Fertcare® technical standards for nutrient management planning on Australian dairy farms

Dairy Australia

AGRICULTURE VICTORIA

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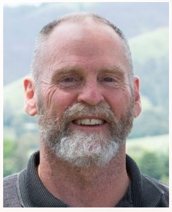
Prepared by:



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Contents

Image provided by Webber Chivell Fertilisers

1. Purpose

This technical guidance document outlines the performance standards expected of Fertcare® Accredited Advisors (FAA) offering dairy specific nutrient management advice.

The technical guidance document:

- Ensures that nutrient management plans (NMP) and fertiliser advice provided to dairy farmers is based on objective measures such as soil and plant analysis, follows sound sampling and laboratory practices, nationally recognised interpretation guidelines and accounts for environmental risks,
- Informs dairy specific content for Fertcare® Assessed Systems training (Fertcare® Full and Qualifying Services), leading to FAA recognition of dairy focused agronomists,
- Outlines the minimum standard to assess the competence of advisors and quality of nutrient management plans and recommendations in ongoing FAA audits,
- Assists the Australian Dairy Sustainability Framework in providing assurance to Dairy Industry customers.

2. Introduction

Nutrient management continues to be a high priority for both production and environmental performance on dairy farms. Dairy production systems commonly have large nutrient fluxes and relatively low nutrient use efficiency (NUE) at the whole-farm level.

As dairy production systems intensify, increased cow numbers result in greater reliance on imported feed and fertiliser. Increased animal densities can mean excessive nutrient loads from excreta directly deposited in concentrated areas, and an increasing proportion of manure deposited in housing or feeding areas requiring collection, storage and land application (Figure 1).

A dairy farm nutrient management plan can assist farmers to make effective use of all sources of nutrients on their farm. This should be part of a strategic plan. The Fert$mart planning cycle https://fertsmart.melbourneonline.com.au/planning-cycle-overview/ provides dairy farmers with a suggested strategic framework.

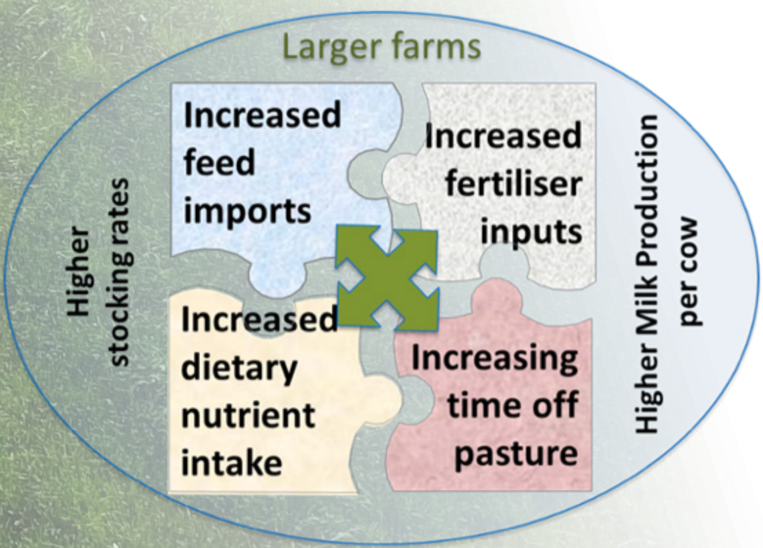

Figure 1. Implications of intensifying dairy production systems on nutrient fluxes within a dairy farm.

3. What is a dairy farm nutrient management plan?

A dairy farm nutrient management plan (NMP) is a strategy for obtaining the optimal return from on-farm and commercial nutrient resources in a manner that minimize nutrient losses to the environment.

A NMP should be tailored to an individual farm and should efficiently utilize all sources of nutrients to meet pasture / crop needs and minimize nutrient losses to groundwater, surface waters and the atmosphere. In many regions around the world such as Europe, United States of America and New Zealand, developing and utilising a NMP is often a mandatory requirement for the operation of a dairy farm.

Information required for a dairy farm NMP:

- Farm map/plan and physical farm characteristics such as soil types, slopes, waterways, native vegetation,
- Farm production characteristics such as herd size, feed and fertiliser purchases and milk and animal sales, to determine nutrient inputs and outputs, and nutrient use efficiencies,
- Identified current and previous paddock use and management,
- 'Management zone' specific soil test reports and nutrient recommendations,
- Relevant regulatory requirements,
- On-farm nutrient resource inventory of solid and liquid manure, compost, and other recycled organics,
- Fertiliser / manure / effluent spreading history.

Nutrient management plans aim to integrate system level information such as milk production, feed, manure and fertiliser management practices to optimize NUE.

A better understanding of nutrient fluxes will assist nutrient management decisions at the farm- and within-farm scale, to assist nutrient management decisions for improved productivity and environmental outcomes.

A dairy farm NMP should rely on readily available and farmer accessible information, should be easily understandable, provide clear guidance, and enable benchmarking of nutrient management performance.

Components of a dairy farm nutrient management plan:

i. Defined dairy farm system boundaries
ii. Whole-farm nutrient budget & nutrient use efficiency
iii. A soil sampling plan
iv. Soil analysis and interpretation
v. Defined regulatory requirements
vi. A dairy manure nutrient inventory
vii. Specific management-zone nutrient recommendations
viii. Management strategies to reduce nutrient losses
ix. Planning & record keeping

Each of these key components of a dairy farm NMP are discussed in further detail.

It is important to ensure that each of the components within a NMP are adequately considered and that the approach meets the required 'Competency Standards'. Some components of a NMP will be of greater importance than others, due to the individual characteristics of the dairy production system.

Table 1. Relative importance of fertiliser and manure nutrients with differing dairy production systems.

Importance of fertiliser nutrients

Importance of manure nutrients

	Grazing-based	Grazing + bail feeding	Grazing + confined feeding	Confined feeding + grazing	Confinement-based
Reliance on imported feed	<20%	20-30%	30-50%	50-70%	>70%
Stocking rate	<2cows/ha	>2 cows/ha	>3 cows/ha	>4 cows/ha	>5 cows/ha
Time-off pasture	<5%	5-15%	15-30%	30-60%	>60%

- Manure nutrient management will require greater emphasis when dairy systems import a large proportion of feed and animals are largely confined in feeding infrastructure.
- Fertiliser nutrient management will require greater emphasis when dairy systems are predominantly grazing-based and primarily reliant on pasture production.

4. Defining farm system boundaries

An important part of developing a NMP is to ensure that the land-base used for dairy production is well defined. Grazing-based dairy farms that predominate in Australia, generally have land where dairy cows are located during the lactation for grazing and supplementary feeding and which directly contributes to milk production and nutrient cycling. There are often other land uses within a dairy farm boundary such as native vegetation, wetland and riparian areas, that do not contribute to milk production. Many dairy farms may also have separate land areas (i.e. dairy support areas), where young and dry cows are contained and where additional pasture and forage will be grown and conserved.

The dairy farm land area most relevant to nutrient management planning is the "Principal Productivity Area," also referred to as the milking platform. This is the total hectares of land directly contributing to milk production and includes grazed and harvested forage (pasture and crops) and designated feeding and sacrifice areas.

The Principal Productivity Area is therefore used as the land area for determining nutrient inputs, outputs and net nutrient balance, reported on a per hectare basis. Whole-farm nutrient use efficiency measures, being a ratio, is not affected by assumptions about the land base.

An aerial photograph (Figure 2) or detailed farm map is useful for determining the Principal Productivity Area. In addition to detailed property and paddock boundaries and dimensions, infrastructure such as buildings, roads and laneways, gates and watering points should be identified. The farm map should also categorise bushland, hydrological characteristics such as waterways and gullies, flood plains, soaks and wetlands, and topographic characteristics (i.e. step-rises, sandy ridges, etc.).

Figure 2. It is essential to identify property and paddock boundaries and the Principal Productivity Area of a dairy farm

With the ubiquity of mobile devices and Geographical Information Systems (GIS), aerial photography, satellite imagery and other coverages such as farm and paddock boundaries are often accessible both online and offline to assist with this task.

The Principal Productivity Area is where the greatest nutrient inputs, manure deposition, nutrient cycling, pasture, crop and milk production and potential for nutrient losses, is occurring.

5. Whole-farm nutrient budget & nutrient use efficiency

A whole-farm nutrient budget considers the quantity of nutrients coming onto the dairy farm Principal Productivity Area as inputs and the quantity of nutrients leaving in products, usually determined over a 12-month period (Figure 3).

The sum of nutrient inputs and outputs enable the determination of nutrient surpluses and deficits, and the efficiency of nutrient use (nutrient use efficiency, NUE) at the farm scale.

A nutrient budget calculation for nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) therefore requires information about the key fluxes of nutrient imported and exported for an individual dairy farm, as determined by their mass and corresponding nutrient concentration. Key nutrient imports generally include feed (forage and grain-based), fertiliser and N from biological N fixation. However, there can also be a wide range of additional nutrient imports such as by-product feeds, bedding, alternative fertiliser products, atmospheric deposition and irrigation of reuse water. Key exports largely involve milk and animal sales. Additionally, manure may be an important source of nutrient exports on some farms.

While the mass or volume of imported and exported nutrient sources can usually be determined, nutrient budget calculations usually rely on nutrient concentrations sourced from lookup tables provided by commercial suppliers as well as published and scientifically credible industry standards.

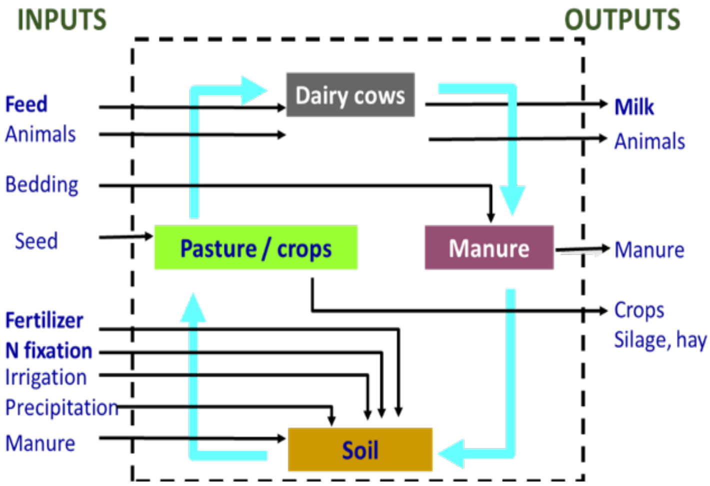

Figure 3. The key nutrient fluxes into and out from a dairy farm and cycling of nutrients within the farm boundary.

A national dairy farm nutrient budget calculator (Ellinbank Dairy Farm Nutrient Budget calculator) which provides Australian dairy industry standard nutrient concentrations, is accessible from the Dairy Australia Fert$mart website (http://fertsmart.dairyingfortomorrow.com.au/services-testing-planning/planning-tools/).

Whole-farm nutrient surplus and use efficiency estimates provide a simple and largely standardised way to quantify and differentiate the utilisation of imported nutrients, and when combined with information on key components of nutrient fluxes on dairy farms can greatly assist in targeting improvements in management (Table 2).

Table 2. Whole-farm nutrient use efficiencies on dairy farms (Gourley et al. 2012).

Nitrogen	Phosphorus	Potassium	Sulphur
Normal range: 14 – 50%	Normal range: 6 - 158%	Normal range: 9 – 48%	Normal range: 6 – 110%
Target range: 35 – 45%	Target range: 60 – 90%	Target range: 30 – 50%	Target range: 30 – 50%

A higher nutrient use efficiency indicates a greater utilisation of nutrients in exported animal products, and/or reduced inputs. However, very high nutrient use efficiency, sometimes >100%, indicates more nutrients are being removed than replaced, mining the soil of nutrients. For farms with excess reserves of soil P and K, this may be appropriate. High N use efficiency may however be decreasing soil N supply and degrading soil carbon.

It is unreasonable to expect a farm to be 100% efficient as there are natural losses of nutrients in any ecological system, and agricultural systems are inherently inefficient.

Whole-farm nutrient budget information is increasingly required by national and international food manufacturers and retailers as part of the demonstration of sustainable nutrient management practices.

While whole-farm nutrient budget and NUE are used as broad environmental indicators, the diverse climatic and soil conditions experienced in Australia, makes it difficult to make general predictions about the forms and amounts of nutrient losses from dairy farms. To quantify actual environmental losses, or even to determine relative losses, more detailed measures or predictive modelling is required that includes the partitioning of nutrient losses between various loss pathways. Use of tools such as the Farm Nutrient Loss Index (FNLI) can assist in determining the risk of P and N losses at the landscape and paddock scale (https://www.asris.csiro.au/themes/nutrient.html).

MORE INFORMATION CAN BE FOUND FROM:

1. Dairy Australia. http://fert$mart.dairyingfortomorrow.com.au/
2. Rugoho I, Lewis H, Islam M, McAllister A, Heemskerk G, Gourley ADP, Gourley CJP (2017). Quantifying dairy farm nutrient fluxes, balances and environmental performance. Animal Production Science 58(9) 1656-1666 https://doi.org/10.1071/AN16440.
3. Rugoho I, Gourley CJP, Hannah MC (2016). Nutritive characteristics, mineral concentrations and dietary cation-anion difference of feeds used within grazing-based dairy farms in Australia. Animal Production Science. http://dx.doi.org/10.1071/AN15761.
4. Gourley CJP, Dougherty WJ, Weaver D, Aarons SR, Awty I, Gibson D, Hannah M, Smith A and Peverill K (2012). Farm-scale nitrogen, phosphorus, potassium and sulphur balances and use efficiencies on Australian dairy farms. Animal Production Science 52, 929–944.
5. EU Nitrogen Expert panel (2016) Nitrogen Use Efficiency (NUE) - Guidance Document for assessing NUE at farm level. Wageningen University, Alterra, PO Box 47, NL-6700 Wageningen, Netherlands.
6. FAO (2018). Nutrient Flows and associated environmental impacts in livestock supply chains. Guidelines for assessment (2018). (http://www.fao.org/partnerships/leap/en/).

6. Developing a soil sampling plan

Soil testing and plant analysis are invaluable tools to diagnose constraints to crop and pasture production and can also assist to identify nutrient loss risk areas. Fertiliser recommendations require supporting soil and plant chemical analysis and interpretation, underpinned by samples that represent the relevant soil environment.

An on-farm soil testing program should adhere to the Australian Fertcare® Soil Sampling Guide (http://www.fertilizer.org.au/Fertcare/Nutrients-And-Fertilizer-Information) and be conducted at a time that allows for analysis of the sample and its interpretation in advance of the recommended fertiliser treatment.

It is important that a farm specific 'Soil sampling map' be developed. Paddocks or blocks that have differing management regimes need to be identified and categorised. In grazed dairy pasture systems, these regimes may include day and night paddocks, regular fodder harvesting, high feeding areas, regular effluent application areas and extensively managed run-off blocks. Areas that may be prone to greater nutrient loss should also be identified.

Figure 4. Paddocks closer to the dairy commonly have high to excessive nutrient levels.

The most comprehensive strategy is to sample every paddock (or even sub-paddock areas) every year to support an evidence-based approach to fertiliser decision making.

Other options include cycling around the farm over a 3-4-year period until the whole farm is completed or selecting 'typical or representative' paddocks with similar characteristics.

Collecting a representative soil sample is essential for meaningful soil analysis. Many of the differences in soil test results and ultimately in divergent fertiliser recommendations, can be traced back to sampling errors or varied sampling approaches.

The number of areas selected to be sampled should recognise the diversity of groups of paddocks identified. Setting up a simple matrix based on paddock ID and matched against defined management practices (i.e. production potential, grazing practices, effluent applications, previous fertiliser inputs, etc.) can assist in grouping paddocks and identifying representative areas to sample. For paddocks or blocks with the same soil types, and that have a similar management regime, an individual or group of paddocks with an average productivity can be selected to represent the rest of the paddocks or blocks in that group (Figure 5).

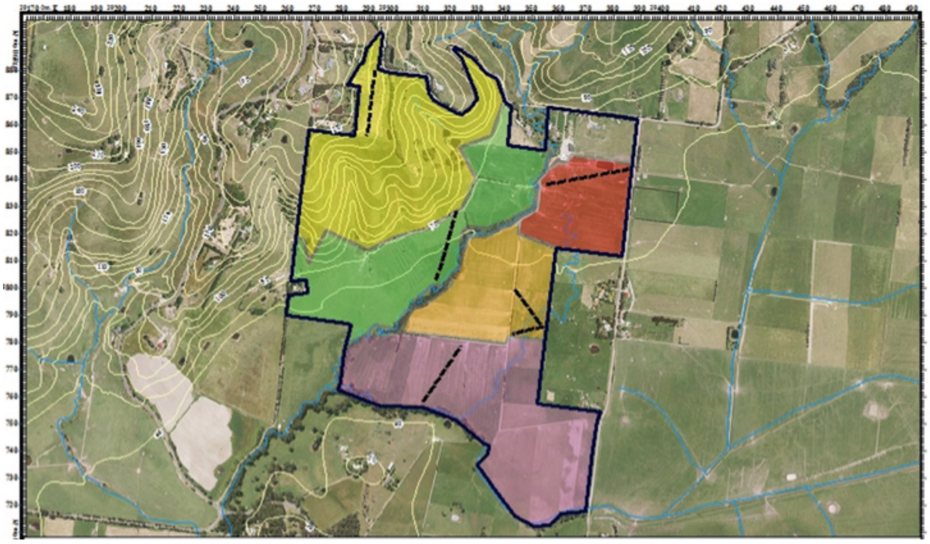

Figure 5. An example of five identified farm management zones within a dairy farm and the paddocks and transect paths used to collect representative soil samples.

The number of areas to sample should consider the cost of soil testing against the potential production benefits, savings in fertiliser, and costs to implement alternative approaches to fertiliser management.

It is important to record the specific location sampled (i.e. using GPS) within each representative paddock, block or management zone, so that you can return to the location and identify trends in fertility status site over time.

The sampling approach adopted should have an organized and systematic pattern to ensure that a collected bulk paddock sample is repeatable, labour efficient, adequately addresses the variability within the paddock and minimized bias (Table 3).

Table 3. Paddock/block sampling patterns and attributes. More asterisks are better

Pattern[1]	Repeatability for monitoring	Labour efficiency	Ability to automate	Likelihood of representative sample	Reducing risk of bias
Transect	*****	*****	*****	***	***
Zigzag	*****	****	*****	****	****
Cluster	*****	****	***	**	**
Uniform Grid	**	**	**	*****	*****
Random	*	**	*	*****	****

[1] Use of geo-coordinates and GPS map enables highest repeatability.

Within-paddock variability in nutrient or other soil parameters can be significant (Figure 6).

Some atypical paddock areas may be easily identified (i.e. current fence lines, gates, troughs, stock camps, feed-out areas, stock tracks), while others may not (previous fence lines, fertiliser or lime dumps, timber burns).

Collecting an adequate number of cores to account for within-paddock variability is critical to achieving a representative sample. Paddocks with high variability require more cores to achieve the same error estimate than paddocks with low variability.

Soil sampling depth should reflect the zone of root activity and align with nationally accepted soil test calibration experiments for relevant pastures and crops. The required soil sampling depth is 10 cm for pastures and forage crops in all States and Territories.

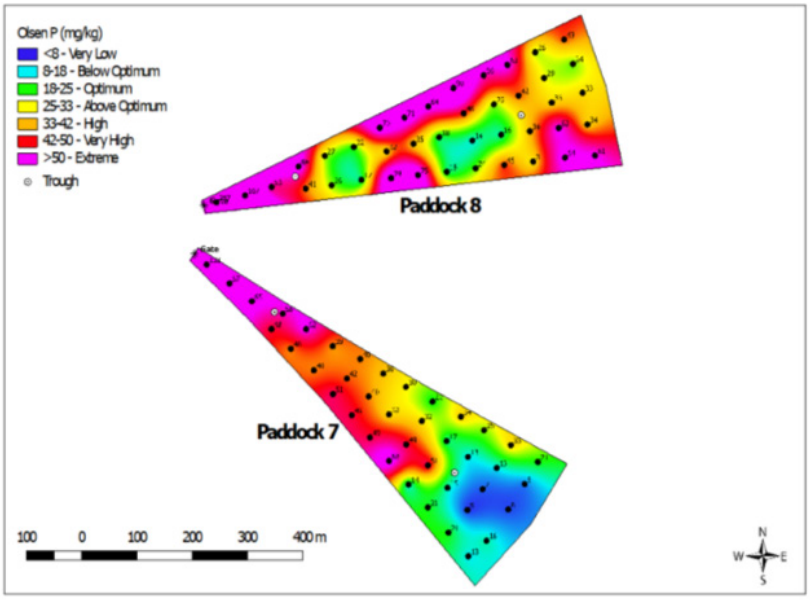

Figure 6. Variability of Olsen P within a paddock grazed by dairy cows (Cotching et al. 2019).

The number of soil cores bulked should be 30-40 for 19 mm diameter cores and 20-30 for 25 mm diameter cores (accepting a ±15% error), irrespective of paddock size, as long as within-paddock variability has been accounted for.

MORE INFORMATION CAN BE FOUND FROM:

7. Fertilizer Australia (2019). A guide for fit for purpose soil sampling. www.fertilizer.org.au/Fertcare/SoilSamplingGuide.pdf
8. Gourley CJP, Aarons SR, Hannah MC, Dougherty WJ, Burkitt LL and Awty IM (2015). Soil phosphorus, potassium and sulphur excesses, regularities and heterogeneity in grazing-based dairy farms. Agriculture Ecosystems and Environment. 201, 70 – 82.
9. Aarons SR, Gourley CJP (2015). Between and within paddock soil nutrient, chemical variability and pasture production gradients in dairy pastures. Nutrient Cycling in Agroecosystems. 102 (3), 411-430.
10. Cotching WE, Talyor L, Corkrey RS (2019) Spatial variation of soil nutrients in dairy pasture paddocks. New Zealand Journal of Agricultural Research: Vol 40, 3

7. Soil analysis and interpretation

The quality of analytical services is critical in determining fertiliser and soil amendment advice provided to farmers. In selecting a laboratory service provider, the following factors need to be considered and confirmed:

i. Participation in independent laboratory proficiency testing programs, whereby common homogeneous samples are sent for analysis to laboratories. The Australasian Soil and Plant Analysis Council (ASPAC) conducts the Proficiency Testing Programs for Australian laboratories. ASPAC publishes certification of test competence for all participating laboratories in the program triennially, so comparisons against the means and medians are available. Laboratories are certified for particular test analytes if their results meet the qualifying criteria, with their annual certification status updated on the ASPAC website.

ii. The use of recognised analytical methods which generate results that can be interpreted for Australian conditions, published interpretation data and/or historical records,

iii. Presence of a Quality Control system, by way of internally-driven procedures or by verification to the AS/ISO 17025 standard through an authority such as the National Association of Testing Authorities (NATA).

Interpretation of soil test results must be underpinned by the national and soil specific soil test - pasture and fodder crop yield response functions and the derived critical soil test values for near-maximum growth of improved pastures and fodder crops across Australia.
Soil testing will also identify potential soil constraints (e.g. soil acidity, soil sodicity, soil salinity and soil dispersion) that will impact on pasture nutrient uptake and that soil amendment requirements will also be identified.

Derived relationships for P, K and S form the basis of national standards for soil test interpretation and fertiliser recommendations for Australian pastures and fodder crops and are incorporated within the major Australian fertiliser company decision support systems. The most common tests are Olsen P (Victoria and Tasmania), Colwell P (NSW, SA, WA, ACT), Colwell K and exchangeable K (nationally), and KCl_{40} S (nationally). Colwell P also requires the phosphorus buffering index (PBI) measure for interpretation (Table 4). Soil testing for N in dairy pastures may be useful in determining residual mineral N in the soil profile but is generally poorly related to responses to applied N fertiliser.

Optimum nutrient status will be in the lower ranges on farms where pasture utilisation is low or when pastures contain poorer producing species. Whilst 95% of pasture production potential is regarded as ideal in grazing-based dairy systems, optimum soil nutrient status is often regarded as 95 - 98 % of pasture production potential (Table 4). It is a business decision where a farmer chooses to operate, but it is not economically or environmentally sensible (Table 5) to operate above the 95% pasture performance level. Standard soil test information, such as PBI, can also be useful in assessing Environmental Risk (see section 11).

It is important to recognise that with increasing soil nutrient levels comes diminishing economic, and ultimately negative financial returns if fertiliser continues to be applied, as well as increase risk of nutrient losses and offsite impacts.

Table 4. National interpretation guidelines for common soil tests for dairy pastures.

Soil test targets for 0-10cm samples accounting for pasture performance goals					
			Critical value range		
Pasture yield performance compared with potential	80 - 89%	90 - 94%	95 - 97%	98 - 99%	>99%
			Olsen P (mg/kg)		
All soils	8 - 10	11 - 14	15 - 20	21 - 26	>26
PBI value			**Colwell P (mg/kg)**		
<5	7 - 8	9 - 11	12 - 15	16 - 19	>19
10	9 - 12	13 - 16	17 - 22	23 - 27	>27
20	13 - 17	18 - 23	24 - 30	31 - 37	>37
50	16 - 21	22 - 28	29 - 37	38 - 44	>44
100	18 - 24	25 - 32	33 - 42	43 - 51	>51
200	21 - 29	30 - 38	39 - 50	51 - 60	>60
350	25 - 35	36 -46	47 - 60	61 - 72	>72
600	32 - 45	46 - 59	60 - 77	78 - 92	>92
1000	45 - 64	65 - 83	84 - 109	110 - 129	>129
			Colwell K (mg/kg)		
Sand	85 - 94	95 - 125	126 - 155	156 - 200	>200
Sandy/Silty loam	94 - 104	105 - 138	139 - 175	176 - 210	>210
Sandy/Silty clay loam	99 - 109	110 - 142	143 - 185	186 - 220	>220
Clay loam and Clay	110 - 119	120 - 160	161 - 210	211 - 270	>270
			Exch K (meq/100g)		
Sand	0.19 - 0.23	0.24 - 0.31	0.32 - 0.39	0.40 - 0.51	>0.51
Sandy/Silty loam	0.21 -0.26	0.27 - 0.34	0.35 - 0.44	0.45 - 0.54	>0.54
Sandy/Silty clay loam	0.22 - 0.27	0.28 - 0.35	0.36 - 0.46	0.47 - 0.56	>0.56
Clay loam and Clay	0.24 - 0.30	0.31 - 0.40	0.41 - 0.53	0.54 - 0.68	>0.68
			Sulfur (KCl-40) (mg/kg)		
All soils	4.5 - 5.5	6.0 - 7.5	8.0 - 10.0	10.5 - 12.0	>12.0
			Sulfur (CPC S) (mg/kg)		
All soils	1.6 - 2.2	2.3 - 3.0	3.1 - 3.8	3.9 - 4.5	>4.5

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1. Critical value defined as 95% of potential maximum yield for grass - legume pastures.
2. Production goals defined by management.

Table 5. Risk of phosphorus loss corresponding to soil test P levels.

	Loss pathway	Risk of loss: Low → High				
		Olsen P (mg/kg)				
		<9	9 - 14	15 - 20	21 - 27	>27
PBI range		Colwell P (mg/kg)				
< 5	Leaching	7	9	12	16	> 19
10	⇧	9	13	17	23	> 27
20	⇧	13	18	24	31	> 37
50	⇧	16	22	29	38	> 44
100	⇧	18	25	33	43	> 51
200	⇩	21	30	39	51	> 60
350	⇩	25	36	47	61	> 72
600	⇩	32	46	60	78	> 92
1000	Runoff	45	65	84	110	> 129

Soil fertility and chemical condition mapping allows translation of soil test results into a visual representation of fertility and chemical conditions across the farm and highlights between-paddock or block variability (Figure 7). Mapping of soil test results across the farm is also useful in defining nutrient transfers such as regular forage harvesting, animal feeding areas and application of manure/effluent, or identifying the risk of metabolic problems in livestock. This approach can also identify areas close to dairy sheds that often have high or excessive nutrient levels, and those further from the dairy that may have nutrient levels below critical values which can accept effluent.

Different colours, depending on the context, may be used to correspond to soil nutrient status and targets (i.e. very high, high, adequate, marginal and deficient). Paddocks or blocks are then colour coded based on soil test results. Soil pH and salinity maps similarly determined are useful for targeted soil amendment decisions such as lime and gypsum.

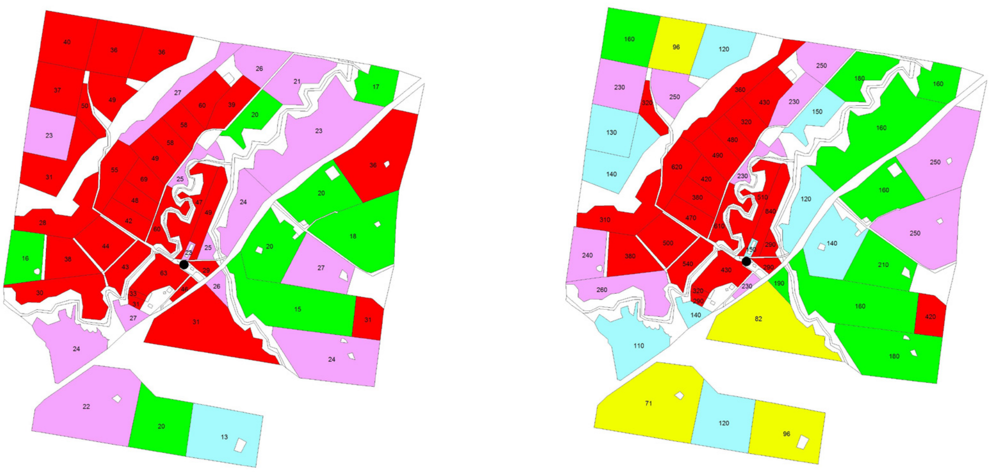

Figure 7. A nutrient map on an Australian dairy farm for Olsen P (left) and Colwell K (right). P or K availability: Red is very high, purple is high, green is adequate, light blue is marginal and yellow is deficient. The dot represents the location of the dairy shed. Source: Gourley et al (2007).

MORE INFORMATION CAN BE FOUND FROM:

11. Soil Analysis: An Interpretation Manual (CSIRO – Peverill).
12. Plant Analysis: An Interpretation Manual (CSIRO – Peverill).
13. Gourley CJP, Weaver DM, Simpson RJ, Aarons SR, Hannah MM, Peverill KI (2019). The development and application of functions describing pasture yield responses to phosphorus, potassium and sulphur in Australia using meta-data analysis and derived soil-test calibration relationships. Crop and Pasture Science 70, 1065-1079.
14. Better Fertiliser Decisions for Pasture (2007). https://www.asris.csiro.au/downloads/BFD/Making%20Better%20Fertiliser%20Decisions%20for%20Grazed%20Pastures%20in%20Australia.pdf

8. Addressing any regulatory requirements

A Fertcare® Accredited Advisor offering dairy specific nutrient management advice should be aware and understand all the relevant industry guidelines and codes of practice for manure and effluent management. These are available in the national dairy effluent and manure management database (https://www.dairyingfortomorrow.com.au/tools-and-guidelines/effluent-and-manure-management-database-for-the-australian-dairy-industry/) and the relevant state agencies (i.e. Department of Primary Industries and EPA websites).

9. Determining the manure nutrient inventory

Collecting, storing and land applying manure is a part of day-to-day dairy farm management and critical to nutrient management planning. Manure is a valuable source of organic matter and nutrients which enhance pasture and crop production. Manure can also be used as a source of energy through anaerobic digestion.

Dairy cows inefficiently utilise nutrients, with only ~20%, 24% and 8% of the N, P and K, respectively, consumed by lactating dairy cows being secreted in milk. An average producing Australian dairy herd of 260 cows per farm and a lactation period of 305 days, would excrete ~35,000 kg N, 5,000 kg P, and 27,000 kg K in dung and urine each year. As total feed intake and milk yield increases per cow, so does the amount of nutrients excreted (Table 6).

Table 6. Minimum, median and maximum annual nutrient excretion for lactating dairy cows with a range of liveweights, dry matter intake and milk production in Australia (Aarons et al. 2017).

	Cow live weight (kg)	Total DM intake (tonne/cow)	Milk yield (litres/cow)	Excreted nutrients (kg/cow)		
				N	P	K
Minimum	430	3.8	2628	73	7.3	51
Median	500	6.5	6741	157	22.3	122
Maximum	680	10.4	11285	289	48.2	245

Intensification of dairy production has resulted in animals spending more time in confined feeding areas and less time grazing. Consequently, there is a greater need for improved capture, storage and sustainable reuse of dairy cow excreta.

Figure 8. A typical uncovered dairy feed pad.

Manure quantity and nutrient content will be influenced by the number and size of cows, diet and milk production, the amount of time spent on feeding areas, and methods of manure collection and storage.

Manure collection usually occurs in the dairy and holding yards, concentrated feeding areas such as feedpads (covered and uncovered) and occasional and permanent housing facilities (Figure 8).

Collected dairy manure is generally classified according to moisture content (Figure 9), i.e. liquid effluent, slurry, semi-solid and solid manure. The moisture, total solids and nutrient content of manure are influenced by many factors, including animal (e.g. breed, age etc), herd management (e.g. diet), environment (season, region) and how the manure has been collected and stored.

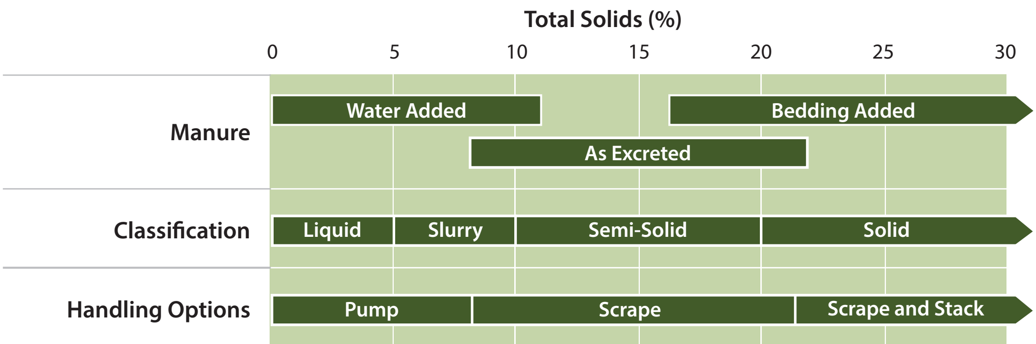

Figure 9. Moisture content, manure classification and manure handling. (Source: Fert$mart, Dairy Australia).

Dairy effluent is excreted dung and urine generally mixed with yard wash and rain water. Effluent can also contain chemicals, small amounts of milk and waste feed. Slurry is dung and urine, usually scrapped from concreted surfaces and largely undiluted, but may contain waste feed, bedding and contaminants such as gravel. Semi-solid and solid material has usually undergone some gravitational or mechanical separation (i.e. weeping wall, settling pond, sieve, screw press), to separate larger fibrous components from smaller sized material remaining in the liquid. The moisture content of manure affects how it can be handled.

Pond systems are the most common effluent management systems on Australian dairy farms. Dairy effluent drains (or is pumped) into the first (sedimentation) pond and then gravity fed into any adjacent effluent storage ponds.

The first pond is intended to retain most settleable solid material which then undergoes slow anaerobic digestion. The formation of a thick surface crust of organic material is common. Accumulated sludge is mechanically removed periodically and either immediately applied to pasture paddocks or stockpiled and composted.

The second (and additional ponds) contains largely dissolved and suspended material. Most second pond effluent is commonly anaerobic (except maybe the very top layer). These larger ponds provide an essential store for green water, either as reused wash water and/or a source of irrigation water.

In single ponds, the sludge and effluent storage function is combined into one structure, so solids and nutrient concentrations are typically higher.

These pond systems may be preceded by solids traps with weeping walls, or mechanical separators (sieves, screw press) where a proportion of manure solids can be removed before entering the first pond. Removed semi-solid material may be further treated or stockpiled.

Increasing herd size, reliance on imported feed and use of feedpads and housing infrastructure are common reasons for excess manure loads beyond the capacity of the traditional pond systems.

Larger scale dairy systems are increasingly managing dairy manure through liquid-solid separation, recycling of wash water, and manure stockpile infrastructure; all of which increase management and labour, electricity and maintenance costs.

Nutrients available for land application from manure storage facilities are determined from the dry mass and nutrient concentration of each manure source. Information required include pond or stockpile volume and density, moisture and nutrient content.

Manure pond volumes are determined using the surface area and depth and adjusting for batter wall angles. However, it is difficult to arrive at an accurate gauge of pond depth and batter wall angles and so the calculated volume needs to be recognised as informed estimates.

Manure stockpile volumes can be determined by collecting length, height and shape data either manually or using software packages that use photogrammetry to capture a detailed 3-D image (Figure 12). Density of manure can be estimated or calculated from the weight of manure in a known container volume (i.e. bucket).

Figure 10. Sedimentation pond on grazing-based dairy farm being pumped into tankers for land application.

Figure 11. Separating liquid and solid manure fractions using a sieve and mechanical screw-press.

Figure 12. Determining volumes of manure stockpiles.

Average nutrient content values are available for different manure types (Table 6). However, it is important to note that the actual nutrient content of manure sources on any farm can vary widely, so laboratory analysis of farm-specific manure stores is recommended. For example, many ponds may have a sludge dry matter content in the range of 8 - 20% and therefore will have a higher NPKS content.

Collecting a representative sample of manure sources is important (Figure 13). This is particularly challenging in single or primary ponds where stratification of liquid manure occurs. Sampling methods for different manure sources are provided in the Australian dairy effluent and manure management database. Alternatively, P and K amounts in manure may be calculated based on known feed characteristics and intakes.

The minimum recommended laboratory analysis of manure should include moisture content, total and mineral N, total P, K and S.

Figure 13. Collecting a representative sample of pond or stockpiled manure for laboratory analysis.

Note: Collecting effluent and sludge samples from manure ponds can be dangerous. Ponds can be deep and viscous, with organic matter crusts and vegetation concealing the pond surface and edges. A safety assessment is essential prior to sampling.

Table 7. Average and range of nutrient values determined for differing manure sources collected on commercial dairy farms [1].

Manure Source	Estimated dry matter (%)	N (kg/ML or % DM)	P (kg/ML or % DM)	K (kg/ML or % DM)	S (kg/ML or % DM)
Yard wash (directly applied) n=14	1-3%	419[2] 87-1334[3]	77 19-237	573 99-1900	51 9-143
Single pond effluent n=46	3-15%	323 56-1800	75 9-622	432 27-3130	38 7-476
First pond effluent n=50	5-15%	524 62-2290	118 22-654	556 150-1300	87 6-484
Second pond effluent (green water) n=88	>1%	211 5-1080	53 6-250	462 79-1320	17 2-60
Third pond effluent (green water) n=14	>1%	161 7-828	26 6-156	369 70-1110	16 4-59
Pond sludge n=24	6-8%	0.60% 0.26-2.13%	0.23% 0.05-0.37%	0.36% 0.12-1.01%	0.39% 0.07-0.71%
Stockpiled solids n=23	15-30%	1.2% 0.11-3.02%	0.32% 0.20-0.87%	0.62% 0.12-3.01%	0.26% 0.07-2.59%

[1] Agriculture Victoria Dairy Effluent data base (unpublished). [2] Average, [3] Range.

Many physical, chemical, and biological processes can alter manure characteristics from that directly excreted by cows. The rapid transformation of urea N to ammonium which occurs on hard surfaces results in significant ammonia emissions to the atmosphere. Nitrogen concentrations will continue to decrease in storage ponds as ammonia is lost to the atmosphere. More soluble elements such as ammonium and potassium will remain in liquid fractions, while phosphorus and organic nitrogen will stratify and concentrate in more solid fractions. Consequently, the nutrient concentrations of manure between and within different storage systems will vary (Table 7).

Composting and medium to long-term storage of manure stockpiles will further reduce nutrient concentrations and nutrient availability, therefore reducing the fertiliser value to crops and pasture. As well as emitting carbon dioxide, methane, nitrous oxide and ammonia to the atmosphere, stockpiles may also produce nutrient rich leachate.

Figure 14. Windrows and composting of manure prior to land application will reduce moisture content and overall volume, but also decrease nutrient availability.

MORE INFORMATION CAN BE FOUND FROM:

15. Fert$mart. https://www.dairyingfortomorrow.com.au/tools-and-guidelines/effluent-and-manure-management-database-for-the-australian-dairy-industry/
16. Aarons SR, Gourley CJP, Powell JM (2020). Nutrient intake, excretion and use efficiency of grazing lactating herds on commercial dairy farms. Animals 10(3), 390; https://doi.org/10.3390/ani10030390.
17. Farm Crap App. https://www.swarmhub.co.uk/managing-manures/the-farm-crap-app/
18. Nutrient Flows and associated environmental impacts in livestock supply chains. Guidelines for assessment (2018). (http://www.fao.org/partnerships/leap/en/).
19. http://fertsmart.dairyingfortomorrow.com.au/dairy-soils-and-fertiliser-manual/chapter-13-using-dairy-effluent/13-4-sampling-and-testing-of-effluent-ponds/
20. Sheffield RE, Norell RJ (2007). Manure and Wastewater Sampling. https://www.extension.uidaho.edu/publishing/pdf/CIS/CIS1139.pdf
21. Wallace T (2005). Nutrient management plans: Defining the key components for Alberta Producers. Alberta Food and Rural development, Red Deer, AB.

10. Nutrient applications

The 4R nutrient stewardship principles are globally recognised, but how they are used locally varies depending on site-specific characteristics such as pasture and cropping system, soil and topography, climate and management techniques. The scientific principles of the 4R framework include:

RIGHT SOURCE – Ensure a balanced supply of essential nutrients, considering both available sources and characteristics of specific fertiliser products, in plant available forms.

RIGHT RATE – Assess and make decisions based on soil nutrient supply and plant demand.

RIGHT TIME – Assess and make decisions based on the dynamics of plant uptake, soil supply, nutrient loss risks, and field operation logistics.

RIGHT PLACE – Address root-soil dynamics and nutrient movement and manage spatial variability within the field to meet site-specific plant needs and limit potential losses from the field.

Manure nutrient applications

The manure inventory enables an estimate of the total nutrients currently available for land application in manure stores. Matching this nutrient supply with estimated nutrient requirements across the farm is an important part of a dairy farm NMP.

The nutrient requirements of pastures and crops on a dairy farm may be totally, partially or only marginally met by the generated and stored manure. This will be influenced by the intensity of the dairy operation, informed by the whole-farm nutrient balance for N, P, K and S, but also depend on the efficacy of manure collection, storage and land application.

Manure applications to deliver P, K and S should be based on soil testing of identified farm management zones. Nitrogen inputs should be applied to optimize pasture and crop yields and use efficiency.

The 'fertiliser value' of nutrients in manure should be discounted depending on the manure source. Nutrients in manure are present in inorganic and organic forms, and hence are often not all immediately available to plants. Organic sources of nutrients must be mineralized into inorganic forms. For example, proteins need to be mineralised to ammonium, where it can be directly adsorbed or further transformed to nitrate. Organic forms of nitrogen will continue to mineralize and become available to crops in subsequent years after the initial application. In contrast, K remains in an inorganic form and is immediately plant available.

The different types of dairy manure (freshly washed or scraped manure, first pond sludge, second pond effluent) will contain varying amounts of organic and inorganic N and P fractions.

Directly collected and applied dairy manure generally has 50% of N as ammonia-N and 50% in organic N forms. However, these proportions of N forms vary depending on the dairy cow diet, how much time cows spend in yards or feedpads, and the frequency of manure collection.

Sludge from the first pond has a high proportion of organic N forms, which may potentially mineralize over several years after land application. Sludge will also contain a smaller proportion of ammonium N which is readily available N to crops or pastures.

Second and subsequent pond effluent typically has a low solids content. Depending on the storage time, this effluent will have a higher ammonia-N content (50% to 90% of total N) and comparatively lower organic N content. Therefore, a high proportion of the total-N is readily plant available, with added N supply comparatively short lived.

Screw press and other separated solids will have a higher P to N ratio, with a higher proportion of N in an organic form, more slowly plant available. Composted solids will also have a higher P to N ratio, with remaining N in largely stable forms, resistant to microbial degradation and poorly plant available.

The rate of mineralization will depend on the manure composition and load applied as well as the soil conditions such as clay content, biological activity, moisture content and temperature.

Most manure nutrient availability tables and decision support calculators will provide discounting factors to use when calculating nutrient availability.

Dairy manure sources rarely provide the correct balance of N, P, K and S when manure is applied to land. Manure applications to meet N requirements will generally result in an oversupply of P and K, above pasture or crop requirements. If K application rates are optimised, then N and potentially P rates are likely to be sub-optimal and require additional commercial fertiliser.

It is important to calculate the required manure application to land, based on the target nutrient application rate (kg/ha).

This may require the calibration of manure application equipment. For irrigation systems the volume of effluent applied will be required (i.e. ML or mm applied per ha). For more solid material, this requires the mass or volume of manure applied (i.e. ton or cubic metres/ha). In both cases the mass or volume is multiplied by the nutrient concentrations (volumes need to be adjusted for density).

Preferred timing of manure applications must balance multiple factors including timing of pasture and crop uptake of nutrients and probability of rainfall events following manure application. The location of manure applications must consider site specific characteristics that influence environmental risks, such as existing soil test values, soil P buffering, slope, erosion potential and proximity to waterways. Effluent (green water) and sludge should not be applied to waterlogged or excessively wet soils. Decision support tools such as the Farm Nutrient Loss Index (FNLI) can assist in quantifying the risk of P and N losses.

Figure 15. A trailing hose tanker spreading effluent from an agitated first pond.

Method of calculating effluent / manure land application rates:

Effluent / pond water / sludge

Target nutrient application (kg/ha) ÷ ((Nutrient concentration (kg/ML) * availability factor))
= Effluent application rate (ML/ha).

- Example for potassium: 60 kg/Ha ÷ (462 kg/ML * 1) = 0.13 ML/Ha or 13 mm
- Example for nitrogen: 50 kg/Ha ÷ (211 kg/ML * 1) = 0.24 ML/Ha or 24 mm

Stockpile

Target nutrient application (kg/ha) ÷ ((Nutrient conc. (%) * availability factor * DM content (%)))
= Solid material application rate (tonne/ha).

- Example for phosphorus: 30 kg/ha ÷ (0.2% * 0.75 * 50%) ÷ 1000 = 40 tonne/ha wet wt
- Example for nitrogen: 60 kg/ha ÷ (1.2% * 0.50 * 50%) ÷ 1000 = 20 tonne/ha wet wt.

Inorganic fertiliser nutrient applications

Fertiliser applications to meet P, K and S requirements should be based on existing soil test results of the identified farm management zones as well as nutrient budget calculations. Fertiliser applications need to also account for nutrient removal and soil retention or losses (soil P fixation, K leaching) when determining 'maintenance fertiliser rates', and surplus nutrient inputs ('capital fertiliser applications') when the build-up of soil nutrient reserves is justified.

The rate of P, K and S should be determined with the use of an accredited nutrient decision support system, or alternatively a transparent calculation process which clearly identifies the scientific justification for the recommended fertiliser application. These can be sourced from the Dairy Australia Fert$mart website.

Nitrogen fertiliser applications, often dominated by urea, is increasingly being used on dairy farms to increase pasture yields. Nitrogen fertiliser can substantially increase pasture yield and feed on offer when conditions are optimal for plant growth (i.e. adequate soil moisture and temperature, appropriate pasture species composition and maturity, and adequate supply of other nutrients). In contrast, yield responses can be low or negligible if soil, season and climate conditions are restricting plant growth, grazing pressure is too harsh or too little, or soil N supply from legumes, manure or mineralisation is meeting or exceeding plant demand. Refer to the Best Management Practices for nitrogen fertiliser use on dairy pastures (https://fertsmart.dairyingfortomorrow.com.au/wp-content/uploads/2020/07/2584-Nitrogen-Guidelines-Best-management-practice-WebReady-final.pdf).

Optimum N fertiliser rates usually range between 30 and 60 kg N/ha per application. Total N applications for most pastures should not exceed 250 kg N/ha/year. Ready reckoners such as 'Dairy N Fertiliser Advisor' enables paddock specific N fertiliser recommendations for pastures based on regional, pasture production, season and cost-benefit analysis.

Blanket applications of fertiliser blends across the farm are rarely justified.

Applying alternative nutrient sources

Dairy farms may also use alternative sources for nutrient inputs. Nutrient content and availability may vary widely in these diverse inputs (Table 8). The determination of nutrient application rates to land from these sources should follow the same methodology as that applied to manure applications.

Table 8. Poultry manure and compost and nutrient concentration averages and ranges on a dry matter basis (Source: Wiedemann 2015).

Source	Approximate percentage and ranges of principle nutrients			
	Nitrogen %	Phosphorus %	Potassium %	Moisture %
Poultry (cage)	3.4 (2.8 - 4.8)	2.5 (1.9 - 4.0)	1.5 (1.2 - 2.1)	35 (15 - 65)
Poultry (litter)	2.6 (1.4 - 4.2)	1.8 (1.6 - 2.8)	1.0 (1.1 - 1.9)	25 (10 - 51)
Organic compost[1]	0.93 (0.36 - 1.60)	0.24 (0.05 - 0.53)	0.5 (0.10 - 1.10)	40 (10 - 60)

[1] Variable sources of organic material can result in large ranges in nutrient concentrations.

MORE INFORMATION CAN BE FOUND FROM:

22. 4R Plant Nutrition Manual: A manual for improving the management of plant nutrition. (TW Bruulsma, PE Fixen, GD Sulewski, eds). International Plant Nutrition Institute, GA, USA. https://www.nutrientstewardship.com/4rs/.
23. www.dairyingfortomorrow.com.au/tools-and-guidelines/ DairySat Best Management Practices (BMP) for soils and fertilisers.
24. Making Better Use of Dairy Nutrients. https://frds.dairyaustralia.com.au/events/nutrients-manure-and-composting/
25. Dairy Australia Fert$mart. http://fertsmart.dairyingfortomorrow.com.au/dairy-soils-and-fertiliser-manual/chapter-15-nutrient-planning/15-8-capital-nutrient-applications/
26. https://lpelc.org/estimating-crop-nutrient-availability-of-manure-and-other-organic-nutrient-sources/
27. Dairy Farm N fertiliser Advisor http://vro.agriculture.vic.gov.au/dpi/vro/vrosite.nsf/pages/nitrogen-advisor
28. Mundy GN (1999) A review of nitrogen research with irrigated pastures in Northern Victoria. Department of Natural Resources and Environment [Melbourne].
29. Eckard RJ (2007) Guidelines for N fertiliser use on rain-fed pastures. The Institute of Land and Food Resources, University of Melbourne. http://www.nitrogen.unimelb.edu.au/Guidelines
30. Wiedemann SG 2015. Land Application of Chicken Litter: A Guide for Users. https://www.agrifutures.com.au/wp-content/uploads/publications/14-094.pdf

11. Managing environmental risks

The main environmental issues which relate to nutrients include P and N losses to surface waters - leading to excessive growth of aquatic plants and algae and reduced oxygen availability (anoxia) and excess N leading to nitrate leaching to groundwater. The loss of ammonia, nitrous oxide and methane from the storage and land application of manure, is of increasing importance due to their contribution to greenhouse gas emissions.

On-farm nutrient use is highly regulated in many regions of the world. Some regulations are now evident in Australia, with controls on fertiliser use being introduced to protect the Great Barrier Reef (Qld). In other regions there are 'softer' policy responses, with combinations of research, extension, incentives and regulation, supported by Federal and State governments, industry organisations, farmers, processors and retailers. Wise use of nutrients, and demonstration of NMP, will reduce the risk of increased regulation of farming activities.

Agronomic nutrient targets may however be greater than safe environmental limits. It is important to consider the impact of current nutrient availability and further nutrient inputs on environmental losses, as well as pasture, crop and farm production goals.

Beyond the economic benefits of reducing expenditure on fertilisers, there are potential positive water quality outcomes using soil testing and adherence to agronomic critical values. Water quality risks will be reduced by allowing current soil P levels to rundown to the critical values.

The Phosphorus Buffering Index (PBI) soil test provides an estimate of the potential phosphorus retention of a soil (Table 9). Soils which have a low to very low P retention may be prone to leaching of stored and applied P (fertiliser or manure) through the soil profile and increased horizontal P losses through surface water movement.

Table 9. Phosphorus Buffering Index (PBI) interpretation

PBI Range	P Loss Risk Classification
< 5	Very High
5 – 25	High
25 – 50	Moderate
50 – 100	Low
> 100	Very low

A higher P availability in soil, as measured by the Olsen P and Colwell P soil tests, associated with a lower P retention, will result in a higher concentration of P in surface runoff (Figure 16).

Inputs of N and P from fertiliser and animal excreta and existing soil nutrient levels provide information about nutrient loss 'source' factors. 'Transport' factors are also crucial as they influence the delivery of N and P to water bodies. These factors include erosion, ground-cover, infiltration, surface and subsurface hydrology and proximity to waterways.

Tools such as the Farm Nutrient Loss Index (FNLI) provide a risk assessment of nutrient loss at the paddock scale (www.asris.csiro.au/themes/nutrient.html).

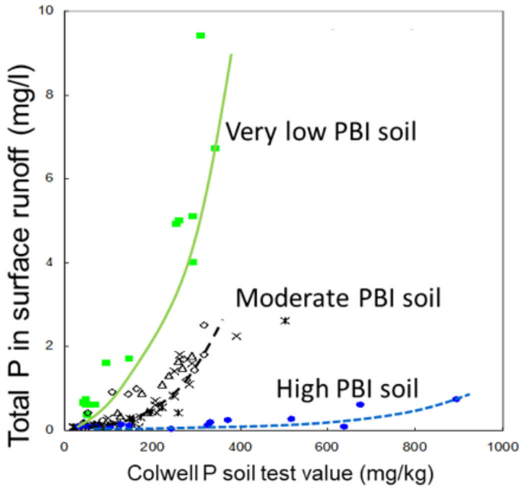

Figure 16. Influence of soil PBI and Colwell P value on phosphorus in surface runoff (Source: Burkitt et al. 2010).

Minimizing direct losses from fertiliser applications

- Know your soil fertility levels and do not fertiliser or apply manure/effluent to soils with above-optimum soil fertility targets.
- Ensure fertiliser applications do not directly impact surface waters such as waterways, drainage lines and water storages – maintain the appropriate buffer distance when spreading.
- Avoid spreading fertiliser on critical source areas with connectivity to waterways, such as excessively wet paddocks adjacent to streams.
- Avoid areas with potentially above optimum nutrient levels (i.e. around gateways, feed pads, etc).
- Do not apply fertilisers to buffer strips or the end of irrigation bays.
- Do not apply N and P within 5 days of an anticipated run-off event.
- Ensure adequate ground cover and minimize soil erosion potential.
- Minimise urea applications to warm, wet soils and excessively short pasture to reduce ammonia volatilisation.

Minimizing losses from storing and mechanically spreading manure

- Design and maintain correctly sized pre-treatment systems, ponds and manure stockpile infrastructure to effectively capture and store dairy manure and minimise greenhouse gas losses.
- Ensure no direct overflow or leaching losses from ponds or stockpiled manure. Earthen or concrete bunding, drainage lines and ponds should be used to contain any leakage.
- Dairy effluent and manure applications should be directed to areas in need of nutrient applications and applied at the required nutrient rates, accounting for slope, soil moisture content, leaching potential and ground cover.
- Ensure appropriate set-backs from waterways, buffer strips and native vegetation.
- Breakdown alerts and automatic shut-off systems should be used to address effluent irrigation system blockages, disconnections and overflows.
- Minimize the use of splash-plates and muck-spreaders. Concentrating effluent and slurry applications using trickle, trailing hose, or injection applicators will reduce nitrogen losses.

Minimizing losses from animal deposited manure

- Keep stock out of waterways. Fence creek crossings and provide alternative watering points.
- Remove grazing animals from excessively wet soils and poor pasture cover. Restricting grazing to 8 hours a day over the autumn/winter period, and use of 'off-paddock' facilities, such as feed and stand-off pads can reduce N leaching losses.
- Ensure laneway runoff does not concentrate and drain direct to waterways. Construct drainage diversion humps to direct laneway run-off to grassed areas.
- Designated feeding areas, troughs and gateways should also be carefully sited.

MORE INFORMATION CAN BE FOUND FROM:

31. http://fertsmart.dairyingfortomorrow.com.au/dairy-soils-and-fertiliser-manual/
32. Bittman, S., Dedina, M., Howard C.M., Oenema, O., Sutton, M.A., (eds) (2014), Options for Ammonia Mitigation: Guidance from the UNECE Task Force on Reactive Nitrogen, Centre for Ecology and Hydrology, Edinburgh, UK
33. McDowell RW, Monaghan RM, Dougherty W, Gourley CJP, Vibart R, Shepherd M (2017). Balancing water quality threats from nutrients and production in Australian and New Zealand dairy farms. Animal Production Science 57, 1419-1430. http://dx.doi.org/10.1071/AN16646
34. Burkitt L. L., Dougherty W. J., Carlson S. M., Donaghy D. J. (2010) Effect of variable soil phosphorus on phosphorus concentrations in simulated surface runoff under intensive dairy pastures. Australian Journal of Soil Research 48, 231-237.
35. Farm Nutrient Loss Index. https://www.asris.csiro.au/themes/nutrient.html
36. Gourley CJP, Weaver DM (2012). Policy approaches and difficult choices to reduce nutrient losses from grazing systems in Australia. Crop and Pasture Science 63, 805-818.

12. Planning and record keeping

Record keeping improves the planning and reviewing process. It is beneficial to keep structured annual records which include details of farm layout and identifies the principal productivity area, paddock uses, management zones, as well as any setback areas. Information on farm maps should also include soil sampling pathways and be linked to current and previous soil test results. Resources for record keeping can be found at https://fertsmart.dairyingfortomorrow.com.au/dairy-soils-and-fertiliser-manual/chapter-16-developing-a-fertiliser-management-plan/16-3-documenting-the-fertiliser-management-plan/

Manure and fertiliser applications to individual paddocks or at least management zones, should include the type, timing and rate of application and associated nutrient rates applied.

Other useful information may include weather conditions and observed or measured pasture or crop yield responses to applied nutrients.

13. Dairy farm nutrient management advisor checklist

- ☐ Farm area defined, paddocks identified and grouped into farm management zones.
- ☐ Regulatory requirements and environmentally sensitive areas identified.
- ☐ Whole-farm nutrient balances and nutrient use efficiencies determined.
- ☐ Soil sampling areas and sampling routes identified according to Fertcare® soil sampling guidelines.
- ☐ Soil analysis and interpretation according to accepted science in Australia e.g. Making Better Fertiliser Decisions for Grazed Pastures in Australia.
- ☐ On-farm manure nutrient sources quantified and use optimized.
- ☐ Pasture and crop composition and growth performance assessed and considered.
- ☐ Basic soil health indicators have been assessed and considered e.g. waterlogging, pugging, sodicity and soil structure.
- ☐ A manure and fertiliser application strategy incorporating the 4Rs for each farm management zones have been developed.
- ☐ Environmental risks associated with nutrient applications have been identified and documented, and measures to minimise environmental risks implemented.
- ☐ Adequate records are created and retained.

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