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A STOCKTAKE OF NUTRIENT LOSS RISK IN THE AUSTRALIAN DAIRY INDUSTRY

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Abstract

To help safe-guard the Australian dairy industry's reputation for clean and green milk production, a stocktake of the risk of nutrient loss to water was conducted at national and regional scales using readily available landscape and management practice datasets.

Data describing the diverse dairy farming landscape (e.g. soil type, topography, climate) and farm practices (e.g. soil nutrient levels, stocking rates, effluent management, irrigation) were compared across regions. Combined, these data have been identified as important indicators of the potential for nitrogen (N) and phosphorus (P) transfer to waterways using a previously developed Nutrient Loss Index (FNLI).

Landscape pressures were generally low to moderate at the national scale. Pressures from practices were moderate at national and regional scales except for high soil test P levels, presenting a potential P source for loss in runoff or drainage, high modal herd size per farm (500-700 cows) in the DairyTas region and moderate to high effluent rate management risk across all regions. Low risk attributes can be used to promote the industry's environmental credentials whereas high risk attributes can be used to identify where nutrient loss reduction strategies are likely to be most effective.

After applying the FNLI, the priority regions for reducing the risk of N loss in deep drainage were identified as Tasmania, Gippsland, NSW and the Subtropical dairy region. Factors that contributed the most to these water quality risks varied between regions and included landscape pressures of high surplus water, high groundwater tables, and shallow rooting pastures, and management pressures of uninformed effluent rates, risky fertiliser application timing and a prevalence of nutrient hotspots.

The priority regions for reducing the risk of P loss in runoff were identified as Tasmania, Gippsland, Western Australia and NSW. The highest contributing pressures again varied between regions and included landscape pressures of high surplus water and runoff-prone soil types and practice pressures of high soil P test levels, uninformed effluent rates and high stocking rates.

The 2014-2016 stocktake provides a baseline against which to measure the financial and environmental returns on efforts to maintain and improve water quality across the diverse dairy farming landscape of Australia.

Introduction

To help safe-guard the Australian dairy industry's reputation for clean and green milk production, a stocktake of the risk of nutrient loss to water was conducted at national and regional scales using readily available landscape and management practice datasets. In an assessment of the pressures on water quality from dairy farming in Australia and in New Zealand, Scarsbrook and Melland (2015) found that there were few indicators of pressure that could be directly compared between the two countries from readily reported data. In particular was a lack of report on the status and variability of physical landscapes pressures across the diverse dairy farming landscape in Australia.

Landscape pressures can be described as inherent features of the landscape (including climate and weather events) which increase the potential for nutrients, soil and pathogens to be mobilised and transported from land to water. In agricultural environments, landscape and climate characteristics often have a relatively large influence on the quality of receiving waterbodies compared with farm management practices (Melland *et al.*, 2008; Jordan *et al.*, 2012). Concomitantly, predictions of the risk of soil and nutrient loss from agricultural land requires the hydrology of the land to be represented by models (Letcher *et al.*, 2002; Cichota and Snow, 2009; Vigiak *et al.*, 2011; Smith and Western, 2013; Xie *et al.*, 2015) and/or risk indices (Buczko and Kuchenbuch, 2010; Osmond *et al.*, 2012).

The Farm Nutrient Loss Index (FNLI) was developed for the high rainfall grazing industries in Australia as an indicator of the risk of phosphorus (P) or nitrogen (N) loss from fields in runoff and deep drainage (Melland *et al.*, 2007). The index calculates risk based on the weighted additive risk of nine landscape pressures and 10 farm management pressures (Melland *et al.*, 2004). The level of each pressure can be readily assessed by a farmer for fields or groups of fields on their property. In this research, the FNLI was modified from its field-scale applicability and applied at regional and national scales to provide a stocktake of the risk of nutrient loss to waterways across the dairy industry in Australia.

Method

Data describing the diverse dairy farming landscape (e.g. soil type, topography, climate) and farm management practices (e.g. soil nutrient levels, stocking rates, effluent management, irrigation) across Australia that were identified as important indicators of the potential for N and P transfer to waterways using the FNLI were collated and compared across eight dairy regions. The dairy regions that were assessed were those covered by Dairy Australia's Regional Dairy Programs of DairyTas in Tasmania, GippsDairy in Gippsland, Victoria, WestVic Dairy in south-west Victoria, Murray Dairy in northern Victoria/southern New South Wales, Western Dairy in Western Australia, Dairy SA in South Australia, Dairy NSW in New South Wales and Subtropical Dairy (SDP) in Queensland and north coastal NSW (Figure 1).

Figure 1. Regional Dairy Program regions in Australia. Map source: Dairy Australia (2013)

The sources of collated data included publically available national spatial datasets for the landscape pressures, and non-georeferenced survey or research data for the farm management pressures (Table 1). The spatial resolution and sample size varied from high resolution (90 m x 90 m) spatial census to sample sizes of 2-9 farms per region across the pressures. Uncertainty in the representativeness and spatial co-location of the pressures varied accordingly. In many cases, proxy pressure indicators were identified because data on the specific FNLI pressure was not available.

The extent of dairy farmed land within each region was represented using the best-available spatial data, which varied by region, and were the extents of dairy land parcels in Tasmania (DPIWE, 2015), of dairy land parcels with a 1 km buffer in Victoria (DEDJTR, 2014), and of dairy sheds (ABARES, 2016) ground-truthed visually using Google Earth (Google, 2016) plus a 1 km buffer in all other states with dairy farming. Each landscape pressure was assigned a FNLI score according to the pressure class which encompassed the largest spatial extent of dairy land within each region or national extent. Where more than one proxy indicator was identified for a particular pressure (e.g. nutrient hotspots), the highest FNLI score of all the proxy pressures was used in the final assessment.

Table 1. Data used to describe FNLI landscape and practice pressures at national and regional scales

Landscape pressure	**Pressure Indicator**	**Sample type and size**	**Reference**
Surplus water & storm likelihood	FNLI surplus water class	Spatial census at rainfall district scale	(Melland et al., 2007; Commonwealth of Australia, 2014b).
Irrigation	percentage of dairy farm	Survey of percentage of 31	(Watson and Watson,

	irrigated in 2014-15	– 110 farmers per region	2015)
Slope	median 300m radius slope	Modelled spatial census, 90m x 90m	(Gallant and Austin, 2012a)
Waterlogged area	(proxy) Topographic wetness index percentile range classes	Modelled spatial census, 90m x 90m	(Gallant and Austin, 2012b)
Proximity to waterway	proximity of dairy land unit boundary to major and minor waterways and open water	Spatial census, 1:250,000	(Commonwealth of Australia, 2014a)
Soil type	Australian Soil Classification - Dominant Soil Order	Modelled spatial census, 250m x 250m	(ACLEP, 2012)
Topsoil P fixation	median P buffering index for routinely grazed paddocks	Data from 2-9 farms per region, 2007-09	(Gourley *et al.*, 2015)
Management Pressure	**Pressure Indicator**	**Sample type and size**	**Reference**
Stocking rate	mean cows per milking platform area, cows/ha	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
Soil test P	median soil Olsen P for routinely grazed paddocks	Data from 2-9 farms per region, 2007-09	(Gourley *et al.*, 2015)
Fertiliser rate N	(proxy) mean fertiliser N applied in 2014-15, kg N/ha	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
Fertiliser rate P	mean inorganic fertiliser P applied, kg P/ha	ADIS 2003 survey of 68% of dairy businesses at state scale; data from 2-9 farms per region from 2007-09	(Gourley *et al.*, 2012; ABARES, 2015)
Fertiliser application timing	(proxy) % of farmers who match N applications to pasture growth and rotation length	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
	(proxy) modal fertiliser timing relative to runoff and leaching risk	Voluntary self-assessment by 90 farmers	(DairySAT results 2014, Dairy Australia unpublished)
Effluent application timing	(proxy) % distributed to land [assumed cf point source discharge]	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
	(proxy) Modal effluent pond storage practice class	Voluntary self-assessment by 90 farmers	(DairySAT results 2014, Dairy Australia unpublished)
Effluent application	(proxy) % test nutrient value	Survey of 31 – 110 farmers	(Watson and Watson,

rate	of effluent	per region	2015)
	(proxy) modal manure stockpile management class	Voluntary self-assessment by 90 farmers	(DairySAT results 2014, Dairy Australia unpublished)
Nutrient hotspots	% farms with complete waterway fencing	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
	% farms with a feedpad	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
	% area of farm used for effluent application in a year	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
	% of routinely grazed paddocks > 3x the agronomic optimum soil P	Data from 2-9 farms per region from 2007-09	(Gourley *et al.*, 2015)
Pasture type	(proxy) % of average farm area (ha) under crops	Survey of 31 – 110 farmers per region	(Watson and Watson, 2015)
Groundcover	annual median bare ground 2000-2011	spatial imagery census, 500 m x 500 m	(ABARES, 2011)

The FNLI was applied using the calculations and weights specified for each pressure and pressure type (landscape or management) in the FNLI User Manual (Melland *et al.*, 2007). Weights allocated by the FNLI to calculate the N loss in drainage risk differed across rainfall districts within regions whereas all regions and rainfall districts were allocated the same weights by the FNLI to calculate the P loss in runoff risk. The N loss in drainage risk calculation was therefore applied using only the weights for the rainfall district which covered the largest extent (i.e. modal surplus water class) of each region. Landscape features that influence the connectivity of farms with receiving groundwater (i.e. groundwater depth) and features that retain or shed water from the land (i.e. runoff modifying features) were not mapped at national or regional scales due to lack of appropriate data. These factors were set at their lowest risk class when applying the FNLI to provide a conservative assessment of risk. The ‘dominant land shape’ pressure was not mapped separately and was scored at its lowest risk class because this pressure was considered to be represented by the ‘waterlogged area’ pressure.

Results and Discussion

Landscape pressures

Landscape pressures were generally moderate to low at the national scale. Low risk attributes can be used to promote the industry’s environmental credentials whereas high risk attributes can be used to identify where nutrient loss reduction strategies are likely to be most effective.

High pressures from landscapes at the regional scale included high surplus water in the DairyTas, Gippsdairy, Dairy NSW and Western Dairy regions, and in the Murray Dairy region after accounting for irrigation, soils with high runoff potential in the Western Dairy and Subtropical dairy regions and soils with high deep drainage potential in the DairyTas region. There was also a high potential for P fixation by the soil in the DairyTas region, presenting a risk for P loss via erosion but a low risk via drainage. Whilst the majority of dairy farm land boundaries were more than 300 m from a surface waterbody, more than 25% of dairy land was naturally <30 m from major or minor waterways nationally, and in WestVicDairy, DairyTas, Murray Dairy, and DairySA. Management of paddocks close to waterways therefore may warrant priority in these regions. However, some waterways may have been calculated to be closer to farm boundaries than they are in reality due to the best-available spatial datasets of dairy farm land extent, in all states but Tasmania, including a 1 km buffer around land parcels or dairy sheds.

Because landscape pressures are generally inherent characteristics of the land, reducing these pressures is difficult or not possible. Instead, in regions with high landscape pressures and low management pressures, nutrient loss may be minimised by managing structures and natural features that modify runoff and drainage such as retaining eroded sediment in dams and diverting laneway runoff away from streams (Wilcock *et al.*, 2013; Ockenden *et al.*, 2014), and by careful management of nutrients at high risk times such as storms and wet periods (Shore *et al.*, 2016) and in high risk places such as near streams (Wilcock *et al.*, 2013). Any strategy needs to be assessed in terms of its applicability at field and catchment scale, its cost-effectiveness (McDowell and Nash, 2012), and its potential for 'pollution swapping'. Pollution swapping occurs when mitigation of one aspect of environmental degradation leads to an increase in another aspect of degradation. For example, in sandy catchments, riparian buffers are likely to decrease streambank erosion but consequently increase the proportion of bio-available P in waterways (Weaver and Summers, 2014).

Management pressures

Pressures from practices were moderate at national and regional scales except for high soil test P levels, presenting a potential P source for loss in runoff or drainage, high modal herd size per farm (500-700 cows) in the DairyTas region and moderate to high effluent rate management risk across all regions. Effluent rate management risk was assessed as the proportion of farmers who test their land-applied effluent for nutrient levels, and this proportion was ≤ 30% of survey respondents across all regions (Watson and Watson, 2015). Data on actual effluent rates and nutrient values applied would better inform this risk factor. The high effluent rate management risk, along with a moderate effluent hotspots risk assessed for most regions, present diffuse (field) nutrient management issues. In contrast, the point source risk of direct discharge of effluent to waterways was low, with at least 81% of survey respondents within regions applying dairy shed effluent to land (Watson and Watson, 2015).

Nutrient loss risks

After applying the FNLI and combining the landscape and practice pressures, priority regions and practices for reducing the risk of N loss in deep drainage and P loss in runoff were identified.

Nitrogen loss in deep drainage

Priority regions and practices for reducing the risk of N loss in deep drainage was N management on well-drained soils in Tasmania, Gippsland, NSW and the Subtropical dairy region (Figure 2),

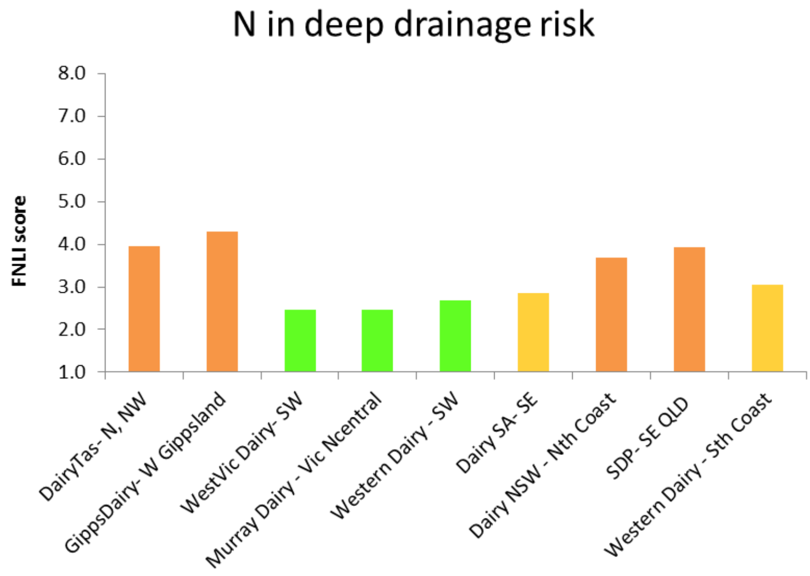

Figure 2. Nitrogen in deep drainage risk for modal extents of rainfall districts within regions (green is low is, orange is medium risk, and dark orange is high risk). Two rainfall districts in the Western Dairy region were in the modal surplus water class and had different FNLI weights so were calculated separately.

Low, medium and high risk classes broadly correlate to annual N loss in deep drainage of <5 and 5-10, and 10-30 kg/ha, respectively (Melland, A. unpublished data). In the FNLI, weightings specific to rainfall districts are applied to factors contributing to the risk of N in drainage (Melland *et al.*, 2007) so the FNLI was not applied at the national scale. In contrast to other regions, landscape (transport) pressures were given lower overall weightings of importance than farm management (source) pressures in the FNLI in the rainfall districts selected to represent the Dairy NSW and SDP regions in this assessment (Melland *et al.*, 2007), and this increased the risk levels identified for farm management pressures in these regions, relative to other regions.

After multiplying the risk class scores with the factor weightings, the three factors that contributed the most to a high risk of N loss in deep drainage were:

- high surplus water and well-drained soil types in the Tasmania and Gippsland regions,
- shallow rooting pastures in the Gippsland region,
- high water-tables in the Tasmanian region which pose a risk for hydrological connectivity, even when scored conservatively, and
- in the Dairy NSW and Subtropical dairy regions,
  - effluent rates not always being informed by nutrient testing,
  - timing of fertiliser application carrying a high risk even when managed well relative to periods of high leaching loss, and
  - a prevalence of nutrient hotspots of excessive Olsen P, small effluent application areas, feed pads, and unfenced waterways.

Management practices that may therefore reduce the risk of N loss in drainage in these regions are maximising pasture uptake of soil-water and N, especially during the wettest periods of the year, and minimising the development of nutrient hotspots in areas of naturally or artificially well-drained soil. Critical also is to match the rate and timing of applied effluent and N fertiliser to pasture needs and avoiding applications during periods of high water tables and soil saturation.

Phosphorus loss in runoff

Priority regions and practices for reducing the risk of P loss in runoff was management of runoff of P in the DairyTas, GippsDairy, Western Dairy, and Dairy NSW regions (Figure 3).

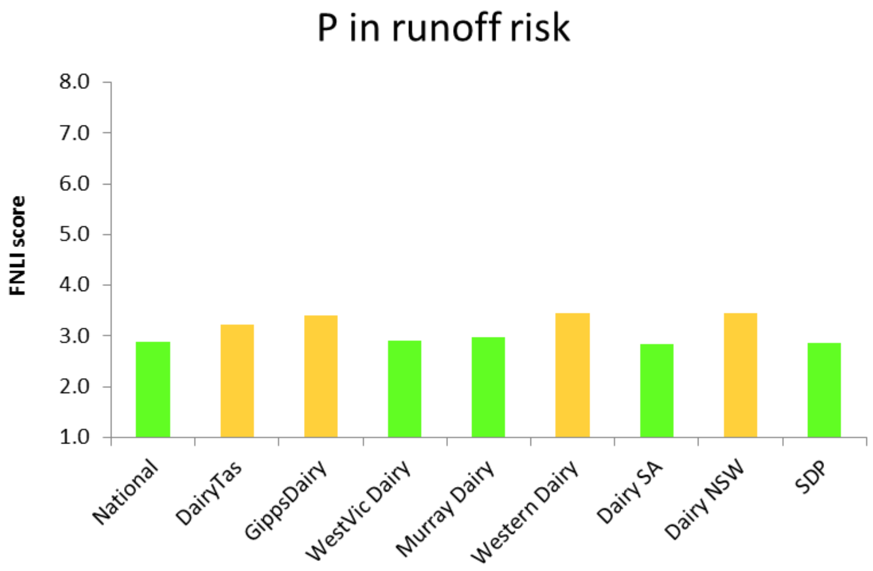

Figure 3. Phosphorus in runoff risk across RDP regions, and nationally (green is low is, orange is medium risk).

Low and medium risk classes broadly correlate to annual P loss in runoff of <0.5 kg/ha and 0.5-2 kg/ha, respectively (Melland, A. unpublished data). Transport factors combined were most influential to P runoff risk in 5 of the 8 regions and source factors combined were more influential at national scale and in WestVic Dairy, Dairy SA and SDP regions.

After multiplying the risk class scores with the factor weightings used in the FNLI, the three factors that contributed the most to medium risk of P loss in runoff in each of the DairyTas, GippsDairy, Western Dairy and Dairy NSW regions were:

- surplus water and effluent application rates across all four regions,
- soil type in Western Australia only,
- soil test P levels in Gippsland, Western Australia and Dairy NSW, and
- stocking rate in Tasmania only.

Management practices that may therefore reduce the risk of P loss across these regions are minimising fertiliser and effluent applications and grazing in high risk paddocks (e.g. waterlogged and connected or close to waterways) and unbunded hard surface areas (e.g. lanes) and at high risk times (e.g. storms or prolonged wet periods) for soil or dissolved P loss in runoff.

Conclusion

Management pressures at the national scale were high for soil test P levels and effluent application rates indicating more efficient nutrient management may reduce water quality risks. Landscape pressures at the national scale were generally moderate to low suggesting a high overall potential for retaining nutrients on the farm across the industry.

Dairy regions that could be a focus for management of N to minimise loss in drainage are those in Tasmania and Gippsland due to inherently high landscape pressures, and the northern tablelands of NSW and south-east Queensland, where management factors are given a high weight of importance in the FNLI risk calculation. The dairy regions identified as having the lowest relative risk of N loss in drainage were those in western Victoria, the Murray-Dairy region and in Western Australia.

Phosphorus management to minimise loss in runoff could be prioritised in dairy regions of Tasmania, Gippsland and Western Australia where both landscape and management practice pressures contributed to medium risks of P loss. All other regions were identified as having a relatively low risk of P loss in runoff.

The 2014-2016 stocktake identified a diversity of nutrient loss risk profiles across the dairy farming landscapes of Australia. These profiles provide a baseline against which to measure the financial and environmental returns on efforts to maintain and improve water quality across the industry over time. Increased spatial resolution of collection of management practice data, and of analysis of risks, would help to improve the evaluation of risk profiles across and within regions.

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