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OUTLOOK FOR LONG-TERM P FERTILIZER DEMAND AND ASPECTS OF ORGANIC P RE-CYCLING IN NEW ZEALAND

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Outlook for long-term P fertilizer demand and aspects of organic P re-cycling in New Zealand

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Summary

Livestock production (mostly dairying, sheep and beef cattle) is the main agricultural land use in New Zealand and grasslands occupy more than 85% of the total farmed area (15.3 x 10^6 ha). Ninety five percent of P applied in New Zealand is used to maintain productivity of the more productive legume-based pastures of dairy, sheep and beef and deer farms. Past variations in the amounts of P applied can be explained by the volatile profitability of the export sheep and beef industry. Analysis of fertiliser recommendations for the pastoral industries indicates that the current (2009/10) amount of P applied, 108 x 10^3 t P/y, is 40 x 10^3 t P/y less than the application rate required to maintain soil P fertility status.

The financial outlook for sheep and beef farms is relatively stable, whereas dairying is predicted to expand with the market place continuing to support increasing prices for milk products. Current and future expansion of dairying is predicted to take a larger share of the P applied. The opportunities for further replacing imported P fertiliser with organic P recycled from farm effluents and urban wastes are limited because low amounts of P are contained in such wastes, which with the exception of sewage are already applied to land, some being accounted for in farm nutrient budgets.

Given that the current amount of P applied nationally is calculated to be below “maintenance” levels for pastoral farms, then both future fertiliser recommendations, and the finances of the overall pastoral industry (led by dairying), should support a slow recovery in the amounts of P applied to maintenance levels of approximately 174 x 10^3 t P/y. This expectation is predicated on the fact that increases in farm income will stay apace with increases in farm costs, including fertiliser. Increased farm costs are expected from the introduction of a greenhouse gas (GHG) emissions trading scheme (NZETS) for agriculture from 2015 onward. It is expected that this will be managed carefully as exports of agricultural produce currently return 48% of New Zealand’s export revenue.

Land use and fertiliser demand

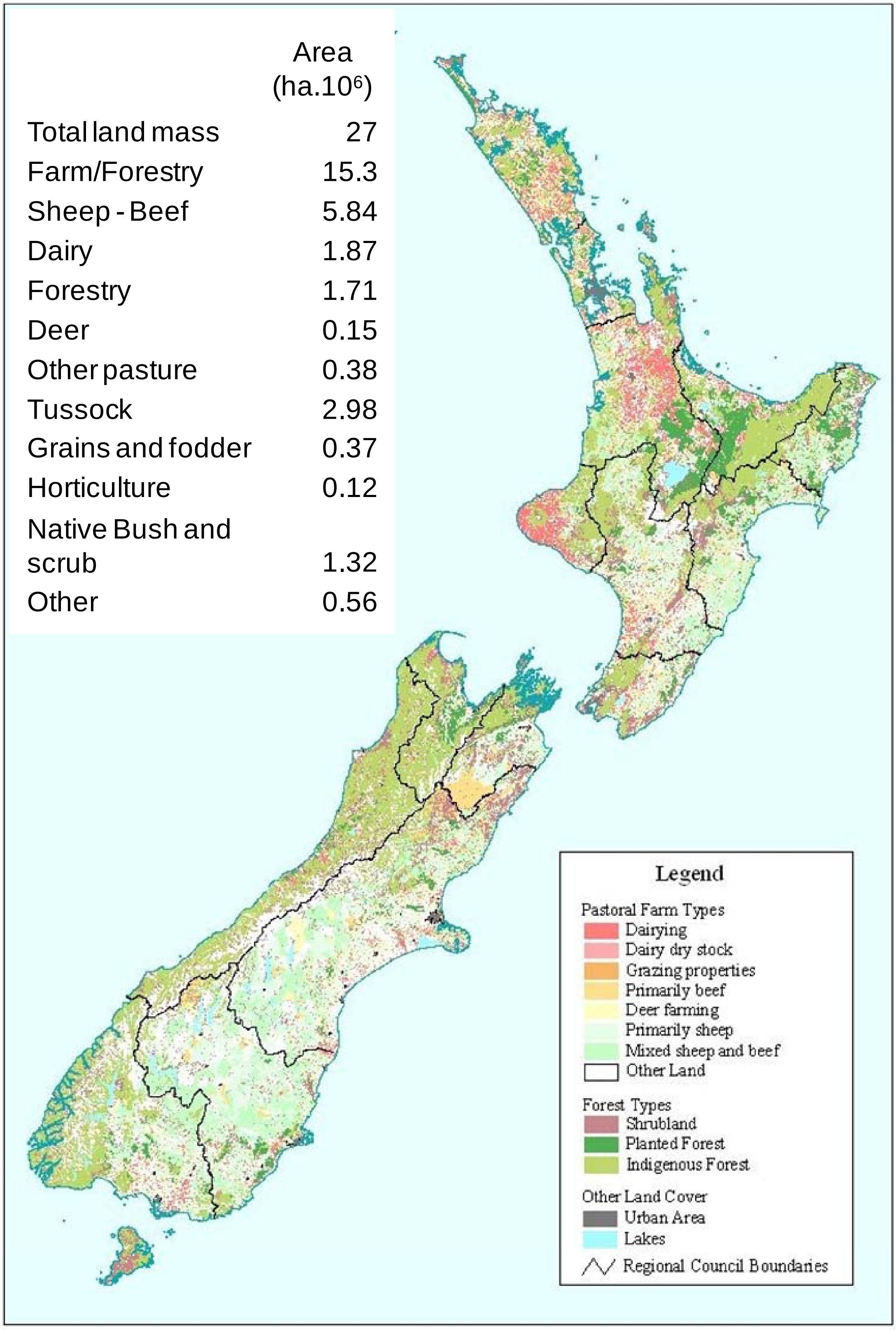
New Zealand (land area 268,675 km^2) comprises two main islands (Figure 1), which lie between the latitudes of 34^0 and 47^0 S. Both islands have a temperate Mediterranean type climate with mean maximum temperature of 15°C in the South and 20°C in the North, both have rugged mountain landscapes bordered by alluvial plains. In the central and upper North Island various volcanic centres have contributed basaltic, andesitic and rhyolitic soil forming materials. Livestock production is the main agricultural land use and grasslands occupy more than 85% of the total farmed area. It is the more intensively farmed of these grasslands that create 95% of New Zealand's phosphorus (P) fertiliser demand. Topography and elevation determines the type and intensity of livestock grazing system (Table 1) and therefore the rate of P fertiliser application. Intensive dairying is confined to flat to rolling country, where it competes for land with crop production and intensive sheep and beef production systems. The soil orders on flat to rolling land are dominantly Fluvisols, Cambisols, Luvisols and Podzols in the South Island and in the North Island, Fluvisols, Luvisols, Cambisols, Acrisols, Gleysols and Podzols are mixed in the landscape with Andosols and Vitric Andosols.

Table 1. The influence of topography on pasture production and number of livestock carried in New Zealand in 1985 (Bryant and Sheath 1987).

Landscape unit	Area (10^6ha)	Pasture (tDM/ha/y)	Production	Livestock (10^6)		
				Sheep	*Beef*	*Dairy*
High country	4.5	2.0		2.5	0.1	-
Hill country	5.0	7.0		20.3	1.9	0.2
Flat to rolling	4.5	11.0		26.7	2.9	3.4

To predict future phosphorus (P) fertiliser demand for New Zealand it is necessary to examine the economic fortunes of the farming systems that create the demand. Sheep, beef and dairy production systems based on grazing legume/grass pastures dominate land use in New Zealand (Figure 1) and products from these farms provided 48% of New Zealand's export earnings in the 2008/09 (May-June) production season. Currently the value of milk products exceeds the export earnings from meat (beef and lamb) and wool (Figure 2).

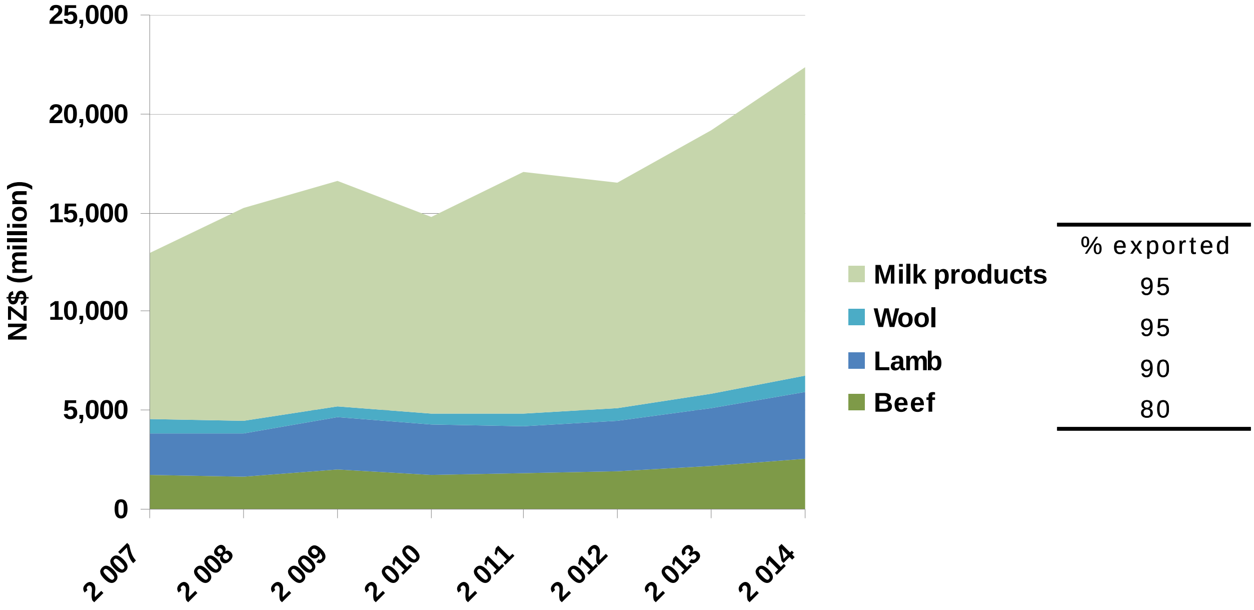
Figure 1. Pastoral land use and Forest cover in New Zealand.
(Source: Ministry for the Environment)



	Area (ha.10^6)
Total land mass	27
Farm/Forestry	15.3
Sheep - Beef	5.84
Dairy	1.87
Forestry	1.71
Deer	0.15
Other pasture	0.38
Tussock	2.98
Grains and fodder	0.37
Horticulture	0.12
Native Bush and scrub	1.32
Other	0.56

Meat production from sheep and beef systems in New Zealand are based on the efficient use of grazed pasture, which with supplements made from pasture (hay and silage), contributes the animal's total feed requirements, with the exception of small areas of winter (e.g. swedes, turnips, kale, oats) or summer forage crops (e.g. swedes, lucerne, chicory) that are grown to meet seasonal pasture growth deficits.

Figure 2. New Zealands export earnings from pastoral farm produce.
(Source NZMAF 2010)



Meat production in sheep systems is based on late winter - spring (late July – September) lambing with most lambs being sold before they are 1yr old. In beef systems calving is at a similar time to capture new seasons grass growth but beef is mostly produced from animals that have stayed on farms for 18 months or longer.

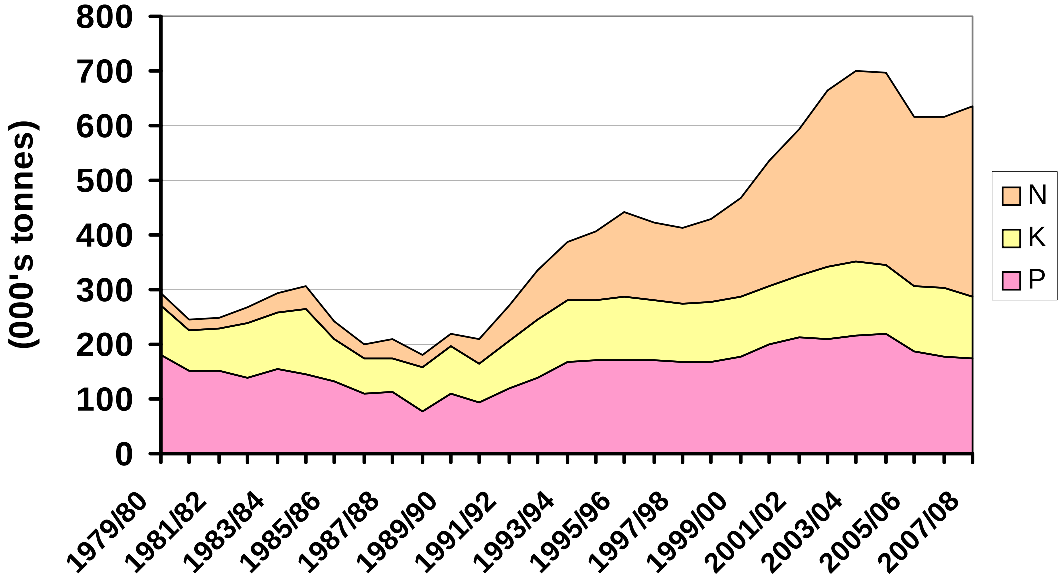
Similarly, dairying systems are largely based on the efficient use of grazed clover-ryegrass based pasture, which contributes about 90% of animal feed requirements. Milk production is based on a seasonal calving cycle in which the majority of cows calve in a limited period in late winter-early spring (Holmes et al., 2002). In 2010, the national dairy herd was estimated to be 4.6 million cows in milk having increased 30% in the last 10 years to occupy 1.5 million hectares (LIC, 2009). Over the same period the intensiveness of dairy farming has increased with milk solids (MS) production per hectare increasing by 20% (Table 2) and total national output of milk solids increasing 44%, partially stimulated by greater feeding of purchased off-farm supplements of maize silage and palm kernel expeller meal brought on to the previously all-grass managed farms.

Table 2. Changes in area occupied by milking herds, herd size, stocking rate (cows/ha), production per cow and per hectare (kg milk solids) in the New Zealand dairy industry, 1999/00 to 2008/09.

	1999/00	**2008/09**
Total area (10^6 ha)	1.29	1.52
Herds	13,861	11,618
Herd size (cows)	236	366
Stocking rate (cows/ha)	2.67	2.83
Milk solids (kg MS)		
per cow	288	323
per ha	768	921
National total (10^6)	981	1,394

Source: LIC (2009)

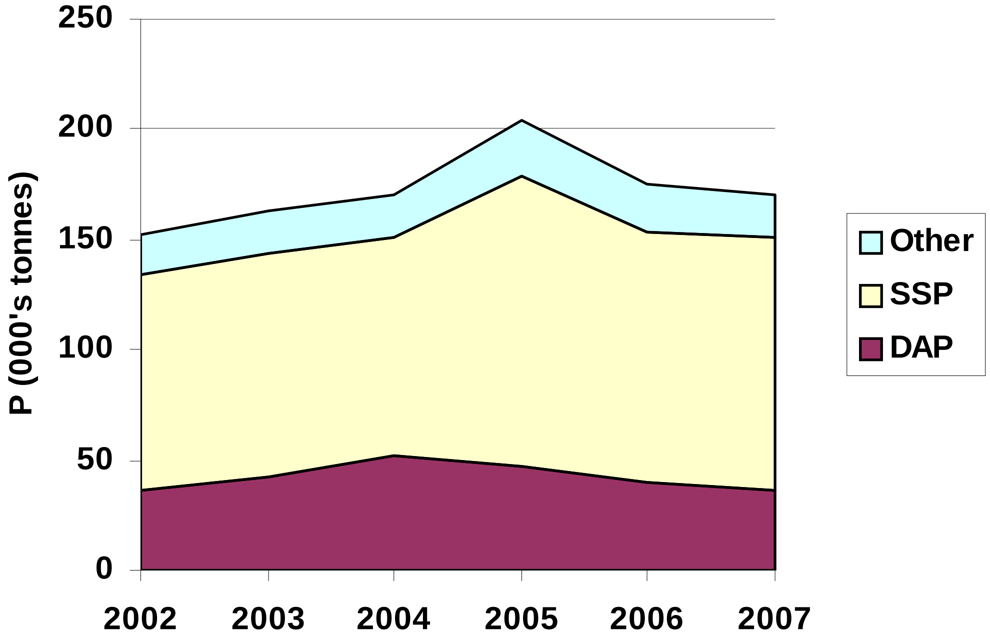
Figure 3. Fertilizer nitrogen (N), phosphorus (P) and potassium (K) use in New Zealand (Source NZFMRA, Hilton Furness pers.comm.)



Recent and current trends in fertiliser use

Prior to 2000 the largest quantity of element applied as fertiliser to clover-ryegrass pastures in New Zealand was phosphorus (P) (Figure 3). Applied mostly in the form of domestically manufactured single superphosphate (Figure 4, SSP, 0-9-0-11) it indirectly met the sulphur (S) limitations caused by accelerated leaching of sulphate from the urine patches of grazing animals.

Figure 4. The amount of P applied in New Zealand as single superphosphate (SSP), diammonium phosphate (DAP) and other phosphate fertiliser.
(Source NZMAF statistics 2010)



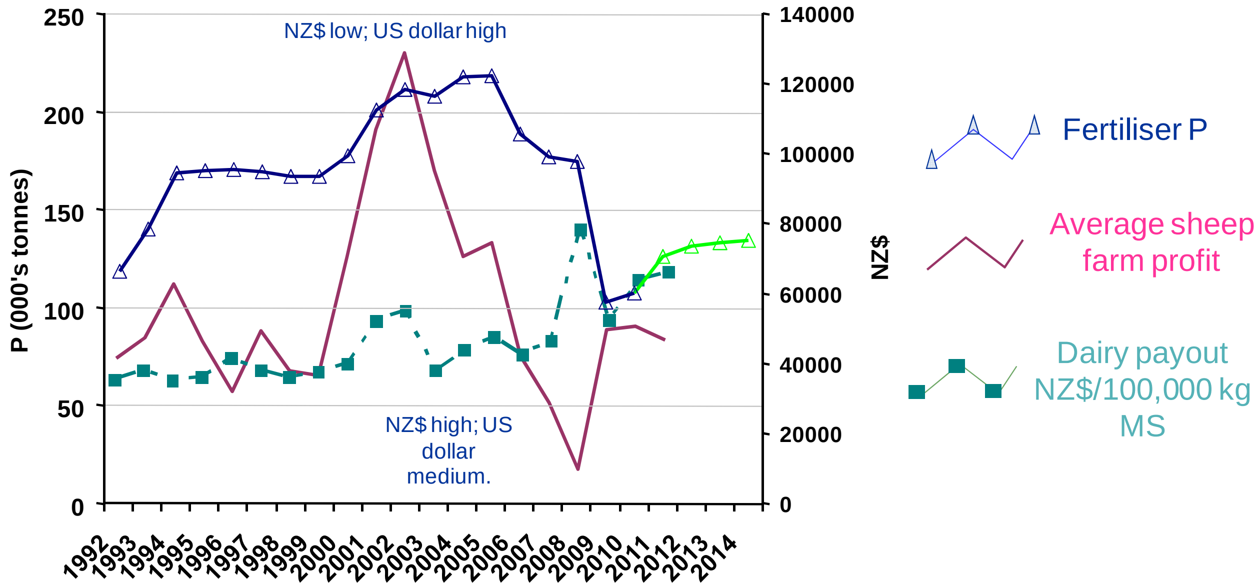
In dairy systems accelerated potassium (K) losses, also from dairy cow urine patches, required the introduction of blends of potash (KCl) with SSP (Potassic supers). Nitrogen fertiliser use in New Zealand prior to the early 1990's was limited to strategic applications of mostly urea and smaller amounts of ammonium sulphate and diammonium phosphate (DAP) applied to clover-ryegrass pastures during periods when grass growth needed boosting. The P and K use by the pastoral industry has remained relatively constant increasing and decreasing with the economic fortunes of the sheep and beef and dairy industries. With increasing financial returns from milk products (Figure 2) dairy farming intensified and from the early 1990's N application to dairy farms has increased. Year round applications of urea are now used to boost pasture production above that which the annual supply of biologically fixed N by clover (typically 70- 170 kg N/ha/y) can support.

The latest agricultural census, (NZMAF Statistics 2010) conducted in 2007, still shows SSP to be the dominant form of P fertiliser used with imported DAP based fertiliser sales making up approximately 25% of the market and other P fertilisers, mostly based on direct application of reactive phosphate rock (RPR), making up less than 10% of the market.

Predicting future trends in total P fertiliser use from farm profitability

A considerable amount of the temporal variation in P fertiliser sales (Figure 5) can be explained by the average sheep and beef farm profit and the dairy payout ($/kg MS) received by farmers.

Figure 5. Quantities of total P applied to pastoral farms, the average sheep farm profit and the milk solids payout to dairy farms (2011-2014 predicted values).



The increasing P sales from 1992 to 2006 were funded from increasing returns from lamb contributing to increasing sheep and beef farm profits, which peaked in 2001, when the low exchange rate delivered a greater return in NZ$ to the farmers, who responded with a greater discretionary expenditure on fertiliser. In times of lower profit, particularly in 2007/08, when many sheep and beef farms made losses, discretionary purchases such as fertiliser were reduced, particularly in the face of large increases in fertiliser costs in 2008/09. During this same period, 1992 – 2008, dairy farmers continued to receive increasing but fluctuating payouts for milk solids and continued to purchase annual maintenance fertiliser.

Between 80% and 95% of all agricultural produce is exported (Figure 2) from New Zealand to a wide range of markets e.g. America, Asia, Australia, China, Europe and Russia. Despite the global economic crisis of 2008/2009 the wholesale prices of meat and milk products continued to rise, which offset increases in value of the NZ$ against the US$. In particular, the dairy product prices continued to rise from 2009, as importers sensing recovery from the recession, rebuilt inventories of depleted stock. The increase in wholesale milk product prices is predicted to continue at least until 2014, which will drive further expansion of dairying in New Zealand (NZMAF, 2010).

The largest lamb markets, UK and Europe, are expected to have a slow recovery from the global recession but slight increases in lamb wholesale prices are expected because domestic lamb production in these markets and the other major exporter, Australia, continues to decline. Continued profit from lamb production is predicted to cause New Zealand sheep numbers to remain relatively stable with small increases (NZMAF, 2010). Beef exports are also expected to remain relatively stable to 2014 as the recession has created less demand for prime beef.

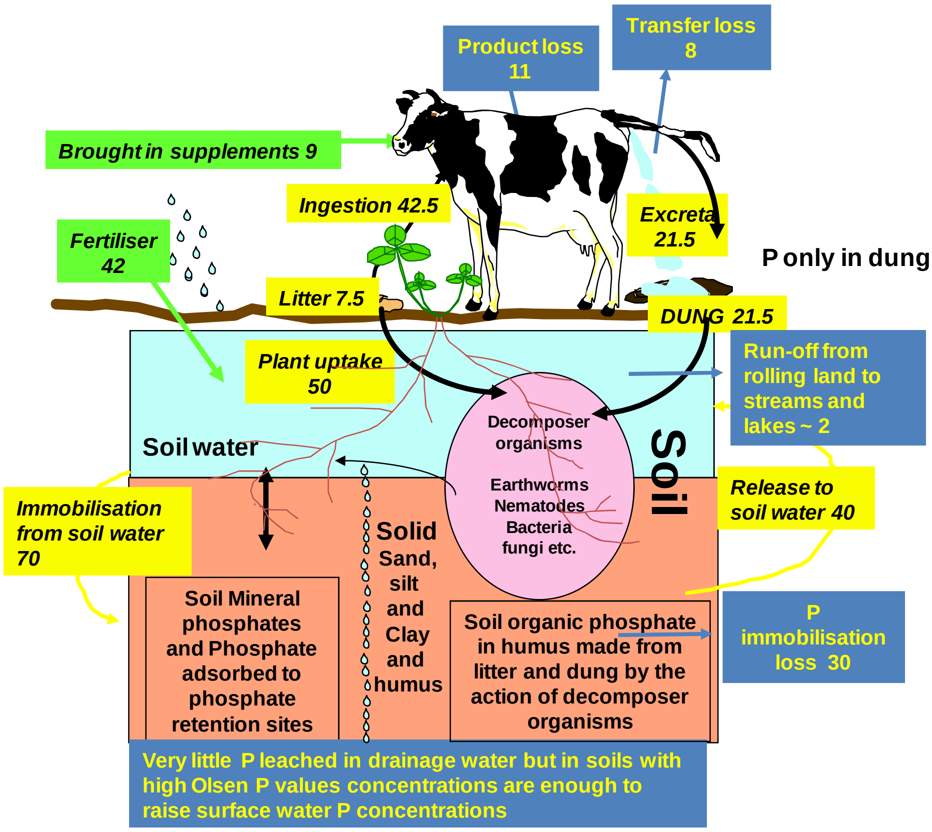
Stable production from sheep and beef farms till 2014, accompanied by increased dairy production is predicted to continue to create a slow recovery in fertiliser P sales, which began in the 2009/10 season. This expectation is predicated on the fact that increases in farm income will stay apace with increases in farm costs, including fertiliser. Increase costs are expected from the introduction of a greenhouse gas (GHG) emissions trading scheme (NZETS) for agriculture from 2015 onwards. The NZETS is the tool that the New Zealand

Government, a signatory to the Kyoto protocol, has introduced to encourage agriculture to decrease its GHG (carbon) footprint. In its proposed form, the NZETS is managed at the milk and meat processor level as a tax per kg meat or milk solids produced by the farmer. From July 2010 -2012, farms are expected to pay 50% of the carbon cost of processing and the full carbon cost of any fossil fuel they use. For the average sheep and beef farm (used in our earlier calculations) this will amount to approximately NZ$ 1,500 per farm (@NZ$ 25/tonne CO_2eq). The ETS tax will increase such that the full processing carbon cost is covered by 2015 raising the tax to approximately NZ$3,000 per farm. On the average dairy farm the respective costs for the 2010-2012 period are NZ$ 4,000 rising to NZ$8,000 in 2015. By 2030 the additional taxes to cover the on farm rumen methane and nitrous oxide emissions are planned to be introduced. This more comprehensive ETS plan could bring large costs, increasing the farm ETS tax payments approximately 10 fold, unless research can provide GHG mitigation options for farmers. Its proposed introduction is extremely unpopular with farmers because it would significantly reduce the profitability of sheep and beef farms by an amount roughly equal to their annual fertiliser expenditure. The government, however, is optimistic that it's focussed investments in rumen methane and soil nitrous oxide emissions research will deliver practical, on-farm mitigation options to reduce rumen methane and nitrous oxide emissions to coincide with its introduction. Exports of low carbon footprint food and fibre may command premium prices in the market place, which may partially offset the cost of implementing GHG mitigation practices on-farm. In an ideal world globally responsible consumers would bear the full carbon cost of the food they eat allowing farmers to implement costly mitigation practices.

Predicting future trends in total P fertiliser use from farm nutrient budgets

The nutrient and fertiliser requirements of farms in New Zealand are assessed and implemented by field officers (of the farmer co-operative fertiliser companies) and farm consultants trained in the use of Overseer™ Nutrient Budgets II software (AgResearch, 2010). In 2006/07 all dairy farms were required to have a nutrient budget as part of their supply agreement with their co-operative milk processor. This was part of an initiative called the "Clean Streams Accord", in which the dairy farming co-operatives agreed with regional council river authorities and freshwater quality lobbyists that nutrient budgeting would be the way forward to assess and manage dairy farm's nutrient inputs. Implementation of nutrient budgeting was designed to increase nutrient use efficiency on farm, and highlight, and then mitigate situations of farm nutrient surpluses that potentially were contributing to N and P enriched drainage waters. Overseer Nutrient budgets requires farm information on soil properties (including soil type, soil test status, % P retention, drainage characteristics and topography), climate, all nutrient inputs (purchased fertilisers, manures and supplementary feed), farm management that leads to major nutrient transfers on farm (e.g. stock type, age, sex and weight, stock grazing management, silage and hay making and dairy effluent re-application) and finally all out puts (e.g. sales of milk, stock and excess silage or hay). The immediate impact of this nationwide nutrient budgeting exercise in 2006/07 was an estimated 10% reduction in P fertiliser sales (Hilton Furness, pers. comm., Figure 5). This experience, and the current focus of New Zealand's agricultural export industries on sustainable farm management practices, indicates that nutrient budgeting methods for more accurately assessing fertiliser requirements will have an impact future on fertiliser use, independent of the relationship between farm profitability and fertiliser costs.

Figure 6. Dairy farm annual phosphorus cycle (kg P/ha/y) as modelled by Overseer Nutrient Budgets II.

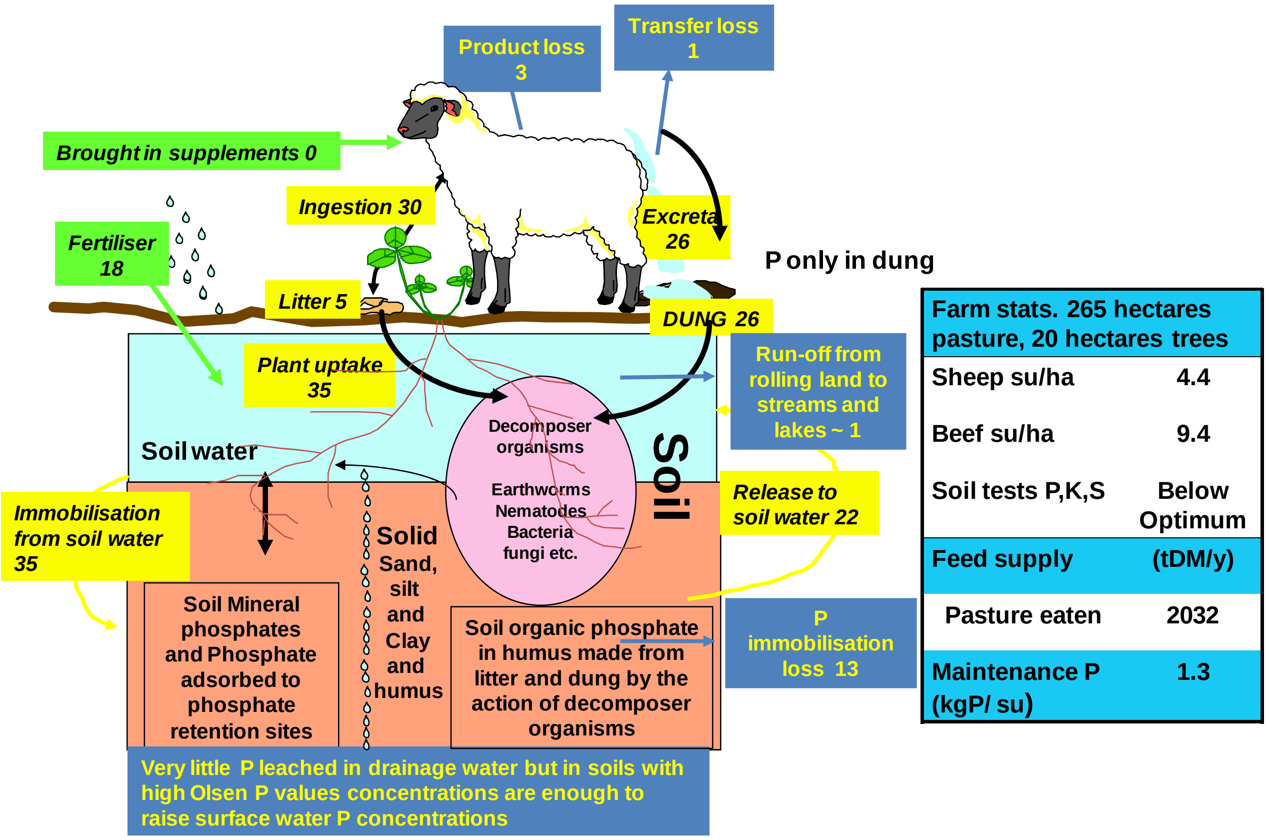


Farm stats. 153 hectares pasture	
Cows/ha	2.7
Milksolids/ha/y	1000
Soil tests P,K,S	Optimum plus
Feed supply	**(tDM/y)**
Pasture eaten	1571
Grass silage	80
Maize silage	84
Palm kernel	165
Maintenance P (kgP/kg MS)	0.05

We have used Overseer Nutrient Budgets II to calculate the nutrient requirement of a typical dairy farm (Figure 6). The amounts of fertiliser P required to replace losses from the dairy farm in product, soil P fixation (soil P loss) and uneven transfer of P in dung to unproductive areas such as race ways etc., termed “maintenance P”, was 0.05 kg P/kg milk solids. This is in agreement with Roberts and Morton (1999), who conducted case studies on dairy farms on soils with varying P loss status and concluded that on average maintenance P on high P loss soils (e.g. Allophanic, Pumice soils developed from volcanic parent materials, representing 47% of the national herd, LIC 2010) and low P retaining soils (soils developed from sedimentary parent materials representing 53% of the national herd) were 0.051 and 0.046 (kg P/kg MS), respectively.

In a similar exercise (Figure 8) for an average sheep and beef farm (data from Beef and Lamb, 2010) on rolling to hilly topography with soils developed from sedimentary parent materials with a history of low to medium soil P status (Olsen P soil test values 12 mg P/L soil), the maintenance P requirement was 1.3 kg P/su (su is a *standard stock unit* of 1 ewe raising one lamb consuming approximately 550 kg DM per year). This also agrees with two other sources that have surveyed the maintenance P requirements for sheep and beef systems. Morton and Roberts (1999) reported farms using between 1.35 and 1.8 kg P/su and Gillingham et al (1998) concluded a maintenance rate of 1.38 kg P/su was necessary to maintain soil P status for sustainable sheep and beef farming on medium to low fertility hill soils.

Figure 7. Sheep and beef farm annual phosphorus cycle (kg P/ha/y) as modelled by Overseer Nutrient Budgets II.



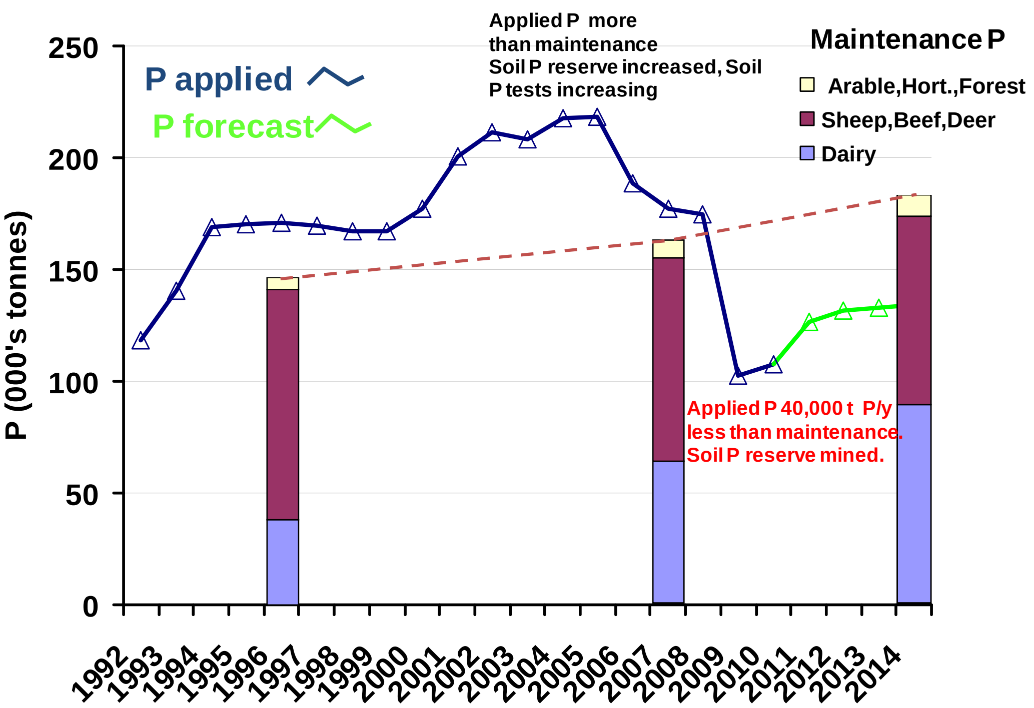
We have applied these maintenance P fertiliser recommendations (Table 3) to the national inventories (NZMAF Statistics, 2010) of dairy cattle, sheep and beef, deer and estimated the amounts of fertiliser used by arable and horticultural crops using methods described by Williams (1998) and for forestry by Payn (1998). In 2007, the national maintenance P application was estimated to be 163 x 10^3 t P/y, calculated as the sum of 64.72 million su of sheep, beef and deer requiring 1.4 kg P/su (91 x 10^3 tP/y), 619 x 10^6 kg MS produced on volcanic soils requiring 0.051 kg P/kg MS (32 x 10^3 t P/y), 697 x 10^6 kg MS produced on sedimentary soils requiring 0.046 kg P/kg MS (32 x 10^3 t P/y), 369,000 ha of arable requiring 9 kg P/ha (3.3 x 10^3 t P/y), 66,000 ha of vegetable production requiring 68 kg P/ha (4.5 x 10^3 t P/y) and a forestry annual maintenance application of 0.6 x 10^3 t P/y. This calculation was repeated for 1996, 2007 and from projections of farming activities in 2014 (NZMAF, 2010). When plotted against the temporal variation in P sales (Figure 8) it is clear to see that in the period 1994 to 2008 fertiliser P sales exceed the estimate of the amount of P required for maintenance. During this period soil testing laboratories reported increases in farm soil P test values, another indication of above maintenance P application.

Table 3. An estimate of the New Zealand national fertiliser P maintenance requirement for pastoral and arable farms and forestry.

Sheep, beef, deer etc (mil. su)	Dairy milk solids production (mil. kg MS)		Arable	Veg	Forestry	Total
	Volcanic Soils	Sedimentary soils	ha		Annual	
64.72	619	697	369000	66000	maintenance	
@ 1.4 kg P/su	@ 0.051 kg P/kg MS	@ 0.046 kg P/kg MS	@ 9kgP/ha	@ 68kgP/ha		
P (000's tonnes)						
91	32	32	3.3	4.5	0.6	163

The recent decrease in sheep and beef farm profitability and the rapid rise in fertiliser costs in 2008/2009 has caused sales to drop below maintenance rates. We conclude that if farms are to operate sustainably in the future using maintenance P fertiliser application then P fertiliser sales should increase to a level higher than that predicted (Figure 5) from the financial outlook for dairy and sheep and beef farms (NZFMRA Hilton Furness pers.comm).

Figure 8. . Quantities of total P applied to pastoral farms (line) and the national maintenance P requirement (columns) calculated from livestock inventories using recommended P replacement rates given in Table 3. (2011-2014 predicted values).



What role can re-cycling of organic P wastes play in reducing fertiliser P inputs.

In countries with large urbanised populations significant amounts of P in feedstuffs both for the human population and housed animal production systems (particularly poultry and pig production) are recovered in manures and sewage that can be applied to land partially or fully meeting crop or pasture P requirements (Hedley and Sharpley, 1997). New Zealand operates a different model, the low human population (4.4 x 10^6 people) supports a limited poultry and pig industry (Table 4), from which it is estimated that the annual output of P in manure is 2.1 and 2.3 x 10^3 t P/y, respectively. Even when combined with a sewage output of 3.2 x 10^3 t P/y from an urban population of 3.1 million, the total of 7.6 x 10^3 t P/y is less than 5% of the national P requirement of 163 x 10^3 t P/y and only a small part of the current 40 x 10^3 t P/y difference between the maintenance P requirement and total P sales (Figure 8).

Table 4. Estimates of the amount of P contained in poultry, pig and raw urban sewage in New Zealand.

	No. (10^6)	Total P (10^3 t/y)
Poultry		
Broilers Meat	81	1.7.
Layers	3.4	0.4
Subtotal		2.1
Pigs		
Breeding	0.047	0.9
Market	0.319	1.4
Subtotal		2.3
Raw sewage		
Urban population	3.1	3.2
Total		**7.6**

The largest single input of P in feedstuffs imported into New Zealand is that which enters as palm kernel expeller meal (PKE), which is fed as a supplement to dairy cows. In 2008/09 imports of PKE totalled 662 x 10^3 t, supplying a total of 4.3 x 10^3 t P/y. A typical 153 ha dairy farm milking 413 cows may feed 165 t/y of PKE as a supplement at no more than 1 - 4 kg DM/day to cows grazing pasture. This would add 7 kg P/ha/y in cow dung distributed around the farm during grazing. Dairy farm nutrient budgets already account for this P input from PKE and there would be a recommendation to decrease P inputs from fertiliser accordingly.

With the introduction of nutrient budgeting considerable effort has been made by fertiliser company field officers and dairy farm consultants to utilise the nutrients that can be recycled on a dairy farm from effluent collected while the cows are being milked, or fed maize silage or PKE on feed pads. During lactation (approx. 260-280 days) cows are brought from pastures to the dairy shed for milking twice a day. Depending on the time spent in the dairy shed and collecting yards 5 to 15% of dairy cow excreta is deposited within the farm dairy and collecting yards (Cameron and Trenouth, 1999). The farm dairy effluent (FDE, approx. 50L/cow) contains 8% excreta, 4% teat washing and 86% wash down water (Longhurst *et al*., 2000).

The physical, chemical and biological characteristics of FDE are highly variable across farms and within farms across seasons. Longhurst *et al*. (2000) found mean nitrogen (N), phosphorus (P) and potassium (K) concentrations for raw FDE, from a number of different research trials, to be 269 mg N litre^{-1} (range 181 – 506, n=37) and 69 mg P litre^{-1} (range 21-82, n = 73) and 370 mg K litre^{-1} (range 164 -705, n = 73). If it is assumed that: a) dairy cows spend approximately 2 hours per day over the milking season (280 days), in the farm-dairy or yards , which are washed down with 50 litres/day/cow and b) the raw effluent has the average nutrient concentrations described above, then this indicates that the national dairy herd produces annually approximately 52 million cubic metres of raw FDE that is normally reapplied by spray irrigators to pastures, containing 14,100 tonnes of N, 3,600 tonnes of P and 19,400 tonnes of K. Land treatment allows FDE to be considered a fertiliser resource that supplies N, P, and K as well as trace elements Ca, Mg and Na to the land in a liquid form. (Hart and Speir, 1992; Heatley, 1996; Longhurst *et al*., 2000). Effluent can represent a 10 – 12 % saving of a farm's annual fertiliser requirements, however, because FDE is not a balanced fertiliser, additional applications of P are usually required (Ledgard *et al*., 1996; Longhurst *et al.,* 2000).

Conclusions

Ninety five percent of P applied in New Zealand is used to maintain productivity of the legume-based pastures of dairy, sheep and beef and deer farms. Past variations in the amounts of P applied can be explained by the volatile profitability of the sheep and beef industry. Current and future expansion of dairying will take a larger share of the P applied. The opportunities for further replacing imported P fertiliser with organic P recycled from farm effluents and urban wastes are limited because low amounts of P are contained in such wastes, which with the exception of sewage are already applied to land, some being accounted for in farm nutrient budgets.

The financial outlook for sheep and beef farms is relatively stable whereas dairying is predicted to expand with the market place continuing to support increasing prices for milk products. Given that the current amount of P applied nationally is calculated to be below "maintenance" levels required to maintain soil P status on pastoral farms, then both future fertiliser recommendations, and the finances of the overall pastoral industry (led by dairying), should support a slow recovery in the amounts of P applied to maintenance levels of approximately 174 x 10^3 t P/y.

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