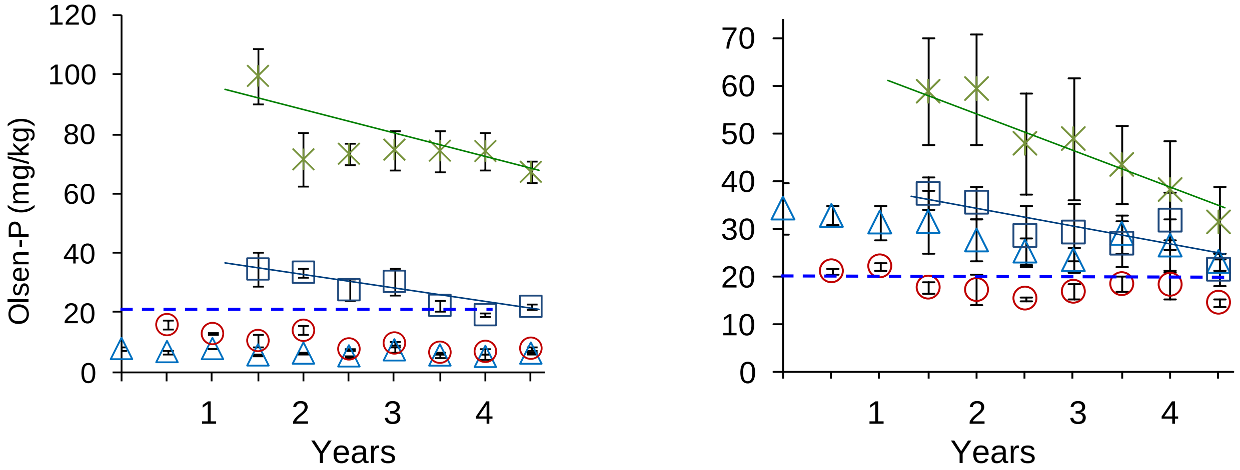

Figure 7. Examples of rates of decline in Olsen P for two soils highlighting the slow decline in soil P with time when fertiliser is with-held.

Barriers to changes in P management

A key barrier to change in P management is the lack of drivers. In Australia, P management in key dairying regions is generally not constrained by regulation. In Western Australian and areas of Queensland near the great barrier reef there are policies in place to drive change but these dairying regions only represent small components of the dairy industry. There is no Federal Legislation in Australia driving water quality protection and State Legislation is ambiguous and not an effective tool for driving practice change. Furthermore, agriculture is only a small proportion of GDP (~2%) so provision of economic incentives to change behaviour is not a priority. These contrast with the existence of strong regulatory and economic incentives that drive improvements in nutrient management in Europe, the USA and New Zealand.

There is also substantial uncertainty relating to what should be done, and where within the farm investments and remedial activities should be undertaken. Are investments best made in laneways or paddocks for instance? Recent advances in our knowledge as discussed above are eroding these barriers.

However, there is not a clear relationship between actions and investments on farm with a view to reducing nutrient export and change in condition of water systems. The improvements in water quality because of on farm practice change may not occur, not be detectable, or simply take a long time to occur. In a substantial proportion of dairying catchments, dairying is interspersed with other agricultural activities which can mask the impacts that reductions in nutrient export from dairies may be having on nutrient loads in catchments. Limited water quality monitoring programs also limit the ability to detect changes in water quality.

There are also some institutional barriers to change. The dominance of state based R&D organisations in Australia can fragment RD&E in the dairy industry. There is also fragmentation of stakeholders that arises because of regional boundaries, the existence of different milk processors, differing dairy industry bodies and a range of regional dairy groups.

Industry lead initiatives

Despite some of the barrier and lack of incentives to improve P management there have been recently and continue to be a number of industry lead initiatives that are driving improvements in management. The Better Fertiliser Decisions project defined universally accepted critical soil test P values that now improve the consistency of soil test interpretation. This contributes to a reduction in the incidence of unnecessary fertiliser P addition.

Dairy Australia have recently launched a key nutrient management initiative titled Fert$mart (http://fertsmart.dairyingfortomorrow.com.au/). This tool provides a central repository for state of the art understanding on nutrient management and provides practical guidance and tools to assist with nutrient planning. Murray Goulburn has also launched their MGf@rm website which has a toolkit that includes fertiliser recommendations and nutrient budgeting tools.

More broadly, Fertiliser Australia has been implementing a set of standard for those making fertiliser recommendations and those spreading fertiliser to improve the quality and consistency of fertiliser advice and application.

In the future, the need to comply with and demonstrate wise environmental stewardship is likely to be a key driver of improvements in P management in Australia as it is in New Zealand.

Conclusions

The Australian dairy industry has made some major reductions in nutrient export and its potential to impact on off-site water quality. Key achievements over the last 20 years have been to eliminate the direct discharge of effluent into waterways and restrict direct cow access to waterways. However, despite well in excess of 20 years of interest in soil P management, there is still far too much P in dairy systems as evidenced by high proportion of excessive soil test results, which poses a threat to water quality.

As the single biggest source of nutrients generation in runoff on farms, paddock soil P needs reducing. Despite a wide spread awareness of high soil P levels, fertiliser P is still a key source of P surpluses on dairy farms. New data supports the power of with-holding fertiliser in reducing excessive soil P and consequently reducing potential threats to the broader environment, in particular waterways. Further efforts to highlight the risks of continued fertiliser use and to re-assure farmers of the low risk to their production systems of with-holding P is required.

Farmers and their advisors need better P management metrics and tools for decision making. There is a need for simple yet robust systems that can provides metrics of P management performance such as whole farm and paddock scale P balances and greater utilisation of data that soil testing provides. There are evolving industry initiatives in this space such as MG Farm®.

Finally, there needs to be an increased focus on the integration of science, farm systems understanding, economics and policy development. There has been a substantial body of research undertaken on P management at a paddock scale. However, the integration of this knowledge into a farming systems context and consideration of the economic impacts has been somewhat less common. The combination of these will drive improvements in P management with both production and environmental benefits for farmers.

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