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Trends in Olsen P Test Over Time for the Waikato Region

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Executive Summary

Olsen P data extracted from database of soil fertility data obtained from commercial soil testing lab for the period 1988-2001. Samples were categorised accounting to land use or soil group (sedimentary, volcanic, pumice, peat). The change in Olsen P levels over time was examined.

- Olsen P on dairy farms increase over time from an average of 23 in 1988 to an average of 35 in 2001. The rate of increase in Olsen P was higher for pumice soils than other soils.

- There were no significant long term trends in average Olsen P levels for samples from sheep/beef or crop samples.

- On diary farms for the period 1997-2001:
  - With the exception of peat soils, 9-27% of samples had Olsen P below the lower limit of the range for near maximum production, and 51-84% of samples with Olsen P above than the upper limit of the range.

  - Peat soils had a higher percentage of samples with Olsen P below the lower limit of the range for near maximum production than other soils (45%) and lower percentage with Olsen P below the lower limit of the range for near maximum production (34%).

  - Between the periods 1988-1996 and 1997-2001, the percentage of samples below the lower limit of the range decreased by about 20%, the percentage of samples above the upper limit of the range increased by about 20%, and there was little change in the percentage of samples within the range, except in pumice soils.

- In pumice soils on both dairy and sheep farms, there was a larger decrease in the samples below the lower limit of the range for near maximum production for the period 1988-1996 to 1997-2001. This coincided with the period that recommended target Olsen P levels for pumice soils increased from 20-25 to 35-45

- The data indicates that there is scope to decrease Olsen P on some dairy farms without reducing pasture production, and to increase productivity on some sheep/beef farms by increasing Olsen P levels.

- It is not possible to determine the impact of nutrient budgeting on soil test results. However, data is this report could be part of a benchmark to examine any changes in soil fertility since the introduction of nutrient budgeting.

1 Background

Nutrient losses from farmland are a contributor to excessive nutrient in surface water. Better farm management can be used to reduce the amount of nutrient used on the farm and thus lost into water bodies. Soil tests combined with a nutrient budget are one way of ensuring that soil fertility isn't excessive and this helps to reduce the amount of nutrient lost from the farm.

Farmers and their soil fertility consultants commonly measure soil fertility status on pastoral farms as a decision aid when planning fertiliser programs to meet their farm business objectives. These soil analyses are usually undertaken at commercial soil testing laboratories, and the results from these analyses can potentially provide a useful database to assess soil fertility at a national and regional scale.

Maintenance of soil fertility is an essential component of sustainable land use, and examining soil fertility trends through time can show whether the land management is increasing, maintaining or depleting soil nutrients. The agricultural industry is also proposing to use soil testing and nutrient budgets to prevent excess soil fertility. One way of measuring their success in avoiding excess fertility is to track changes in soil fertility over time.

Soil fertility test results for some 246 000 commercial samples from dry stock (sheep/beef) and dairy farms in both North and South Islands covering the period 1988 to 2001 have been analysed (Wheeler et al. 2003). The data set includes QuickTest (QT) values for exchangeable Ca, Mg, K, Olsen P and soil pH.

Olsen P measurements lend themselves to monitoring change over time. This report gives trends in Olsen P levels over time for different land use and soil types for the Waikato region.

2 Methods

2.1 Database

Soil fertility test data from samples submitted commercial to an analytical laboratory were extracted from three separate datasets that covered the time periods 1988-1991, 1992-1999 and 1999-2001 and combined into a single database. The datasets represented differences in computer systems and methods of classifying data.

The 1988 data came from the South Island only, and there were only 3 months of data in 1991. The numbers of samples per year suggest that about half the 1999 samples where present in this database.

Wherever possible, each record was classified according to year, land use, and soil group. In the original records, a range of soil and land use categories were used, and the information used to classify region varied.

For this study, soil group information were reclassified into five soil types (sedimentary, volcanic, pumice, peats, others), land use information into two land use types (dairy, sheep/beef including deer) and farm property information (location codes, addresses, phone numbers) into regions (see Table 1). The Waikato region was centre around the Pukekohe, Hamilton, Te Awamutu, Morrinsville, Matamata and Thames. It didn't include the Taupo district (in BOP/Central Plateau region) or Otorohanga region, which was mainly in the Te Kuiti district and hence in the King Country/Taihape region.

Additional details on soil group and region classifications are given in the following section.

Within the Waikato region there were 44,466 samples, of which 75% were from dairy farms, 20% from sheep farms and 5% could not be classified. The proportion of samples for each soil group was similar between dairy and sheep/beef farms, being 63%, 20%, 6 and 11% for volcanic, sedimentary, pumice and peat soils respectively for dairy, and 66%, 20%, 8% and 6% respectively for sheep/beef farms.

For samples identified as pastoral samples, soil sampling depths that were not the standard pastoral sampling depth of 0-75 mm were omitted from the database. All other pastoral samples were assumed to be 0-75 mm samples.

In addition, records that were designated as from non-pastoral land was extracted. Data was only available from 1992 onwards. Non-pastoral samples were omitted from the supplied 1988-1991 data set. Most of the non-pastoral samples were a mix of cropping and horticultural samples although the split could not be determined.

The soil test data extracted were the volumetric modification of the bicarbonate-extractable phosphate (Olsen P) test (Olsen et al. 1954).

2.2 Classification of Records

Soil group

The soil types for the 1988-2001 dataset were coded as in Cornforth (1980), and were classified as:

Sedimentary	N01 – N07, N18, S01-S11, S21, S22
Volcanic	N08-N12, N17, N20, S12-S16
Pumice	N19
Peats	N13, S17

The soil groups for the 1992-1999 dataset were coded as follows:

Sedimentary	YB loamy sands, YB sands, BGE, YBE, YGE & intergrades
Volcanic	YBL (HB), YBL (Waikato, BOP, Taranaki), BG L/C, R&B L
Pumice	YB Pumice
Peats	peats, peaty loam

The soil group codes were already coded as sedimentary, volcanic, pumice and peat soils respectively in the 1999-2001 dataset.

Region

For the 1988-2001 dataset, the regional code was derived from the consultant code by assigning the consultant's residential region to the records under his/her code.

For the 1992-1999 dataset, regions were coded by extracting a location from one of the 4 farm owner address fields, assigning this location to a district, and then a region. A cross check was made with phone numbers where available. Some address fields were consultant addresses.

For the 1999-2001 dataset region was entered by the laboratory based on the address results were sent to. There was only a subset of regions available, and these were assigned to the region as shown in Table 1.

2.3 Bias

Care is needed when interpreting results from datasets such as this, particularly when the effects of any likely bias are largely unknown. In particular, no information was available to determine whether the samples submitted to the laboratory represented the entire range of soil fertility status found in New Zealand or within the various soil groups. We also had no information on whether there was a bias towards low or high fertility sites being sampled. However, the data did conform to what is known about soil fertility trends in general and thus this bias may be minimal.

Table 1: Regional categories ascribed to the SFS records over time

Region	Region	Region (1999-2001)
1	Northland	Northland
2	Waikato	Central
3	BOP/Taupo	
4	Taranaki	Taranaki
5	King Country/Taihape	
6	Manawatu/Wellington	Lower North
7	East Coast/Hawkes Bay/Wairarapa	Hawkes Bay
8	Marlborough/Nelson	Upper South
9	Canterbury	Central South
10	Otago	
11	Southland	Lower South
12	West Coast	West land

Some other possible biases have been identified. Some miscoding could be identified, for example soil groups occurring in regions where those soils do not occur, errors in entering farm identity codes, and place names that do not exist. Such known cases occurred in about 0.1% of cases and thus incorrect coding probably had little impact on the final result.

There was inadequate information on the number of multiple submissions, either as number of blocks or number of samples from the same farm over time, to asses how many farms were monitoring soil test results. However, the data that were present indicates that there were few farms with more than two blocks per sampling, or more than two sampling times over an eight-year period, and hence multiple submissions probably only had a small effect on the overall trends.

2.4 Analysis

After a preliminary perusal of the soil fertility data, values considered to be atypical of 'normal' pastoral farms were recoded as missing. Some of these may have been from paddocks where farm dairy effluent or dairy factory effluent has had been continually applied. Thus all values greater than 100 for Olsen P (2276 values) and QT Mg (1192 values) and greater than 50 for QT K (152 values) and Ca (13 values) were recoded. The effect of removing these values was to reduce the mean for Olsen P from 26.9 to 25.6 and QT Mg from 23.9 to 23.3, and to reduce standard deviations for Olsen P from 22.8 to 16.8, and for QT Mg from 16.0 to 13.8. On soils that could be classified for farm type and soil group, Olsen P only decreased by 0.7 units.

A multiple Bayesian spline, based on the Bayesian spline reported by Upsdell (1994), was fitted to the model (soil * land use * year + unit) against mean log Olsen P values. The mean value for each combination of year, land use, soil group and region was used. The unit term was used to separate out the error associated with estimation of the mean from the general error term. The unit variance was estimated as the standard error of the mean, with degrees of freedom approximately equal to the number of observations making up each mean. Thus the spline tended to pass closer to data points with low standard errors of means and high number of observations, provided other data points around a given data point also indicated that a similar trend could occur. The first derivative (slope) for each factor, and its 95% confidence interval were also determined. This analysis was used to test for significant differences in the relationships between Olsen P and time.

The percentage of samples within the range for near maximum pasture production (range), or below or above the lower or upper values of the range respectively, was based on cumulative distribution curves. The range required for near maximum pasture production are based on an analysis of a large number (>1500) of P field trials carried out in New Zealand, and the ranges are reported by Morton & Roberts (1999) and Roberts & Morton (1999) for sedimentary, volcanic and pumice soils and O'Connor & Legg (2001) for peat soils. The ranges are higher for peat and pumice soils due to a bulk density effect.

Economically optimum Olsen P values for sheep/beef farms were estimated using the OVERSEER® econometric fertiliser model (Metherell 1994) using typical farm production and farm economic data from each year (unpublished data). The economic returns from sheep/beef farming from 1994 to 2001 were such that the economically optimum Olsen P ranged around 15-20. The percentage of samples below 15 (sedimentary, volcanic) or 20 (pumice, peat soils) were also determined.

Recent advice has higher Olsen P target ranges for high producing (top 25% producing farms within a region) dairy farms (Morton et al. 2003). The percentage of samples with Olsen P greater than the upper range for high producing farms was also determined.

3 Results

The relationship between average Olsen P in the Waikato region and time for each land use is shown in Fig. 1 for sedimentary and volcanic soils, and in Fig. 2 for peat soils.

The area covered by Environmental Waikato also includes the Taupo region, which is dominated by pumice soils. Most of the pumice soils within the database came from the BOP/Taupo or the Waikato region (63 and 25% of all samples from pumice soils respectively). There were no significant differences in the relationship between pumice soils from the Waikato and BOP/Taupo regions. Therefore the trends for all pumice soils are shown in Fig. 2 as being represented of pumice soils in the Environment Waikato area.

Relationship for crop soils from the Waikato region is shown in Fig 3. Is should be noted that it is a mixture of crop and horticulture soils.

3.1 Olsen P Over Time

Within the Waikato region, Olsen P levels in dairy farms increase over time (Fig. 1) from an average of 23 to an average of 35. There were no significant differences between sedimentary, volcanic or peat soils in the trend. From 1992, the rate of increase in Olsen P was higher for pumice soils than other soils, leading to higher average values for pumice soils from 1992 onwards. There were insufficient samples from sheep/beef farms in 1991 and 1992 (volcanic soils) or 1992 (sedimentary soils) to provide an estimated mean Olsen P. For the period 1997-2001, Olsen P on pumice average 51 compared to 40 on other soils. In all soil groups except volcanic soils, Olsen P was lowest in 1991 and there was a higher yearly rate of increase from 1991 to 1992.

There were to long term trends in Olsen P on sheep/beef farms, although Olsen P was higher from 1992 to 1999 than either side of this period.

Similarly there were no consistent long term trends for Olsen P on crop soils. The range in values was similar to that found on dairy farms for the period 1996-2001.

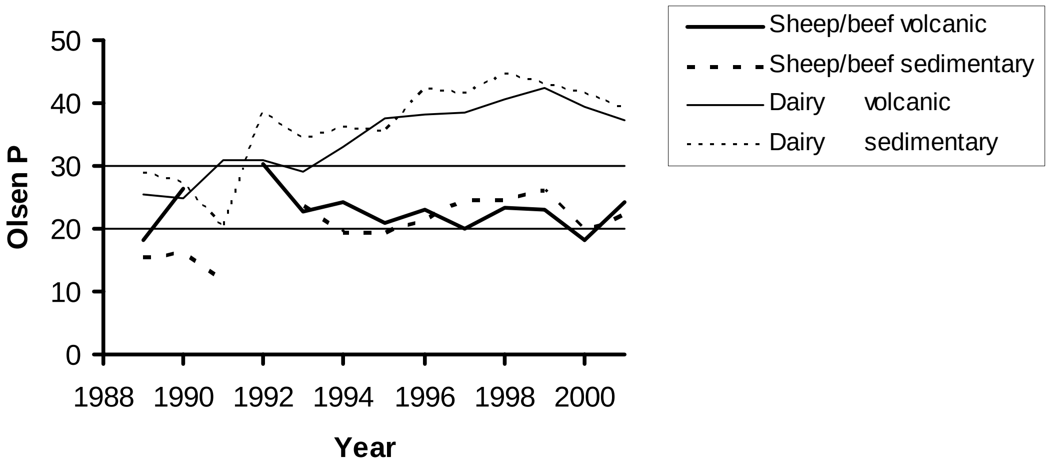

Figure 1. Average Olsen P over time for sheep/beef and dairy farms on volcanic or sedimentary soils for the Waikato region. The upper and lower values of the range for near maximum pasture production for volcanic soils (20-30) are also shown as horizontal lines.

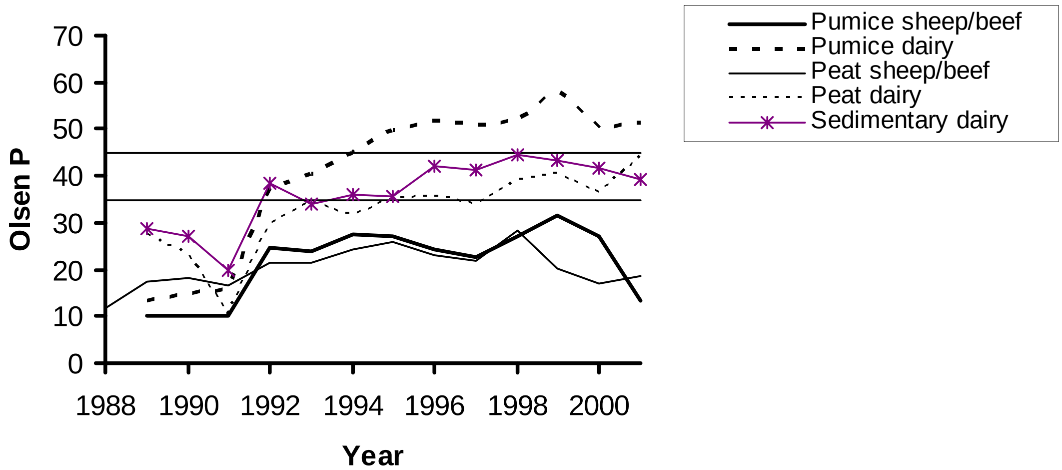

Figure 2. Average Olsen P over time for sheep/beef and dairy farms on peat soils for the Waikato region. The relationship for pumice soils is for all pumice soils found in the database. The relationship for sedimentary dairy is repeated in this figure for a comparison with Fig 1. The upper and lower values of the range for near maximum pasture production for pumice and peat soils (35-45) are also shown as horizontal lines.

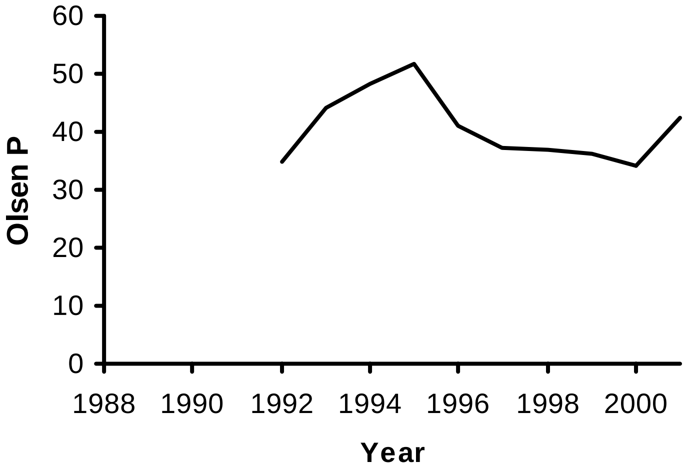

Figure 3. Average Olsen P over time from crop land use (crop + horticultural samples) in the Waikato region.

3.2 Distribution of Samples

The percentage of samples within the range for near maximum pasture production (range), or below or above the lower or upper values of the range respectively, is shown in Table 2. The range required for near maximum pasture production are based on an analysis of a large number (>1500) of P field trials carried out in New Zealand, and the ranges are reported by Morton & Roberts (1999) and Roberts & Morton 1999. Data was split into 2 periods, 1997 -2001 when Olsen P test values were more stable, and pre 1997 when Olsen P test values were increasing. On dairy farms 31-78%, depending on soil group, of dairy farms had Olsen P below the lower limit of the range for the period 1988-1997, and 9-45% for the period 1997-2001. Pumice and peat soils had a higher proportion of samples with Olsen P values below the lower limit of the range.

As the mean Olsen P test increased (Figs. 1 & 2), the proportion of samples higher than the upper limit of the range increased from 15%-60% to 34%-84%, depending on soil group, The proportion of samples higher than the upper limit of the range for near maximum pasture production on high producing dairy farms also increased from 6%-23% to 19%-50% of samples. In the period 1997-2001, 4-15% of samples had Olsen P below 15 or 20. Some of these samples could be from runoff or new blocks, where Olsen P levels may be low prior to a capital dressing program. The decrease in the percent of samples below the lower limit of the range from 1988-1996 to 1997-2001 period was about 20% except on pumice soils, where the decrease was 50%.

In contrast, on sheep/beef farms < 30% of samples had Olsen P values that were above the upper limit of the range. The percentage of samples within the range remained about the same between the two periods. In the period 1997-2001, 33-50% of samples had Olsen P values below the estimated economic Olsen P values for average sheep/beef farms. This indicates that there is scope to increase economic returns on these farms by increasing Olsen P levels.

Peat soils generally had a higher percentage of samples below the lower limit of the range and the economic range than other soil groups.

4 Discussion

The economic returns from dairying are such that all dairy farmers should be applying the appropriate rates of fertiliser nutrients to reach and maintain soil fertility levels within the target ranges. Despite this, there was a steady rise in Olsen P over time (Fig. 1 & 2) particularly in the dairy section (Fig. 1). During this time, a large analysis of fertiliser trails was completed and new target values for near maximum pasture production were set (Roberts & Edmeades 1993). In particular, the target Olsen P values for pumice soils were re-defined in 1993 to be between 35-45 (Roberts & Edmeades 1993), rather than the previous 25-30 range. The confirmation of the higher target range appears to have resulted in a large decrease in the percentage of samples below the lower limit of the range for pumice soils from 1988-1997 to 1997-2001 (50% reduction in pumice soils compared to a 20% reduction in other soil groups) (Table 2). The target range for peat has also recently been confirmed to be the same as for pumice soils (O'Connor & Legg 2001). A similar reduction in the percentage of samples below the lower limit of the range for peat soils is expected in the future (post 2001) with these new target ranges.

The high percentage of dairy farms with Olsen P above the upper limit of the range for near maximum production, particularly on sedimentary and volcanic soils, may be a reflection of the advice prevailing at that time which was to aim for higher Olsen P values. The advice, based on a single trial from Taranaki, has since been superseded. Recent advice has higher Olsen P target ranges for high producing (top 25% producing farms within a region) dairy farms (Morton et al. 2003). This would indicate the scope for some dairy farms to reduce fertiliser P inputs without reducing pasture production, even allowing for the recently released higher Olsen P target ranges for high producing dairy farms.

Table 2. Percentage of samples that had Olsen P less than lower limit (< lower) of the range in Olsen P for near maximum pasture production (range), within the range and greater than the upper limit (> upper) of the range for the period 1988-1997 when Olsen P levels were generally increasing over time, and 1997-2001 when Olsen P levels were higher but more stable over time. Also shown are the percentage of samples less than the estimated lower range (15) for the economic maximum for sheep/beef farms (< econ), and greater than the upper limit for the range in Olsen P for near maximum pasture production on high producing farms (> high).

Land use	Soil group	range[1]	1988-1996					1997-2001				
			< econ	< lower	within	> upper	> high[2]	< econ	< lower	within	> upper	> high[2]
Dairy	sedimentary	20-25	11	31	9	60	23	4	9	7	84	50
	volcanic	20-30	16	32	30	38	18	5	11	22	67	44
	pumice	35-45	57	78	7	15	9	7	27	22	51	34
	peats	35-45	31	71	13	16	6	15	45	21	34	19
Sheep/beef	sedimentary	20-25	58	72	12	16	4	33	55	16	29	11
	volcanic	20-30	48	65	20	15	2	39	56	24	20	9
	pumice	35-45	64	85	8	7	3	36	73	13	14	8
	peats	35-45	59	72	14	14	4	50	76	13	11	6

1 as reported by Morton & Roberts (1999) and Roberts & Morton (1999) for sedimentary and volcanic soils, Roberts & Edmeades (1993) for pumice soils and O'Connor & Legg (2001) for peat soils.

2 > 40 in sedimentary and volcanic soils and > 55 in pumice and peat soils

Olsen P soil tests above the upper limit of indicate scope for some farmers to reduce fertiliser inputs without reducing pasture growth. Research has shown that dissolved reactive P (DRP) concentrations in runoff increase rapidly when Olsen P has reached a critical value (McDowell et al. 2003). Below this value, DRP losses in runoff tend to be low and less responsive to changes in Olsen P concentrations. The critical value varies with soil type, being higher in volcanic soils than sedimentary soils. Data is still been collected on pumice soils. In brown soils, the critical P value is similar to the range for near maximum pasture production (Morton et al. 2003). This would suggest that on sedimentary soils, allowing Olsen P levels to reduce to values to be within the range for near maximum pasture production by applying less fertiliser (maintenance rates to maintain soil tests within these ranges) could result in lower DRP concentrations in runoff. However, it should also be noted that Olsen P is only one factor defining risk of increase P loss (McDowell 2003), and other factors such as animal and pasture management may be as important or more important than controlling Olsen P levels..

There is also evidence suggesting that some sheep and beef farmers could profitably increase production by improving soil P (Table 2) and K levels (Wheeler et al. 2003).

To determine whether a farm soil fertility status is being maintained sustainably requires a history of soil test results over time. To determine trends over time in soil values, Wheeler & Edmeades (1991) recommended at least three samples, and probably five samples, over time to overcome temporal variability. However, only 20% of farms had more than one sampling over time (Wheeler et al. 2003). Even allowing for different methods of recording farm data (e.g., change in owners, address etc), this would still suggest that sampling intensity over time is still not high enough to determine the sustainability of any fertiliser regime, and that measures should be adopted to ensure that soil fertility status is monitored on a regular basis.

These results indicate that farmers respond to changes in target rates that lead to increase pasture productivity. Nutrient budgeting and the possibility of limiting high Olsen P levels will have only had a impact on soil samples post 2001, and hence will not be seen in this study. If nutrient budgeting does have an impact, it is expected to see a decrease in the proportion of samples above the upper limit for the range for near maximum pasture production. This may not necessarily result in changes in average soil test if farms with low levels increase them towards the optimum. It is also expect that Olsen P for sheep/beef farms will increase over time due to increased intensification. To be able to monitor these factors over time requires access to soil test data held by commercial labs.

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