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Soil phosphorus levels in diffuse pollution priority catchments: SEPA contract reference 30107

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1. Executive summary

1.1 Introduction

Phosphorus (P) is one of the major causes of waterbodies in Scotland being at less than good ecological status. Historically the cumulative effect of annual P surpluses (i.e. total P inputs > total P outputs) has raised the soil P test (SPT). In 1992 the national P surplus was calculated as 10 kg P/ha, which if accumulated over 25 years would be expected to be measurable in advisory top soil data. This report aims to identify the potential role of soil P levels by examining SAC's unique advisory extractable soil P data base and assessing if it can be linked to soil P saturation and the increased risk of P leaching.

1.2 Method

Data has been extracted from mid 1996 to 2010 for SAC advisory soil samples from over 19,000 clients that have been submitted from the 23 SAC agricultural office areas within Scotland. Samples are not collected in a systematic way and therefore cannot be viewed as truly representative e.g. while they might form the basis of a regular (~5 year) sampling plan they might also reflect 'problem' situations. They will certainly be biased towards soils likely to receive fertilisers and manures, which is a strength of the dataset, but this does not guarantee that all sites having a potentially high P status will be included. The use of advisory soil data to consider environmental implications is extending the method and interpretation beyond their original application. The data have been summarised and interpreted at three geographical scales; a) national (full database; b) regional (Scottish Government sub-regions); and c) SEPA priority catchments (plus 2 Diffuse Pollution Monitored Catchments, DPMCs). This approach has been adopted so that the maximum number of soil samples and therefore data can be interpreted. The situation c) accounts for <30% of the total soil samples and in addition ~20% of samples do not have any post code and therefore can only be used in summaries for situations a) and b) above.

1.3 National data

More than 130,000 soil samples were analysed since 1996 and assuming an average field size of 5ha then ~20% of the arable and rotational grass is sampled over a 5-year sampling cycle.

Agricultural soil P status varies widely across Scotland reflecting a wide range in production systems. About 30 % of samples require more than maintenance P fertiliser applications (very low and low; <1.8 and 1.8 - 4.4 mg P/l respectively) and 15 % of samples require less than maintenance (high and very high; >13.4 mg P/l). The data showed an increase with time in the number of samples in the very low (VL) and low (L) status, a decrease in the number in the upper moderate (M+), high (H) and very high (VH) status, and the number in lower moderate (M-) remaining very similar across the entire time period.

The frequency of samples falling into the VH status (2-3% of total for each year) is greatest where vegetables are part of the crop rotation. About 25% of the samples are in the VH status following a vegetable crop and about 15% of samples prior to vegetables as the next crop. One complex cropping system involves potatoes, which regularly show economically significant benefits from P applications. Samples following potatoes typically have higher soil P status (just over 30% of samples in H or VH status) compared with just under 30% of samples prior to growing potatoes. An apparent trend towards lower P status in recent years for potato land probably reflects the historic, relatively high P fertiliser recommendations for potatoes which have now been lowered. This is an important finding and needs highlighted as an area of high potential risk.

1.4 Regional data

A clear regionalisation of main agricultural systems and farm enterprises was evident, and summarised as >90% grass in the west and north compared with <50% in the east with the lowest value for Fife (35%) where arable predominates (>50%). The main potato, vegetable and fruit areas are Tayside, Fife, Lothian and NE Scotland. The estimated soil sampling density varies widely between Scottish sub-regions, tending to be the smallest (i.e. greater number of samples) for the east coast (mixed-arable) sub-regions. Regional differences in the soil P status are apparent with a greater proportion of samples falling into the VL and L categories for the SW areas compared to a larger proportion of samples having a H or VH status in the East coast areas. The distribution for Highland and Orkney are similar.

1.5 Priority and Diffuse Pollution Monitored catchment data

The number of soil samples collected from individual priority catchment areas varied greatly with east coast catchments and especially the South Esk having the greatest sampling density. Soil sampling is a less common practice for grassland farmers (South West) who possibly perceive that it is not a necessary or a cost effective nutrient management tool. Typically soils from the west coast catchments had greater organic matter contents and lower pH values which is consistent with grassland being the dominant land use

Differences were apparent in the soil pH, derived organic matter (DOM) and P status between catchment areas. Consistently the samples from the River Garnock had the greatest median DOM content, lowest pH and soil P status compared to the Lunan Water and River South Esk with about half the DOM content (5.3%) and double the median soil P status. This means that the majority of soils sampled from the River Garnock catchment were classed as L compared to M- for the Lunan and South Esk.

1.6 Conclusions and recommendations

An increase in soil P status represents a higher risk for P derived from surface erosion. Soil having a VH status continue to be evident but a degree of uncertainty exists regarding the extent and specific locatities of these hotspots. Fertiliser recommendations and reducing the P surplus will contribute to reducing soil P status where required and reducing P loss. This suggests that additional targeted and structured soil sampling together with advisory soil sampling should reduce this uncertainty. Raising awareness of the value of advisory soil sampling as ~20% of the arable and rotational grass is presently sampled is a key recommendation. Computer programs aimed at promoting nutrient management should be encouraged (e.g. PLANET http://www.planet4farmers.co.uk/).

Soil and site attributes combine to modify the relationship between SPT and leaching risk. An understanding of the individual soil characteristics will be required to develop a risk assessment process for P leaching that extends beyond basic SPT. Recent studies for Irish soils suggest a P desorption index using SPT and soil attributes (estimate of P saturation predicted using a combination of soil texture, oxalate extractable iron and aluminium together with organic matter) could be applied across sub-catchments of varied typology with modest success. It is likely that a wider range of soil types are represented in Scotland compared to Ireland and therefore a case study involving the SW and NE is recommended.

2. Introduction

SEPA is concerned about the impact phosphorus has had on the quality of waterbodies in Scotland. This has happened in conjunction with current nutrient management and possibly increasing soil P concentrations. Knowledge of soil P saturation and leaching risks will aid SEPA's understanding of measure effectiveness and will feedback into the targeted advice SEPA can give to landowners regarding nutrient management in high risk areas. SEPA would like to know if SAC can link SAC's Advisory extractable soil P data to soil saturation and risk of leaching. SEPA agreed to supply an excel spreadsheet of postcodes for each waterbody catchment within a Priority catchment. This will be used by SAC to filter SAC's Advisory soil data for reporting to SEPA and to evaluate what further information can be drawn from data.

SAC will produce a report covering the following:

- Mean concentrations across each of the 14 Priority Catchments and 2 DPM catchments (River Ythan and Lunan Water) for soil pH, extractable P and derived organic matter where data exist.
- Current and future crop where data are available in order to relate concentrations of extractable P to crop types to help SEPA build up a picture of which crop types are associated with high extractable P.
- Raw data for soil pH, extractable P and derived organic matter for the 14 Priority Catchments and 2 DPM catchments will be supplied to SEPA in spreadsheet format in order to allow SEPA to use the date in future reports as SEPA see fit.
- Description and discussion of geographical differences across the catchments.
- How general soil quality in the catchments compare nationally.
- Trends over time and discussion.
- Look into the underlying factors which may explain very high extractable P values.
- An expert assessment of what information could be gleaned from available data to help the risk assessment process, using 2 catchments (Rivers Ythan and Irvine) as examples.
- A draft report by 31st March.

3. Method

3.1 Historical review

Reith (1980) reported the number of samples and P status of soils collected as part of advisory testing between 1940 and 1978 from the North of Scotland College of Agriculture (NOSCA) advisory area (Table 1). This area covered the current Scottish Sub-regions of Shetland, Orkney, Eileanan an Iar, Highland and NE Scotland (Figure 3). Reith reported that most of the soils in north Scotland are naturally deficient in P and the mineral soils have high P retention capacities. There was a gradual improvement in P status from 1940 to 1978, reaching a maximum of 29% of samples in the high (H) category and 53% in the moderate (M) category. The M category was defined as the soil PK levels where recommended PK fertiliser rates should produce optimum yields of all crops (Anon, 1985). This category is equivalent to the current soil moderate (M) status (Sinclair et al., 2010b).

Table 1. Number of samples and percentage grouping of NOSCA advisory soil samples into P status from 1940 to 1978.

Years	Number of samples	Soil P status		
		Low	Moderate	High
1940-44	11,992	38	48	14
1952-54	23,776	38	50	12
1960-64	43,568	28	52	20
1970-74	31,725	22	52	26
1975-78	23,102	18	53	29

During the 1980s a Scottish Soil Fertility Information System was set up between SAC and the Macaulay Institute for Soil Research (now The James Hutton Institute) with a view to making better use of soil test data. At the time of soil sampling, data on farm type, Soil Series, cropping, and lime and fertiliser use were coded together with the 8 character grid reference for each sample. This allowed comparisons to be made for different farming systems. Data from soils sampled in the NOSCA area during 1985, 1986 and early 1987 showed that few samples analysed from continuous cropping farms had very low or low P status (15%), whereas 26% had high P status (Sinclair et al., 1988; 1989). The authors concluded that there appeared to be scope for reducing the amount of phosphate fertiliser applied to a number of arable fields. In contrast, samples from grass farms showed an over-all poorer P fertility with a further decline on farms of lower N inputs and hill farms.

During 1987 SAC advisory soil testing was transferred from Aberdeen and Auchincruive to Edinburgh and data for farm type, Soil Series and grid reference were no longer collected for each sample. The extraction method changed from acetic acid to modified Morgan's in 1989. During the period from 1987 to1995, sample numbers for the whole of Scotland varied between 15,080 and 18,844.

Currently the soil test data from 1996 to the present time are stored in a Laboratory Information Management System (LIMS) database. The SAC laboratory has dealt with over 19,000 clients since 1996. Data has been extracted from mid 1996 to 2010 for advisory soil samples that have been submitted from the 23 SAC agricultural office areas within Scotland which vary widely in area and farming systems.

3.2 SAC soil testing system

SAC recommends that soils should be sampled every 4 to 5 years and analysed for soil pH, extractable P, K and Mg. Samples are not collected in a systematic way and while they might form the basis of a regular (~5 year) sampling plan they might also reflect 'problem' situations. They will certainly be biased towards soils likely to receive fertilisers and manures, which is a strength of the dataset as it is these soils which are expected to have a higher risk of P loss. For example, only 1 of the ~130,000 soil samples in the database analysed here from mid 1996 to 2010 was taken from 'rough pasture'. Sampling usually involves a fixed depth basis (~20 cm for arable and 10 cm for grassland) and is usually taken to reflect the plough layer. Importantly it needs to be remembered that using advisory soil data to consider environmental implications is extending the method and interpretation beyond their original application. The SAC soil test method (Modified Morgan's based on an ammonium acetate/acetic acid solution), in line with most soil P test (SPT) methods, uses a closed, batch type system, which is the complete opposite of the open leaching system. The SAC soil test method was developed in order to define a pool of P that is likely to be or become plant available while also providing a basis to make fertiliser recommendations through a status system (Reith et al., 1987). Further details on SPTs are given in Appendix 1.

Soil pH is determined in 0.01M $CaCl_2$ solution using a soil: solution ratio of 1:2 (w/v). In order to correspond approximately to water pH values, the reported pH is 0.6 higher than the value measured in 0.01M $CaCl_2$ solution.

Derived organic matter (DOM) is determined from the weight of a fixed volume of air-dried, soil gently ground to pass a 2 mm round-hole sieve, after comparison with a regression equation of soil density and organic matter.

3.3 Target soil pH and P values

The optimum availability of most plant nutrients in soil occurs over a small range of soil pH values. The aim is to achieve an optimum soil pH of 6.0 to 6.2 in all parts of the field on mineral soils where arable crops/grass rotations occur. A lower pH of between 5.7 and 5.9 is recommended on organic soils. Clover is more sensitive to soil acidity than are many grass species and soil pH should be maintained to encourage a clover-rich sward. An optimum soil pH of 6.0 on grassland mineral soils is recommended compared to a lower value of pH 5.3 between 5.5 on grassland peaty soils (Sinclair et al., 2010a and b).

Fields are best sampled immediately before potatoes which often give a yield response to PK fertiliser in the year of application. Cereals and oilseed rape do not generally respond on moderate PK status soils and sampling time is therefore not so crucial, but the application of fertilisers and manures may influence results for up to 12 weeks after application. Results may be lower than expected if fields are sampled during periods of maximum nutrient uptake, but higher (or more variable) than expected in the spring due to decomposition of crop residues. Fields should be sampled between September and February, depending on timing of fertiliser applications. Analyses for K can vary considerably and more than P, especially at higher K values. SAC classify extractable soil P values into 6 categories as shown in Table 2 (Sinclair et al., 2010b).

Table 2. Classification of mg/l values into Status for extractable soil P.

SAC Status	SPT (mg/l)
VL	0 – 1.7
L	1.8 – 4.4
M-	4.5 – 9.4
M+	9.5 – 13.4
H	13.5 – 30.0
VH	>30.0

Soil analysis does not predict crop uptake of P only whether sufficient is available for crop uptake over a growing season. Actual uptake depends on crop, yield potential, rooting depth and weather. Large responses to P and K in the year of application are only expected where the soil P Status is very low, and are infrequent on soils of moderate Status. Potatoes are more responsive to P and K fertiliser than cereals and oilseed rape. For cereal-based arable rotations, the target soil P Status is moderate (M). For rotations with potatoes, target P levels are at the upper half of moderate (M+). It is important that the soil P Status is not built up over and above the target level. Besides being wasteful, the loss of soluble P in sediment during bouts of surface run-off can contribute to poor water quality. For soils that are above the target levels for P and K, savings can be made in both P and K applications.

Phosphate helps root development and early growth. Newly seeded grass and clover benefit from applied soluble phosphate since their root systems are insufficiently developed to tap the main P reserves in the soil. Clover is more susceptible than grass to P deficiency due, in part, to the grass having a more extensive and finely branched root system that enables the grass to compete more effectively. This difference between grass and clover has resulted in a slightly higher target soil P status for grass/clover swards (middle of the moderate status) compared to grass only swards (M-). P deficiency is generally more common in the wetter upland areas than in drier lowland areas, partly because the availability of P is low in acid soils, and acid soils are more widespread in upland areas. Soil P supply to the plant is dependent on soil reserves, which must be converted to a soluble form before being absorbed by plant roots. P availability is reduced at low temperatures such as when growth is beginning in early spring. A fresh boost of soluble P at this time can have a greater impact on growth until soil temperatures rise sufficiently to increase P-release from the soil reserve. Trials in Scotland have shown that an enhanced response to P applied in early spring is obtained on soils of low or very low P status if P is combined with nitrogen. A number of proprietary fertilisers include NP formulations. In all other situations P applications to established grass are aimed primarily at maintaining target P status in the soil rather than increasing grass growth.

It is possible to explore two aspects of using the data, the first is developing some relationship between SPT and leaching loss, the second is really assuming that any reduction in soil P status should reduce loss.

3.4 Environmental interpretation of SPT data

Soil analysis in Ireland uses Morgan's reagent and they collect samples to 10 cm depth (Daly and Casey, 2005) and importantly for our current study it was shown that SPT could be related to dissolved reactive P (DRP) in surface runoff from two experimental plots. Table 3 below summarises these findings for a range of soil P extraction methods, unfortunately there were only two plots. The Morgan's reagent showed the closest similarity of ratio between the two treatment plots to the estimated ratio.

Table 3. Phosphorus loss (kg/ha) from site 1 and 3 and soil-test P results (mg/kg), and loss ratios based on actual P loss and soil-test P values (from Daly and Casey, 2005).

	Method for P concentration						
	Estimated P loss kg P/ha	Morgan's P	$CaCl_2$-P	FeO-P	WSP	M3-P	P_{Sat} (%)
Site 1	0.065	3.1 (2.8)[1]	0.8 (0.8)	18.2 (16.5)	6.1 (5.6)	38.2 (35)	4.3
Site 3	0.457	20.6 (17.6)	4.7 (4)	82 (70.1)	29.5 (25.1)	124 (106)	16.3
Ratios[2]	7.0	6.6 (6.3)	5.9 (5)	4.5 (4.2)	4.8 (4.5)	3.2 (3)	3.8

[1] ( )Values on volume bases (mg/l).
[2] Value for Site 3 relates and corresponding value for Site 1.

Note of caution – it is likely that these results are not directly transferable to the SAC procedure as there are some differences in the two methods and it would appear that the Irish method extracts less P. However, we are exploring the possibility of cross correlating between the two methods.

McDowell et al. (2001) compared change points for a range of soils and these ranged between 20 – 112 mg P/kg. The critical change point has been estimated using various soil/extractant combinations, interestingly Horta and Torrent (2007) compared Olsens P with various water:soil extractant ratios. The narrower the ratio the lower is the Olsen P concentration.

These important conclusions were taken from Styles et al. (2006) '*It is inferred from the strong linear relationships observed between Morgan P and moist sample P solubility that the risk of elevated surface water P concentrations, and consequent eutrophication, increases linearly with increasing soil Morgan P content. This emphasises the importance of controlling soil Morgan P concentrations within management strategies aimed at limiting diffuse soil P losses. The average Irish soil Morgan P concentration of 9 mg P/L is at the upper end of recommended agronomic optimum soil P status, and concentrations above this level pose unnecessary risk to surface waters.*

Soil OM content was found to significantly affect P solubility in soils, once the dominant Morgan P effect was accounted for. There were insufficient data in this study to differentiate all the soil groups differentiated by Daly et al. (2001), but there was a clear difference between the P solubility of predominantly mineral compared with peat soils. At a given Morgan P content, P solubility in peat soils was approximately one quarter of that in mineral soils.

The modest success of the P desorption index developed here, when applied across subcatchments of varied typology, indicates an importance of both Morgan P and soil-type in determining the scale of diffuse soluble P losses. In Ireland there is a large database of Morgan P, and a nationwide soil map, which could be used to assess relative soluble P loss risk on a catchment-scale, following the example set by Daly et al. (2002).'

3.5 Investigation of advisory data collected from 1996 to 2010

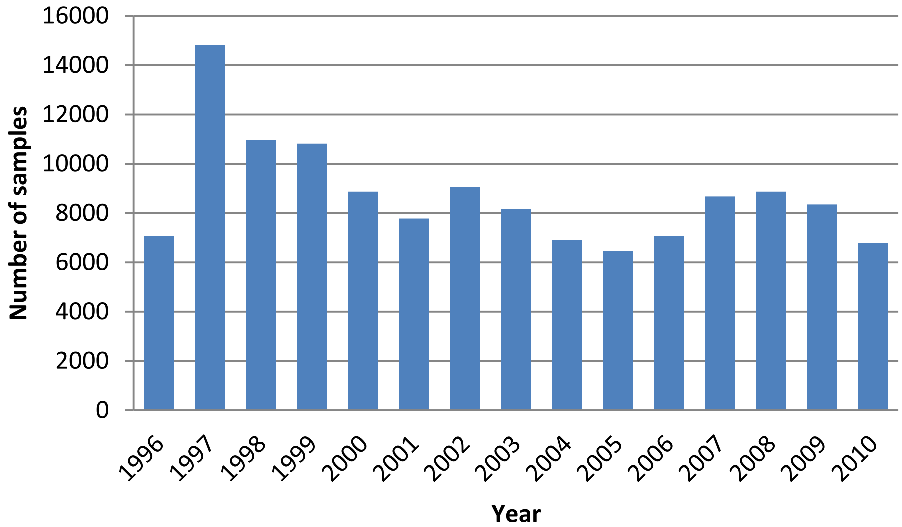
The data have been summarised and interpreted at three geographical scales; a) full database (national scale); b) Scottish sub-regions; and c) SEPA priority catchments (plus 2 DPM catchments). This approach has been adopted so that the maximum number of soil samples and therefore data can be interpreted. The situation c) above accounts for <30% of the total soil samples and in addition ~20% of samples do not have any post code and therefore can only be used in summaries for situations a) and b) above.

4. National data

4.1 Full data set

The full data set comprises of >130,000 topsoil samples. Numbers of samples tested annually declined from ~15,000 pre 1997 to between 7000 and 10,000 (Figure 1).

Figure 1. Total numbers of samples by year (1996-2010), 1996 is a part year.



The distribution by P status is summarised in Figure 2 and Tables 4 and 5. The lower half of moderate (M-) status is the target for intensive grassland and the upper half of moderate (M+) for arable rotations that include vegetables and potatoes. Maintenance levels of fertiliser to replace crop P offtake are recommended on moderate (M) P status soils with repeat soil analysis every 4 to 5 years.

Figure 2. Distribution of soil P status within the complete dataset of ~130,000 samples.

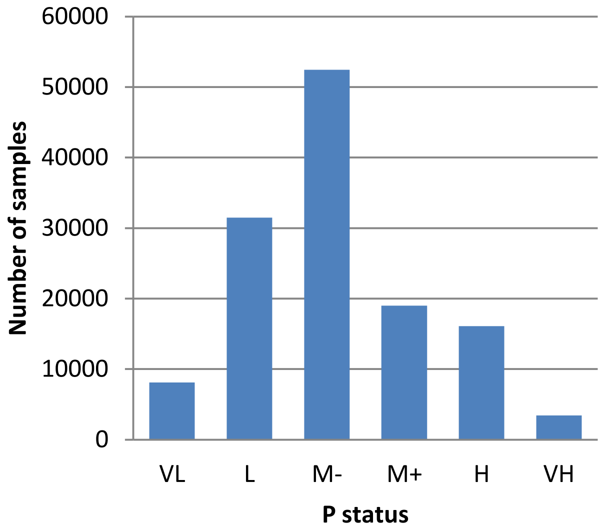


Table 4. Breakdown of P Status into percentage of the complete dataset.

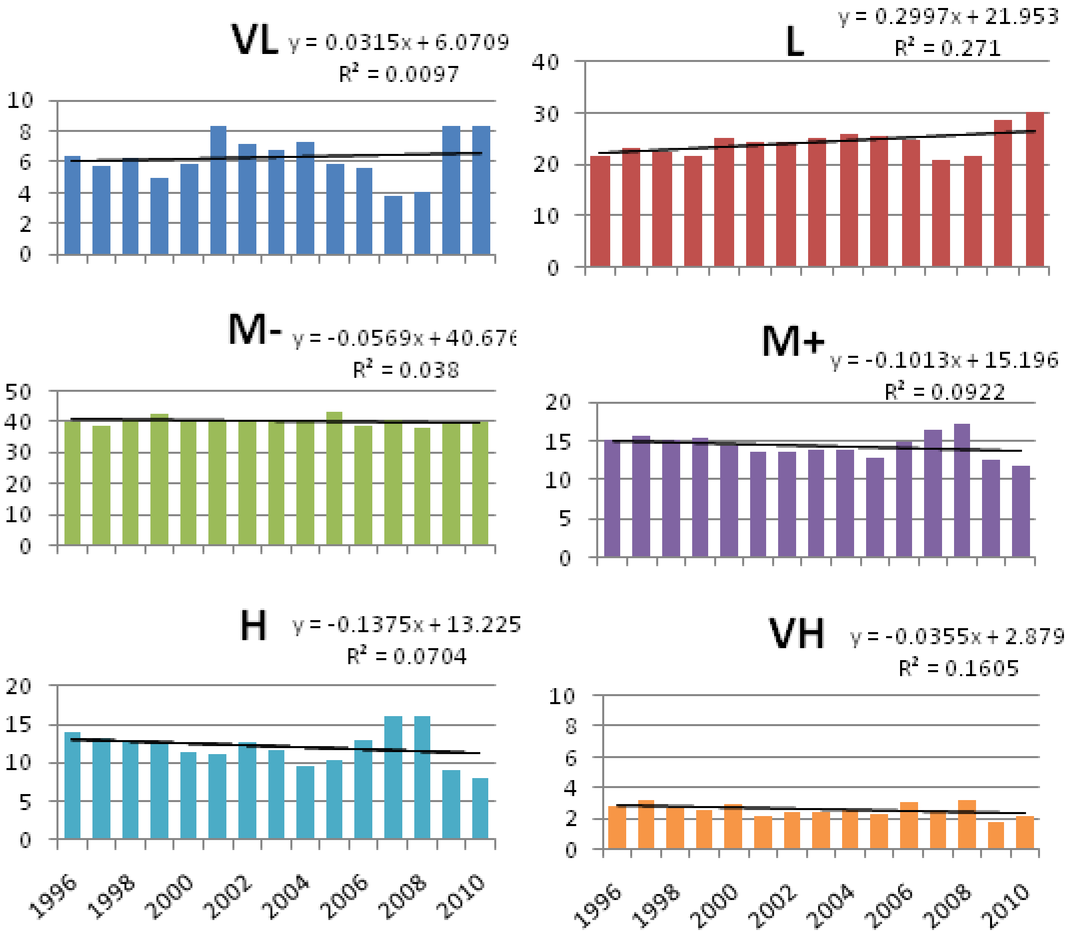
P Status	Very Low (VL)	Low (L)	Moderate (M-)	Moderate (M+)	High (H)	Very High (VH)
Range (mg P/l)	< 1.8	1.8-4.4	4.5-9.4	9.5-13.4	13.5-30	>30
Percentage of total samples	6.2	24.1	40.2	14.6	12.3	2.6

Table 4 shows that about 30 % of samples (VL + L) require more than maintenance fertiliser P applications and 15 % of samples (H + VH) require less than maintenance. What is clearly evident is the range in soil P status of agricultural soils nationally and this presumably reflects a wide range in intensity of farming. One important aspect of the dataset to be explored is any change in soil P status that might have occurred over time. Table 5 shows a suspicion of a movement with time towards more samples in the L status and fewer in the H status. Figure 3 shows this movement more clearly with an increase with time in the number of samples in the VL and L status, a decrease in the number in the M+, H and VH status, and the number in M- remaining very similar across the entire time period. While these changes may at first appear small, a movement of 1% between P status categories represents around 100 soil samples.

Table 5. Distribution of samples by soil P status as a proportion (%) of total number of samples for individual years.

Sample year	VL	L	M-	M+	H	VH
1996	6.5	21.9	39.9	15.0	13.9	2.9
1997	5.7	23.3	38.9	15.8	13.1	3.2
1998	6.2	22.5	40.5	15.1	13.0	2.7
1999	4.9	21.7	42.7	15.3	12.8	2.6
2000	5.9	25.1	40.1	14.4	11.5	2.9
2001	8.4	24.2	40.5	13.6	11.1	2.2
2002	7.2	24.4	39.7	13.5	12.8	2.5
2003	6.7	25.2	40.4	13.7	11.5	2.4
2004	7.3	26.0	40.7	13.8	9.6	2.5
2005	5.9	25.6	43.0	12.7	10.3	2.4
2006	5.6	24.7	38.8	14.8	12.9	3.1
2007	3.9	20.9	40.3	16.4	16.0	2.5
2008	4.1	21.5	38.0	17.2	16.1	3.1
2009	8.3	28.4	40.0	12.5	9.0	1.8
2010	8.4	30.0	39.6	11.7	8.0	2.2

Figure 3. Distribution of samples by soil P test result as a proportion (%) of total number of samples for individual years.

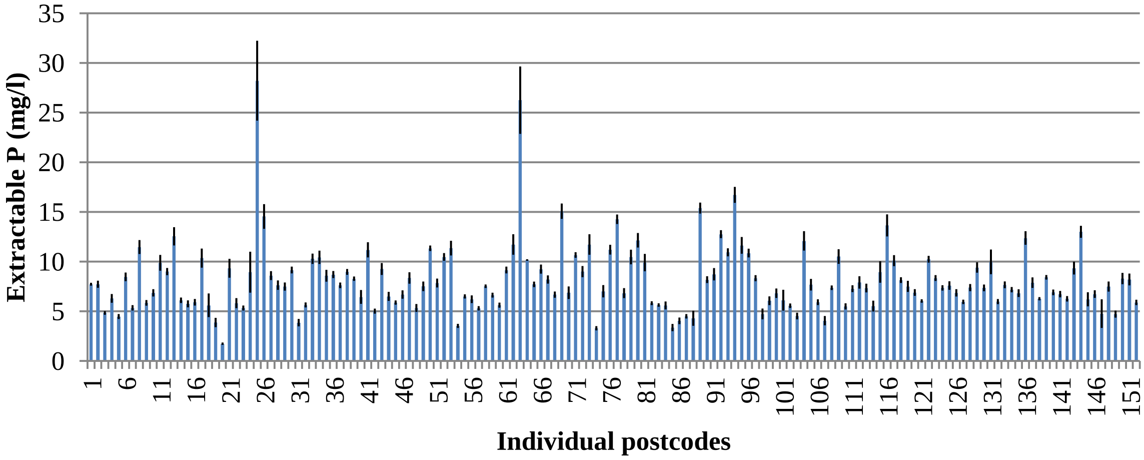


Assuming an average field size of 5 ha and 8,000 samples per year this would mean that ~ 40,000 ha of land would be tested per year. The total area of tillage and grassland <5 years old is ~ 1 million hectares which means the annual area sampled is equivalent to ~ 4%, which over a 5-year cycle would be equivalent to 20%. Extreme caution should be applied to any extrapolations up to a national basis if the general assumption is made that the pattern is similar.

4.2 Distribution of soil samples with postcode

One further aspect of the data is the geographical component that can be obtained by employing a separation based upon the postcode. Because of anonymity rules it is not possible to show the full post codes so data are summarised using the whole postcode only where more than 40 samples have been collected (Figure 4). This more detailed level of separation suggests that some variability does occur between neighbouring areas, ranging from < 5 mg P/l to >25 mg P/l.

Figure 4. Summary of mean and standard error averaged for each full post code within the whole data set where more than 40 soil sample results exist.



4.3 Distribution of soil P status and crop

In some cases additional information such as previous and next crop is available for the soil samples. This provides a mechanism for assessing the possible influence of different fertiliser strategies for individual crops. The distribution of soil P status is summarised for the major previous crops in Figure 5 and next crop in Figure 6. Potatoes and vegetables usually receive more fertiliser P than most cereal crops and grass and therefore it might be expected that soil P status varies according to cropping information. The frequency of VH samples is greatest where vegetables are part of the rotation. About 25% of the samples are in the VH status following a vegetable crop and about 15% of samples prior to vegetables as the next crop. Samples following potatoes have higher soil P status (just over 30% of samples in H or VH status) compared with just under 30% of samples prior to growing potatoes. A total of 5,605 samples were taken prior to growing potatoes and 1,569 after potatoes. The P data indicate that P status is higher immediately after potatoes and declines during the rotation being lower prior to sampling for potatoes. This key feature probably reflects the historic relatively high P fertiliser recommendations for potatoes. This P recommendation has been reduced in the most recent SAC technical note (Sinclair *et al*., 2010b). Soil samples collected when either previous or next crop was grass showed an essentially similar distribution with approximately 40% of samples having either a VL or L status. The general distribution of P status was essentially similar for winter and spring sown crops.

Figure 5. Distribution of soil P status summarised for the major previous crops (number of samples 90,857). (W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B - berries).

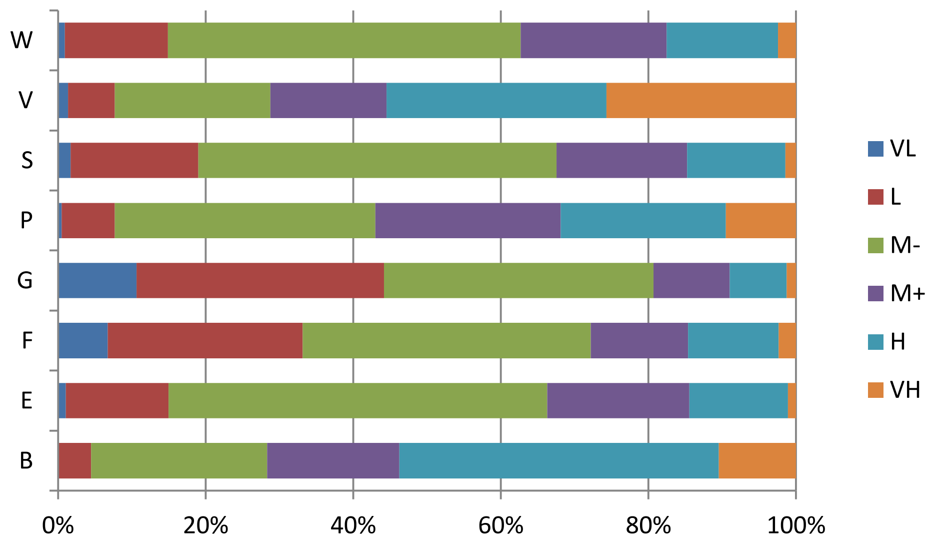
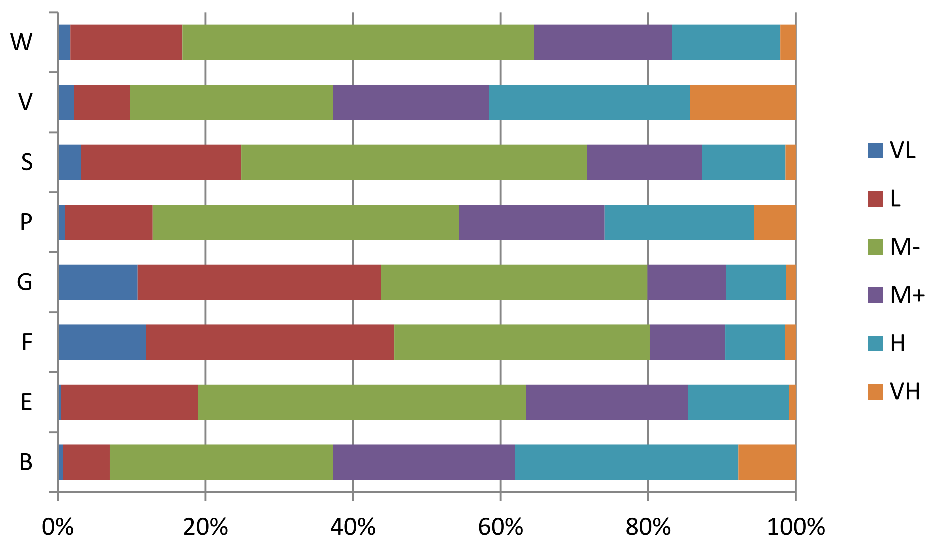
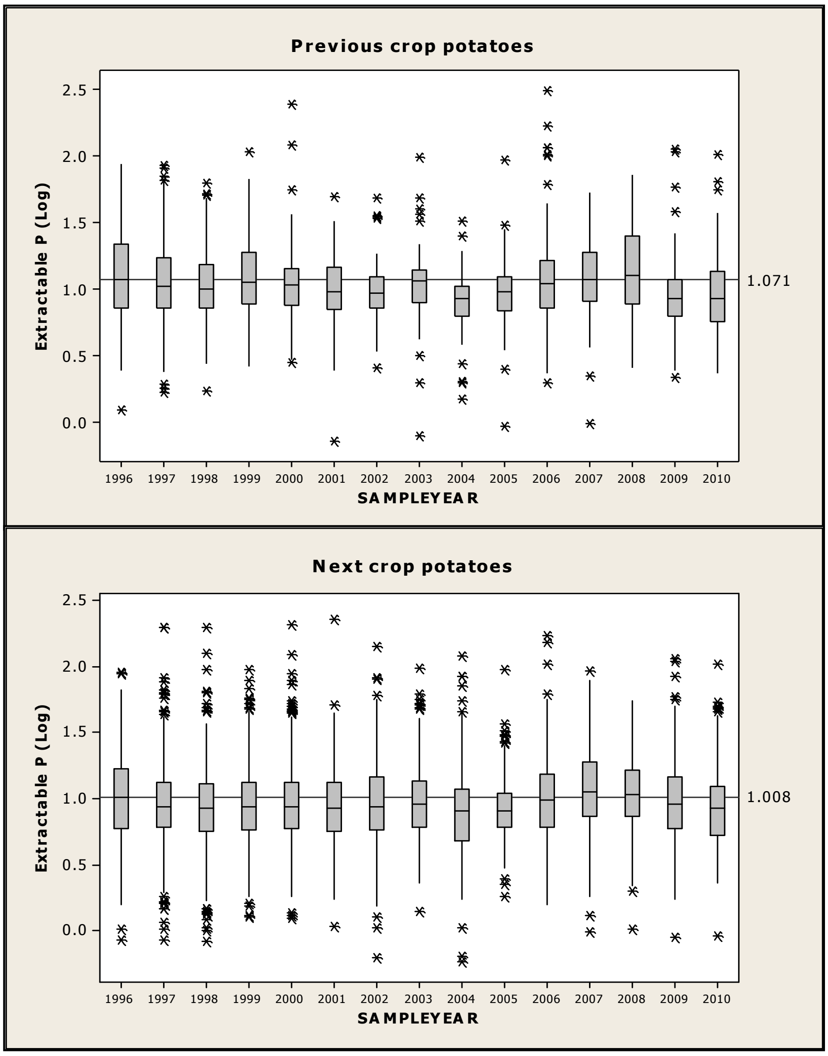


Figure 6. Distribution of soil P status summarised for the major next crop (number of samples 96,001). (W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B - berries).



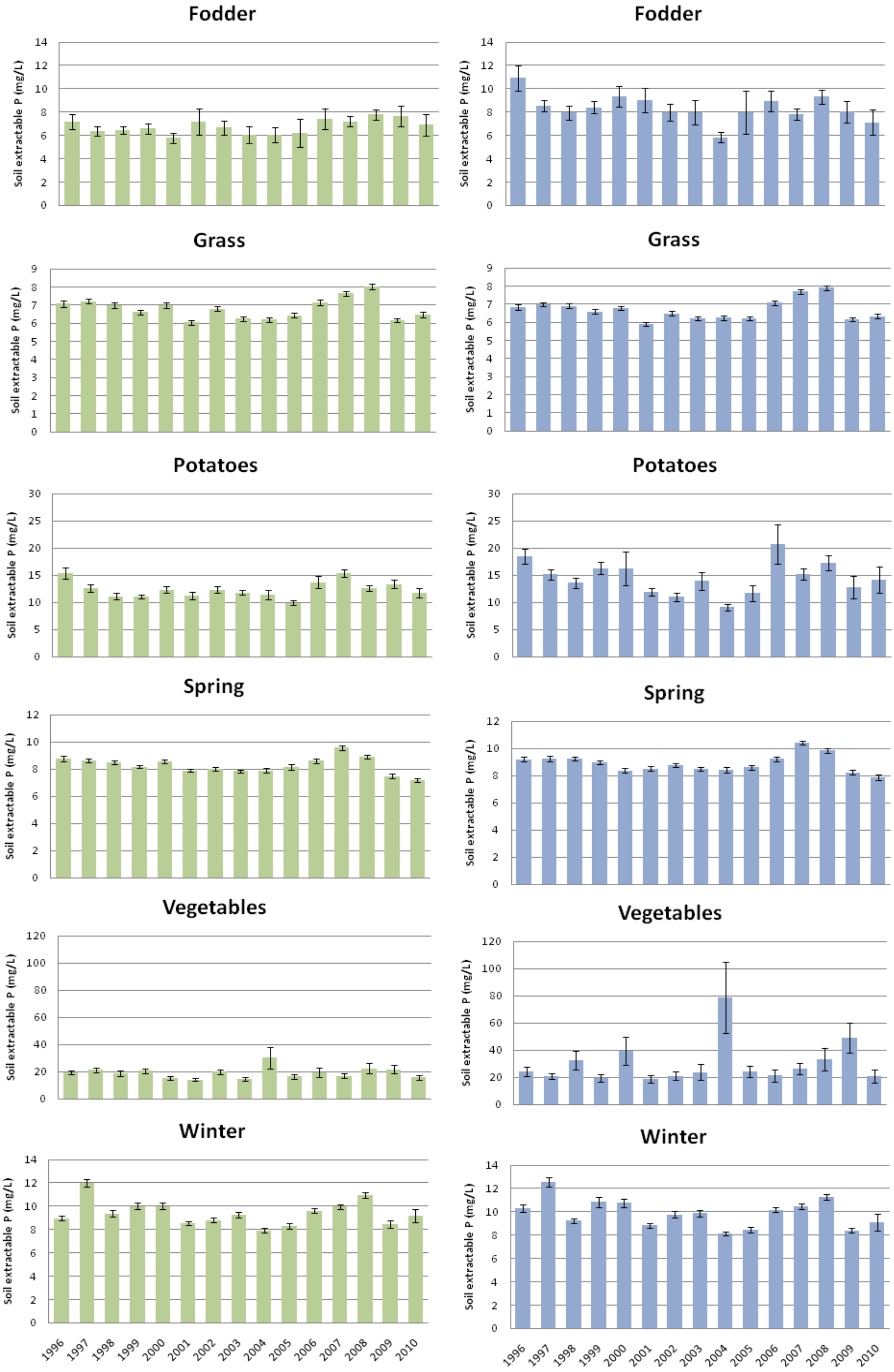
Changes to fertiliser recommendation rates for potatoes would hopefully reduce number of soil samples having an extremely high P status. The P status of soil collected after and before potatoes, summarised for the whole dataset by year, is given in Figure 7. These box plots show the distribution of the data where the boxes represent the inter quartile range, and extreme values are shown as individual points. The median line is shown for each year and this has been extended from the first year 1996 just to allow comparison. The tremendous range in soil P status means that showing soil extractable P as log values helps identify changes in the extreme values. There appears to be a trend towards lower P status in recent years in both sets of samples collected after and before potatoes which is accompanied by a smaller number of extreme values. Any reduction in soil P status is likely to be linked with a change in fertiliser use which is discussed in more detail in Section 8.

Figure 7. P status of soil collected after and before potatoes, summarised for the whole dataset by year. Box and whisker plots are a way of describing large amounts of data, the rectangular box represents roughly the middle 50% (interquartile range) of the data, and lines ("whiskers") extending to either side indicate the general extent of the data. The median value inside the box and the outliers are also shown.



The P status of soil collected before and after the main crop groups are summarised for the whole dataset by year in Figure 8 where the value of collecting this additional information is clearly demonstrated. Various patterns are suggested which can be summarised as very similar P concentrations for land under grass, and winter/spring sown cereal crops irrespective of whether samples were collected before or after the specific crop. This contrasts very much with the data for fodder crops, potatoes and vegetables where soil P concentrations are generally higher and particularly after one of these specific crops, suggestive of a higher residual amount of fertiliser P remaining after harvest. This sub-division of the data highlights an unexpected property where some of the annual variability appears to be mirrored for each crop. This suggests some underlying factor, perhaps climate related, that influences extractable P.

Figure 8. P status of soil collected before and after main crop groups (next crop green and previous crop blue) averaged for individual years. Each crop pair has been given the same scale allowing a direct comparison and the bars represent the standard errors



4.4 Distribution of soil samples with concentrations greater than 30 mg P/l

A significant number of advisory soil samples were evaluated as having extractable P concentrations greater than 30 mg P/l, putting them into the very high category. There is no agronomic reason why soils should be fertilised to this level and irrespective of situation these soils represent a high risk for P loss. Any knowledge that can identify the typical situations where these conditions have developed will help the advisory service direct efforts to reduce soil P concentrations. Of the 3459 samples with an extractable soil P >30 mg/l just over 50% of these also had information on the previous crop. The proportion of total samples analysed annually which had a very high P status falls between 2-3% for each year (Table 6). It is possible that numbers are declining.

Table 6. The number of samples and this shown as a proportion of total number collected annually having an extractable P concentration >30 mg/l.

Year	Total number of samples with >30 mg P/l	As a proportion (%) of the total number of samples
1996	202	2.9
1997	482	3.3
1998	297	2.7
1999	279	2.6
2000	257	2.9
2001	173	2.2
2002	223	2.5
2003	198	2.4
2004	175	2.5
2005	152	2.4
2006	222	3.1
2007	216	2.5
2008	280	3.2
2009	152	1.8
2010	151	2.2

A breakdown on the basis of previous crop (Table 7) shows the greatest number of samples had some form of grass as the previous crop. As the total number of samples varies widely across the groups of previous crops then Table 7 also shows the proportion relative to the total number of samples. When this comparison is made then it is very clear that vegetables, potatoes and berries had a much greater proportion of samples with a very high P concentration.

Table 7. Summary of the distribution of soil samples having an extractable P concentration greater than 30 mg/l in relation to information on the previous crop. (W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, B - berries).

Previous crop	Number of samples >30	Proportion (%) of all samples >30	Proportion (%) of total samples for each crop
B	7	0.4	10
F	38	2	2
G	615	37	1
P	149	9	10
S	358	22	1
V	151	9	26
W	336	20	2

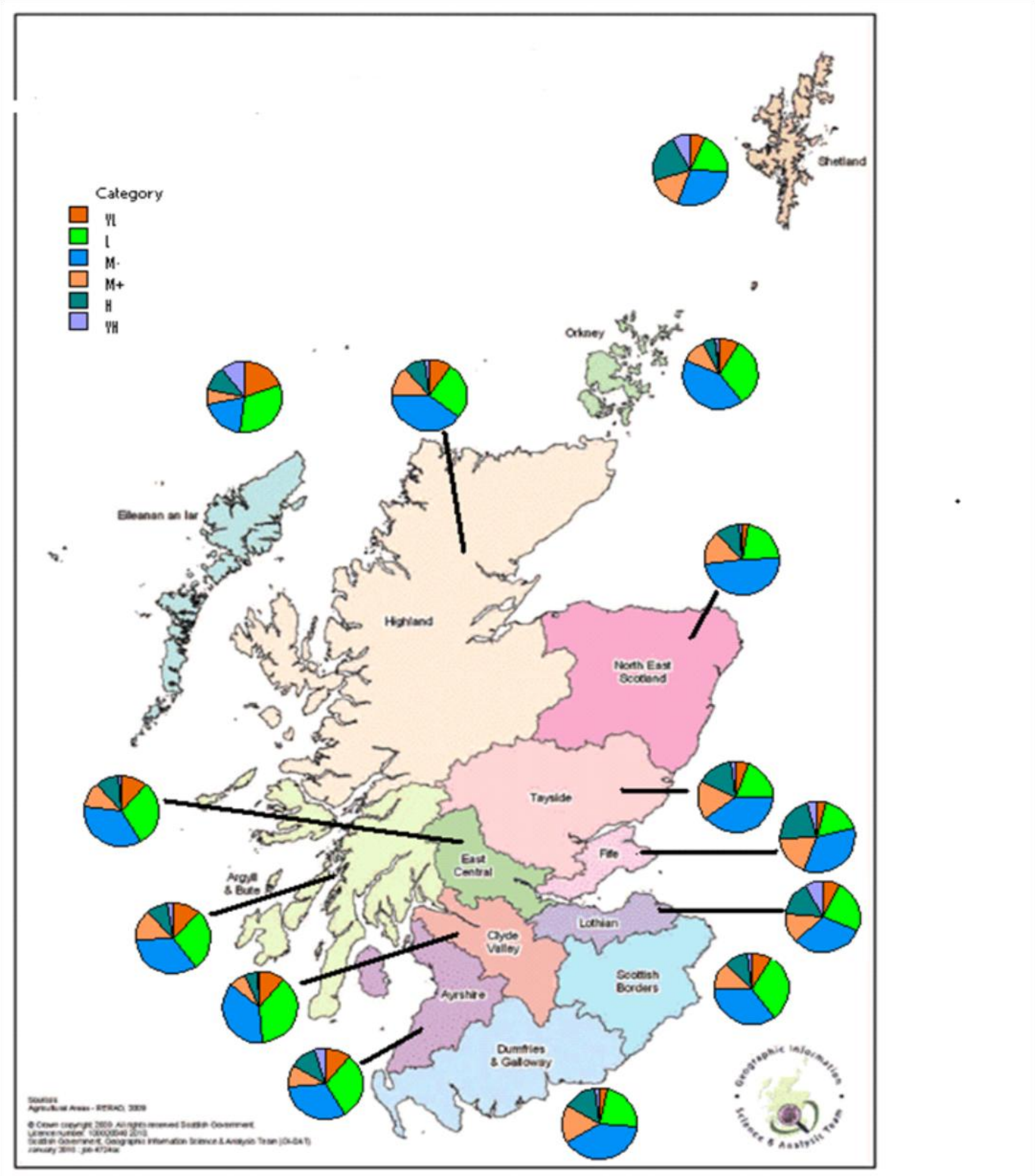
5. Regional data

The suggestion of a relationship between soil P status and crop types discussed in the previous section would mean that geographical differences in relation to P status might be expected. In Figure 9 the soil P status data has been summarised using proportional pie charts for Scottish Government sub-regions that are used in Agricultural Census data reports. Regional differences in the soil P status are apparent with a greater proportion of samples falling into the VL and L categories for the SW areas compared to a larger proportion of samples having a H or VH status in the East coast areas. The distribution for Highland and Orkney are similar.

A large proportion of the difference in soil P test can be attributed to the clear regionalisation of main agricultural systems and farm enterprises which is evident from Table 8, and summarised as >90% grass in the west and north compared with <50% in the east with the lowest value for Fife (35%) where arable predominates (>50%). The main potato, vegetable and fruit areas are Tayside, Fife Lothian and NE Scotland.

A relationship between soil P status and cropping pattern is suggested by Figure 10, where the median soil P concentration for each sub-region is plotted against the proportion of land under potatoes (including vegetables and fruit). There is a strong suggestion of a relationship and this is explored in greater detail in the following sections. The two points shown as an outline are Shetland and Eileanan an Iar.

Figure 9. Scottish sub-region identification and also showing a summary of the soil P status as proportion pie charts.



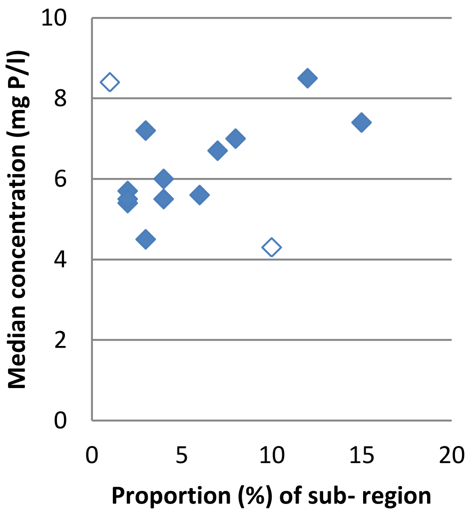
Map sourced from: http://www.scotland.gov.uk/Publications/2010/03/16165732/1

Table 8. Sub-region area and percentage breakdown (arable crops and grass excluding rough grazing).

Crops	Grass (not rough grazing)	Barley	Wheat	Oilseed Rape	Oats	Other inc potatoes
	%	%	%	%	%	%
Shetland	99	0	0	0	0	1
Orkney	90	8	0	0	0	2
Eileanan an Iar	89	0	0	0	1	10
Highland	76	14	2	1	2	4
NE Scotland	51	33	5	3	1	7
Tayside	41	27	12	3	2	15
Fife	35	27	20	3	3	12
Lothian	43	24	21	3	0	8
Scottish Borders	62	14	12	3	2	6
East Central	77	12	4	0	2	4
Argyll & Bute	95	3	0	0	0	2
Clyde Valley	90	6	1	0	0	3
Ayrshire	91	6	1	0	0	2
Dumfries & Galloway	90	6	1	0	0	3

Adapted from The Scottish Government June Census 2008

Figure 10. Comparison of the median soil P concentration and the proportion of land under potatoes (vegetables and fruit) for each agricultural sub-region.



The total number of samples per sub-region is summarised in Figure 11. Numbers varied widely with more than 35,000 collected from NE Scotland. The data in Figure 11 requires further qualification as the total areas as well as the relative proportion of agricultural land varies widely between agricultural sub-regions.

Figure 11. Total number of samples per sub-region.

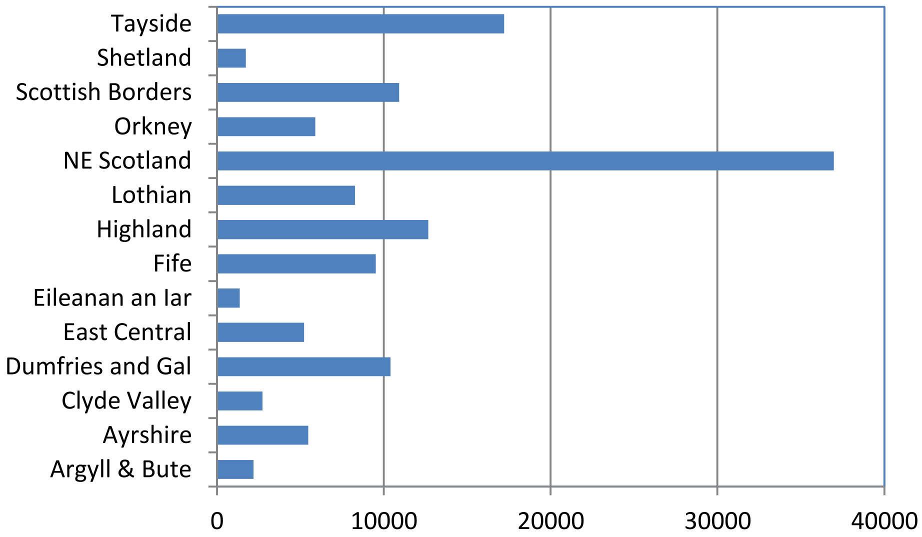


Table 9 shows an estimate of the density of soil sampling across the various sub-regions, where the sample density represents the averaged number of samples collected annually for each sub-region divided by the area of crops and grass (excluding rough grazing).

Table 9. Estimated density of soil sampling across the various sub-regions.

	Area crops and grass (ha)	Number of soil samples	Area (ha) associated with each sample
Shetland	23940	115	208
Orkney	54391	393	138
Eileanan an Iar	23850	91	263
Highland	177385	844	210
NE Scotland	391582	2465	159
Tayside	222478	1148	194
Fife	86616	635	136
Lothian	90183	552	163
Scottish Borders	197019	729	270
East Central	59594	349	171
Argyll & Bute	52769	146	361
Clyde Valley	114334	182	630
Ayrshire	123743	365	339
Dumfries & Galloway	237867	694	343

The estimated soil sampling density varies widely between sub-regions, tending to be the smallest (i.e. greater number of samples) for the east coast (arable) sub-regions. The higher number of samples from the NE Scotland sub-region is probably partly a reflection of the presence of a technical member of SAC staff based at the SAC Thainstone office that is available for soil sampling. For many of those sub-regions dominated by grassland production such as Ayrshire, Shetland, and Argyll & Bute the sample number indicate that soil testing is either not being conducted, is not submitted for analysis using a postcode, or is being done by laboratories other than SAC. For many farmers soil testing is supplied free of charge as part of their fertiliser or off farm feed purchases. The analysis of these soils is often done by separate labs or not submitted with a reference to the farm they are taken from. For Dumfries and Galloway which is also dominated by grassland production the use of soil testing is high which is due to a focus of the FBS office on their use.

The total advisory dataset of extractable soil P, soil pH and derived organic matter is summarised by sub-region in Table 10, and distribution into status and groups in Figures 12, 13 and 14.

Table 10. Summary of total dataset of extractable soil P, soil pH and derived organic matter by sub-region.

Extractable-P

Region	Count	Mean	SE Mean	Minimum	Median	Maximum
Argyll & Bute	2190	8.2	0.25	0.1	5.7	198.0
Ayrshire	5472	8.8	0.15	0.1	5.5	254.0
Clyde Valley	2724	6.3	0.15	0.4	4.5	167.3
Dumfries and Gal	10404	9.1	0.09	0.0	7.2	198.0
East Central	5233	7.3	0.11	0.0	5.5	185.4
Eilealan an Iar	1362	11.4	0.50	0.1	4.3	160.2
Fife	9527	11.8	0.15	0.0	8.5	268.3
Highland	12664	7.9	0.10	0.0	6.0	400.0
Lothian	8276	12.8	0.27	0.1	7.0	543.3
NE Scotland	36971	8.3	0.04	0.0	6.7	260.5
Orkney	5894	7.8	0.23	0.1	5.4	736.6
Scottish Borders	10929	8.1	0.11	0.2	5.6	325.0
Shetland	1730	12.7	0.36	0.1	8.4	164.7
Tayside	17224	9.4	0.08	0.0	7.4	331.0

DOM (%)

Region	Count	Mean	SE Mean	Minimum	Median	Maximum
Argyll & Bute	2190	9.6	0.11	1.3	8.5	42.0
Ayrshire	5472	8.4	0.06	1.3	7.7	83.5
Clyde Valley	2724	8.9	0.07	2.1	8.3	46.2
Dumfries and Gal	10404	10.0	0.04	1.8	9.5	84.0
East Central	5233	7.6	0.05	1.4	7.0	58.9
Eilealan an Iar	1362	19.4	0.47	1.4	12.8	102.9
Fife	9527	5.4	0.02	1.3	5.0	71.5
Highland	12664	7.0	0.05	1.3	5.8	150.9
Lothian	8276	6.2	0.03	1.3	5.2	41.6
NE Scotland	36971	6.8	0.01	1.3	6.7	153.3
Orkney	5894	10.2	0.05	2.1	10.0	53.3

Scottish Borders	10929	6.8	0.03	0.9	5.9	152.8
Shetland	1730	20.3	0.37	1.6	15.2	152.8
Tayside	17224	6.3	0.02	0.9	5.8	54.4

pH

Region	Count	Mean	SE Mean	Minimum	Median	Maximum
Argyll & Bute	2190			3.7	5.6	8.1
Ayrshire	5472			3.8	5.7	8.4
Clyde Valley	2724			3.8	5.8	9.3
Dumfries and Gal	10404			3.7	5.8	8.2
East Central	5233			3.7	5.9	9.1
Eilealan an Iar	1362			3.8	5.2	8.7
Fife	9527			2.8	6.2	8.1
Highland	12664			3.5	5.9	9.7
Lothian	8276			3.6	6.2	9.1
NE Scotland	36971			3.6	5.9	9.1
Orkney	5894			3.9	5.8	8.6
Scottish Borders	10929			3.8	6.1	9.2
Shetland	1730			3.4	5.6	8.2
Tayside	17224			3.2	6.0	8.9

Averaged values (Table 10) in 13 areas fall between 8 and 10 mg P/L, Lothian and Fife are above this possibly reflecting higher P inputs because of the higher percentage area of winter wheat. The higher average values in Lothian and Fife reflect the greater proportion of H and VH P status soils (Figure 12). Eileanan an Iar has the highest average soil P concentration and this probably reflects the inappropriateness of the acidic soil P test on high pH (Machair) soils (see Figure 13). The pattern of DOM tends to show higher concentrations for the westerly sub-regions with the majority of soils in the eastern areas having less than 10% DOM (Figure 14).

Figure 12. Distribution of soil P status by sub-region summarised into 6 classes.

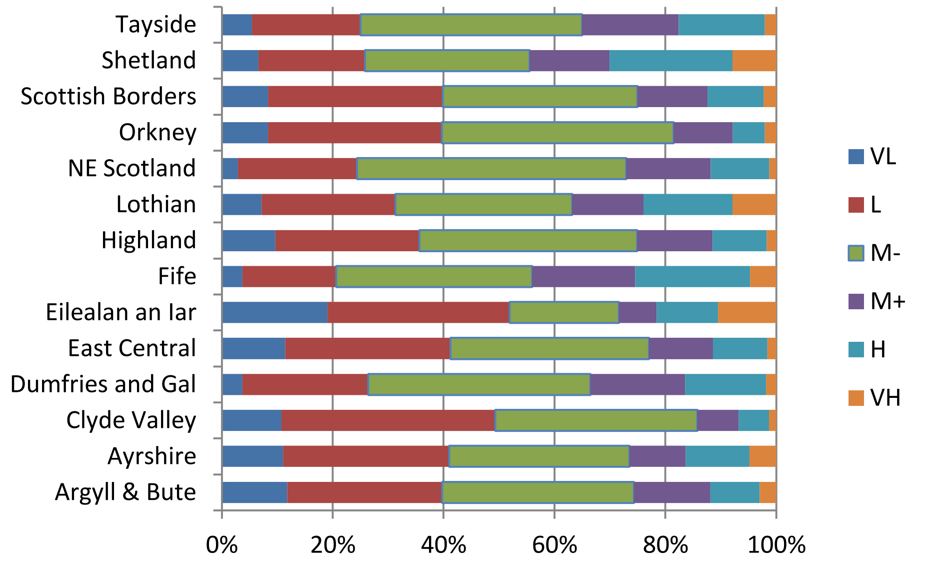


Figure 13. Distribution of soil pH across sub-regions, summarised into 5 pH ranges.

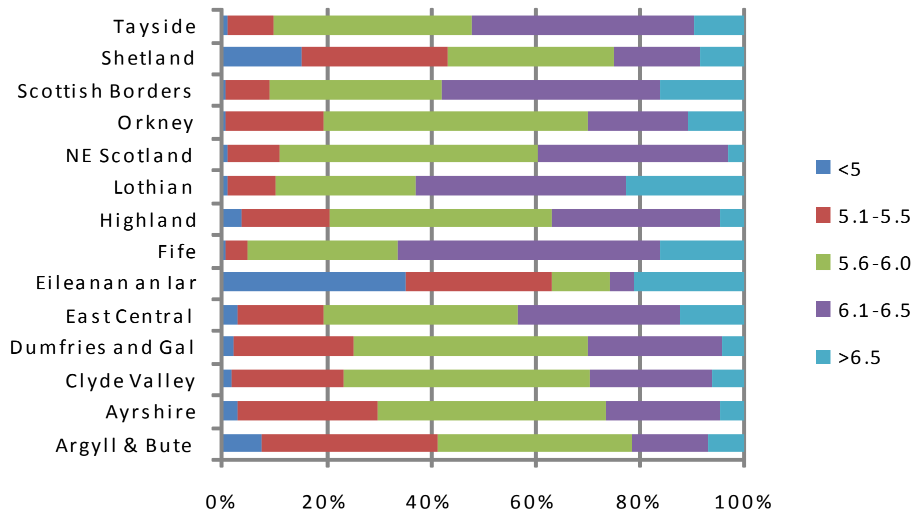
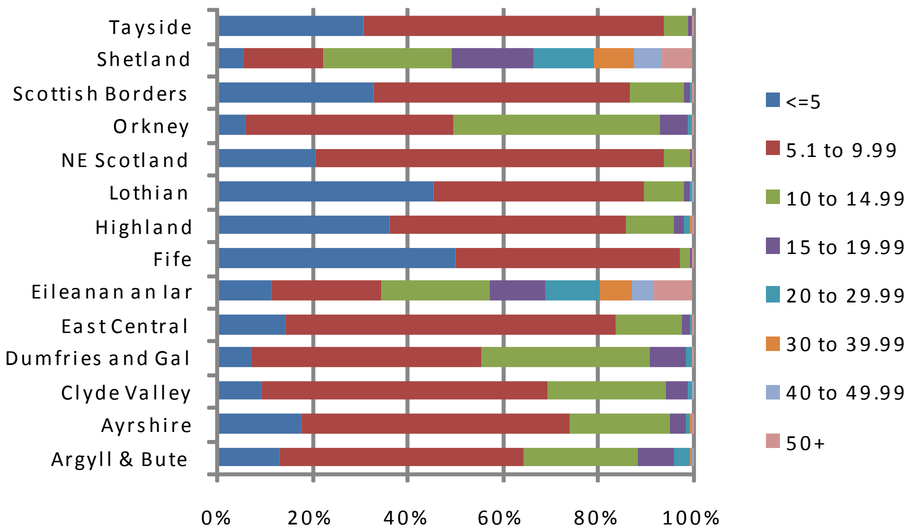
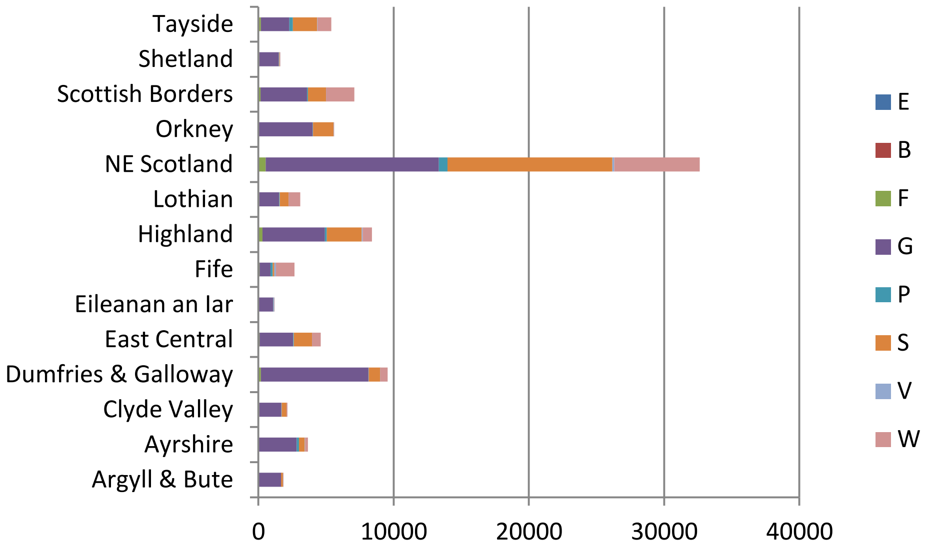


Figure 14. Distribution of DOM across all sub-regions, summarised into 8 DOM classes.



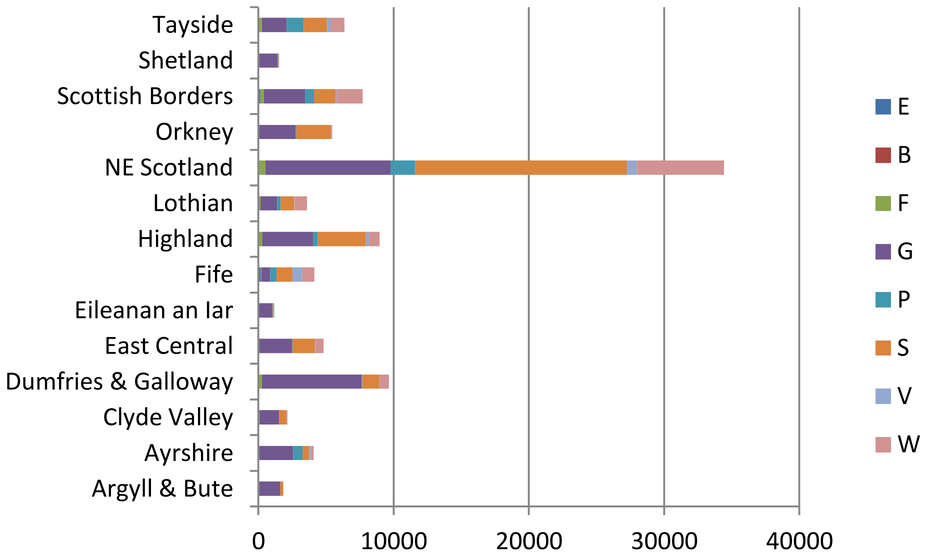
Soil fertility has generally been managed over a rotation but there are fewer areas where mixed arable/grass rotations are still practiced and soil samples typically collected every 5 years. The dominant crops vary between regions as we might expect from the differences in farm enterprises/types. This is indicated in Figure 15 which shows the crop immediately prior to soil sampling. A large proportion of samples are collected from grassland, spring barley and winter oilseed rape and only 67 samples after berries. Figure 16 shows the crop immediately after sampling.

Figure 15. Numbers of soil samples summarised by sub-region and previous crop.



(W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B - berries).

Figure 16. Numbers of soil samples summarised by sub-region and next crop.

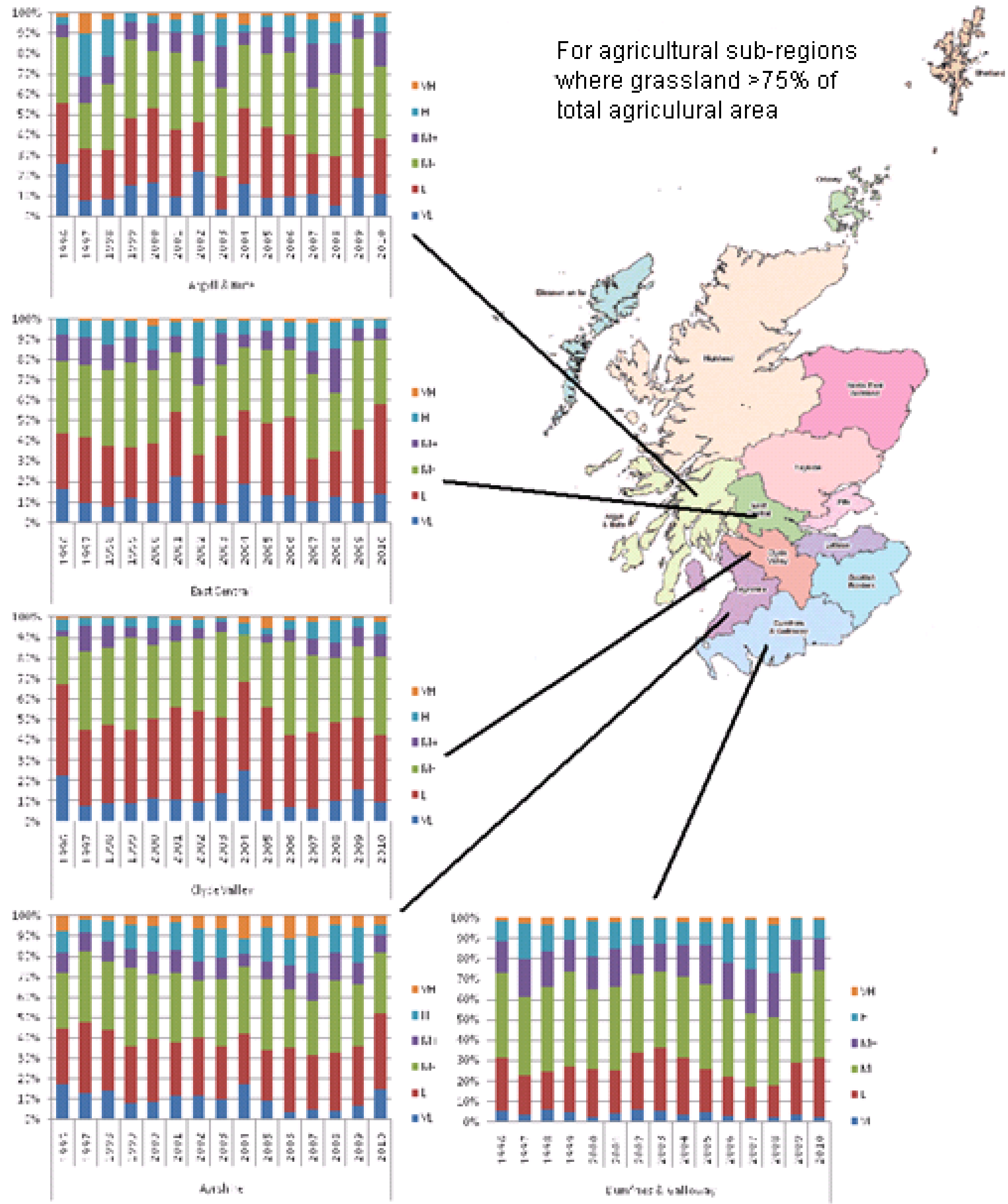


(W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B - berries).

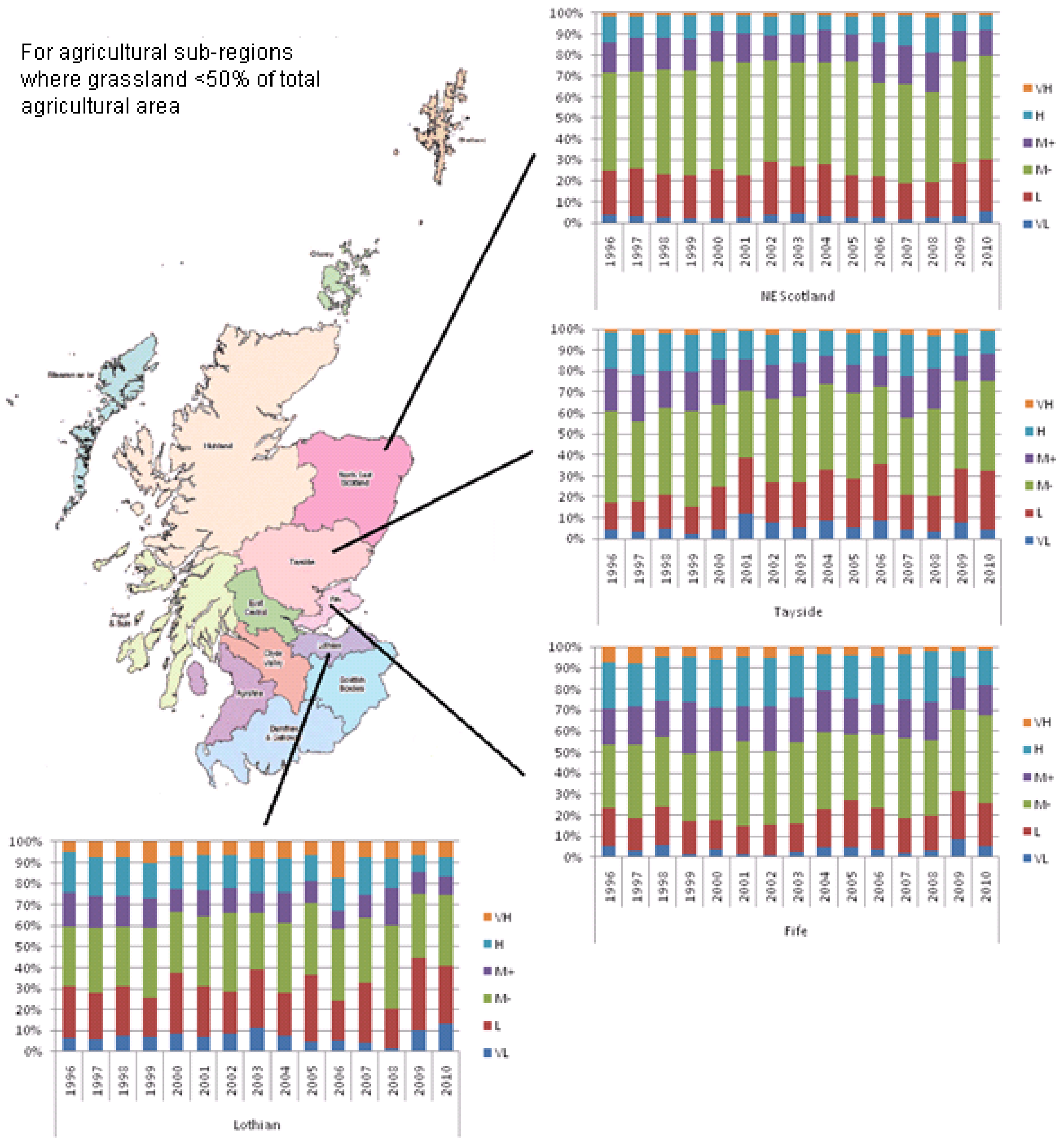
Trends in extractable soil P with time are summarised by Scottish sub-regions in Figure 17, and it should be remembered that total numbers of samples within each box plot start to get smaller.

Figure 17. Trends in extractable soil P status with time summarised by Scottish sub-regions grouped according to land use, where a) those regions where grassland represents >75% of agricultural area, b) those regions where grassland represents <50% of agricultural area and c) intermediate regions and the Islands.

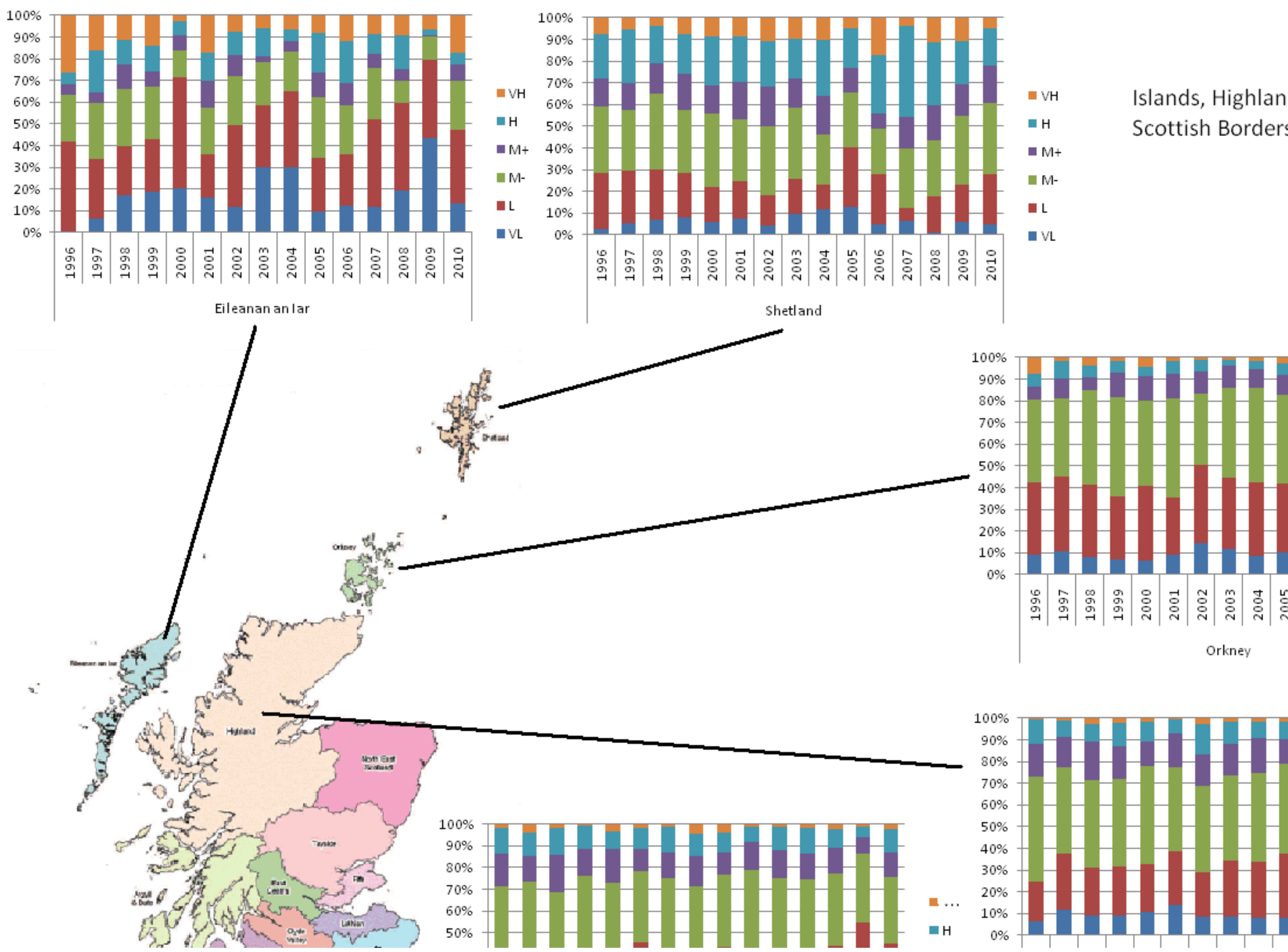
a)



b)


For agricultural sub-regions
where grassland <50% of total
agricultural area
NE Scotland
Tayside
Fife
Lothian
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
VH
H
M+
M-
L
VL

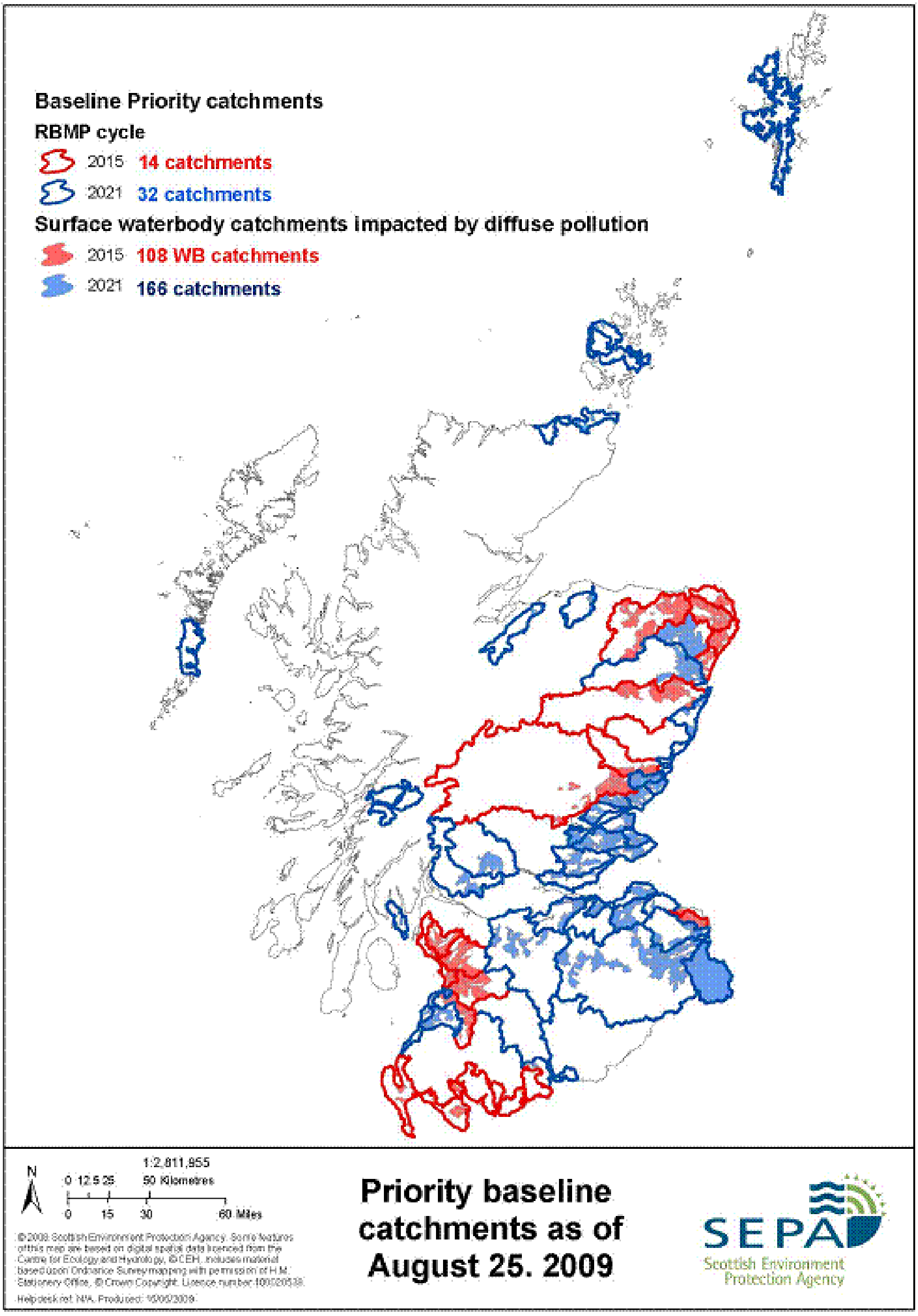
c)


Eileanan an Iar
Shetland
Orkney
Islands, Highlan
Scottish Borders
VH
H
M+
M-
L
VL
Highland
North East Scotland
Tayside
Fife
Lothian
Argyll & Bute
West Central
Clyde Valley

6. Priority and Diffuse Pollution Monitored Catchment data

Data for the 14 SEPA priority catchments plus River Ythan and Lunan Water (DPMCs) using post codes to locate soil samples within catchments are summarised in the following Figures/Tables. Figure 18 shows the SEPA 14 Priority catchment areas and Table 11 provides further details. In this section the advisory soils data have been selected and summarised on the basis of the priority catchment boundaries.

Figure 18. Map showing the SEPA 14 Priority catchment areas (in red) and the possible 2015-2021 Priority catchments (in blue).



The number of soil samples collected from each catchment area varied greatly (Tables 11 and 12) and some indication of the sampling density can be obtained by dividing the average number of samples collected per year by catchment area. The greatest sampling density was for the east coast catchments and especially the South Esk.

Table 11. Number of advisory soil samples collected from within each of the 14 Priority catchments (plus River Ythan and Lunan Water DPMCs).

Catchment number	Catchment	Area arable plus improved grass (ha)	Samples per year	Representative area (ha) per sample
32	River Ugie	27972	90	312
33	River Ythan	50127	258	194
37	River Dee (Grampian)	40780	175	233
30	River Deveron	77238	263	294
46	River Tay	94886	355	268
41	River South Esk	18036	508	36
89	River Ayr	26864	21	1287
90	River Irvine	23616	19	1274
91	River Garnock	9744	7	1405
67	Eye Water	10126	25	413
77	Stewartry Coastal	35040	44	795
87	River Doon	25769	13	1942
88	North Ayrshire Coastal	18212	93	195
80	Galloway Coastal	91605	60	1518
31	Buchan Coastal	43815	180	244
42	Lunan Water		30	

(red assumed 80% of total area arable plus improved grass)

Figure 19 summarises the soil P status for the SEPA Priority catchments (plus 2), shown as a proportion of the total number of samples. Differences are apparent, with about 60% of samples from the River Garnock being very low and low compared with only ~ 10% for the Lunan and South Esk. The proportion of samples with either a H or VH status varied between 20% (Galloway Coastal) to <1% (Garnock). Extractable soil P concentrations are shown in the individual catchment summaries.

Figure 19. A summary of the soil P status for the SEPA Priority catchments (plus 2 DPMCs) shown as a proportion of the total number of soil samples.

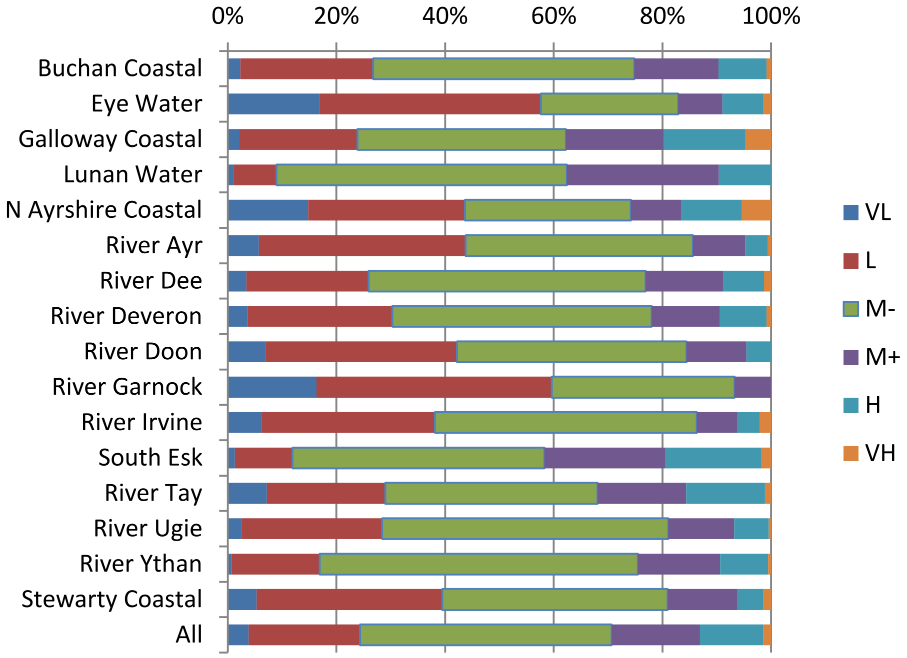


Table 12 summarises Derived organic matter (DOM), soil pH and soil P in each catchment. Typically soils from the west coast catchments had greater organic matter contents and lower pH. The generally lower organic matter of east coast catchments is evident by the maximum values of Lunan Water and South Esk.

Table 12. Summary of soil P, Derived organic matter (DOM) and soil pH in each catchment (no means for pH are given as this is a log number and should not be averaged).

Extractable-P

Catchment area	Count	Mean	SE Mean	Minimum	Median	Maximum
River Deveron	3939	7.5	0.12	0.2	6.1	158.4
Buchan Coastal	2693	7.9	0.13	0.3	6.6	162.5
River Ugie	1344	7.0	0.12	0.9	6.1	43.5
River Ythan	3876	8.0	0.08	0.6	7	74.6
River Dee (Grampian)	2629	7.9	0.16	0.2	6.6	160.4
River South Esk	7615	10.1	0.08	0.1	8.5	198
Lunan Water	447	9.0	0.18	1	8.6	27.2
River Tay	5320	8.4	0.11	0	6.9	198
Eye Water	368	6.1	0.40	0.2	3.8	96.8
Stewartry Coastal	661	7.1	0.38	0.7	5.3	174.2
Galloway Coastal	905	11.0	0.53	0.9	7.7	198
River Doon	199	6.0	0.26	0.1	5.3	22.2
North Ayrshire C	1399	9.5	0.44	0	5.4	259.3
River Ayr	313	6.1	0.27	0.4	5.1	44.1
River Irvine	278	7.6	0.99	0.6	5.2	254
River Garnock	104	4.4	0.28	0.6	3.7	13.5

DOM (%)

Catchment area	Count	Mean	SE Mean	Minimum	Median	Maximum
River Deveron	3939	7.4	0.04	1.9	7.3	82.7
Buchan Coastal	2693	6.8	0.04	1.3	6.8	25.9
River Ugie	1344	7.2	0.06	2.8	7	34.1
River Ythan	3876	7.4	0.03	1.9	7.3	20.9
River Dee (Grampian)	2629	6.6	0.06	1.3	6.1	58.6
River South Esk	7615	5.5	0.02	1.2	5.3	21.9
Lunan Water	447	5.6	0.07	2.8	5.3	13.4
River Tay	5320	6.3	0.04	1.1	5.8	51.1
Eye Water	368	8.0	0.13	3.5	7.7	26.6
Stewartry Coastal	661	11.2	0.14	3.3	10.9	29.1
Galloway Coastal	905	9.1	0.13	1.8	8.5	41.2
River Doon	199	9.7	0.37	4.3	8.1	46.6
North Ayrshire C	1399	8.8	0.18	0.8	7.3	80.9
River Ayr	313	8.5	0.16	3.3	8.4	20.9
River Irvine	278	8.3	0.27	3.3	7.5	72.6
River Garnock	104	10.8	0.27	3.9	11.2	17.7

pH

Catchment area	Count	Mean	SE Mean	Minimum	Median	Maximum
River Deveron	3939			4.1	5.9	7.9
Buchan Coastal	2693			4.7	5.9	7.8
River Ugie	1344			4.0	5.9	7.8
River Ythan	3876			3.9	6.0	7.9
River Dee (Grampian)	2629			4.1	5.9	7.7
River South Esk	7615			4.0	6.1	8.1
Lunan Water	447			4.3	6.0	7.0
River Tay	5320			3.8	6.0	8.0
Eye Water	368			4.8	6.1	6.9
Stewartry Coastal	661			4.7	5.8	6.9
Galloway Coastal	905			4.5	5.8	8.2
River Doon	199			4.6	5.9	7.1
North Ayrshire C	1399			3.3	5.9	8.4
River Ayr	313			4.9	5.7	7.4
River Irvine	278			4.5	5.7	7.3
River Garnock	104			5.1	5.5	7.6

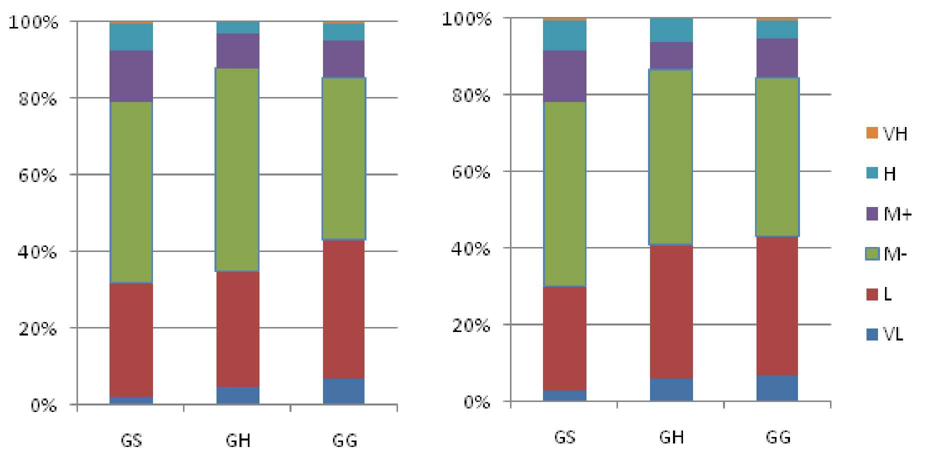
Table 13 shows the proportion (%) of samples having ‘next crop’ information for each catchment which again vary widely. Typically grassland samples were dominant in the SW catchments compared to mixed arable/grassland for those catchments located in the NE of Scotland. The greatest proportion of samples that were expected to have potatoes as the next crop was from the Lunan followed by the Ythan catchment areas.

Table 13. Proportion (%) of samples having 'next crop' information (B- berries, E – peas, F- fodder, G- grass, P- potatoes, S- spring, V- vegetables, W- winter and X- set aside/other).

	B	E	F	G	P	S	V	W	X	Missing
Buchan Coastal	0	0	1	30	1	38	0	21	4	6
Eye Water	0	1	2	38	0	14	0	12	2	30
Galloway Coastal	0	0	1	57	1	18	0	7	2	12
Lunan Water	0	0	0	2	16	6	1	3	0	72
N Ayrshire Coastal	0	0	0	18	0	2	0	2	1	77
River Ayr	0	0	0	61	0	16	2	8	2	11
River Dee	0	0	4	38	5	38	1	5	3	7
River Deveron	0	0	1	20	3	50	0	20	3	3
River Doon	0	0	1	68	0	5	0	9	5	14
River Garnock	0	0	1	77	0	7	0	5	1	10
River Irvine	0	0	0	56	1	15	0	14	2	12
South Esk	0	0	0	1	2	1	0	1	0	94
River Tay	0	0	1	13	6	10	1	4	2	61
River Ugie	0	0	0	16	1	47	0	27	3	5
River Ythan	0	0	1	15	11	32	4	30	2	4
Stewarty Coastal	0	0	1	78	0	6	1	4	1	8

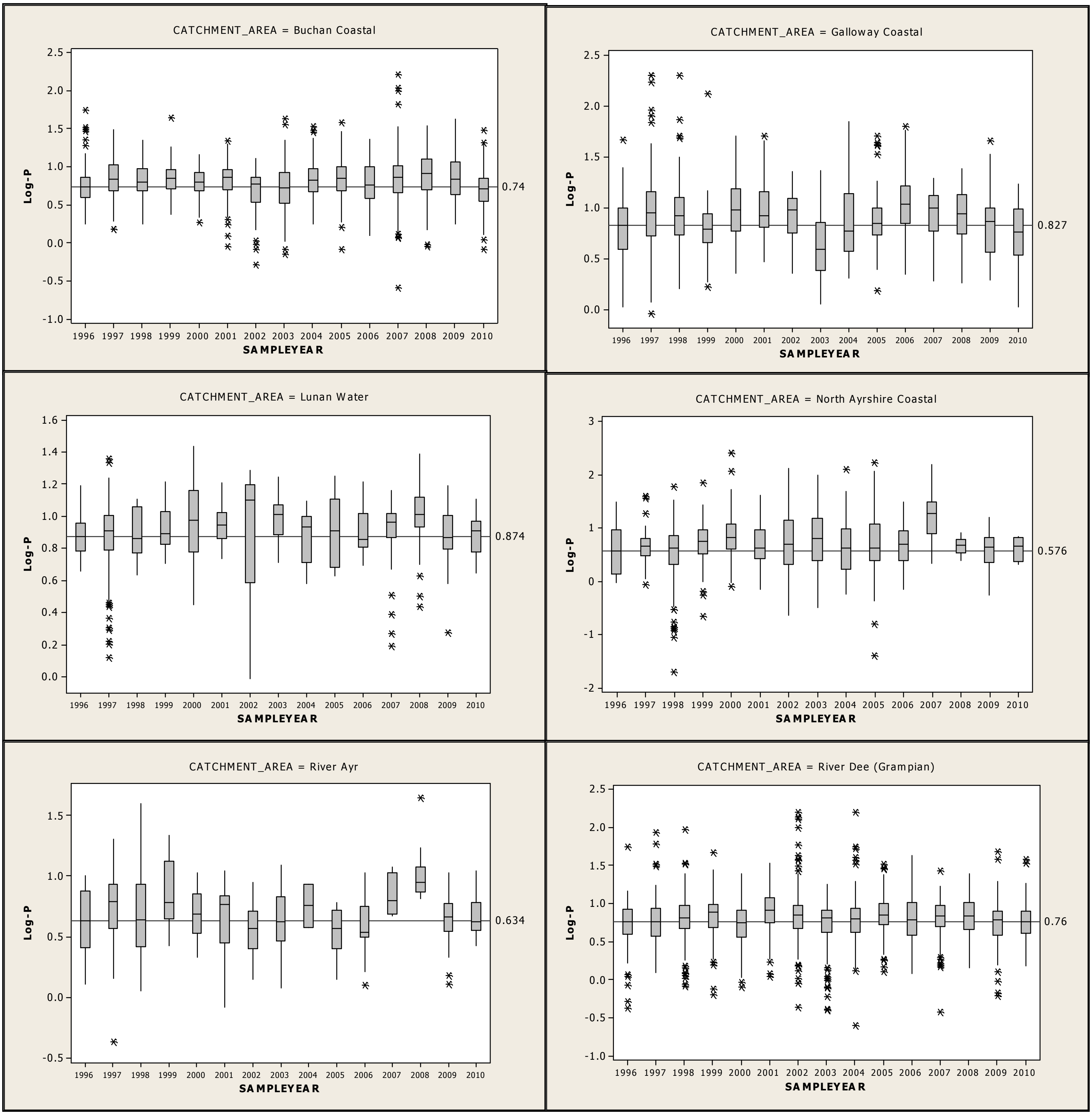
One aspect of grassland ("Grass") is that it can represent a wide level of potential productivity (i.e. fertiliser/manure input) and management. Some information is provided regarding the management involved which allowed a further division into three management types: silage, hay and grazed. Soil P data are summarised for priority catchments in Figure 20 using these divisions. The suggestion is that the soil P status is higher for grassland used to produce silage.

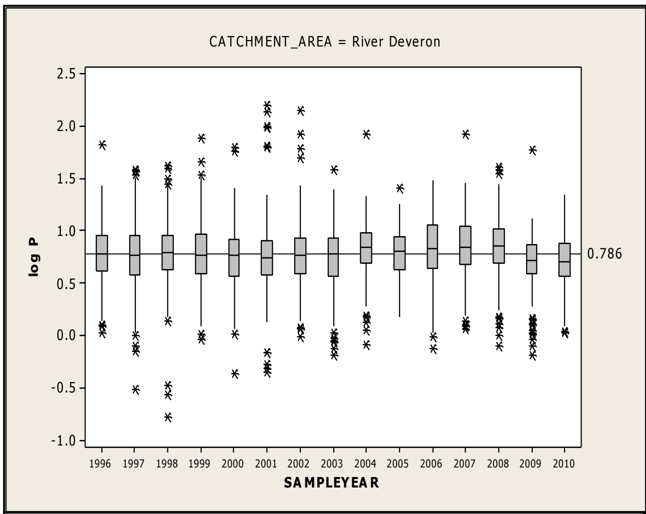
Figure 20. Summary of soil P data for priority catchments for various types of grass (GS – silage, GH – hay and GG – grazed) as previous (left, total samples GS-1339, GH-124, GG-5115) and next (right, GS-1084, GH-83, GG-3602) crop.

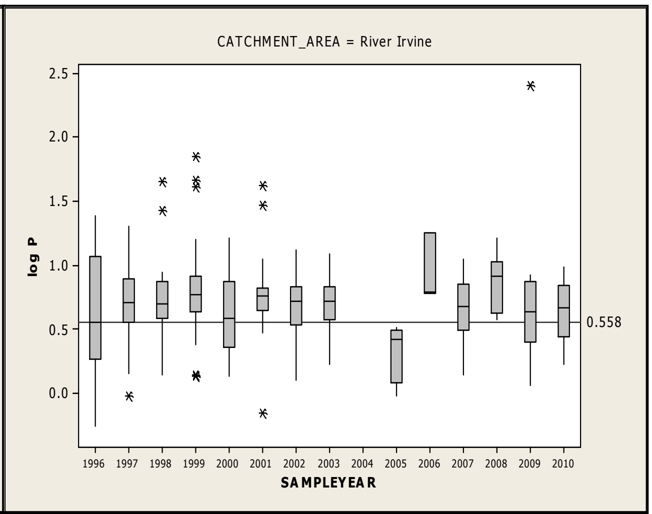


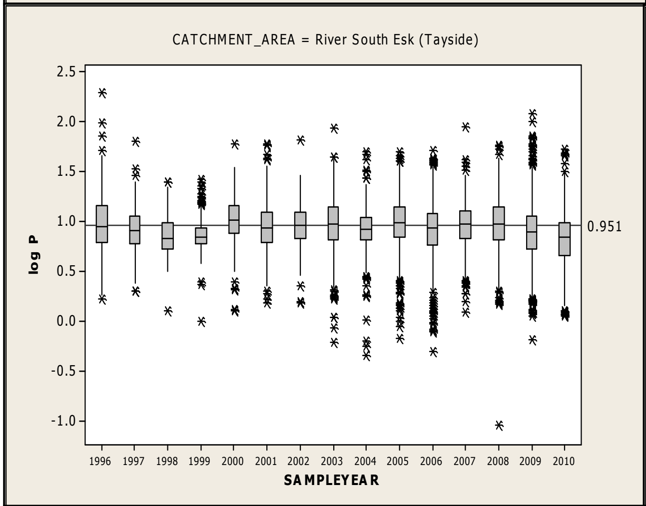
Trends in extractable soil P with time are summarised by Priority catchments (plus 2 DPMCs) in Figure 21.

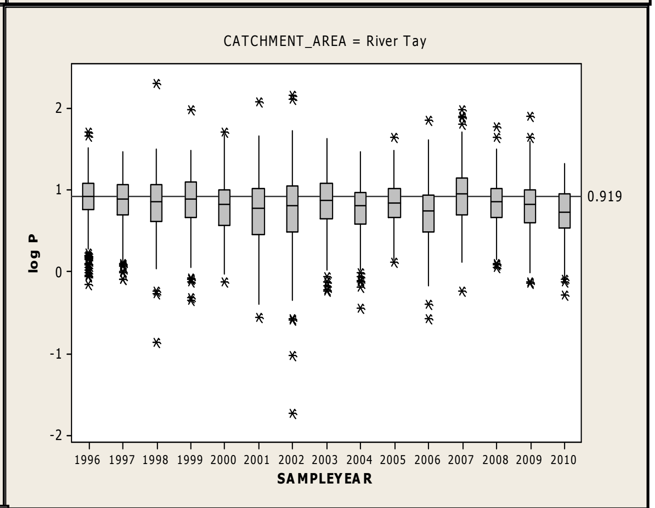
Figure 21. Trends in extractable soil P (log) with time summarised by Priority catchments (plus 2 DPMCs).

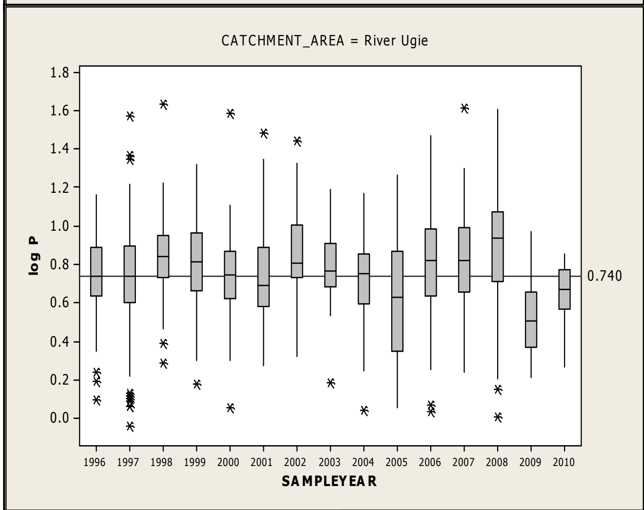


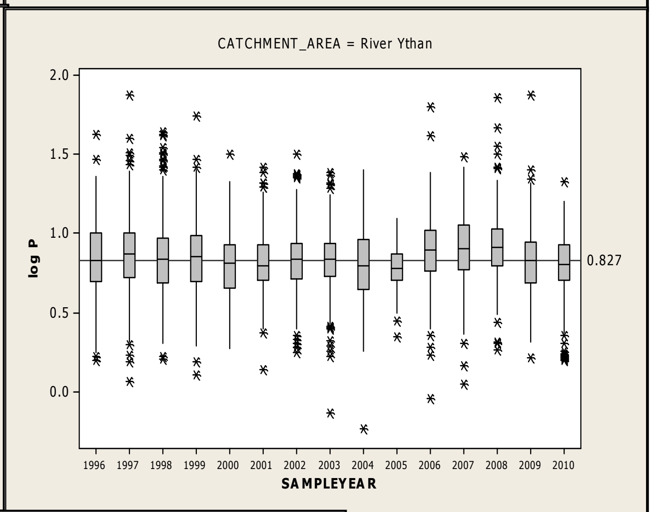

CATCHMENT_AREA = River Deveron
log P
0.786
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

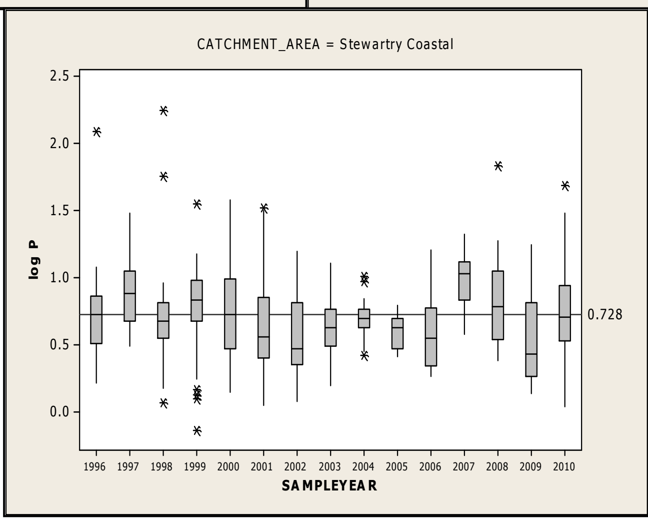

CATCHMENT_AREA = River Irvine
log P
0.558
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


CATCHMENT_AREA = River South Esk (Tayside)
log P
0.951
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


CATCHMENT_AREA = River Tay
log P
0.919
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


CATCHMENT_AREA = River Ugie
log P
0.740
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


CATCHMENT_AREA = River Ythan
log P
0.827
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010


CATCHMENT_AREA = Stewartry Coastal
log P
0.728
SAMPLEYEAR
1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010

7. Case studies Rivers Ythan and Irvine catchments

The Rivers Ythan and Irvine have been selected as the two catchments for an assessment of what information could be gleaned from available data to help the risk assessment process. These two catchments differ with respect to climate, soil attributes and farming systems, which together mean that they have a range of contrasting issues. They also allow some general conclusions to be made regarding the key processes that are likely to operate and environmental issues that are likely to arise together with the value of any national risk assessment of P leaching.

7.1 River Ythan catchment data

Extractable P data for the period 1996-2010 are summarised in Figures 22 and 23. The mean of 3876 samples is 8.01 mg P/l and the whole sample population shows a normal distribution with 50% of the samples falling between 5.15-9.42 mg P/l. Although not consistent there is an apparent reduction in samples with either a H or VH status, which is also suggested in the whole soil data base. Table 14 summarises extractable P, DOM and soil pH for individual years. Table 15 shows the number of soil samples distributed by soil P status prior to next crop where two thirds of the samples were expected to have either spring or winter sown crops. The majority of the remaining samples were either potatoes or grass.

Figure 22. Summary of soil extractable P in River Ythan catchment.

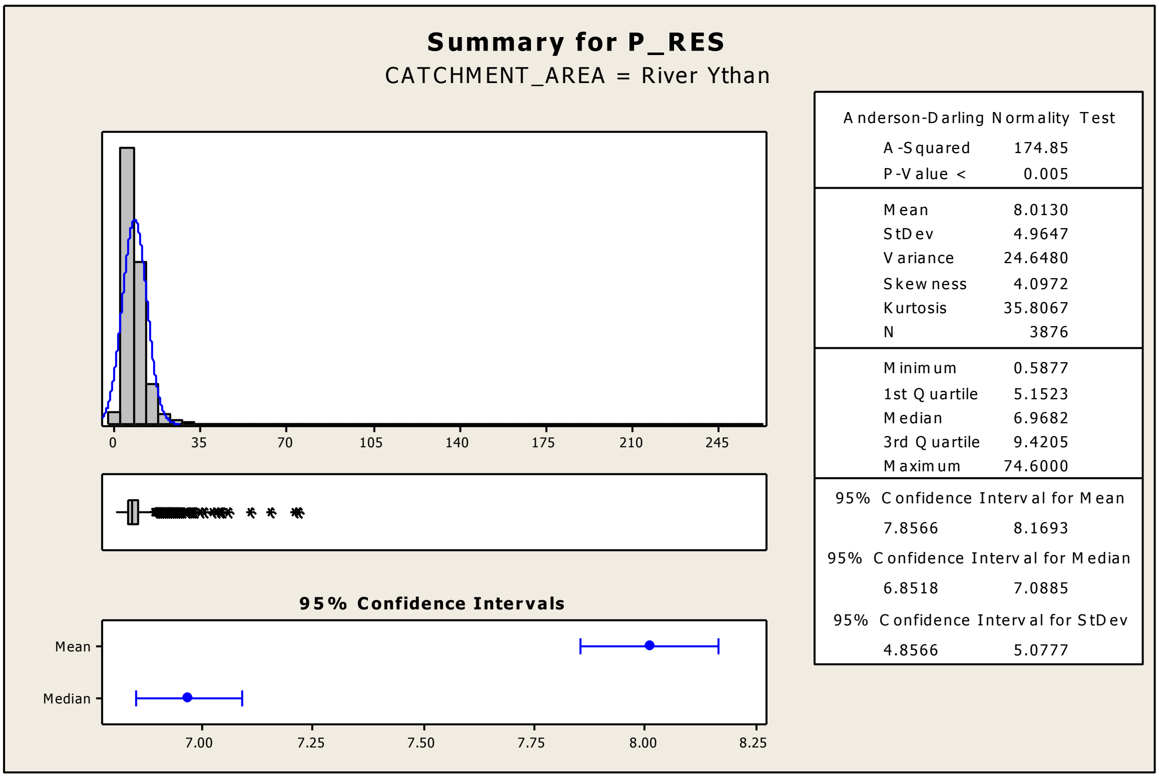


Table 14. Summaries of extractable P, DOM and soil pH for individual years.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	208	8.2	0.35	1.6	6.7	42.6
1997	417	8.7	0.30	1.2	7.4	74.6
1998	347	8.3	0.32	1.6	6.9	43.6
1999	348	8.2	0.28	1.3	7.2	55.2
2000	231	7.1	0.24	1.9	6.5	32.1
2001	242	7.4	0.25	1.4	6.3	26.1
2002	372	7.5	0.20	1.8	6.8	32.0
2003	212	7.6	0.26	0.7	6.8	24.1
2004	191	7.3	0.28	0.6	6.2	25.2
2005	160	6.3	0.15	2.2	6.0	12.4
2006	245	8.8	0.36	0.9	8.0	62.7
2007	266	9.0	0.27	1.1	8.0	30.4
2008	274	9.3	0.38	1.8	8.3	72.8
2009	153	7.9	0.55	1.6	6.8	74.5
2010	210	6.8	0.20	1.6	6.4	21.4

DOM (%)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	208	8.0	0.18	3.0	7.5	20.9
1997	417	7.5	0.11	2.2	7.1	17.0
1998	347	7.0	0.09	2.4	7.0	14.6
1999	348	7.2	0.10	2.2	7.4	14.9
2000	231	7.7	0.09	3.8	7.6	14.9
2001	242	8.1	0.10	4.0	7.9	16.1
2002	372	7.8	0.08	4.5	7.6	14.3
2003	212	7.1	0.09	4.2	7.0	11.3
2004	191	7.4	0.11	1.9	7.2	13.3
2005	160	7.7	0.14	4.0	7.5	15.0
2006	245	7.4	0.09	4.9	7.2	15.5
2007	266	7.7	0.14	2.1	7.6	19.4
2008	274	5.2	0.12	4.0	4.0	12.8
2009	153	7.3	0.10	5.1	7.2	13.3
2010	210	8.0	0.11	4.1	7.8	13.2

Soil pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	208			3.9	6.0	6.7
1997	417			4.0	5.9	7.6
1998	347			4.8	6.0	7.8
1999	348			4.7	6.0	6.9
2000	231			4.8	6.0	7.4
2001	242			4.9	6.0	7.0
2002	372			4.9	6.0	6.9
2003	212			5.2	6.0	6.6
2004	191			4.8	5.9	7.9
2005	160			5.2	6.0	6.5
2006	245			5.2	6.0	7.1
2007	266			4.8	5.9	6.8
2008	274			4.8	6.0	6.9
2009	153			5.0	6.0	6.8
2010	210			5.0	6.0	6.5

Figure 23. P status distribution with time.

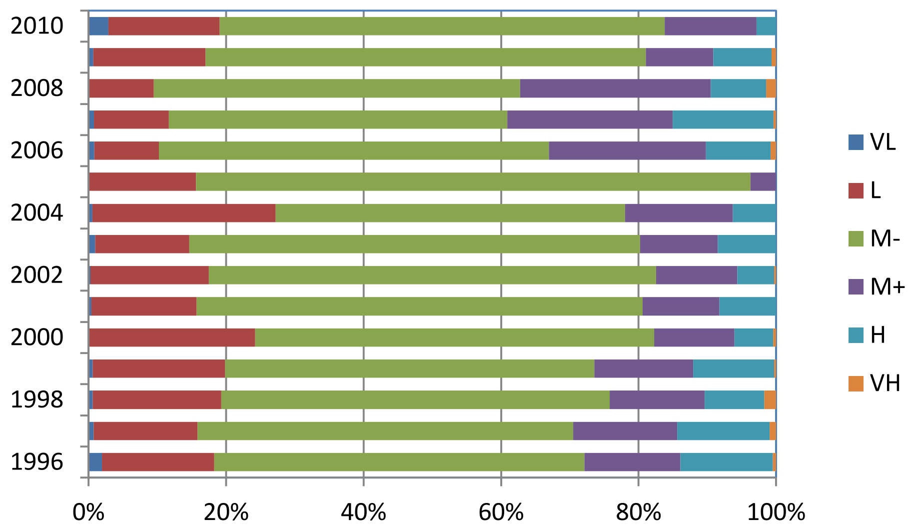


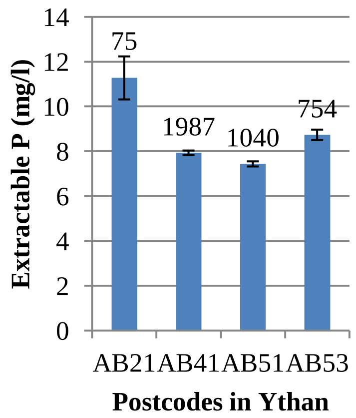
Table 15. Number of soil samples distributed by soil P status prior to next crop. (W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries, X – other crops and set aside).

River Ythan	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	14	4	7	1	1	0	0
L	0	0	8	177	101	215	8	86	14	19
M-	2	2	16	324	260	751	42	748	51	75
M+	0	0	1	53	54	170	47	228	13	21
H	0	0	1	24	25	97	48	116	6	24
VH	0	0	0	2	0	4	6	1	5	4
All	2	2	26	594	444	1244	152	1180	89	143

7.2 Identification of hotspots of extractable P within the Ythan catchment

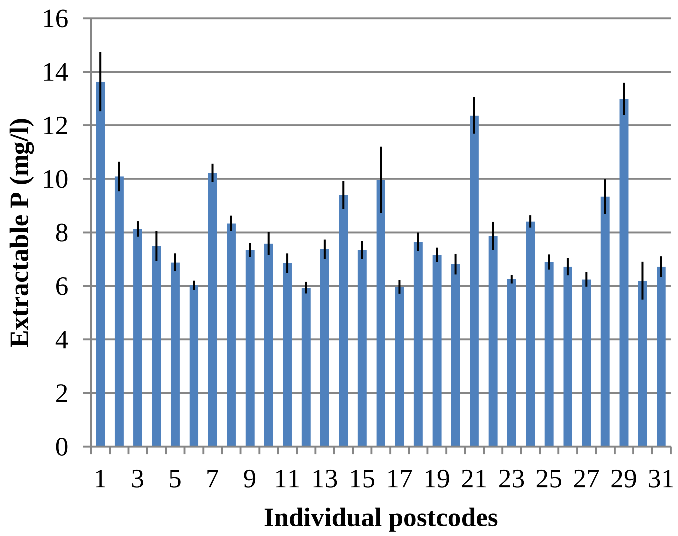
Data were extracted using the first 4 letters of the postcode and summarised in Figure 24. For those three areas having the largest number of samples the variation between means was small.

Figure 24. A summary by postcode (first 4 digits) of extractable P data 1996-2010 from the Ythan catchment NE Scotland. Showing the mean, SE and total number of samples within each postcode.



A further separation has been made making use of the whole postcode but only where more than 40 samples have been collected (Figure 25). Because of anonymity rules the full post codes are not shown but 31 of the 126 full codes had more than 40 samples over the time period. This more detailed level of separation suggests that some variability does occur within this catchment.

Figure 25. Summary of mean and standard error averaged for each full post code within the Ythan catchment where more than 40 soil sample results exist.



7.3 River Ythan catchment overview

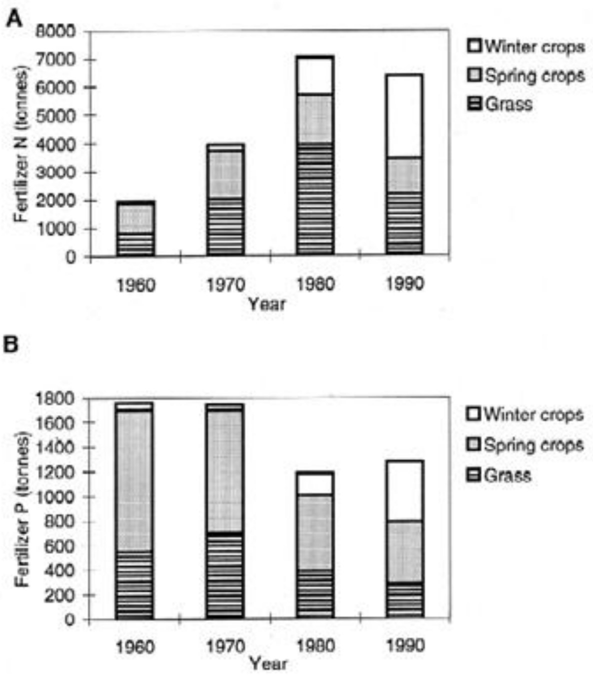
During the mid 1990s an intensive study of various farming activities were collated for the Ythan catchment and this was a direct result of potential designation as a Nitrate Vulnerable Zone. The project funded by the Scottish Office involved staff from the Macaulay Institute and SAC. Catchment specific information was obtained through a survey questionaire which was detailed and had the backing of NUFS. Some of the relevant figure and tables are reporduced here and provide a background to nutrient use in Scottish agriculture for the period 1960 to 1990. Domburg et al. (1998) reviewed the use of fertilisers for the main crop types in the Ythan catchment from 1960 to 1990 (see Table 16 and Figures 26 - 29). Importantly this information shows a complex trend in fertiliser use for different crops. In general the amount of N applied increased over time while in many cases the amounts of P applied declined. N and P budgets for main farm types and the whole catchment are given in Tables 17, 18 and 19.

Table 16. Average fertiliser use around 1960, 1970, 1980 and 1990 (from Domburg et al., 1998).

Crops and Grass	N (kg/ha)				P (kg/ha)			
	1960[1]	1970[2]	1980[3]	1990[4]	1960[1]	1970[2]	1980[3]	1990[4]
Winter wheat	58[a]	89[b]	195	193	36[a]	20[b]	27	35
Barley spring	43	75	78	78	32	35	21	25
winter	43	75	197	176	32	35	27	29
Spring oats	30	32	65	63	27	34	19	21
Turnips / Swedes	55	85	70	70	101	64	61	62
All potatoes	93	104	152	124	66	91	70	78
Oilseed rape spring	–	–	-	75[c]	–	–	–	26[c]
winter	–	–	–	204	–	–	–	28
Grass								
Cut for silage	48	214	195	162	34	46	19	16
Cut for hay	48	36	91	88	34	43	22	18
Grazing	16	56	117	60	10	11	9	9

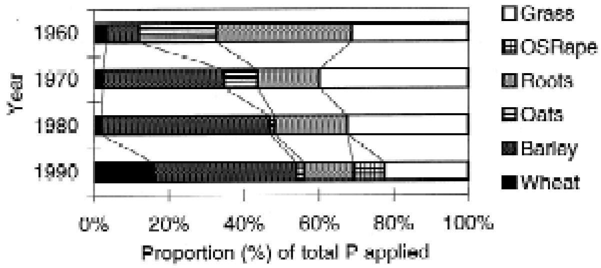
[1]North of Scotland College of Agriculture & the Agricultural Research Council, Unit of Statistics, Aberdeen (1965).
[2]Based on field trials carried out by the Macaulay Institute for Soil Research on farms within the Ythan catchment area around 1970.
[3]Scottish Colleges of Agriculture, Rothamsted Experimental Station & Fertiliser Manufacturers Association (1984).
[4]AFRC (1991).
[a]North of Scotland College of Agriculture & the Agricultural Research Council, Unit of Statistics, Aberdeen (1958).
[b]Agricultural Development and Advisory Service, Rothamsted Experimental Station & Fertiliser Manufacturers Association (1975).
[c]SAC (1992b).

Figure 26. Use of fertilisers for the main crop types in the Ythan catchment. A) Fertiliser N; B)



Fertiliser P (from Domburg et al., 1998).

Figure 27. Changes in the distribution of fertiliser P applied to the main crops (data from Domburg et al. 1998)



The overall effect of these differences in rates of application and cropping areas is a change in the distribution of fertiliser P. Since 1960 there is a decline in the proportion applied to the root crops (swedes and potatoes) compared to a large increase in that applied to cereal crops.

Using the specific questionnaire survey for the cropping year1994 allowed the grouping of data on the basis of robust farm type showed differences in the rates of P applied to individual crops. Potatoes received by far the most fertiliser P.

Figure 28. Area weighted application rates of inorganic fertiliser P in 1994 to a range of crops per farm type: (WW, winter wheat; WB, winter barley; WOSR, winter oilseed rape; SB, spring barley; SO, spring oats; SOSR, spring oilseed rape; POT, potatoes; TS, turnips/swedes; H, hay; SI, silage ; GR, grazing. Farm types: ○, cereals ; ●, general cropping; □, pigs; ■, dairy; △, cattle and sheep (LFA); ▲, cattle and sheep (low ground); ◇, mixed (from Domburg et al., 2000).

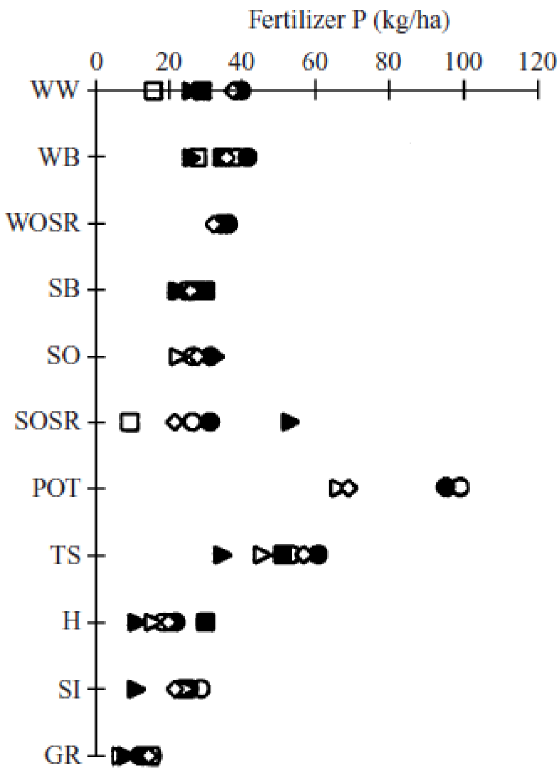


Figure 29. Comparison between Left - fertiliser P application rates in Scotland and those in the Ythan catchment in 1994 and Right - application rates of inorganic P fertilizer on individual crops between farms that do and those that do not apply animal manure (farm yard manure (FYM) or slurry).

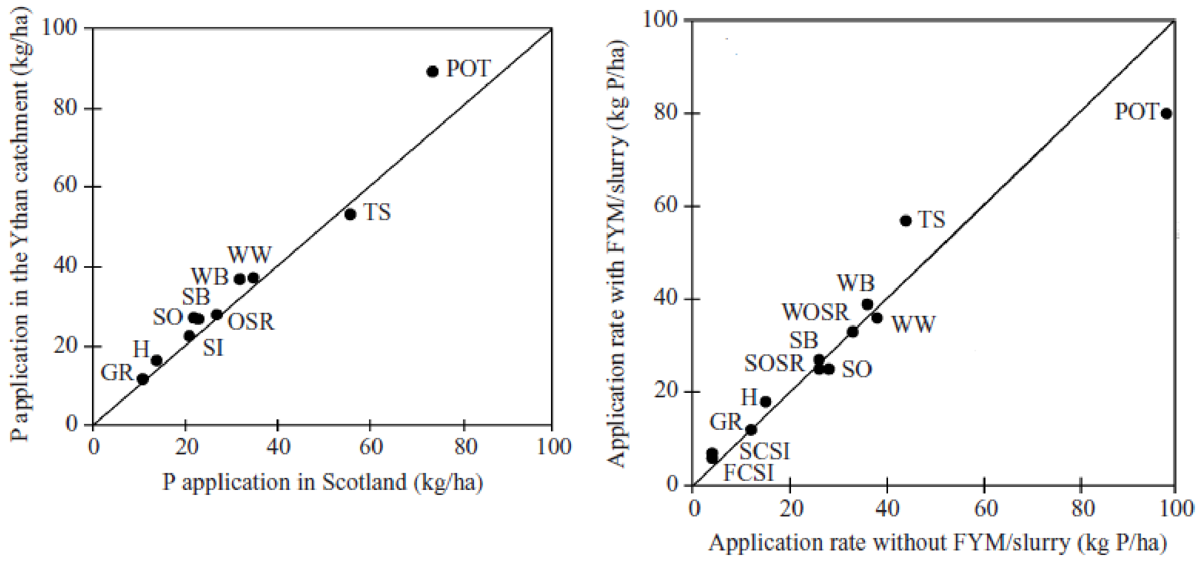


Table 17. Annual input, output and surplus of N and P per farm type (kg ha^{-1} y^{-1}).

	N			*P*		
Farm type	*Input*	*Output*	*Surplus*	*Input*	*Output*	*Surplus*
Cereals	154	84	70	30	16	14
General cropping	212	108	104	56	23	33
Pigs and poultry	1030	510	520	320	119	202
Dairy	239	66	173	44	14	30
Cattle and sheep (LFA)	134	15	119	19	4	15
Cattle and sheep (lowground)	192	74	118	17	8	10
Mixed	190	71	119	40	16	24

Table 18. Catchment N and P budgets (tonnes) for the Ythan in 1994 related to seven farm types (totals in kg ha^{-1} y^{-1} in parentheses) (Domburg et al., 2000).

Catchment budget	*N*	*P*
Input		
Seed	75	13
Fertiliser	6231	1163
Feed	1527	817
Animals	610	188
Fixation	1079	
Atmosphere	798	12
Total	10 320 (194)	2193 (41)
Output		
Crops	2903	490
Milk	136	29
Eggs	41	5
Animals	1472	421
Total	4552 (86)	945 (18)
Surplus	5769 (108)	1248 (23)

Table 19. Total catchment N and P budgets (t) divided over arable and livestock farming, based on seven main farm types (totals in kg ha^{-1} y^{-1} in parentheses) for the year 1994.

	N		*P*	
Budget	*Arable*	*Livestock*	*Arable*	*Livestock*
Total input	4707 (175)	6963 (350)	1144 (43)	1430 (72)
Total output	3518 (131)	2481 (125)	631 (23)	697 (35)
Surplus	1189 (44)	4482 (225)	513 (19)	733 (37)

7.4 River Irvine catchment data

Extractable P soils data for the period 1996-2010 are summarised in Figures 31 and 32. The mean of 278 samples was 7.62 mg P/l with half the samples falling between 3.6 – 7.33 mg P/l with a slightly skewed population towards higher concentrations. The median was 5.32 mg P/l. Table 20 summarises extractable P, DOM and soil pH for individual years. The data for the Irvine, and other grass-dominated catchments' show that soil pH for most of the samples are below optimum. To justify maximum inputs of P, soil acidity must be managed since it will restrict maximum yields resulting in a P surplus.

Figure 31. Summary of soil extractable P for River Irvine catchment.

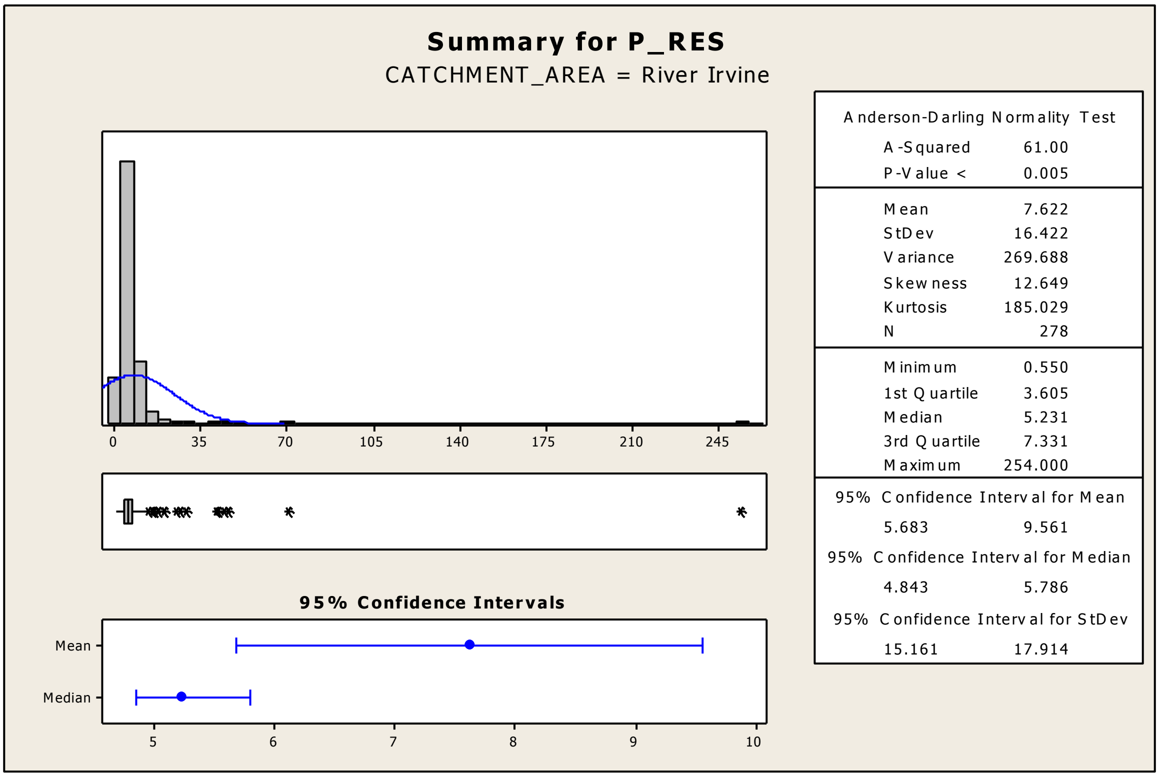


Table 20. Summaries of extractable P, DOM and soil pH for individual years.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	11	6.5	2.15	0.6	3.6	24.5
1997	44	6.5	0.70	1.0	5.1	20.2
1998	20	8.1	2.24	1.4	5.0	44.7
1999	55	8.7	1.53	1.4	6.0	70.5
2000	14	5.3	1.08	1.4	3.8	16.3
2001	30	7.5	1.47	0.7	5.7	41.8
2002	27	5.2	0.49	1.3	5.2	13.3
2003	30	5.5	0.41	1.7	5.2	12.3
2005	4	2.4	0.50	1.0	2.7	3.2
2006	3	10.0	3.84	6.1	6.2	17.7
2007	9	5.3	0.98	1.4	4.8	11.1
2008	10	8.2	1.29	3.7	8.3	16.2
2009	9	31.9	27.80	1.2	4.3	254.0
2010	12	4.9	0.67	1.7	4.7	9.6

DOM (%)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	11	9.9	0.63	7.3	10.2	13.7
1997	44	7.8	0.37	4.6	7.2	14.5
1998	20	7.3	0.45	5.4	6.4	13.1
1999	55	8.2	0.34	4.0	7.4	15.0
2000	14	8.6	0.52	5.6	8.4	11.2
2001	30	7.3	0.25	3.3	7.4	9.6
2002	27	7.1	0.28	4.3	7.2	9.7
2003	30	8.1	0.37	5.6	7.3	12.9
2005	4	6.3	0.33	5.4	6.6	6.8
2006	3	7.5	1.15	5.9	6.8	9.7
2007	9	9.3	1.12	3.7	8.5	14.7
2008	10	5.8	0.88	4.0	4.0	10.8
2009	9	17.6	6.91	7.6	11.1	72.6
2010	12	10.5	0.45	8.8	10.1	13.5

Soil pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	11			5.3	6.1	6.7
1997	44			4.9	5.7	6.8
1998	20			4.5	5.7	6.4
1999	55			5.2	5.7	7.3
2000	14			5.1	5.5	6.2
2001	30			4.6	5.8	6.2
2002	27			5.3	5.9	6.5
2003	30			5.1	5.8	6.6
2005	4			5.4	5.7	5.9
2006	3			5.2	5.6	6.9
2007	9			5.2	5.8	7.1
2008	10			4.7	5.4	5.8
2009	9			5.0	5.4	5.8
2010	12			5.3	5.5	6.1

Figure 32. P status distribution with time in the River Irvine catchment.

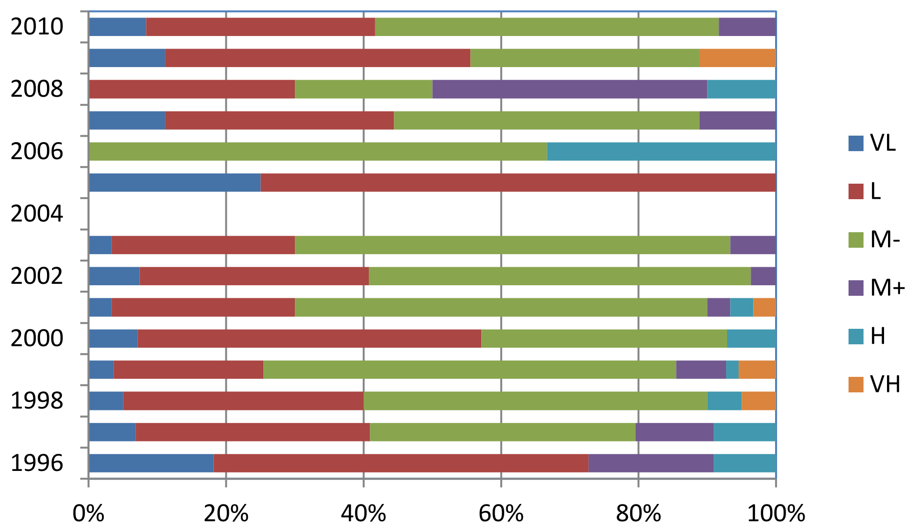


Table 21 shows the number of soil samples distributed by soil P status prior to next crop where two thirds of samples were going into grass and the majority of the remainder being sown with winter or spring arable crops.

Table 21. Number of soil samples distributed by soil P status prior to next crop. (W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries, X – other crops and set aside).

River Irvine	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	12	0	2	0	1	1	1
L	0	0	0	52	0	14	0	13	1	9
M-	0	0	0	72	1	21	0	20	2	18
M+	0	0	0	12	1	3	0	1	0	4
H	0	0	0	8	0	1	0	0	1	1
VH	0	0	0	1	0	0	0	3	1	1
All	0	0	0	157	2	41	0	38	6	34

The River Irvine catchment is underrepresented in the current soil data base given its size and the number of farms (>500) present. Anecdotal evidence supplied by SAC analytical services and the local SAC farm advisors suggest that some farmers do not use a postcode or field identifiers when submitting samples. For many farms the sampling and analysis of soil is done as part of contractual agreement when purchasing fertiliser or off-farm feeds and the analysis may not be conducted by SAC or not submitted under the farm name. There is also a perception among some grassland farmers that soil testing is not a necessary or cost effective nutrient management tool.

The revised SAC technical note TN632 "Fertiliser recommendations for grassland" (Sinclair *et al*., 2010a), and the recently introduced PLANET (Planning Land Applications of Nutrients for Efficiency) (http://www.planet4farmers.co.uk) nutrient management software system, emphasise the need to test grassland soils in individual fields for available nutrients every 4 to 5 years.

Farmer's lack of analytical information on soil P levels forms a risk due to the potential for excessive P build-up with the loading occurring from soil erosion and leaching of soluble forms of P. Targeting a moderate P status (recommendation that extractable soil P is maintained at between 4.5 to 13.4 mg/l based on SAC testing) is still the general guidance advice. The P value of manures, slurries, and other bulky organic fertilisers is generally either discounted or ignored. Increased awareness of diffuse pollution issues combined with increasing and uncertainty in fertiliser prices are resulting in a gradual improvement in understanding and value of organic sources of P, but it is not clear if this has translated into changes in management decisions. Nutrients such as P are often applied systematically by farmers in the Irvine cathcment based on past practice rather than on demonstrated crop requirment. The data show that P levels for over 50% of those soils analysed are at or above moderate P status and P inputs should be restricted accordingly.

7.5 River Irvine catchment overview

Potential agricultural pressure on water quality in the River Irvine catchment is due to the number of livestock reared in the catchment and intensive nature of their production. Current statistics have not been fully correlated as part of this study and the following catchment summary is based in part on SERAD data acquired in 2000 and on the results of the 2008 and 2010 agricultural census data for Ayrshire.

In Ayrshire over 75% of the managed land is under grass and in the Irvine catchment 70% of this is improved grassland. Approximately 20% of Scotland's dairy cows occur in Ayrshire which comprises only 10% of the total area managed as grassland. Only 22% of the land in Ayrshire is arable with the majority of this in the Irvine catchment being for whole crop and strongly linked to animal production. Grass and associated forage crops dominate agricultural production in the Irvine catchment.

The soils in the Irvine catchment are primarily imperfectly drained brown forest soil and surface-water gleys which cover ~ 40% of the catchment area. These soils are moderately permeable sandy loams and sandy clay loam topsoils overlying slowly or imperfectly drained clay loam or clay subsoil. Imperfectly to poorly drained gley topsoils cover ~ 25% and overlay clay subsoil. These topsoils are slowly permeable and the subsoils are very slowly permeable. The remaining intensively managed soils over the rest of the catchment are either light textured or freely drained (11%) or alluvial soils (3%) that are associated with the River Irvine valley. The remainder (14%) are a mixture of peaty gleys, peaty podzols and peat.

The above review provides a general overview of the soils in the catchment. However, they vary much more widely in terms of their parent material and chemistry. For example, both the Kilmarnock and the Darvel Series occur in the catchment and have similarities in texture but arise from different parent material. The soils of the Kilmarnock Series are naturally rich in phosphorus while the Darvel Series have low reserves of available plant nutrients.

Through increased awareness and targeted funding under programs such as SRDP the total slurry storage capacity across the catchment is increasing. The intention is to allow for spreading activities to be target to the spring when crop requirement is high. Most inorganic fertilisers are applied at this time creating the risk of excessive amounts of P being applied over a short period of time if the P value of the slurries is not fully accounted for.

The growth and ensilage of home grown feeds (whole crop) is rapidly expanding across the catchment. This will increase the annual area of land being cultivated with implications for soil erosion. Specialised P fertiliser recommendations for whole crop production are not common. The Land Capability for Agriculture for much of the Irvine catchment shows that it is unsuitable or marginally suitable for production of many cereals and forage crops. Using generalised recommendations for phosphate fertilisers is likely to result in excess P availability due to reduced production levels and differences in length of growing season and harvest times.

The P content of animal feedstuffs supplied to dairy and beef is becoming increasingly important in efforts to maximise production. The P content of manures and slurries is increasing as a result.

7.6 Soil erosion risk in the River Irvine catchment

Phosphorus bound to eroded soil remains the most understood source of loading. If this is occurring from agricultural sources in the Irvine Catchment then specific evidence to this effect will need to be produced that extends beyond risk assessment.

The majority of the Irvine catchment has a moderate to low risk of susceptibility to surface erosion based on soil type and slope class (Lilly et al., 2002: Aitken el al., 2001). This combined with the predominance of long term grass as the dominate crop would be expected to give the catchment low to moderate risk for significant sediment loading from surface erosion. As other factors not directly related to soil type or slope are taken into consideration then this risk levels can vary (Anthony et al., 2006).

Phosphate preferentially binds to finer soil particles and the impact of clay soils found in the Irvine on P loading may be proportionally higher then courser textured soils.

Much of the intensive grassland in the catchment will have pipe-drainage systems the majority of which where installed in the 1970 and 1980s and will be at the end of the expected lifespan and becoming inefficient. Failing drainage systems can increase sediment loading due to elevated surface runoff on land that is overly compacted and reliant on a working drainage system to compensate. Adequate drainage is also required for efficient usage by the crop of those nutrients applied and as production decreases due to poor drainage there is a risk of excess nutrient availability leading to a build-up that can increase loading from surface erosion.

Based on the soil types and rainfall levels in the Irvine catchment overland flow and subsequent loading arising from the surface spreading of mineral and bulky organic fertilisers is potentially a significant direct source of P. Under the HOST classification system the majority of the River Irvine catchment would likely be dominated by lateral water movement but this has not been fully reviewed.

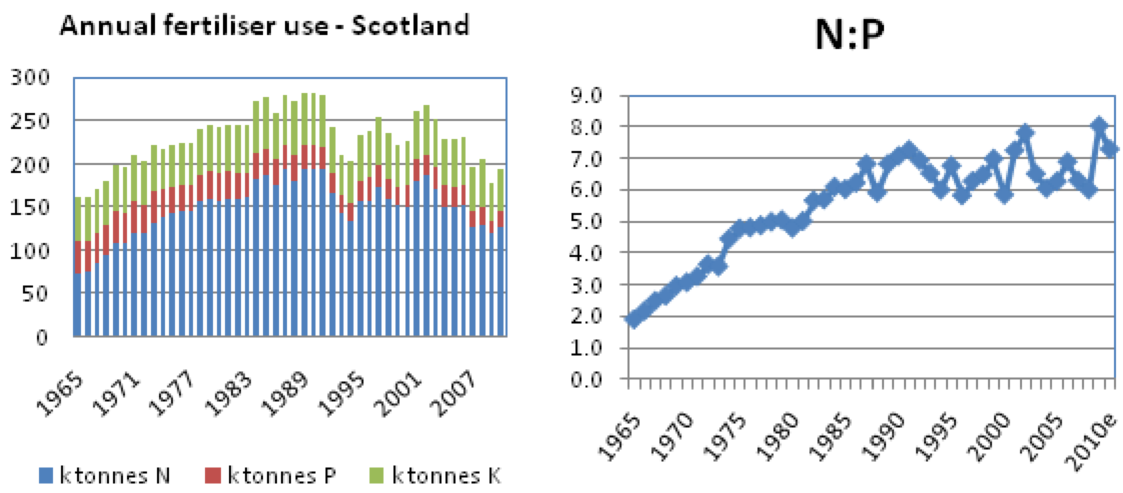
There should be a seasonal variability if this is occurring since fertiliser and manure spreading is becoming increasingly concentrated to a few months in the early spring and the direct water quality monitoring that is being done along the Irvine should be able to confirm any seasonal trends.

8. Towards a national understanding of agricultural soil P balance

8.1 Fertiliser use

There are various sources of information that describe fertiliser use over time and for different crops. In particular the British Survey of Fertiliser Practice 2010 has been used as an important source (Tables 22-26). There has been little change in the total agricultural area during the twentieth century and therefore any changes in fertiliser use will reflect a change in application rate per unit land area. The summary of total annual fertiliser use since 1965 is shown in Figure 33 where a complex pattern is evident. The total amount of nutrient applied increased until 1991 which was followed by a sharp decline but more variable annual use and finally a steady decline. Interestingly, the change in use differed between individual nutrients, with a continual widening of the N: P ratio from ~2 in 1965 up to 7 by 1991 and have since varied between 6 and 8.

Figure 33. Change in total annual fertiliser use, by element (N, P and K) for Scotland and the calculated N: P ratio. Data source - British Survey of Fertiliser Practice 2010



The rate of P use is greater for tillage crops compared to grass with both showing a period of constant rate followed more recently by a steady decline (Figure 34). What this suggests is that because crop yields and therefore removal of major nutrients have either remained similar or increased over recent years then this should reduce the annual P surplus on a national scale. As fertilisers represent the main source of 'fresh' P that enters the national P balance then it might be expected that soil P content should also respond with a declining P status. The temporal and spatial aspects of any change in soil P status will be expected to vary.

Figure 34. Annual application rates of P (kg/ha) to tillage crops and grass averaged for Scotland.

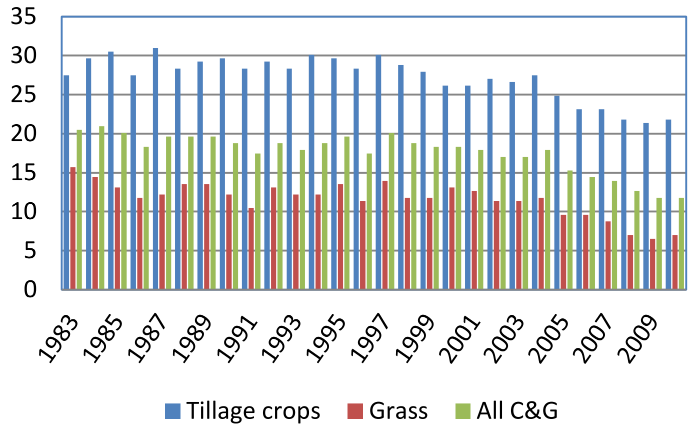


Table 22. Averaged rates of fertiliser P use for various crops in 2010, together with the crop area receiving fertiliser.

	Crop area receiving dressing (%)		Average field rate (kg/ha)	Overall application rate (kg/ha)	Fields in sample
Crop	P	FYM	P	P	
Winter Wheat	80	18	24	19	97
Spring Barley	94	37	22	21	247
Winter Barley	85	32	26	22	68
Oats	78	28	22	17	37
Potatoes	96	10	64	61	33
Winter Oilseed Rape	62	11	28	17	35
Other crops	67	38	31	21	98
All tillage	87	31	25	22	615
Grass<5 years	82	37	15	12	279
Grass >5 years	57	19	9	5	379
All grass	64	24	11	7	658
All crops and grass	71	26	17	12	1273

Both the rate and the proportion of individual crop area that receives fertiliser P vary between crops (Table 22). The average application rate for all tillage crops is 25 kg/ha which is applied to 87% of the total area and compares to 15 kg/ha applied to 82 % of grass <5 years old. The largest averaged rate was 64 kg/ha for potatoes, although actual rates varied widely (Table 23). One aspect of nutrient management that has been raised earlier (Figure 22) is the degree of compensation in fertiliser application that is made in situations where organic materials (e.g. FYM and slurry) are added. Up to 30% of the tillage area is likely to be involved (Table 24). A comparison for grassland between different farm types is shown in Table 22 which seems to suggest a very mixed response. The pattern over time (Table 25) for Great Britain seems to be variable and this may help explain some of the variability associated with the advisory data (Figure 14). There are also differences in fertiliser practice between regions (Figure 24) which probably reflect a combination of differences in dominant farm types, availability of manure and potential crop yields.

Table 23. Percentage of crop area by field application rate of P for 2010.

	Application rate (kg P/ha)										
%	0	<11	11-	22-	33-	44-	55-	66-	77-	>88	Sample size
WW	20	9	19	38	12	1	-	-	-	-	97
SB	6	9	36	37	12	1	-	-	-	-	247
WB	15	3	24	35	21	2	-	-	-	-	68
Oats	22	14	19	32	12	-	-	-	-	-	37
Potatoes	4	10	2	0	4	23	20	1	23	14	33
WOR	38	5	5	39	8	5	-	-	-	-	35
Other crops	33	5	13	15	24	3	2	3	1	1	98
All tillage	13	8	27	34	13	2	1	0	1	-	615
Grass <5 years	18	27	38	12	2	1	0	1	-	-	279
Grass >5 years	43	37	16	3	-	-	-	-	-	-	379
All grass	36	35	22	6	1	-	-	-	-	-	658
All crops and grass	29	26	24	15	5	1	-	-	-	-	1273

Table 24. Rates of fertiliser P use (kg P/ha) on grassland where either manure or no manure has been applied and by robust farm type for 2010 (British Survey of Fertiliser Practice 2010).

Cereals	with manure	without manure
Grass <5 years*	13	14
Grass> 5 years*	12	9
All grass	12	10
Dairy		
Grass <5 years	11	18
Grass> 5 years	11	9
All grass	11	10
General cropping		
Grass <5 years*	38	18
Grass> 5 years*	3	10
All grass	13	15
Mixed		
Grass <5 years	18	13
Grass> 5 years	16	9
All grass	17	10
Other livestock		
Grass <5 years	11	16
Grass> 5 years	10	8
All grass	10	10
All farm types		
Grass <5 years	13	16
Grass> 5 years	10	9
All grass	11	10
*** small number of fields**		

Table 25. Overall field rate (kg P/ha) of manufactured P fertiliser for tillage crops in GB with or without manures.

	2006		2007		2008		2009		2010	
Crop	with manure	without manure	with manure	without manure	with manure	without manure	with manure	without manure	with manure	without manure
WW	8	16	9	14	7	13	4	8	7	13
SB	21	14	18	16	17	14	15	13	15	16
WB	15	17	15	16	11	16	9	10	11	15
PM	39	68	40	66	61	55	47	72	43	59
Sbeet	8	20	5	22	7	17	6	10	5	17
WOR	11	15	8	14	6	14	2	10	4	14
FM	19	9	17	12	15	14	17	9	13	15

PM – potatoes main crop, FM – Fodder Maize

Table 26. A comparison of fertiliser use between three regions of Scotland for the cropping year 2004/05. Data from British Survey of Fertiliser Practice 2005.

	NE	SE	SW	NE	SE	SW	NE	SE	SW	NE	SE	SW
Crop	% area receiving P			% area receiving FYM			Average field rate kg P/ha			Overall application rate kg P/ha		
SW	-	44	-	-	0	-	-	26	-	-	11	-
WW	100	82	100	9	4	61	30	28	22	30	22	22
SB	97	91	100	50	13	79	24	24	23	24	22	23
WB	100	77	100	8	3	73	33	31	30	33	24	30
Oats	100	64	-	36	3	-	19	25	-	19	16	-
PS	-	75	-	-	70	-	-	65	-	-	49	-
PM/2ndE	-	100	-	-	24	-	-	79	-	-	79	-
WOR	100	78	-	13	4	-	31	37	-	31	28	-
Root stockfeed	100	100	-	80	35	-	51	44	-	51	44	-
Leafy forage crops	-	35	-	-	26	-	-	25	-	-	9	-
Beans animal	-	100	-	-	6	-	-	15	-	-	15	-
All tillage	96	82	100	38	9	73	28	28	24	28	23	24
Grass <5 years	86	68	86	27	17	56	14	14	16	12	9	14
Grass >5 years	91	47	83	12	5	50	10	12	13	10	6	11
All grass	88	55	84	20	10	52	12	13	14	11	7	12
All crops and grass	92	69	85	29	9	53	21	22	15	19	15	13

8.2 Background to use of advisory soils data and the soil P balance

Various site specific factors operate to influence the sources and transport routes of P loss that occur at a catchment scale. Soil represents the major potential source of P, which for an average total P concentration of 1100 mg P/kg and depth of 30 cm equates to ~ 3.3 tonnes of P/ha. Other risk factors related to agriculture sources of P are the inappropriate application of bulky organic and inorganic fertilisers, direct deposition of manures in surface water, and diffuse runoff from steadings. These are not mediated by soil processes or management and are not included in this assessment

Soil P is typically distributed unevenly, declining with soil profile depth and proportionally more in the finer particle sized material. Most agriculturally managed soils tend to develop a distinct profile of declining extractable P concentrations with depth, this will be most obvious in permanent grassland and longer-term leys. Under the prevailing soil conditions a large proportion of this P is chemically and physically relatively inert with measured loses of P rarely exceeding 2 – 3 kg/ha/y indicate the importance of selective transport processes. The continued need to apply P (as either fertilisers or organic manures) in order to maintain agricultural productivity emphasises the strong tendency for soils to immobilise and limit the plant availability of the P it contains. Generally, P fertiliser products have high water solubility and therefore offer a potentially high risk for loss during and immediately after application. Long-term applications will be expected to increase the plant available proportion in soil and therefore the potential for P loss.

Reijneveld et al. (2010) calculated the cumulative average surplus during the 20th century for the Netherlands of ~4500 kg P_2O_5/ha. Using advisory soil data they showed differences between regions and between land uses have remained high since the first records in 1930s. In general the areas with high livestock densities have high soil P status. For the Netherlands variation in P values reflected more crop market value and regional availability of animal manure than fertiliser recommendations (Reijneveld *et al*., 2010). Despite a change to more restrictive manure policy since 1984, these authors suggest little change reflected in soil P, indicating the time lags that can often exist.

Withers et al. (2001) showed that the productive grassland and arable area of UK have accumulated an average P surplus of *c.* 1000 kg ha^{-1} over the last 65 years. Over the period 1935–1970, the annual P surplus more than doubled due to an increase in animal numbers and associated requirements for inorganic fertilisers and livestock feeds. Since 1970, surplus P has declined by *c*. 40% as crop yields and P offtake have continued to increase while fertiliser and manure P inputs have remained relatively constant. In 1993, P use efficiency (P imports/P exports) in UK agriculture was estimated at 25% leading to an average annual surplus of 15 kg P ha^{-1} yr^{-1}, although this has probably declined slightly due to reduced fertiliser use. Intensification and specialization of agriculture has also increased the range in P surpluses that are likely between livestock and arable dominated systems. The largest P surpluses occur in the relatively limited areas of arable soils which receive manure from intensive pig and poultry units, whilst farms without manure inputs generate only small surpluses, or are in balance. The cumulative P surplus has led to a build-up of soil total and easily-exchangeable P, especially in areas receiving both fertilisers and manures. Fundamental differences in P use efficiency, surplus P accumulation and the potential for P loss to water, exist between arable and grassland farms and it is important to separate these, due to the marked regionalization of UK agriculture.

Tunney et al. (1997) suggested that the national average Morgan extractable P concentrations have increased from 1 to 9 mg/L soil over a fifty year period from 1950 and, overall, agricultural P inputs remained in considerable surplus to P removals. These authors also made the important statement that '*However, relating diffuse P losses in the field to soil P concentrations requires considerable monitoring effort, and isolating the effect of soil P test (SPT) is often complicated by the confounding effects of climate, hydrology, incidental and point-source losses.*'

Fertiliser recommendations and actual use in Scotland has changed considerably over the twentieth century, and can be broadly grouped into a build-up phase, where rates of P and K use were greater than N, followed by a much greater use of N up to the mid 1980s (Figures 33 and 34). In 1992 the national P surplus was calculated as 10 kg P/ha (Withers et al., 2001), which if accumulated over 25 years would be expected to be measurable in advisory top soil data. This surplus was shown to be distributed unevenly across the major farm types. One particular aspect being the larger surplus associated with intensive livestock systems, which in part is due to the continued lack of compensation for organic manures through reduced fertiliser application. This general situation together with the strong geographic distribution of farming systems within Scotland suggests a spatial distribution of P surplus exits. The continuing intensification and specialisation within livestock and arable systems means that this spatial component of the P surplus is likely to become more obvious. The general pattern of fertiliser P use is changing; recently there have been 'P holidays' suggested where fresh applications are omitted for a year, driven by high fertiliser prices. Unfortunately, these geographic differences in P surplus are accompanied by other factors, such as soil type and rainfall patterns which are likely to influence P transport and loss. It is difficult to separate out the direct effect of any change in soil P status; this is likely to be further compounded by management factors that include the degree of cultivation. Surface and sub-surface transport routes will differ in the degree of influence that surface P rich layers are likely to contribute. These include aspects of historical and current P use (fertilisers and manures), land management, soil properties and climate.

9. Risk assessment: extractable soil P and P leaching to watercourses

In a series of papers the work of a short (two-year) study funded by the Scottish Office produced a number of important papers that explored the nutrient dynamics in streams draining six relatively small agricultural catchments (Figure 35). The specific objectives of this study were to: (i) assess and compare phosphorus concentrations and losses from two contrasting regions in Scotland which differ considerably in land use, rainfall, soil type, **P** inputs and other farming practices; (ii) compare upstream and downstream **P** concentrations in order to assess the overall influence of land use and management practices within the catchment reaches; and (iii) examine the distribution of various P fractions in stream flow.

Figure 35. Map showing geographical location of the two study areas.

The west catchments: Logan, Caddell and Killoch (Table 27) are situated in Ayrshire in one of the most intensive dairy farming regions in the UK, and the major land use is maintained grassland on the farms with a mixture of woodland or rough grazing in the upper reaches of Logan and Caddell, respectively. In the NE the catchments Krkhill, Elrick and Glensaugh cover a wider range of land uses, including arable with livestock including beef and poultry systems.

Table 27. Description of study farms; soils are classified according to the Soil Survey of Scotland; P and K were extracted in 2.5% acetic acid. From Hooda *et al*. (1997).

	Catchment					
	West			Northeast		
	Logan	Killoch	Caddell*	Kirkhill	Elrick	Glensaugh
Stream order	First	First	Second	First	First	Second
Final output	River Ayr	River Irvine	River Garnock	River Don	Muchalls Burn of Muchalls	River North Esk
Enterprise	Beef cattle	Dairy cattle	Dairy cattle	Beef cattle/arable	Poultry/arable	Sheep/beef/deer
Farm stocking density (head ha^{-1})	2.0	1.8	3.8	0.6	n.p.	4.0/2.0/2.5
Farm area[a] (ha)	45	29	50	72	177	83
Catchment area[b] (ha)	98	71	705	110	1128	403
Land use[c] (%)						
Maintained grassland	55 (100)	98 (100)	60 (98)	21 (32)	30 (n.p.)	29 (39)
Rough grazing	n.p.	n.p.	26 (n.p.)	n.p.	30 (n.p.)	62 (60)
Arable	n.p.	n.p.	n.p.	28 (40)	30 (90)	n.p.
Woodland	45 (n.p.)	2 (n.p.)	1 (1)	51 (28)	10 (10)	1 (1)

[a]Study farm catchment area (farm inlet to farm outlet).
[b]Area of upper catchment and study farm, to farm outlet.
[c]Expressed as % catchment area, with the % farm area in parentheses. n.p., not present.

	Logan	Killoch	Caddell	Kirkhill	Elrick	Glensaugh
Soils:	Basin peat (Airds Moss), with non-calcareous gleys (Pennyland Series — Auchinleck Association)	Poorly- to very poorly-drained gleys derived from calciferous sandstone (Sorn and Blairkip Series — Sorn Association)	Poorly- to very poorly-drained gleys derived from shale and sandstone of the carboniferous Limestone series (Ashgrove and Caaf Series — Ashgrove Association	Freely-drained iron podzols derived from granite and schist (Countesswells Series and Association)	Imperfectly- and poorly-drained podzols derived from granite and schist (Dess and Terryvale Series — Countesswells Association)	Imperfectly-drained podzols derived from ORS Strathfinella Series and Association) and well-drained brown forest soils from fluvioglacial sands and gravels (Border Series)
Soil nutrient status						
Organic matter (%)	3.92	4.18	3.32	9.24	5.78	38.1
Total N (%)	0.32	0.37	0.31	0.38	0.26	0.84
Extractable P (mg 100 g^{-1})	1.05	1.01	0.89	4.19	4.36	3.40
Extractable K (mg 100 g^{-1})	13.3	20.3	16.1	18.4	20.5	89.9

The soils in the western catchments are mainly noncalcareous gleys, calcareous gleys, and humic gleys, with localised occurrence of basin peat. These soils are generally poorly drained and are medium to very fine in texture (Anon, 1984). Although subsurface tile drains are common on the farms, the combination of rolling topography and slow draining soils means that surface runoff forms a significant component of the catchment water (Boorman *et al*., 1995). Light textured Podzols, with iron Podzols, are the dominant soils in the northeastern catchments, with some brown forest soils (Anon, 1984). These brown forest soils are well-drained while the Podzols vary between poorly- to freely- drained. The soils in the northeastern catchments have much larger content of extractable P compared with those in the western catchments (Table 27).

The inputs of fertiliser N and P in the western catchments vary between 20-300 kg N/ha/y and 9-22 kg P/ha/y respectively, with re-seeded swards generally receiving the largest rates of fertilizer N and P. Like other farms in the region, the western catchments receive regular cattle slurry applications. Farmyard manure is frequently spread in the northeastern catchments where slurry spreading is less common. The inputs of fertilizer N and P in the northeastern catchments are relatively small, varying up to 110 kg N/ha/y and 13 kg P/ha/y for arable areas and up to 80 kg N/ha/y and 9 kg P/ha/yr for maintained pastures. In the western cattle farming areas, fertilizer is generally applied in 3-5 top dressings between early March and mid August. The northeastern catchments receive a single fertilizer top dressing during April-May in Kirkhill, March-June in Elrick and April-August in Glensaugh. The rough grazing areas in both regions receive little or no fertiliser.

Despite both areas having relatively intensive agricultural land use stream water composition differs in a number of key respects, which can be interpreted as showing the important interaction of soil properties on processes controlling nutrient cycling. The most obvious is shown in Table 28 where both nitrate concentrations and loads are much greater for the freely draining and regularly cultivated NE catchments. This is in spite of comparable total soil N contents and larger applications of fertiliser N in the west.

Table 28. Stream nitrate concentrations (mg NO_3-N/L) and outputs (kg NO_3-N /ha/year)

	Stream NO_3-N concentrations[a]			NO_3-N output[b]
	Minimum	Maximum	Mean (Flow-weighted)	
West catchments				
Logan	0.42	2.15	0.54	3.56
Killoch	0.33	3.87	1.04	8.73
Caddell	0.31	8.64	0.86	8.77
North-East catchments				
Elrick	2.02	6.36	4.25	22.95
Glensaugh	0.74	3.17	2.86	20.59
Kirkhill	1.81	6.98	3.09	18.54

[a]Sampling period for Caddell and Kirkhill: 10/93–9/95, for remaining farms 10/93–9/94.
[b]Based on runoff equivalent of 60% of mean annual precipitation and downstream flow-weighted mean nitrate concentrations.

Table 29 shows flow-weighted mean concentrations (as mg P/l) of molybdate reactive phosphorus in farm catchment downstream samples. The mean concentrations were calculated by dividing the sum of the products of individual concentrations and corresponding stream flow values with the sum of the flow values for a given period.

Table 29. Flow-weighted mean concentrations (as mg P/l) of molybdate reactive phosphorus in farm catchment downstream samples.

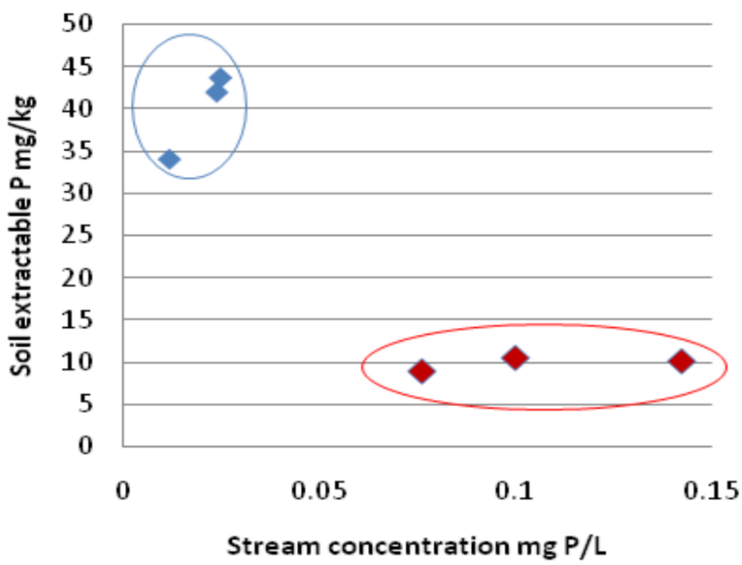
Catchment	Flow-weighted mean concentration[1]	Standard deviation	Range
	Molybdate Reactive Phosphate (MRP)		
Logan	0.100	0.051	0.011–0.193
Killoch	0.142	0.079	0.035–0.295
Caddell	0.076	0.082	0.01–0.396
Kirkhill	0.024 (0.170)[2]	0.057 (0.217)[2]	<0.01–0.324 (<0.01–1.683)[2]
Elrick	0.025	0.019	<0.01–0.085
Glensaugh	0.012	0.027	<0.01–0.113

[1] For the periods 20/10/93–21/9/94 (Logan, Killoch, Elrick and Glensaugh) and 20/10/93–23/10/95 (Caddell and Kirkhill). [2] The Kirkhill values in parentheses include an incidental spillage of phosphatic fertilizer into the stream, following heavy rainfall immediately after winter barley sowing.

One interesting event, an incidental spillage of fertiliser P, was picked up during the sampling campaign and was shown to have a very large but probably shot-term impact on stream water chemistry.

One of the main purposes for re-analysing this very interesting data set was to see if any robust relationship between extractable (advisory) soil P (here acetic acid) and loss of soluble P could be identified (Figure 36). Despite needing to show some caution with extrapolating this data, there is a strong suggestion that a common (national) relationship might not exist. This is perhaps not so surprising considering the very different drainage status of these two groups of soils and the early understanding of the Soil Survey of Scotland that this together with parent material is a key attribute on which to group/classify soils (Williams, 1959).

Figure 36. Comparison of the relationship between extractable soil P (acetic acid) and volume weighted averaged stream water molybdate reactive P for three west coast (red) and east coast (blue) catchments.



In light of Figure 36 it is possible to question the value of 'advisory soil data' in terms of its potential for providing additional information that might have an environmental context/significance. Various strengths and weakness exist.

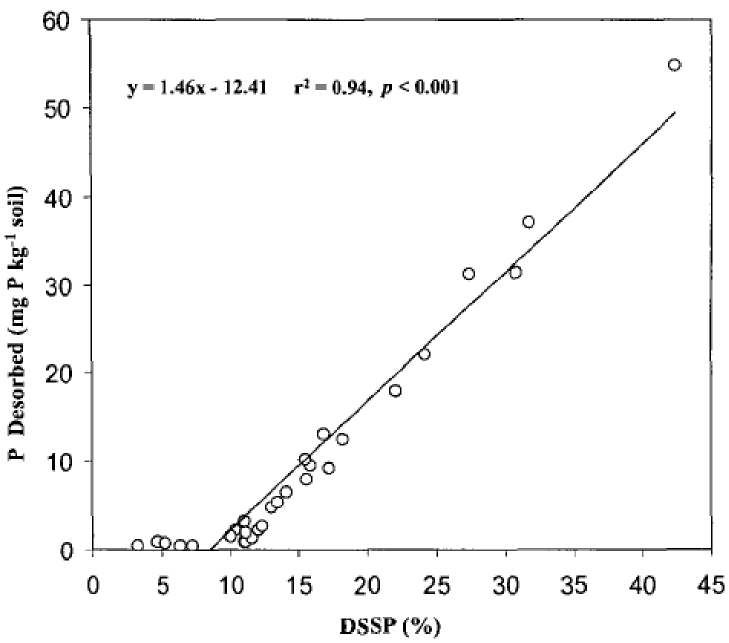
International literature does suggest that useful relationships can be obtained. However, important clarifiers are required, and in particular a need to modify relationship for broad groups of soil, which for Scotland would mean association (parent material) and drainage (series). In fact early advisory information using analytical data based on acetic acid extracts did include an 'association' qualifier.

Advisory soil data is the only widely available data that can provide a time series of change in soil P status against changing land use and nutrient additions.

Some additional studies using Scottish soils showed the potential advantage of including fundamental sorption characteristics (which are again related to parent material and drainage conditions). This would provide a basis against which this advisory data can be re-interpreted. For example, although it is only based on three points there might be the suggestion of a relationship within the NE soils (Figure 36) between soil P status and stream water.

In a second series of papers Hooda *et al*. (2000 and 2001) investigated the potential for relating soil properties to P leaching risk and demonstrated for a wide range of soils that the use of degree of soil saturation with P (DSSP) was superior to many SPT methods (Figure 37). Their conclusions were '*The net total P accumulation in the soils across the sites ranged from 16 to 232 kg P /ha/y. The effects of long-term P surpluses were a significant reduction in P-retention capacity and increase in DSSP. The sites investigated would attain 25% DSSP in 10-150 years, depending upon the size of P surplus and sorption capacity. A combination of large P surplus and low P-sorption capacity could saturate soils to 25% DSSP within 10-30 years.*' These soils would then be of a very high risk for P leaching.

Figure 37. Relationship between P desorbed and DSSP(%)



10. Conclusions and recommendations

10.1 Conclusions

The development of this SAC advisory dataset has provided an important insight into the current nutrient status of Scotland's agricultural soils as understood by the farming community. It has also provided an understating into how agricultural soils are being managed. The primary value of this dataset is its relevance to individual farmers. As will be discussed below the use of advisory soil data to comprehensively understand diffuse pollution issues is open to question, however advisory soil data is understood and used by farmers and provides a direct conduit for expressing concerns over current management practices and putting forward new ideas.

A basic assessment of the entire data shows that the majority of the fields tested are at or below the recommended moderate statues for soil P. There is no evidence in this data base to suggest that there is a systemic over use of P arising from agricultural application of inorganic fertilisers as compared to current best practice.

Approximately 15% of those soils analysed required less than maintenance P applications. On an annual basis this has fluctuated with the highest being in 2008 at approximately 20% and the lowest at 10% in 2010. Individually these fields are of interest since they represent a localised risk to surface water quality. It is unclear if these high P soils are a static set of fields within individual farms or are dynamic and arising as a result of how P is managed for crop rotations.

The assessment of the soil P dynamics surrounding potato production highlights one possible positive correlation between soil P levels following a specific crop. What cannot be answered from this data set is if soils at a low or moderate status have their status increased substantially within one year in response to cropping represents a heightened risk to water quality. Using current recommendations there could be a requirement of upwards of 200 kg/ha of P_2O_5 if a field with a Low soil P status is being brought into potatoes. The capacity of individual soil types to profitably utilise this level of fertiliser amendment without representing a risk to the environment will depend on factors not considered when providing general advisory recommendations. The production of potatoes is used only as an example as other crops such as vegetables and fodder can also be shown to have a positive relationship with residual soil P levels.

The above does not consider processes that are not soil mediated such as surface runoff of manure, slurries and other bulky organic fertilisers which represent a potential risk in those areas dominated by grass production. Soil erosion, which is a one of the most readily understood sources of P loading, must also be considered.

There is a clear disparity in sample numbers between those catchments managed primarily for arable crops versus grassland. This indicates that soil testing has not been adopted by grassland farmers as a meaningful management tool. Due to this it is likely that large numbers of farmers in several of the priority catchments have no ability to reliably manage future application of P to address diffuse pollution issues.

As shown in Figure 20 it is likely that much of Scotland's grassland soils are classified as moderate status for P and should be managed accordingly. The apparent reduction in P fertiliser usage by grassland farmers (Figure 34) needs to be balanced with changes in types of concentrates being used in these systems and increasing prevalence of home grown feeds. It is possible that on a whole farm bases the levels of P being brought onto the farm annually is higher than the fertiliser statistics indicate.

The re-analysis of the Hooda *et al*. (1997) data in Figure 36 has succinctly highlighted the potential highly complex regional aspect to how P loading to surface waters in Scotland will need to be understood and mitigated. The dataset on which this is based is dated and limited but the findings are clear. There is either a highly complex soil dynamics influencing the release of bound P in the west of Scotland or other factors such as surface loading of manures and slurries is the primary source of P loading. It is likely to be a combination of both.

Since the publication of this work by Hooda *et al*. (1997), efforts have been directed at reducing the diffuse loading of manure, slurries, and other bulky organic fertiliser to surface waters in the west of Scotland. The relationship should be reassessed given the investment that has been made over the past decade to mitigate diffuse pollution sources. The lack of soil test and water quality data for these priority catchments will make this impossible at the current time.

Regardless of future efforts to correlate surface water quality with SPT the impact of soil type and drainage status will introduce significant enough variability to make it difficult to predict or model the impact of current soil P reserves on soil water quality. A broader interpretation of the information provided by SPT could be possible if combined with knowledge of relevant soil characteristics that better define key soil properties that control P solubility, such as sorption properties, organic matter content and pH.

If it is accepted that overall P usage is decreasing in Scotland as indicated by the British Survey of Fertiliser Practise 2010 then the classification of agricultural usage of P as a significant source of loading to surface waters needs to be attributed to:

1. Isolated and unprofitable application of P in response to perceived crop requirement.
2. Inherent or managed soil mediated processes that dictate soil P availability.
3. Non-soil mediated loading arising from surface runoff and soil erosion.
4. Underlying principle that soil is maintained as a moderate status for P as part of profitable production.
5. Changes in environment and/or drainage status of Scotland's soil.

10.2 Recommendations

1. The soils of the R Irvine catchment are varied with at least 5 distinct associations occurring. An understanding of the individual soil characteristics will be required to develop a risk assessment process for phosphate leaching that extends beyond basic SPT. Detailed information on the physical and chemical nature of many of these soils already exists and it is recommended that they are compiled and contrasted to identify those soils within the catchment that represent the higher risk for soluble P leaching and are at a greater risk of saturation of the P-sorption capacity.

2. The results of this study suggest that regular soil testing is not undertaken by the farmers in those priority catchments dominated by grass production. In soils that receive significant amount of organic P inputs this lack of baseline information makes it difficult to accurately proportion loading pressures. Future efforts to reduce P usage within these catchments will require farmers and land managers to access and make use of soil testing. Programs aimed at promoting or providing soil testing should be emphasised.

3. As discussed above the current fertiliser advice for grassland farmers is to limit annual application of P to levels that replace crop offtake if their soils are already at a moderate status based on SPT. Aside from regular soil testing this also requires an understating of yields which is difficult to assess for systems involving grazing. The development and extension of methods for understanding grassland yields should be promoted.

4. SPT has been developed to provide farmers with a means of assessing nutrient deficiencies that will impact crop growth. The modified Morgan's test used by SAC has a demonstrated capacity to provide meaningful results for farmers over a wide range of soil types that also vary in soil organic matter levels and acidity. For a specific soil the rate of change in SPT over time will be dictated by its texture, drainage status, SOM and acidity. SPT typically does not account for these additional factors and therefore linking with any other national soil data sets, such as that collected as part of the Soil Survey of Scotland, could help with developing risk classes. This would also provide a mechanism for expressing data spatially and linking to other nationally available data sets e.g. agricultural census. Understanding long-term changes in soil P levels will require targeted sampling of different soil types.

5. An understanding of the individual soil characteristics will be required to develop a risk assessment process for P leaching that extends beyond basic SPT. Recent studies for Irish soils suggest a P desorption index using SPT and soil attributes (estimate of P saturation predicted using a combination of soil texture, oxalate extractable iron and aluminium together with organic matter) could be applied across sub-catchments of varied typology with modest success. It is likely that a wider range of soil types are represented in Scotland compared to Ireland and therefore a case study involving the SW and NE is recommended.

6. Phosphorus will have a long residence time within a catchment and communicating understanding of P loading issues will be facilitated by accounting for the P dynamics of the priority catchments. Information from a range of sources are available that can provide a gross P budget for the watershed. PLANET Scotland (http://www.planet4farmers.co.uk) also has a farm gate nutrient budget tool that can be used by farmers to do the same for their individual farms.

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12. Appendices

I What is soil P test?

A range of soil P tests (~20) are currently in use for agronomic purposes (Tunney *et al.*, 1998) and the majority of methods were developed in order to define a pool of P that is likely to be or become plant available while also providing a basis to make fertiliser recommendations through an index system. The chemical mechanism involved varies and method selection is usually based upon what is considered most appropriate for the main soil types being tested. Typically this later group involve extractants that are either acidic or alkaline (e.g. Olsen's) in nature and preferences usually reflect the dominant soil type e.g. acidic extractant in Scotland and Ireland and alkaline in England and Wales. There is not a single extraction procedure that can be used across all soil. While a wide range of extractants are used by advisory services, there are two distinct extraction actions, those that remove the immediately available P (water and calcium chloride) compared to those that remove greater amounts which are predicted to have a medium (season) to longer-term availability. The choice and interpretation placed upon a SPT value has been regularly aired in the literature. More recently, the use of the SPT has been expanded to include some estimate/predictor of P loss. Various SPT including the Olsen test (England and Wales) and modified Morgans (SAC) have been employed to establish ''environmental'' threshold values (Sharpley et al. 2003) that can be used to develop risk based assessments (e.g. Lemunyon and Gilbert, 1993). While exploring the potential of advisory soil data bases offer useful advantages especially with respect to offering incites of change over time and where there is some geographical reference then a spatial context. However, it should also be noted that various constraints/limitations also exist the main ones being:

Importantly it needs to be remembered that using advisory soil data to consider environmental implications is extending the method and interpretation beyond their original application. Most SPT methods use a closed, batch type system, which is the complete opposite of the open leaching system they are increasingly being used for.

A key question is whether a minority of soils of high (H) or very high (VH) P status is a greater risk to surface water quality than a majority in the lower half of moderate (M^-) status. This tipping bucket analogy for high P soils would have to be clearly demonstrated prior to accepting the influence of a minority of high or very high P status soils. To accurately use this advisory data base to assess risk to surface water quality requires the development of some link between SPT and other soil properties. One common measure is P-sorption capacity which can be roughly described as the total capacity of a soil to immobilise (absorb) P. The P-sorption capacity can be directly measured through addition of varying amounts of P and determining retention or by linking soil properties to those that are known to influence P sorption. Such soil properties include Fe and Al oxide concentrations, organic matter status, texture and carbonate (pH). The link between agricultural production limited by available P and soil P sorption capacity is not fully established.

II History of fertiliser use

The removal of P by most field crops and grasses generally varies between 10-25 kg P ha/year, P application rates have changed over the years, during early period application rates exceeded removal.

One important issue is the level of adherence to recommended rates and it is one area in particular, the compensation of fertiliser rates when manures etc are applied. There is evidence that only small compensations are made, for example, while 66% of the UK grass silage receives manure, the average reduction in fertiliser use was only 2 kg P ha/y when compared with untreated grassland Smith et al. (1998). As a result, intensive slurry/manure applications in cattle farming systems together with fertiliser-P inputs lead to excessive P additions, with a consequent large amount of unutilized surplus. P.

The long-term effects of P surpluses will be a gradual saturation of the soil P-sorption capacity. In the Netherlands, 25% saturation (25% DSSP) is considered sufficient to make the P loss arising from such soils unacceptable in terms of risk of water contamination with P (Breeuwsma and Silva 1992). Large P loss in subsurface runoff could occur from soils with SPT values below 45 mg Olsen-P kg/y, especially in coarse textured or artificially drained soils (Sims et al., 1998; Houba et al., 1996).

Vanderdeelen (2002) suggested that ‘the objectives of these tests are listed as follows: (i) grouping of soils into classes for the purpose of making fertiliser recommendations, (ii) prediction of the probability of getting a profitable response to application of fertiliser P, and (iii) providing an index of the P amount a soil can supply’. From a consideration of the different chemical methods which have been proposed, the following groups can be identified (Sibbesen, 1983; Houba et al., 1996; Sims, 1993):

· methods employing hydrochloric acid and ammonium fluoride. The stronger acid extractant removes more of the P from the less soluble forms. In both solutions the fluoride ion is included for the replacement of sorbed phosphate;

· methods involving stronger acid extractants. These refer to various strengths of HCl in soil solution at various ratios;

· methods involving weaker or very weak extractants: one is a simple water extraction;

· methods employing acetic acid buffered with sodium acetate: the original method, buffered at pH 4, known as the Morgan method;

· methods using a strong complexing agent (lactic acid).

A good soil test should meet the following three criteria:

· the extractant used should extract all or a proportionate part of the available form or forms of the nutrient from soils with variable properties;

· the amount of nutrient extracted should be measured with reasonable accuracy and speed; the amount extracted should be correlated with the growth and response of each crop to that nutrient under various conditions (Reith *et al*., 1987).

Using a comparative study including 12 soils from 4 different countries, Barberis et al. (1996) found a significant difference in the amount extracted by specific methods. Mean values increased in the order: Olsen P (60 mg/kg), CAL-P (98), strip-P (106), and resin P (118 mg/kg). These values represented less than 15% of total P. A value for water extractable P is limited to 2.15 mg/kg.

III Priority and Diffuse Pollution Monitored catchments individual summaries

The distribution of SEPA's Priority Catchments (PC) fall into 5 agricultural sub-regions (Table 1). The accumulative agricultural land areas and soil sampling frequency are compared for the PC and their respective agricultural sub-regions vary widely. The smallest proportion (5%) is for the Eye catchment located within the Scottish Borders sub-region compared to the combined PC's of Doon, Irvine, Ayr, Garnock and North Ayrshire Coastal which represented 84% of the Ayrshire sub-region.

Table 1. Geographical distribution of Priority Catchments in relation to the agricultural sub-regions. The data summarise agricultural land area (arable plus grassland <5 years old) and soil sample number. The proportion of PC as a proportion of total agricultural land area and sample numbers in respective sub-regions are shown in brackets.

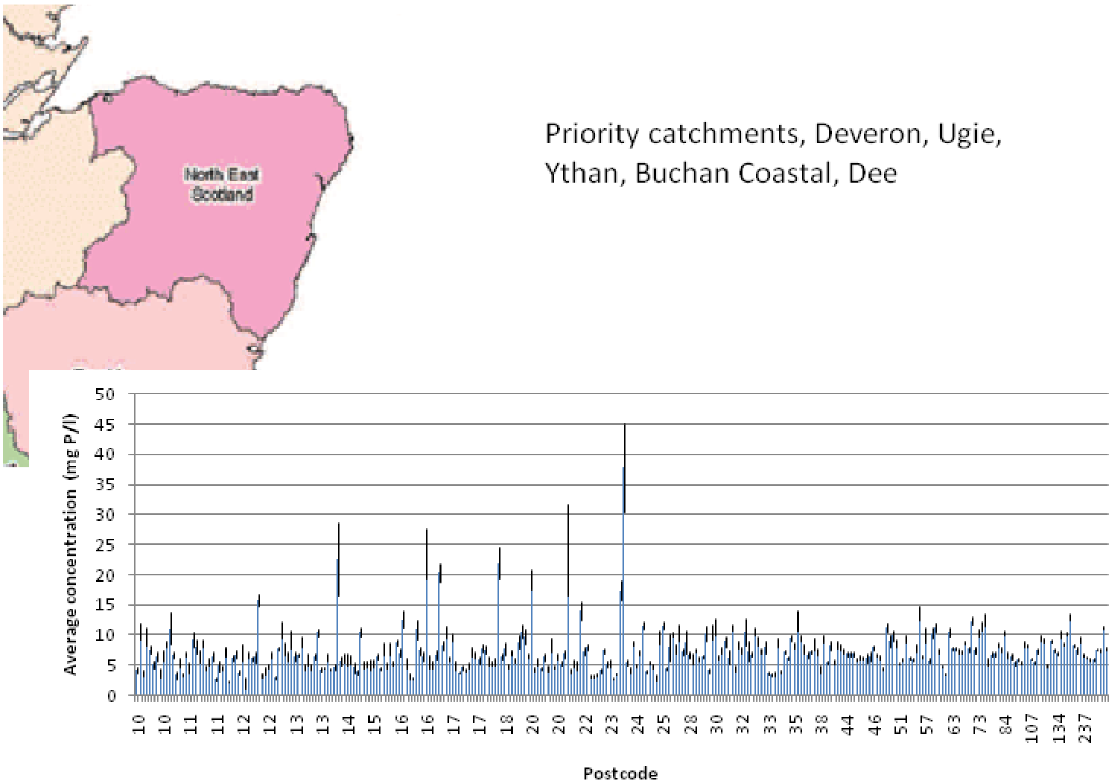
Agricultural sub-region			Priority Catchment			
	Agricultural land area (ha)	Sample numbers	Catch. No.	Catchment	Agricultural land area (ha)	Samples numbers
NE Scotland	391582 (61)	36971 (39)	30	River Deveron	77238	3939
			31	Buchan Coastal	43815	2693
			32	River Ugie	27972	1344
			33	River Ythan	50127	3876
			37	River Dee (Grampian)	40780	2629
Tayside	222478 (57)	17224 (78)	41	River South Esk	18036	7615
			42	Lunan Water	13200	447
			46	River Tay	94886	5320
Ayrshire	123743 (84)	5472 (42)	87	River Doon	25769	199
			88	North Ayrshire Coastal	18212	1399
			89	River Ayr	26864	313
			90	River Irvine	23616	278
			91	River Garnock	9744	104
Scottish	197019 (5)	10929 (3)	67	Eye Water	10126	368
Dumfries & Galloway	237867	10404 (15)	77	Stewartry Coastal	35040	661
			80	Galloway Coastal	91605?	905

(red assumed 80% of total area arable plus improved grass)

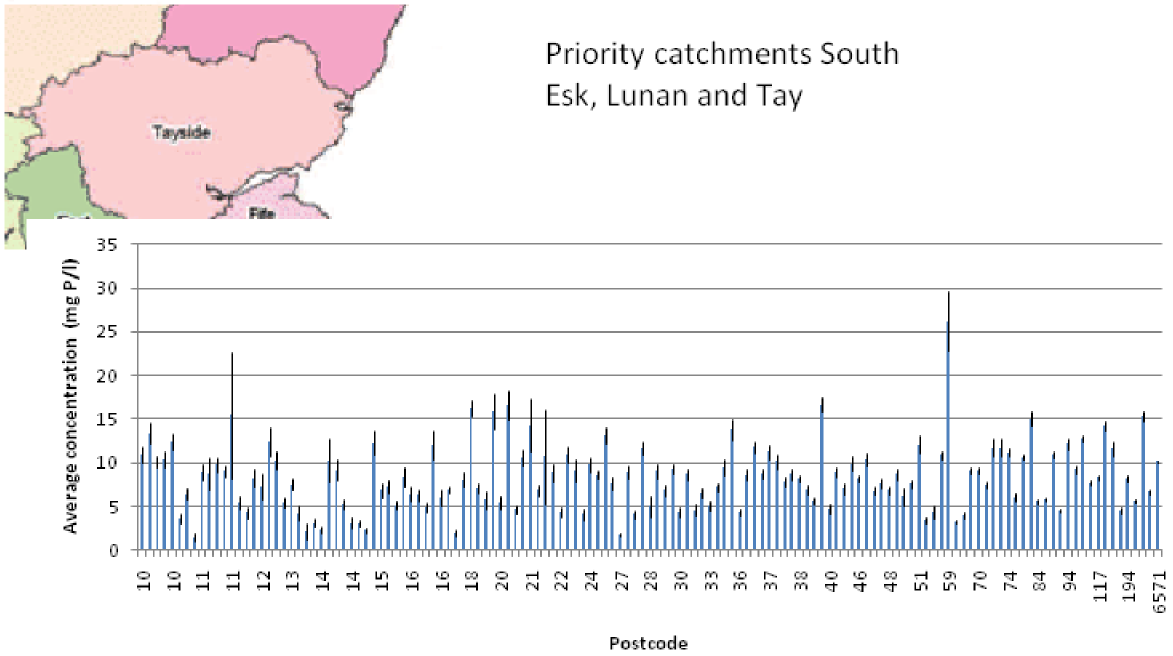
Extractable soil P has been summarised for the PC's within each agricultural sub-regions (Figure 1) averaged for each full postcode with more than 10 individual results. From a total of 1148 eight figure postcodes represented in the PC's, of which just over 50% (624) postcodes had less than 10 individual samples and were not included.

Figure 1. Summary of extractable soil P (mg P/l) average and standard error for individual postcodes with the PC's located in a) NE Scotland sub-region, b) Tayside, c) Scottish Borders, d) Ayrshire and e) Dumfries & Galloway. Numbers on the horizontal axis indicate the number of samples.

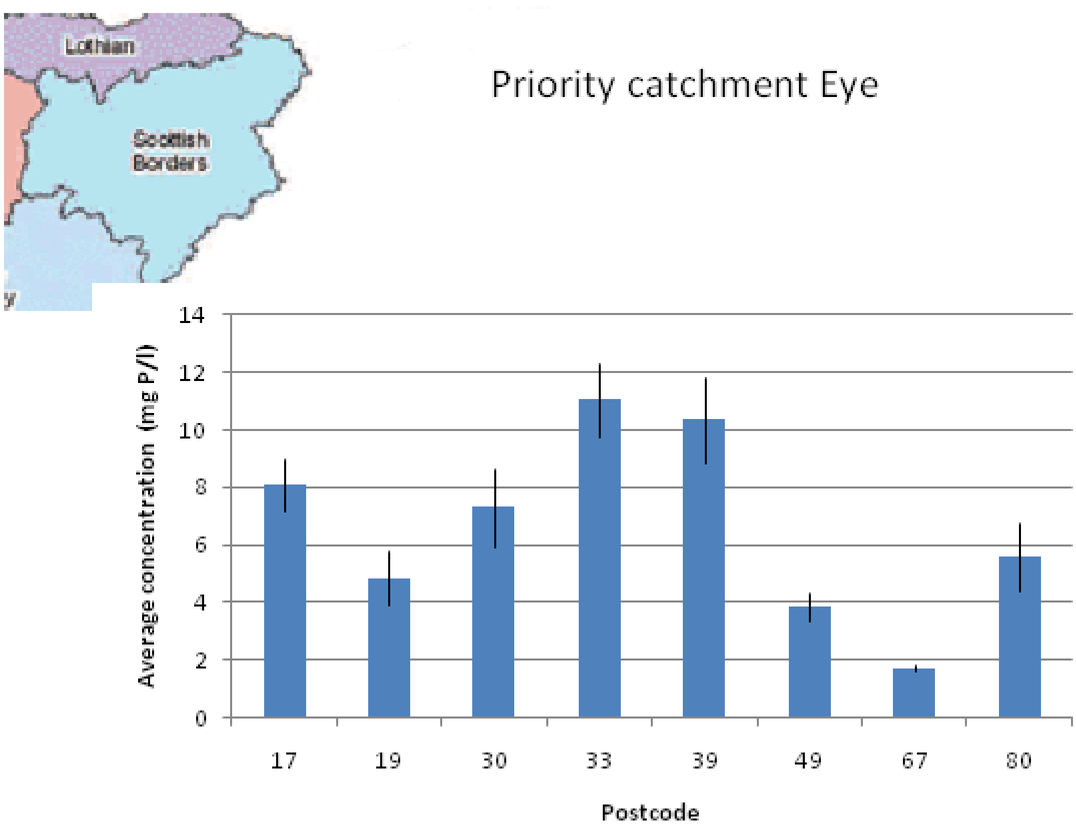
a)



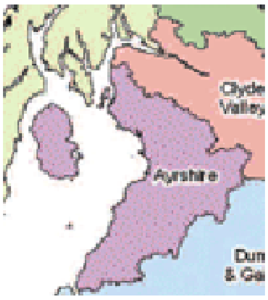
b)


Tayside
Fife
Priority catchments South Esk, Lunan and Tay
Average concentration (mg P/l)
35
30
25
20
15
10
5
0
10 10 10 11 11 11 12 13 14 14 15 16 16 18 20 21 22 24 27 28 30 33 36 37 38 40 46 48 51 59 70 74 84 94 117 194 6571
Postcode

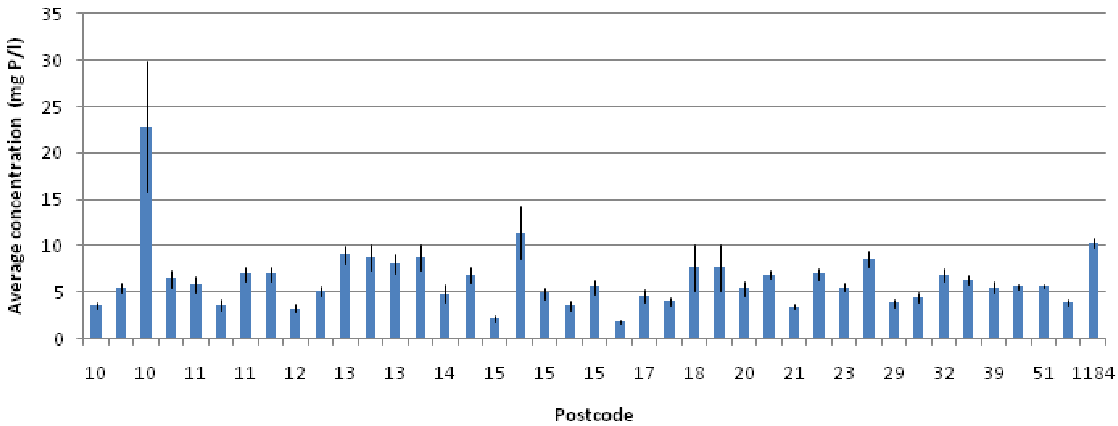
c)


Lothian
Scottish Borders
Priority catchment Eye
Average concentration (mg P/l)
14
12
10
8
6
4
2
0
17
19
30
33
39
49
67
80
Postcode

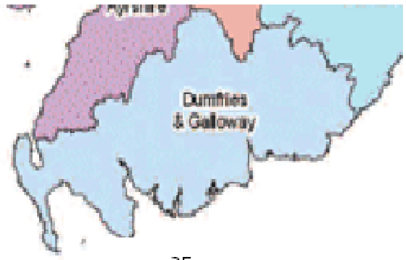
d)



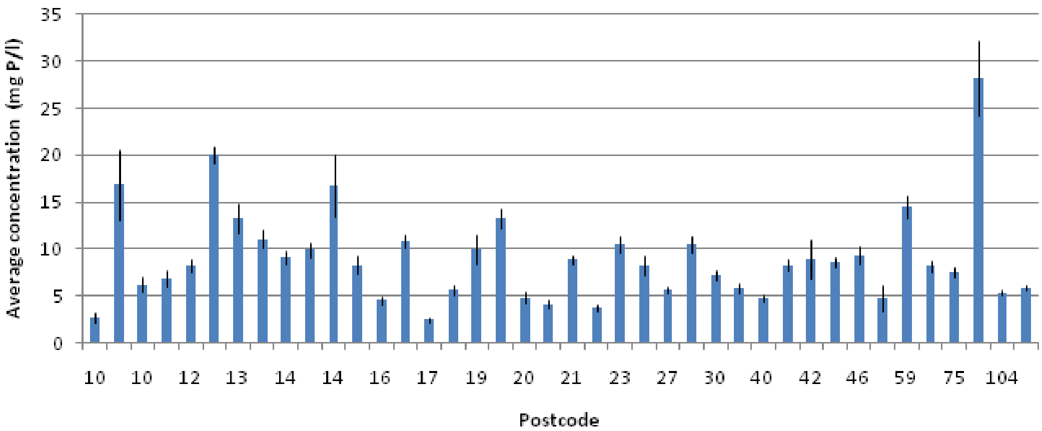
Priority catchments, North Ayrshire Coastal, Ayr, Doon, Irvine and Garnock



e)



Priority catchments, Stewartry Coastal and Galloway Coastal



The degree of variability between averages for individual postcodes was quite large, especially for those catchments located within NE Scotland and Tayside.

Catchment summary – River Ugie (32)

The total number of soil samples collected from within the River Ugie catchment was 1344 with a maximum of 203 collected during the calendar year 1997 and a minimum of 19 during 2010. Median pH, DOM and extractable P were 5.9, 7.0 and 6.1, respectively. The proportion (%) of samples falling within each P class was 3, 26, 53, 12, 6, <1, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	55	6.0	0.36	1.3	5.5	14.6
1997	203	6.4	0.30	0.9	5.5	37.5
1998	144	7.7	0.35	2.0	6.9	43.5
1999	161	7.3	0.29	1.5	6.5	20.9
2000	97	6.2	0.41	1.1	5.6	38.9
2001	115	6.4	0.39	1.9	4.9	30.4
2002	47	8.2	0.77	2.1	6.4	27.8
2003	35	7.0	0.58	1.5	5.8	15.5
2004	89	5.9	0.27	1.1	5.7	14.8
2005	55	5.6	0.58	1.1	4.3	18.6
2006	89	7.5	0.50	1.1	6.7	29.4
2007	74	8.3	0.69	1.7	6.6	41.3
2008	138	9.1	0.45	1.0	8.6	40.8
2009	23	3.7	0.40	1.6	3.2	9.4
2010	19	4.6	0.34	1.9	4.7	7.2

DOM (%)

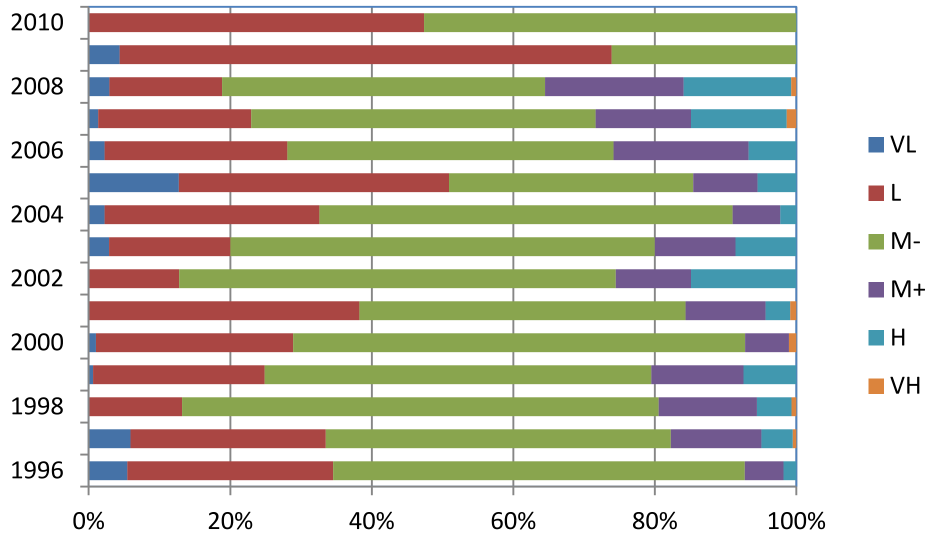
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	55	7.1	0.27	4.1	7.0	17.8
1997	203	7.3	0.19	2.8	6.9	30.7
1998	144	7.1	0.12	3.8	7.0	14.2
1999	161	7.6	0.15	3.9	7.5	18.3
2000	97	7.1	0.16	4.6	7.0	13.5

2001	115	7.7	0.19	4.2	7.4	22.8
2002	47	7.1	0.18	4.4	7.6	9.0
2003	35	6.1	0.22	3.1	6.5	8.8
2004	89	6.9	0.16	3.9	6.5	12.0
2005	55	7.7	0.39	3.6	7.2	18.9
2006	89	7.4	0.14	4.9	7.2	10.7
2007	74	7.8	0.34	4.1	7.4	26.6
2008	138	5.5	0.19	3.9	4.0	13.8
2009	23	8.2	0.53	4.9	7.4	16.2
2010	19	10.2	1.42	6.3	8.4	34.1

pH

Year	Count			Minimum	Median	Maximum
1996	55			5.0	5.8	6.6
1997	203			4.1	5.8	7.8
1998	144			5.1	5.9	6.5
1999	161			4.8	6.0	6.7
2000	97			4.9	5.9	7.1
2001	115			5.0	5.8	6.7
2002	47			5.3	5.9	6.8
2003	35			5.3	6.1	6.4
2004	89			4.9	5.9	6.6
2005	55			4.6	5.6	6.2
2006	89			5.3	5.9	7.7
2007	74			4.9	5.8	7.0
2008	138			4.6	5.9	7.5
2009	23			5.2	5.6	6.3
2010	19			4.0	5.6	6.3

Summary of P status



A summary of the distribution by soil P status for samples collected prior to next crop.

Spring and winter sown crops were the dominant form of crop prior to the samples being taken.

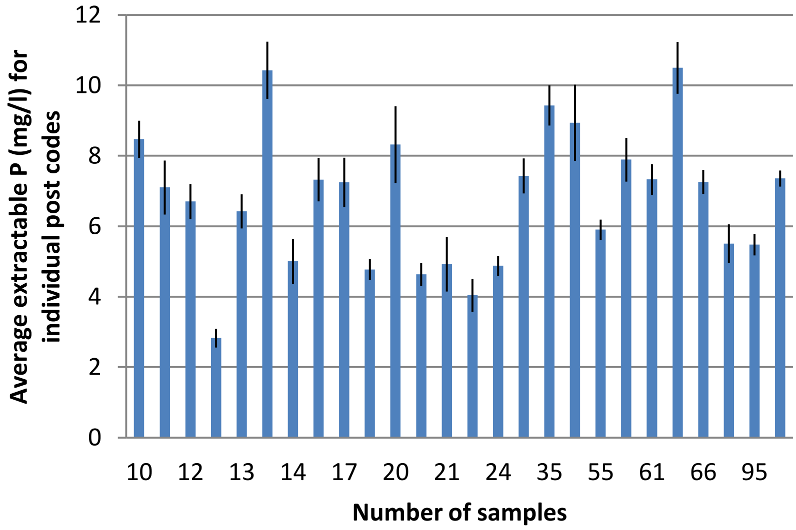
River Ugie	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	1	5	0	13	0	5	7	4
L	0	0	1	90	2	153	0	59	20	22
M-	0	0	2	98	7	342	0	218	12	29
M+	0	0	0	16	1	82	0	53	1	10
H	0	0	0	7	0	37	1	31	4	5
VH	0	0	0	1	0	4	0	1	0	0
All	0	0	4	217	10	631	1	367	44	70

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from one post code area

River Ugie						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
AB42	1025	7.079	0.133	0.9	6.2	41.3
AB43	215	6.48	0.278	1.1	5.6	43.5
AB53	104	7.523	0.564	1.1	6.15	38.9

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Ythan (33)

The total number of soil samples collected from within the River Ythan catchment was 3876 with a maximum of 417 collected during the calendar year 1997 and a minimum of 153 during 2009. Median pH, DOM and extractable P were 6.0, 7.3 and 7, respectively. The proportion (%) of samples falling within each P class was 1, 16, 59, 15, 9, 1, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	208	8.2	0.35	1.6	6.7	42.6
1997	417	8.7	0.30	1.2	7.4	74.6
1998	347	8.3	0.32	1.6	6.9	43.6
1999	348	8.2	0.28	1.3	7.2	55.2
2000	231	7.1	0.24	1.9	6.5	32.1
2001	242	7.4	0.25	1.4	6.3	26.1
2002	372	7.5	0.20	1.8	6.8	32.0
2003	212	7.6	0.26	0.7	6.8	24.1
2004	191	7.3	0.28	0.6	6.2	25.2
2005	160	6.3	0.15	2.2	6.0	12.4
2006	245	8.8	0.36	0.9	8.0	62.7
2007	266	9.0	0.27	1.1	8.0	30.4
2008	274	9.3	0.38	1.8	8.3	72.8
2009	153	7.9	0.55	1.6	6.8	74.5
2010	210	6.8	0.20	1.6	6.4	21.4

DOM (%)

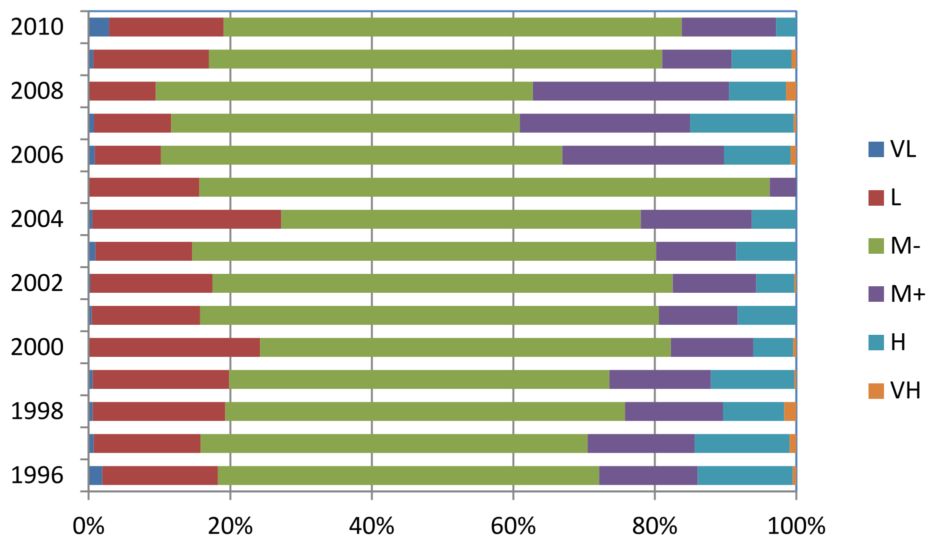
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	208	8.0	0.18	3.0	7.5	20.9
1997	417	7.5	0.11	2.2	7.1	17.0
1998	347	7.0	0.09	2.4	7.0	14.6
1999	348	7.2	0.10	2.2	7.4	14.9

2000	231	7.7	0.09	3.8	7.6	14.9
2001	242	8.1	0.10	4.0	7.9	16.1
2002	372	7.8	0.08	4.5	7.6	14.3
2003	212	7.1	0.09	4.2	7.0	11.3
2004	191	7.4	0.11	1.9	7.2	13.3
2005	160	7.7	0.14	4.0	7.5	15.0
2006	245	7.4	0.09	4.9	7.2	15.5
2007	266	7.7	0.14	2.1	7.6	19.4
2008	274	5.2	0.12	4.0	4.0	12.8
2009	153	7.3	0.10	5.1	7.2	13.3
2010	210	8.0	0.11	4.1	7.8	13.2

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	208			3.9	6.0	6.7
1997	417			4.0	5.9	7.6
1998	347			4.8	6.0	7.8
1999	348			4.7	6.0	6.9
2000	231			4.8	6.0	7.4
2001	242			4.9	6.0	7.0
2002	372			4.9	6.0	6.9
2003	212			5.2	6.0	6.6
2004	191			4.8	5.9	7.9
2005	160			5.2	6.0	6.5
2006	245			5.2	6.0	7.1
2007	266			4.8	5.9	6.8
2008	274			4.8	6.0	6.9
2009	153			5.0	6.0	6.8
2010	210			5.0	6.0	6.5

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

Soil samples were collected prior to a range of crop types and despite the large numbers of potatoes and vegetable crops a few samples had a very high P status.

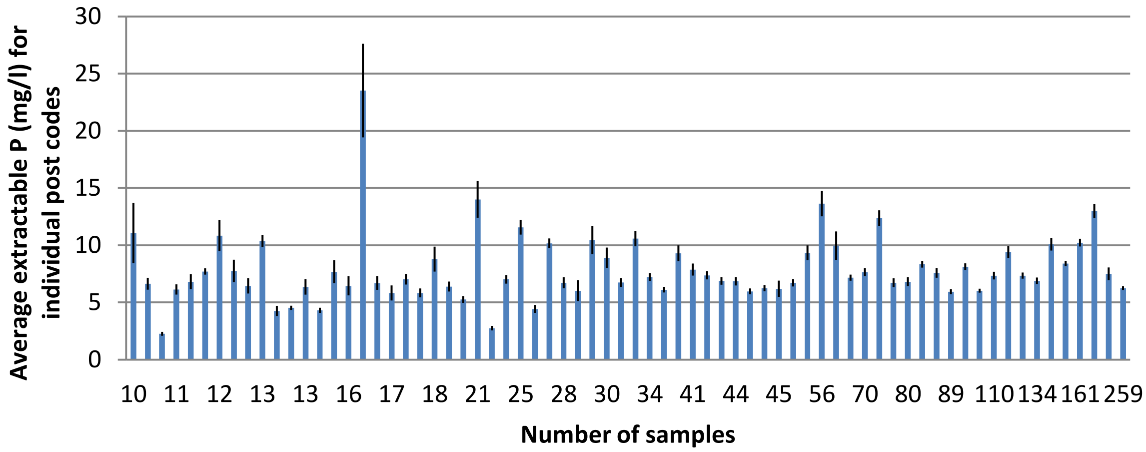
River Ythan	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	14	4	7	1	1	0	0
L	0	0	8	177	101	215	8	86	14	19
M-	2	2	16	324	260	751	42	748	51	75
M+	0	0	1	53	54	170	47	228	13	21
H	0	0	1	24	25	97	48	116	6	24
VH	0	0	0	2	0	4	6	1	5	4
All	2	2	26	594	444	1244	152	1180	89	143

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from three post code areas

River Ythan						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
AB21	75	11.275	0.96	1.1	9.4	55.2
AB41	1987	7.934	0.105	1.4	7.1	74.5
AB42	13	6.677	0.713	4	6.2	11.1
AB51	1040	7.438	0.114	0.6	6.7	26.1
AB53	754	8.734	0.234	1.2	7	74.6
AB54	7	6.771	0.37	5.1	6.9	8

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Dee (Grampian 37)

The total number of soil samples collected from within the River Dee catchment was 2629 with a maximum of 292 collected during the calendar year 2007 and a minimum of 104 during 2010. Median pH, DOM and extractable P were 5.9, 6.1 and 6.6, respectively. The proportion (%) of samples falling within each P class was 3, 22, 51, 14, 7, 1, for the VL, L, M-, M+, H, VH, respectively.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	105	6.6	0.56	0.4	5.8	55.7
1997	263	7.3	0.46	1.2	5.9	86.6
1998	207	8.0	0.53	0.8	6.6	94.3
1999	147	8.4	0.47	0.6	7.8	47.3
2000	168	6.6	0.32	0.8	5.6	25.1
2001	115	9.5	0.58	1.1	8.3	34.3
2002	274	9.8	0.99	0.4	7.0	160.4
2003	180	6.7	0.25	0.4	6.5	18.2
2004	160	8.7	1.11	0.2	6.3	157.3
2005	141	8.8	0.48	1.3	7.1	33.6
2006	148	8.1	0.52	1.2	6.1	43.5
2007	292	7.5	0.20	0.4	6.9	27.3
2008	190	8.2	0.35	1.4	6.9	24.8
2009	135	6.8	0.48	0.6	6.2	48.4
2010	104	7.3	0.58	1.5	5.9	38.2

DOM (%)

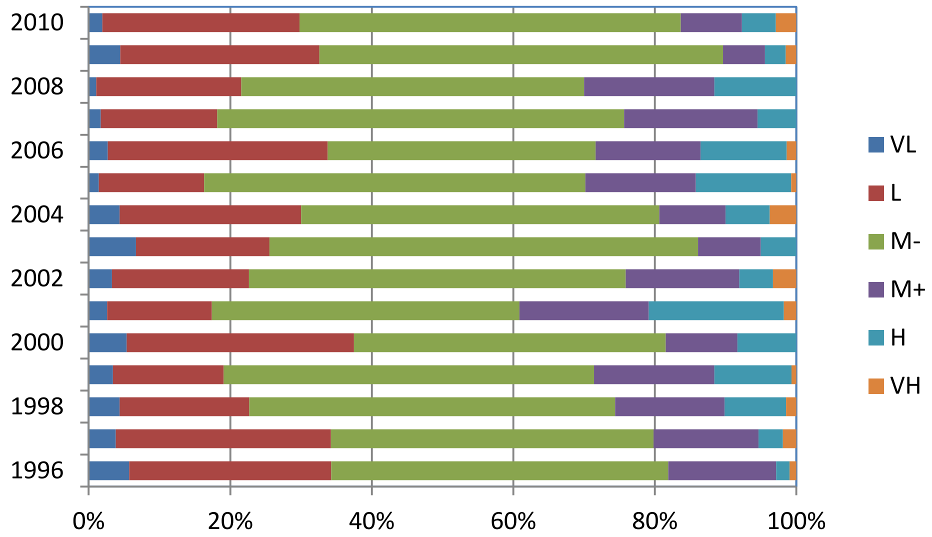
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	105	7.3	0.23	2.5	7.0	21.1
1997	263	7.5	0.39	2.7	6.4	58.6
1998	207	6.3	0.17	1.6	5.9	21.0
1999	147	6.0	0.16	2.7	5.9	20.2

2000	168	6.6	0.16	2.9	6.4	17.3
2001	115	6.9	0.25	2.5	6.5	20.7
2002	274	6.1	0.09	2.4	6.1	12.7
2003	180	6.6	0.40	2.5	5.5	39.9
2004	160	5.8	0.14	1.7	5.7	10.0
2005	141	7.0	0.24	2.9	6.5	26.6
2006	148	6.0	0.16	1.3	5.8	13.7
2007	292	6.9	0.15	1.9	6.5	21.4
2008	190	5.0	0.12	2.7	4.0	11.3
2009	135	7.2	0.18	2.3	7.5	11.6
2010	104	7.9	0.34	2.7	7.4	16.6

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	105			5.1	6.1	6.8
1997	263			4.2	5.9	7.4
1998	207			4.9	5.8	6.9
1999	147			4.7	5.9	7.7
2000	168			4.3	5.9	7.5
2001	115			4.7	5.9	6.8
2002	274			5.0	5.9	7.3
2003	180			4.1	5.8	7.1
2004	160			5.1	5.9	7.0
2005	141			5.1	5.9	6.7
2006	148			4.9	5.9	6.8
2007	292			4.8	5.9	7.2
2008	190			4.9	5.8	6.5
2009	135			4.7	5.8	6.7
2010	104			5.2	5.9	6.5

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

A large proportion of samples were collected prior to a spring sown crop or grass.

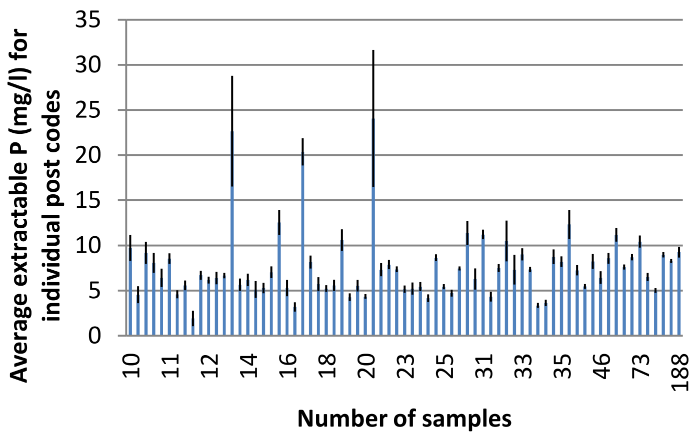
River Dee (Grampian)	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	6	44	0	23	1	2	3	12
L	0	2	37	289	15	186	3	13	10	36
M-	1	3	41	463	76	557	6	78	38	76
M+	3	0	8	128	30	156	2	23	10	16
H	0	0	2	68	9	62	3	11	10	32
VH	1	0	0	6	1	2	8	0	6	11
All	5	5	94	998	131	986	23	127	77	183

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from three post code areas

River Dee (Grampian)						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
AB12	228	9.218	0.818	0.4	6.85	157.3
AB13	174	6.774	0.257	0.4	6.1	27.3
AB14	28	16.16	3.58	1.9	10.45	94.3
AB15	158	8.599	0.56	0.4	7.6	38.9
AB31	541	8.267	0.52	0.6	6.3	160.4
AB32	550	8.635	0.181	1.4	7.9	33.6
AB34	535	6.29	0.202	0.2	5.2	55.7
AB35	263	8.274	0.466	0.8	7	86.6
AB39	97	6.446	0.427	0.8	5.7	34.1
AB51	55	6.462	0.344	2.5	6	12.8

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Deveron (30)

The Deveron catchment area is situated within the NE Scotland agricultural advisory area

The total number of soil samples collected from within the Deveron catchment was 3939 with a maximum of 386 collected during the calendar year 1997 and a minimum of 159 during 2005. Median pH, DOM and extractable P were 5.9, 7.3 and 6.3, respectively. The proportion (%) of samples falling within each advisory P class was 4, 27, 48, 12, 9, 1, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	311	7.5	0.32	1.1	6.1	66.5
1997	386	7.1	0.27	0.3	5.9	38.2
1998	282	7.4	0.32	0.2	6.2	42.0
1999	352	8.0	0.37	0.9	5.9	76.4
2000	245	7.1	0.41	0.4	5.8	63.3
2001	255	8.5	1.01	0.5	5.5	158.4
2002	348	7.6	0.53	1.0	5.8	141.1
2003	288	7.0	0.28	0.7	6.0	37.7
2004	254	7.8	0.38	0.8	7.1	84.1
2005	159	6.9	0.29	1.5	6.3	25.7
2006	227	8.4	0.38	0.7	6.7	30.3
2007	281	8.6	0.40	1.2	7.0	82.3
2008	199	8.4	0.41	0.8	7.3	40.8
2009	169	5.9	0.38	0.7	5.3	58.8
2010	183	5.8	0.24	1.1	5.1	22.2

DOM

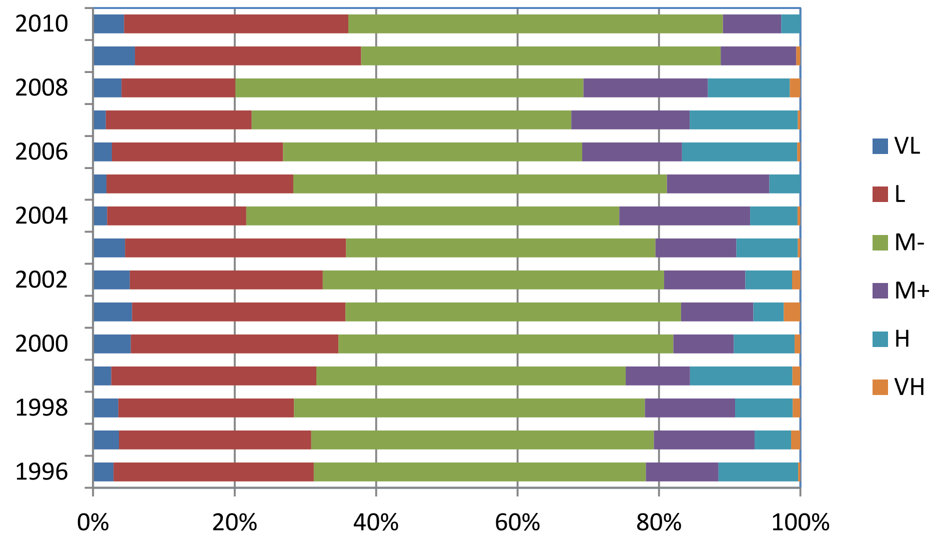
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	311	7.4	0.11	2.4	7.3	24.8
1997	386	7.3	0.09	3.3	7.2	17.0
1998	282	7.3	0.10	3.1	7.3	14.8
1999	352	7.7	0.10	1.9	7.6	13.3

2000	245	8.0	0.12	2.5	7.7	17.2
2001	255	7.6	0.14	2.1	7.7	17.8
2002	348	8.0	0.31	2.7	7.7	82.7
2003	288	7.1	0.10	2.7	7.0	12.6
2004	254	7.2	0.11	2.6	7.1	15.6
2005	159	7.2	0.14	3.0	7.1	13.1
2006	227	7.6	0.11	3.3	7.5	12.8
2007	281	7.7	0.11	2.7	7.7	23.2
2008	199	4.9	0.12	4.0	4.0	10.8
2009	169	7.9	0.14	3.0	7.8	13.5
2010	183	7.5	0.18	2.2	7.2	17.9

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	311			5.0	6.0	7.9
1997	386			4.8	5.9	7.3
1998	282			4.4	5.9	6.9
1999	352			4.7	5.9	6.6
2000	245			4.4	5.9	7.3
2001	255			4.9	5.9	7.4
2002	348			5.1	6.0	7.9
2003	288			5.0	5.9	6.7
2004	254			4.9	5.9	6.8
2005	159			5.0	5.9	6.5
2006	227			5.0	5.9	6.7
2007	281			4.5	5.9	6.9
2008	199			5.0	5.8	6.5
2009	169			4.5	5.9	6.8
2010	183			4.1	5.9	6.6

Summary of P status by year



A summary of the distribution by soil P status for samples collected prior to next crop.

Approximately half the total number of soil samples was collected prior to a spring sown crop, with the other significant crops being winter sown arable and grass.

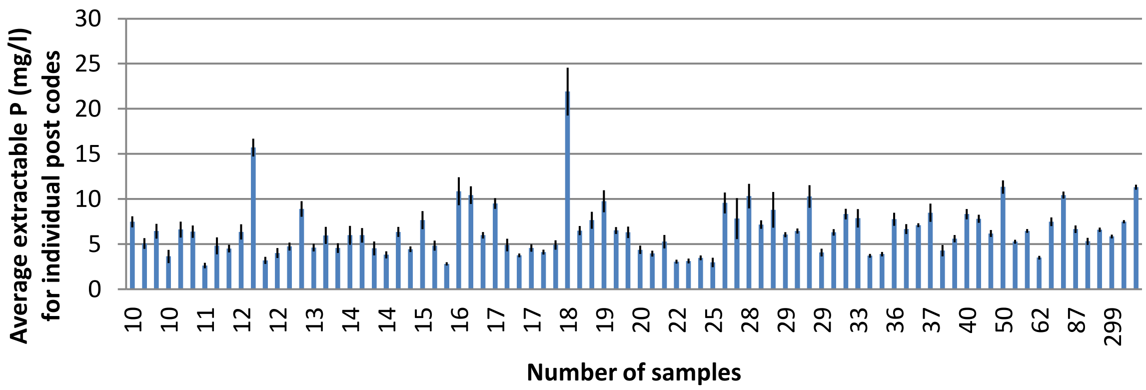
River Deveron	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	4	56	0	58	1	8	8	10
L	0	0	11	328	21	517	4	100	22	45
M-	0	0	17	323	61	1021	3	380	44	31
M+	0	0	4	64	16	236	0	154	9	9
H	0	0	2	23	11	139	1	157	7	1
VH	0	0	0	3	4	10	0	4	9	3
All	0	0	38	797	113	1981	9	803	99	99

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

River Deveron						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
AB43	3	3.53	1.01	1.7	3.7	5.2
AB45	257	9.35	0.742	0.8	6.6	141.1
AB53	1865	8.414	0.149	0.2	7	84.1
AB54	1300	6.144	0.107	0.3	5.4	60.6
AB55	514	6.905	0.516	0.4	5	158.4

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Tay (46)

The total number of soil samples collected from within the River Tay catchment was 5320 with a maximum of 603 collected during the calendar year 2001 and a minimum of 228 during 2003. Median pH, DOM and extractable P were 6.0, 5.8 and 6.9, respectively. The proportion (%) of samples falling within each P class was 1, 11, 47, 22, 18, 2, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	370	9.5	0.32	0.7	8.2	51.5
1997	493	8.6	0.23	0.8	7.8	29.0
1998	365	8.9	0.60	0.1	7.2	198.0
1999	480	9.0	0.31	0.5	7.8	95.7
2000	261	8.2	0.44	0.8	6.8	50.3
2001	603	7.7	0.31	0.3	6.0	117.8
2002	365	9.0	0.64	0.0	6.4	143.7
2003	228	8.8	0.43	0.6	7.5	41.9
2004	288	7.1	0.27	0.4	6.5	29.6
2005	262	8.5	0.35	1.3	7.0	44.5
2006	425	7.0	0.32	0.3	5.4	70.5
2007	313	11.0	0.59	0.6	8.8	93.9
2008	285	8.5	0.37	1.1	7.0	59.3
2009	337	8.0	0.38	0.7	6.6	79.0
2010	244	6.5	0.27	0.5	5.3	21.2

DOM

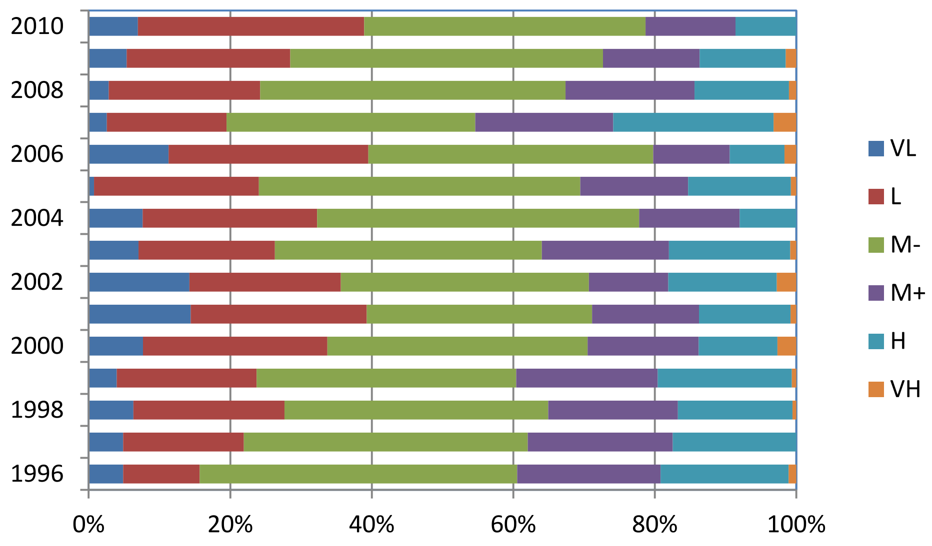
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	370	6.1	0.12	1.5	5.7	18.3
1997	493	6.7	0.13	2.3	6.0	25.0
1998	365	6.4	0.12	2.2	5.9	18.9
1999	480	6.0	0.11	1.5	5.7	30.1

2000	261	6.2	0.19	1.1	5.5	25.2
2001	603	6.9	0.13	1.8	6.4	30.1
2002	365	6.6	0.13	1.9	6.3	18.2
2003	228	5.6	0.15	1.7	5.3	15.4
2004	288	6.0	0.20	2.3	5.5	51.1
2005	262	6.1	0.13	2.0	5.7	17.5
2006	425	6.7	0.12	2.0	6.1	22.4
2007	313	5.7	0.13	2.1	5.0	19.0
2008	285	5.6	0.13	2.3	5.0	21.4
2009	337	6.1	0.11	1.7	5.9	13.2
2010	244	6.8	0.17	1.9	6.1	14.4

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	370			4.4	6.1	6.9
1997	493			4.5	6.1	7.3
1998	365			4.9	6.0	7.2
1999	480			4.8	6.2	7.3
2000	261			4.4	6.0	7.2
2001	603			4.6	5.9	7.8
2002	365			4.8	6.0	7.2
2003	228			4.8	6.0	7.2
2004	288			3.8	6.0	7.9
2005	262			4.5	6.0	7.3
2006	425			4.8	6.0	8.0
2007	313			4.4	6.1	7.2
2008	285			4.9	6.0	8.0
2009	337			4.7	6.0	8.0
2010	244			5.0	6.0	7.0

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The soil samples collected from the Tay catchment showed a wide range of cropping, with the highest being grass followed y spring sown crops.

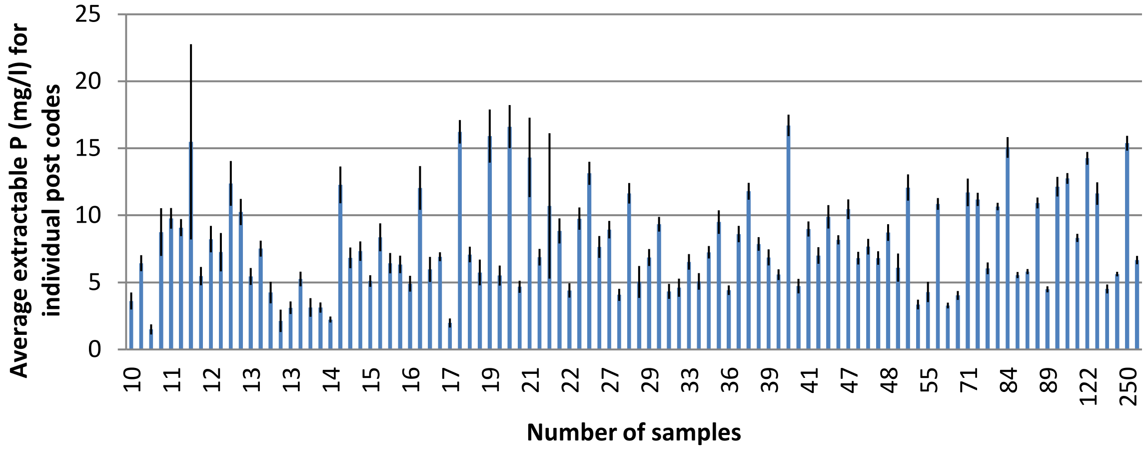
River Tay	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	6	123	3	2	8	0	3	237
L	1	0	21	292	28	54	5	12	18	729
M-	3	6	13	225	134	267	18	117	48	1247
M+	9	3	8	48	81	118	17	63	27	496
H	5	2	3	23	82	108	24	37	13	473
VH	0	0	0	1	5	6	2	0	6	40
All	18	11	51	712	333	555	74	229	115	3222

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from five post code areas

River Tay						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
DD11	7	6.271	0.828	3.3	6.2	9
DD5	17	6.912	0.331	4.5	6.7	9.7
DD8	1611	7.948	0.188	0.3	6.7	198
FK20	14	5.25	0.545	2.5	5.5	10.8
FK21	10	3.61	0.634	1.4	2.8	7.5
PH1	719	9.752	0.23	0.1	8.4	59.3
PH10	601	6.022	0.182	0.6	5.1	41
PH11	243	5.541	0.267	0.3	4.7	36.4
PH12	588	13.687	0.478	1.4	11.5	143.7
PH13	540	10.513	0.313	1.5	9.2	95.7
PH15	194	6.026	0.32	0.7	5.35	44.7
PH16	242	5.364	0.272	0.1	4.65	49.7
PH17	27	4.07	0.45	1.2	3.7	12.4
PH18	185	4.437	0.279	0	3.4	21.6
PH19	3	5.47	2.94	1.2	4.1	11.1
PH2	128	10.188	0.493	1.9	9.4	30.8
PH7	37	7.865	0.506	3.4	7.9	18.3
PH8	90	7.49	1.32	0.5	5.25	117.8
PH9	64	5.51	1.13	0.5	3.05	70.5

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Average extractable P (mg/l) for individual post codes
25
20
15
10
5
0
10
11
12
13
13
14
15
16
17
19
21
22
27
29
33
36
39
41
47
48
55
71
84
89
122
250
Number of samples

Catchment summary – South Esk (41)

The total number of soil samples collected from within the South Esk catchment was 7815 with a maximum of 823 collected during the calendar year 2003 and a minimum of 161 during 1996. Median pH, DOM and extractable P were 6.1, 5.3 and 8.5, respectively. The proportion (%) of samples falling within each P class was 1, 11, 46, 22, 18, 2, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	161	13.1	1.46	1.7	8.9	198.0
1997	184	9.3	0.46	2.0	8.0	63.2
1998	263	7.8	0.22	1.3	6.8	25.1
1999	289	7.9	0.20	1.0	6.9	26.0
2000	272	11.6	0.38	1.3	10.2	60.3
2001	504	10.5	0.32	1.5	8.5	60.1
2002	437	10.1	0.25	1.5	9.3	65.3
2003	823	11.2	0.26	0.6	9.3	85.5
2004	685	9.3	0.18	0.5	8.2	49.7
2005	680	11.4	0.27	0.7	9.8	49.6
2006	640	10.0	0.27	0.5	8.6	51.5
2007	654	10.3	0.24	1.2	9.4	87.7
2008	623	11.2	0.29	0.1	9.5	58.8
2009	682	10.1	0.39	0.7	7.9	120.0
2010	718	8.0	0.21	1.1	6.8	52.9

DOM

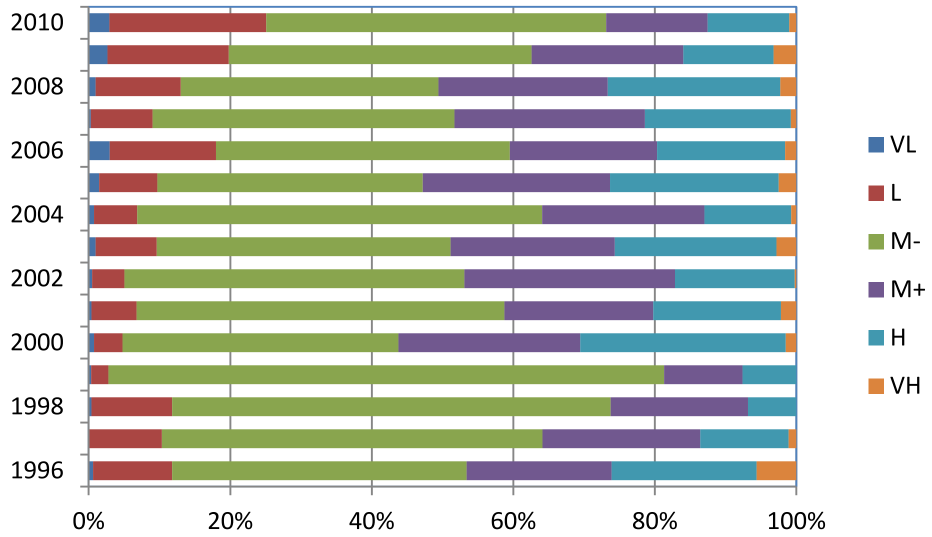
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	161	6.3	0.13	2.0	6.3	11.7
1997	184	6.1	0.15	2.8	5.7	16.6
1998	263	5.0	0.06	2.9	4.8	10.7
1999	289	6.3	0.06	2.5	6.3	10.1

2000	272	5.8	0.07	3.1	5.8	9.7
2001	504	5.4	0.05	2.5	5.4	15.2
2002	437	5.6	0.08	2.4	5.5	16.4
2003	823	5.4	0.05	1.8	4.9	11.3
2004	685	5.6	0.05	2.0	5.4	13.2
2005	680	5.4	0.06	2.0	5.2	15.8
2006	640	5.6	0.09	2.2	5.0	21.9
2007	654	5.6	0.08	1.9	5.0	17.8
2008	623	5.5	0.09	1.6	5.0	17.8
2009	682	5.2	0.05	1.2	5.0	14.0
2010	718	5.6	0.06	2.0	5.4	12.1

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	161			4.4	6.1	8.1
1997	184			5.1	6.2	7.1
1998	263			4.6	5.9	6.8
1999	289			5.3	5.9	6.9
2000	272			4.6	6.2	7.5
2001	504			4.4	6.3	7.3
2002	437			5.2	6.2	7.3
2003	823			4.6	6.1	7.2
2004	685			5.3	6.1	7.8
2005	680			5.2	6.1	7.5
2006	640			4.0	6.1	7.4
2007	654			4.6	6.0	7.3
2008	623			4.9	6.1	7.6
2009	682			5.1	6.1	8.0
2010	718			5.0	6.1	7.6

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of soil samples were collected prior to potatoes and then cereals followed by grass.

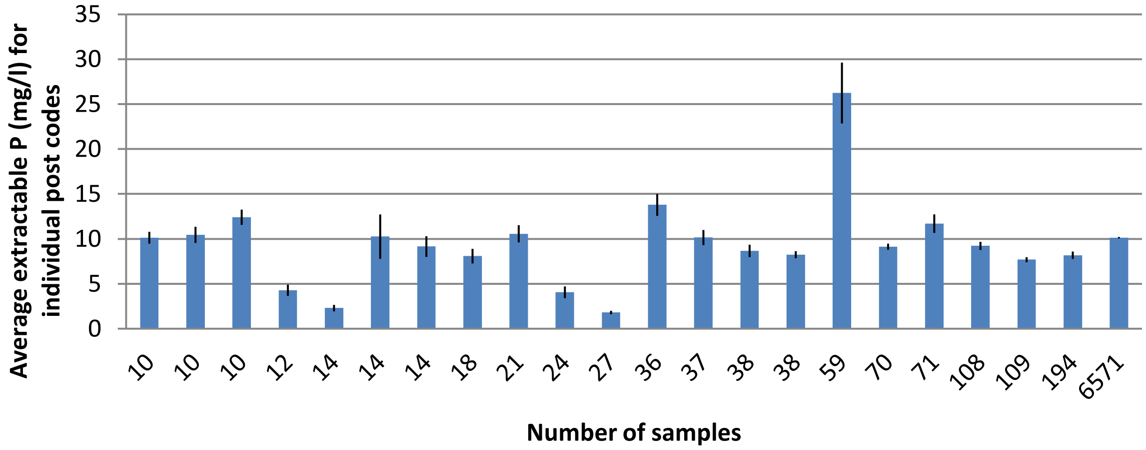
River South Esk	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	1	23	0	0	0	0	0	74
L	0	0	2	24	7	7	0	2	3	765
M-	1	0	0	23	87	56	4	45	24	3292
M+	0	1	2	6	18	20	4	24	2	1621
H	0	0	0	3	14	9	3	15	1	1302
VH	0	0	0	0	0	3	0	1	0	126
All	1	1	5	79	126	95	11	87	30	7180

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from one post code area

River South Esk (Tayside)						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
DD10	4	17	5.57	9.2	12.7	33.4
DD8	432	11.713	0.743	0.5	8.7	198
DD9	7179	10.009	0.0762	0.1	8.5	87.7

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Ayr (89)

The total number of soil samples collected from within the River Ayr catchment was 313 with a maximum of 69 collected during the calendar year 1997 and a minimum of 2 during 2004. Median pH, DOM and extractable P were 5.7, 8.4 and 5.1 respectively. The proportion (%) of samples falling within each P class was 6, 38, 42, 10, 4, 1, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	9	5.0	1.06	1.3	4.3	10.2
1997	69	7.0	0.55	0.4	6.2	20.3
1998	35	6.1	1.13	1.1	4.4	39.8
1999	19	8.9	1.37	2.7	6.1	21.8
2000	18	5.4	0.59	2.2	4.9	10.7
2001	24	5.3	0.61	0.8	5.8	11.1
2002	13	4.1	0.60	1.4	3.7	9.0
2003	20	5.1	0.63	1.2	4.2	12.3
2004	2	6.2	2.43	3.8	6.2	8.6
2005	10	3.9	0.50	1.4	3.7	6.1
2006	19	4.4	0.54	1.3	3.4	10.8
2007	4	7.4	1.65	4.7	6.5	12.0
2008	18	11.5	2.03	6.5	8.9	44.1
2009	41	5.0	0.34	1.3	4.6	10.6
2010	12	5.0	0.66	2.7	4.2	11.1

DOM

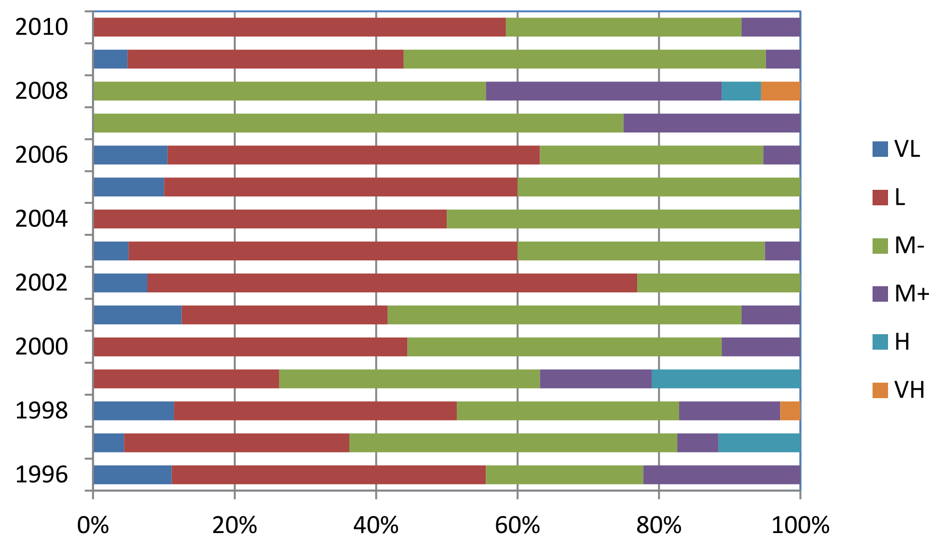
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	9	6.7	0.51	4.2	7.3	8.5
1997	69	7.6	0.28	4.1	7.1	16.0
1998	35	7.1	0.35	4.0	6.9	11.5
1999	19	8.1	0.58	3.8	8.4	11.7
2000	18	8.4	0.66	4.3	7.9	13.6

2001	24	9.1	0.63	3.3	8.6	16.8
2002	13	8.5	0.25	7.2	8.3	10.7
2003	20	8.2	0.67	4.7	8.0	13.9
2004	2	10.0	0.33	9.7	10.0	10.4
2005	10	7.6	0.73	4.3	7.4	11.6
2006	19	9.4	0.41	7.1	9.0	13.6
2007	4	8.8	0.60	7.7	8.8	10.0
2008	18	9.0	0.43	4.0	9.3	11.5
2009	41	11.3	0.47	3.3	11.0	20.9
2010	12	8.9	0.97	5.3	8.2	16.8

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	9			5.0	5.9	6.6
1997	69			5.1	5.7	7.2
1998	35			5.2	5.7	6.3
1999	19			5.3	5.9	6.6
2000	18			5.1	6.0	7.3
2001	24			4.9	5.5	7.4
2002	13			5.3	5.7	6.5
2003	20			5.3	5.7	7.2
2004	2			5.3	6.0	6.7
2005	10			5.5	6.0	6.6
2006	19			5.0	5.6	6.1
2007	4			5.4	5.9	6.4
2008	18			5.3	5.8	6.5
2009	41			4.9	5.6	6.5
2010	12			5.2	5.7	7.0

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

Approximately half the total number of soil samples was collected prior to grass followed by spring and winter sown crops. Only two samples were reported as having a very high P status.

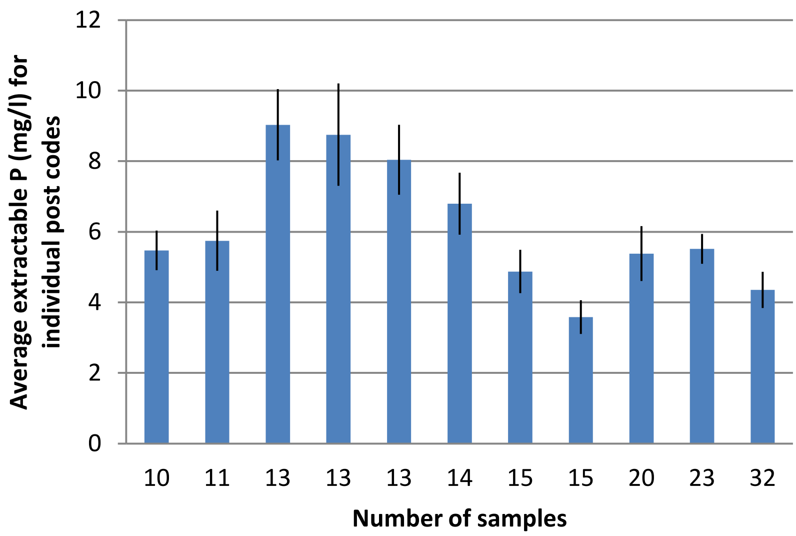
River Ayr	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	13	0	2	0	0	0	3
L	0	0	0	74	0	18	1	7	3	16
M-	0	0	1	82	0	22	1	14	2	9
M+	0	0	0	17	0	5	0	3	0	5
H	0	0	0	6	0	2	3	1	0	1
VH	0	0	0	0	0	0	0	0	1	1
All	0	0	1	192	0	49	5	25	6	35

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

River Ayr						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
KA1	45	5.458	0.552	1.4	4.3	20.2
KA18	118	6.256	0.423	1.3	5.4	44.1
KA5	62	7.663	0.749	1.6	6.2	39.8
KA6	88	5.274	0.433	0.4	3.9	21.8

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Irvine (90)

The total number of soil samples collected from within the River Irvine catchment was 278 with a maximum of 55 collected during the calendar year 1999 and a minimum of 3 during 2006. Median pH, DOM and extractable P were 5.9, 5.7 and 5.2, respectively. The proportion (%) of samples falling within each P class was 6, 32, 48, 8, 4, 2, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	11	6.5	2.15	0.6	3.6	24.5
1997	44	6.5	0.70	1.0	5.1	20.2
1998	20	8.1	2.24	1.4	5.0	44.7
1999	55	8.7	1.53	1.4	6.0	70.5
2000	14	5.3	1.08	1.4	3.8	16.3
2001	30	7.5	1.47	0.7	5.7	41.8
2002	27	5.2	0.49	1.3	5.2	13.3
2003	30	5.5	0.41	1.7	5.2	12.3
2005	4	2.4	0.50	1.0	2.7	3.2
2006	3	10.0	3.84	6.1	6.2	17.7
2007	9	5.3	0.98	1.4	4.8	11.1
2008	10	8.2	1.29	3.7	8.3	16.2
2009	9	31.9	27.80	1.2	4.3	254.0
2010	12	4.9	0.67	1.7	4.7	9.6

DOM

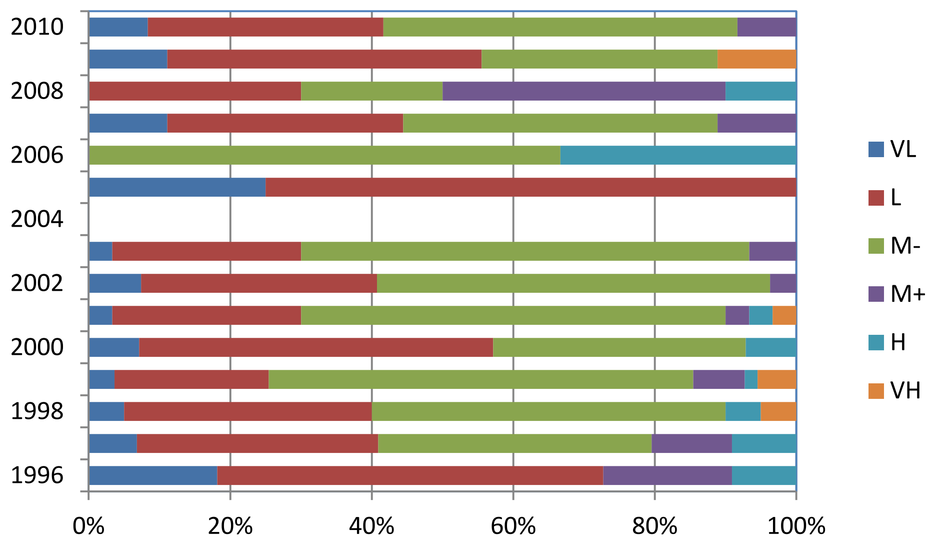
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	11	9.9	0.63	7.3	10.2	13.7
1997	44	7.8	0.37	4.6	7.2	14.5
1998	20	7.3	0.45	5.4	6.4	13.1
1999	55	8.2	0.34	4.0	7.4	15.0

2000	14	8.6	0.52	5.6	8.4	11.2
2001	30	7.3	0.25	3.3	7.4	9.6
2002	27	7.1	0.28	4.3	7.2	9.7
2003	30	8.1	0.37	5.6	7.3	12.9
2005	4	6.3	0.33	5.4	6.6	6.8
2006	3	7.5	1.15	5.9	6.8	9.7
2007	9	9.3	1.12	3.7	8.5	14.7
2008	10	5.8	0.88	4.0	4.0	10.8
2009	9	17.6	6.91	7.6	11.1	72.6
2010	12	10.5	0.45	8.8	10.1	13.5

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	11			5.3	6.1	6.7
1997	44			4.9	5.7	6.8
1998	20			4.5	5.7	6.4
1999	55			5.2	5.7	7.3
2000	14			5.1	5.5	6.2
2001	30			4.6	5.8	6.2
2002	27			5.3	5.9	6.5
2003	30			5.1	5.8	6.6
2005	4			5.4	5.7	5.9
2006	3			5.2	5.6	6.9
2007	9			5.2	5.8	7.1
2008	10			4.7	5.4	5.8
2009	9			5.0	5.4	5.8
2010	12			5.3	5.5	6.1

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of samples were collected prior to grass with some spring and winter sown crops.

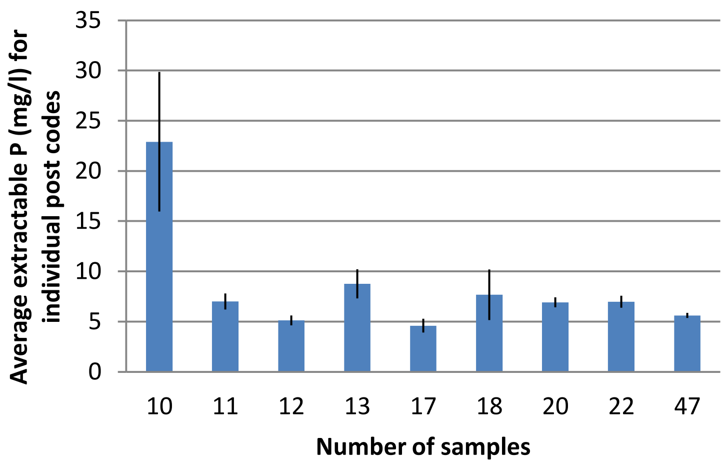
River Irvine	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	12	0	2	0	1	1	1
L	0	0	0	52	0	14	0	13	1	9
M-	0	0	0	72	1	21	0	20	2	18
M+	0	0	0	12	1	3	0	1	0	4
H	0	0	0	8	0	1	0	0	1	1
VH	0	0	0	1	0	0	0	3	1	1
All	0	0	0	157	2	41	0	38	6	34

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

River Irvine						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
KA1	38	12.97	6.64	0.7	4.35	254
KA16	9	15.76	4.69	1.4	10.5	44.7
KA17	8	7.49	1.34	1.7	7.05	12.8
KA2	73	5.804	0.243	1.3	5.5	12.6
KA3	117	6.644	0.771	0.6	4.7	70.5
KA4	9	6	1.61	1.7	5.7	17.7
KA5	22	7.373	0.952	2	6	20
ML10	2	4.1	0.2	3.9	4.1	4.3

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Garnock (91)

The total number of soil samples collected from within the River garnock catchment was 104 with a maximum of 29 collected during the calendar year 2009 and a minimum of 1 during 1998, 2002 and 2003. Median pH, DOM and extractable P were 5.5, 11.2 and 3.7, respectively. The proportion (%) of samples falling within each P class was 16, 43, 34, 7 for the VL, L, M-, M+.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	3	3.7	0.24	3.3	3.5	4.1
1997	10	3.8	0.37	2.0	4.5	5.2
1998	1	10.3	*	10.3	10.3	10.3
1999	15	4.7	0.75	1.0	4.1	11.6
2000	2	0.8	0.08	0.7	0.8	0.8
2001	7	8.0	1.69	1.7	8.6	13.5
2002	1	2.2	*	2.2	2.2	2.2
2003	1	4.5	*	4.5	4.5	4.5
2004	4	1.7	0.57	0.6	1.4	3.2
2007	13	6.6	0.72	2.9	7.7	11.1
2008	4	3.7	0.23	3.2	3.6	4.3
2009	29	3.8	0.40	0.7	3.3	7.7
2010	14	2.9	0.51	1.3	2.0	7.4

DOM

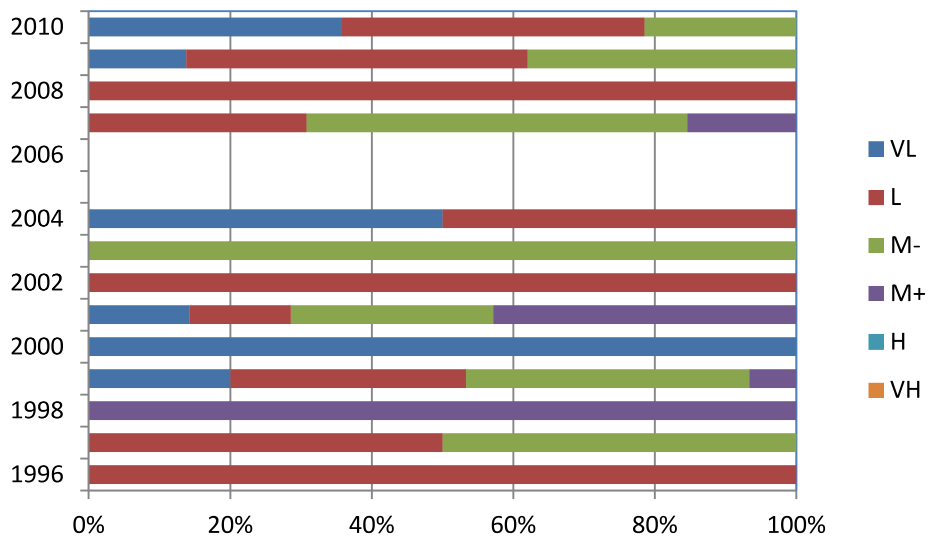
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	3	6.6	0.69	5.7	6.1	7.9
1997	10	11.1	0.84	8.0	10.2	14.7
1998	1	10.8	*	10.8	10.8	10.8
1999	15	10.6	0.58	7.6	10.5	15.0
2000	2	10.5	1.32	9.1	10.5	11.8

2001	7	12.2	1.26	7.0	13.7	16.4
2002	1	14.5	*	14.5	14.5	14.5
2003	1	9.7	*	9.7	9.7	9.7
2004	4	9.8	1.01	8.0	9.5	12.1
2007	13	8.4	0.98	3.9	8.2	14.7
2008	4	6.0	1.14	4.0	5.8	8.3
2009	29	11.6	0.23	8.4	11.5	13.5
2010	14	12.7	0.50	10.7	12.6	17.7

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	3			5.5	5.6	6.1
1997	10			5.1	5.3	6.0
1998	1			5.6	5.6	5.6
1999	15			5.2	5.5	5.9
2000	2			5.1	5.3	5.5
2001	7			5.2	5.9	6.6
2002	1			5.3	5.3	5.3
2003	1			5.4	5.4	5.4
2004	4			5.4	5.8	6.1
2007	13			5.2	5.7	6.0
2008	4			5.4	5.9	6.5
2009	29			5.1	5.4	7.6
2010	14			5.2	5.5	6.3

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of samples were collected prior to grass with no samples having a high or very high P status.

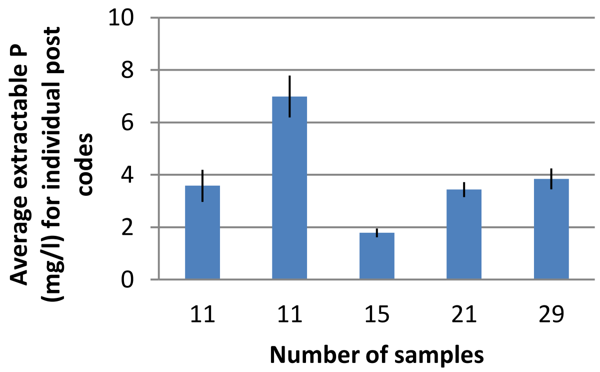
River Garnock	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	15	0	1	0	1	0	0
L	0	0	0	37	0	2	0	3	1	2
M-	0	0	1	24	0	3	0	1	0	6
M+	0	0	0	4	0	1	0	0	0	2
H	0	0	0	0	0	0	0	0	0	0
VH	0	0	0	0	0	0	0	0	0	0
All	0	0	1	80	0	7	0	5	1	10

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

River Garnock						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
G78	1	2.2	*	2.2	2.2	2.2
KA13	1	10.3	*	10.3	10.3	10.3
KA15	47	3.174	0.288	0.7	2.6	7.7
KA21	11	3.582	0.612	0.6	3.4	7.4
KA24	27	4.763	0.596	1	4.1	13.5
KA25	6	7.817	0.669	5	7.9	10.1
KA3	11	6.991	0.799	4.1	6.1	11.6

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – Eye Water (67)

The total number of soil samples collected from within the Eye Water catchment was 368 with a maximum of 60 collected during the calendar year 1996 and a minimum of 0 during 2004. Median pH, DOM and extractable P were 6.1, 7.7 and 3.8, respectively. The proportion (%) of samples falling within each P class was 17, 41, 25, 8, 8, 1, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	60	8.2	0.64	2.1	7.2	22.7
1997	19	11.6	2.96	1.3	5.1	49.4
1998	14	5.1	1.29	0.7	4.1	20.1
1999	13	10.8	2.61	0.6	10.6	29.8
2000	6	4.6	1.19	0.2	4.8	7.7
2001	14	4.3	0.68	1.6	3.4	10.1
2002	47	2.1	0.24	0.5	1.4	7.4
2003	34	7.0	1.26	0.9	4.3	37.7
2005	18	4.4	0.53	1.7	3.7	10.2
2006	6	13.4	3.16	5.0	13.3	21.7
2007	44	5.0	0.96	1.2	2.1	30.2
2008	43	3.9	0.34	0.4	3.3	12.7
2009	32	7.3	2.94	1.0	3.3	96.8
2010	18	5.8	0.87	1.9	4.5	13.6

DOM

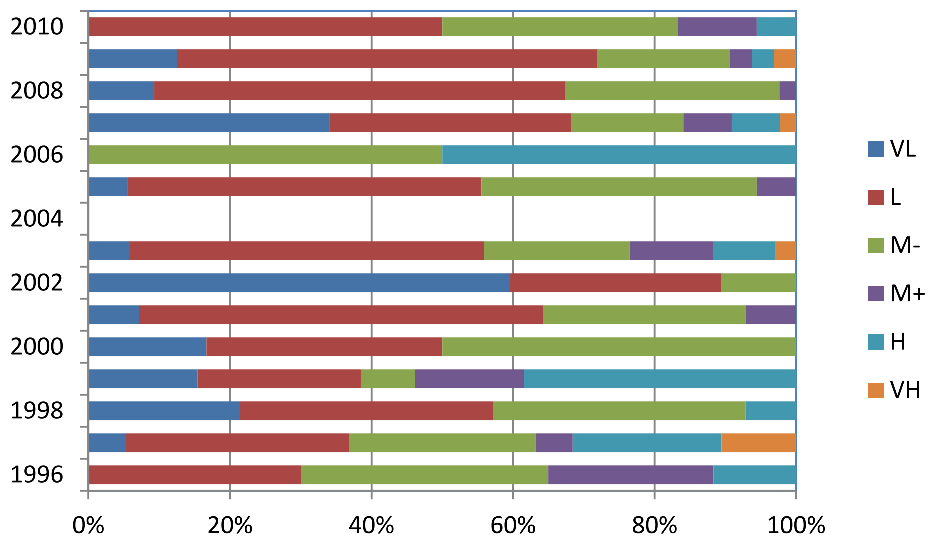
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	60	6.4	0.26	3.5	6.1	15.4
1997	19	7.2	0.46	4.4	6.5	10.6
1998	14	6.5	0.32	4.4	6.2	9.0
1999	13	8.6	1.11	5.6	6.8	17.9

2000	6	6.3	0.60	4.1	6.7	8.2
2001	14	7.6	0.51	5.5	7.3	11.8
2002	47	8.7	0.28	4.7	8.7	15.1
2003	34	8.8	0.67	5.0	8.0	26.6
2005	18	6.7	0.20	5.3	6.6	8.2
2006	6	6.7	0.60	4.8	7.2	8.2
2007	44	8.5	0.35	4.4	9.2	11.7
2008	43	9.3	0.36	5.5	9.3	14.6
2009	32	8.2	0.41	3.6	7.7	13.7
2010	18	8.9	0.53	5.8	8.2	12.8

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	60			5.7	6.2	6.9
1997	19			5.7	6.2	6.8
1998	14			5.5	5.9	6.6
1999	13			4.8	6.2	6.5
2000	6			4.9	5.7	6.5
2001	14			5.5	6.0	6.5
2002	47			5.4	6.2	6.7
2003	34			5.5	6.1	6.8
2005	18			5.4	6.0	6.5
2006	6			5.2	6.1	6.9
2007	44			5.7	6.2	6.9
2008	43			5.3	5.8	6.9
2009	32			5.2	5.8	6.7
2010	18			5.6	6.1	6.9

P Status



A summary of the distribution by soil P status for samples collected prior to next crop.

Approximately half the total number of soil samples was collected prior to a grass crop, with the other significant crops being spring and winter sown arable crops.

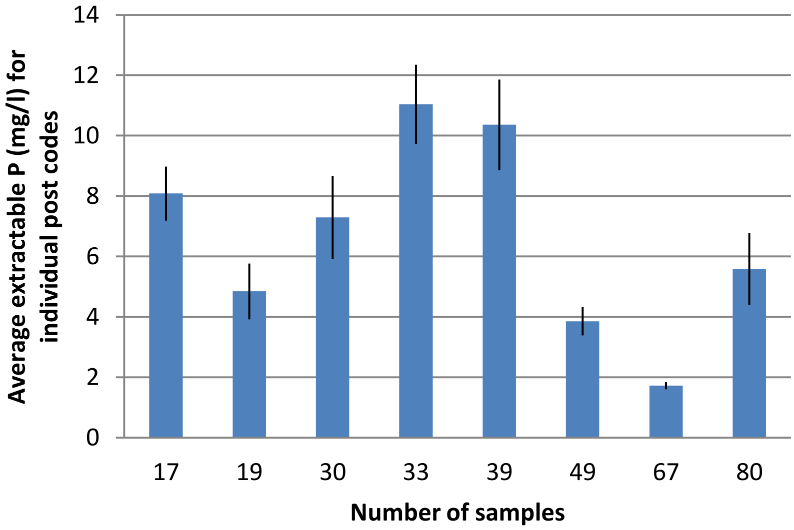
Eye Water	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	1	52	0	1	0	5	0	3
L	0	1	2	67	0	13	0	17	4	46
M-	0	2	2	15	0	20	0	13	4	37
M+	0	0	0	2	1	10	0	1	0	16
H	0	0	1	4	0	9	0	6	0	8
VH	0	0	0	0	0	0	0	3	0	2
All	0	3	6	140	1	53	0	45	8	112

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

Eye water						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
TD11	162	5.225	0.623	0.2	3.85	96.8
TD13	19	4.842	0.924	1.3	3.6	15.6
TD14	187	6.905	0.561	0.5	4.1	49.4

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – Stewartry Coast (77)

The total number of soil samples collected from within the Stewartry Coastal area was 661 with a maximum of 188 collected during the calendar year 1999 and a minimum of 8 during 2005. Median pH, DOM and extractable P were 5.8, 10.9 and 5.3, respectively. The proportion (%) of samples falling within each P class was 2, 4, 9, 13, 5, 2 for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	41	8.2	2.86	1.7	5.3	121.6
1997	42	9.1	0.95	3.1	7.7	29.9
1998	34	11.4	5.18	1.2	4.7	174.2
1999	118	7.5	0.38	0.7	6.9	35.5
2000	54	7.1	0.80	1.4	5.3	37.8
2001	43	6.5	1.08	1.1	3.6	33.3
2002	76	4.4	0.35	1.2	3.0	15.8
2003	27	4.8	0.55	1.6	4.2	12.7
2004	24	5.2	0.36	2.6	5.0	10.1
2005	8	4.2	0.44	2.6	4.2	6.3
2006	10	4.9	1.34	1.8	3.5	16.1
2007	27	10.7	0.97	3.8	10.5	21.0
2008	49	8.7	1.39	2.4	6.0	67.7
2009	21	4.5	0.88	1.4	2.7	17.7
2010	87	6.8	0.68	1.1	5.1	47.9

DOM

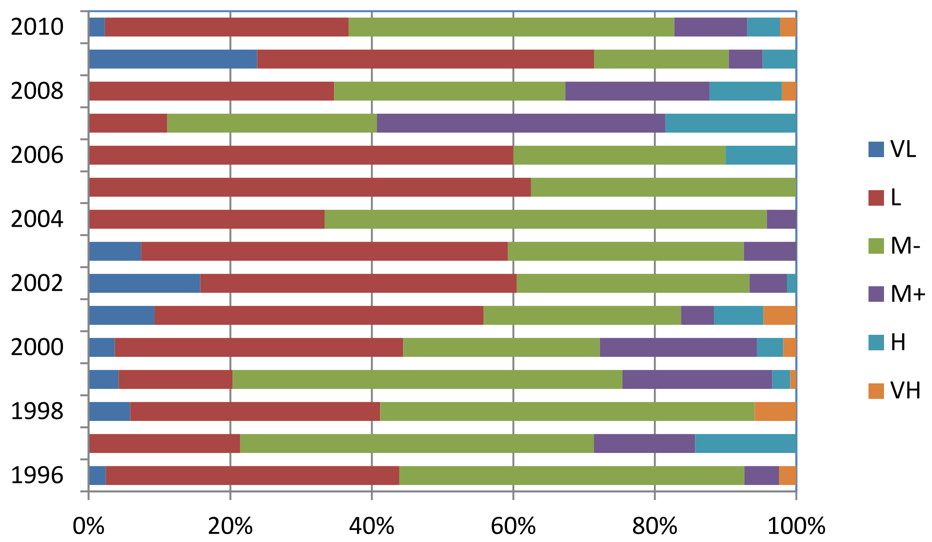
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	41	12.8	0.51	6.5	12.6	25.0
1997	42	9.6	0.59	4.3	8.5	18.0
1998	34	11.8	0.74	5.6	11.3	26.2
1999	118	11.1	0.27	5.3	10.7	29.1

2000	54	12.4	0.41	5.8	12.2	20.8
2001	43	9.9	0.44	5.5	8.9	16.1
2002	76	10.5	0.28	3.3	10.6	19.2
2003	27	12.4	0.66	6.8	12.0	18.4
2004	24	12.8	0.48	8.4	13.1	17.0
2005	8	10.1	0.74	6.8	10.4	12.6
2006	10	9.2	0.73	6.7	9.1	14.2
2007	27	11.9	0.91	5.9	10.5	23.8
2008	49	8.9	0.72	4.0	8.5	19.0
2009	21	10.8	0.81	8.1	9.7	23.8
2010	87	12.2	0.36	6.4	11.6	24.4

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	41			4.9	5.4	6.3
1997	42			5.3	5.8	6.9
1998	34			5.3	5.8	6.3
1999	118			4.9	5.8	6.4
2000	54			4.7	5.9	6.7
2001	43			5.1	5.6	6.5
2002	76			5.2	5.8	6.8
2003	27			5.1	5.9	6.4
2004	24			5.3	5.8	6.4
2005	8			5.7	5.9	6.5
2006	10			5.8	5.9	6.0
2007	27			5.5	6.1	6.5
2008	49			5.1	5.8	6.8
2009	21			5.5	5.7	5.9
2010	87			4.9	6.0	6.8

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of samples were collected prior to grass, with a small number of spring and winter sown arable crops.

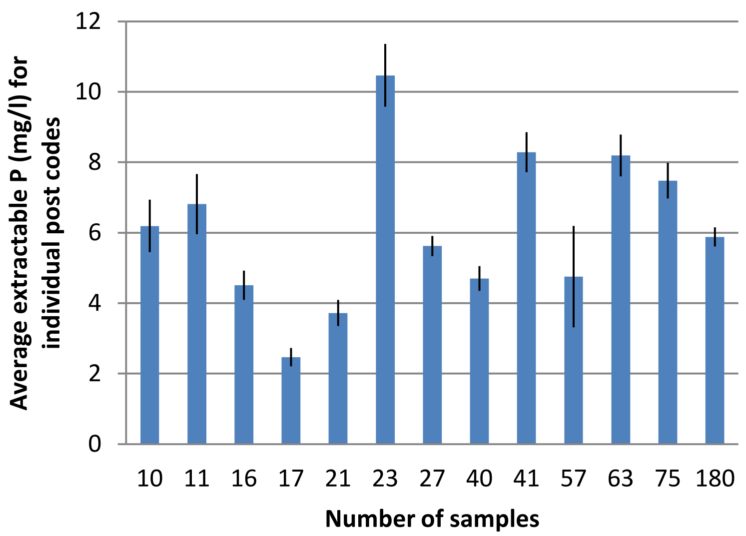
Stewartry Coastal	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	2	23	0	6	0	1	0	3
L	0	0	5	183	1	18	2	3	0	14
M-	0	0	0	223	0	14	0	15	2	20
M+	0	0	0	63	0	3	0	4	2	13
H	0	0	1	21	0	1	0	3	1	4
VH	0	0	0	4	0	0	2	0	2	2
All	0	0	8	517	1	42	4	26	7	56

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

Soil extractable P (mg/l) summarised by post code area

Stewartry Coastal						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
DG2	241	6.12	0.413	1.1	4.8	67.7
DG5	92	7.505	0.584	1.6	6.05	37.8
DG6	92	8.307	0.698	0.7	7.35	56.8
DG7	236	7.583	0.913	1.6	4.9	174.2

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – River Doon (87)

The total number of soil samples collected from within the Doon catchment was 199 with a maximum of 39 collected during the calendar year 1997 and a minimum of 5 during 1995. Median pH, DOM and extractable P were 5.9, 8.1 and 5.3, respectively. The proportion (%) of samples falling within each P class was 7, 35, 42, 11, 5 for the VL, L, M-, M+, H.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	16	8.5	0.88	3.7	8.2	14.7
1997	39	4.5	0.46	0.8	3.6	12.5
1998	13	6.4	1.38	0.1	5.5	14.1
1999	5	8.7	1.49	6.4	7.5	14.5
2000	21	6.2	0.90	1.4	5.6	15.1
2001	21	5.5	0.53	1.4	4.8	11.6
2002	20	4.2	0.43	2.0	4.0	9.0
2003	13	7.3	1.61	1.8	5.5	22.3
2004	9	3.4	0.54	1.2	3.0	6.7
2005	6	5.7	0.88	2.2	6.2	8.7
2006	11	8.1	1.04	3.2	8.3	12.8
2007	7	7.4	1.04	4.4	7.0	13.1
2008	6	6.8	1.72	2.8	6.0	14.0
2009	6	6.7	1.19	2.2	7.3	10.0
2010	6	5.9	1.19	2.7	5.9	11.0

DOM

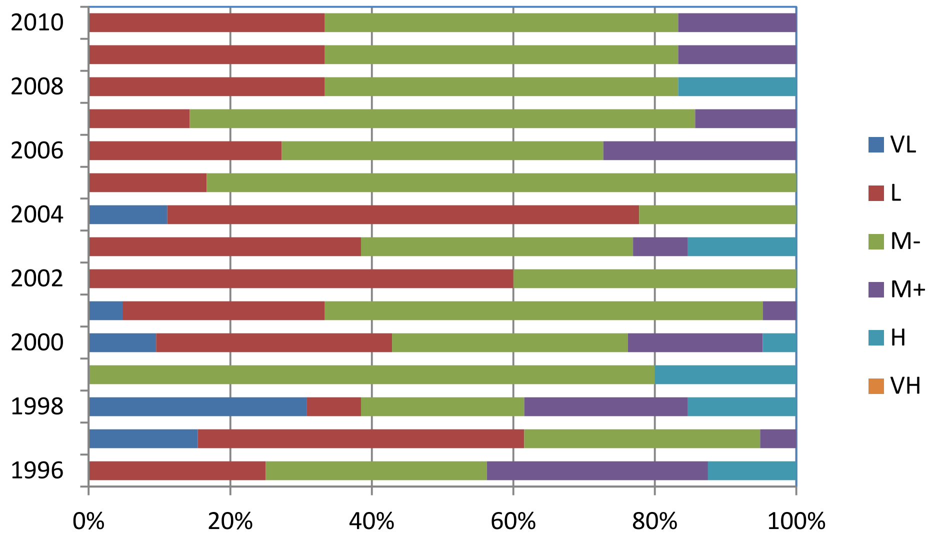
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	16	7.5	0.47	4.9	7.3	10.6
1997	39	8.9	0.49	4.9	8.2	15.5
1998	13	8.1	0.69	4.9	7.0	12.8
1999	5	7.9	1.12	5.2	8.9	10.1

2000	21	11.0	1.07	5.3	9.8	23.7
2001	21	6.8	0.19	5.3	6.7	8.9
2002	20	15.8	0.98	7.9	15.2	24.7
2003	13	7.7	0.52	5.3	6.9	10.8
2004	9	14.2	4.39	4.8	11.0	46.6
2005	6	4.9	0.27	4.3	4.7	6.2
2006	11	12.3	1.69	5.1	11.3	21.7
2007	7	7.2	0.35	5.8	7.2	8.5
2008	6	7.0	0.69	4.9	7.1	8.9
2009	6	16.6	2.33	8.5	18.0	22.3
2010	6	7.2	0.53	5.0	7.8	8.2

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	16			4.9	5.8	6.5
1997	39			5.0	5.5	6.8
1998	13			5.1	5.8	6.4
1999	5			5.2	6.1	6.4
2000	21			5.0	5.8	6.6
2001	21			5.3	6.0	7.0
2002	20			4.8	5.8	7.1
2003	13			5.1	5.9	6.2
2004	9			4.6	6.0	6.4
2005	6			5.5	5.7	5.9
2006	11			5.2	6.0	7.1
2007	7			5.6	5.7	6.0
2008	6			5.4	6.0	6.3
2009	6			5.8	6.3	6.9
2010	6			5.6	6.3	6.5

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of soil samples were collected prior to a grass crop, with no samples having a very high P status.

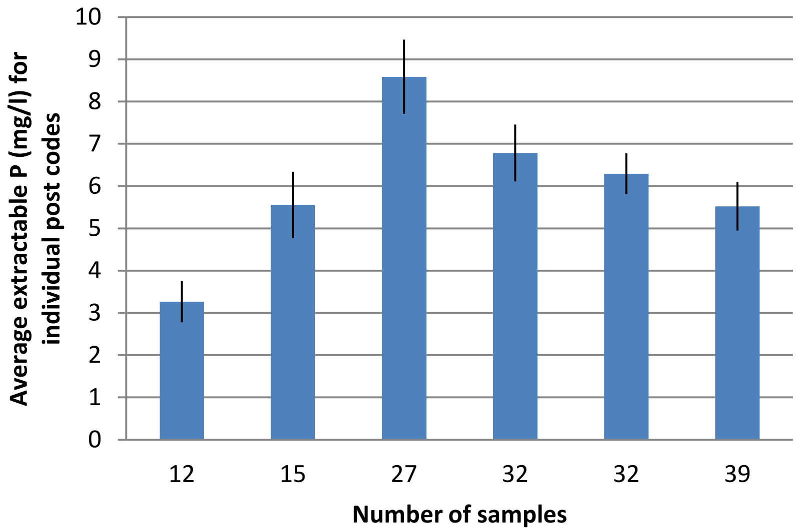
River Doon	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	11	0	0	0	0	0	3
L	0	0	1	52	0	1	0	2	6	8
M-	0	0	1	55	0	7	0	6	1	14
M+	0	0	0	14	0	1	0	6	0	1
H	0	0	0	3	0	0	0	3	2	1
VH	0	0	0	0	0	0	0	0	0	0
All	0	0	2	135	0	9	0	17	9	27

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

River Doon						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
DG7	39	5.521	0.576	1.5	4.5	15.1
KA19	123	6.55	0.335	0.8	6	22.2
KA6	20	3.58	0.502	0.1	3.2	8.5
KA7	17	5.412	0.767	1.8	5.4	14

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – North Ayrshire Coast (88)

The total number of soil samples collected from within the North Ayrshire Coastal catchment was 1399 with a maximum of 381 collected during the calendar year 1998 and a minimum of 4 during 2010. Median pH, DOM and extractable P were 5.9, 7.3 and 5.4, respectively. The proportion (%) of samples falling within each P class was 15, 29, 31, 9, 11, 5, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	24	6.6	1.58	1.0	3.8	31.0
1997	79	6.2	0.80	0.9	4.5	40.2
1998	381	6.0	0.33	0.0	4.2	60.0
1999	256	7.3	0.41	0.2	5.7	72.2
2000	74	16.6	5.01	0.8	6.7	259.3
2001	36	7.7	1.46	0.7	4.3	41.8
2002	76	13.3	2.38	0.2	5.0	133.9
2003	98	14.8	2.12	0.3	6.3	99.0
2004	72	10.4	2.12	0.6	4.2	128.1
2005	55	13.5	3.91	0.0	4.2	171.5
2006	44	6.4	0.82	0.7	5.0	30.8
2007	105	21.5	1.82	2.2	18.5	154.5
2008	12	5.0	0.51	2.5	4.8	8.2
2009	83	5.0	0.36	0.6	4.3	15.8
2010	4	4.7	1.19	2.1	4.9	6.9

DOM

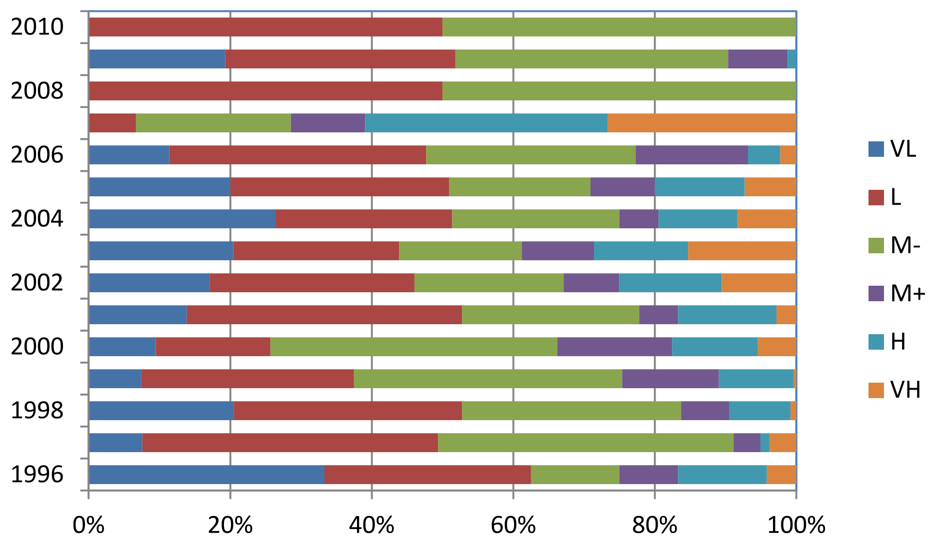
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	24	7.4	0.55	4.2	7.0	14.8
1997	79	6.7	0.35	2.0	6.1	28.2
1998	381	9.2	0.39	1.0	7.8	79.6
1999	256	10.0	0.52	2.0	7.8	80.9

2000	74	7.4	0.35	3.2	6.3	21.5
2001	36	7.1	0.40	3.3	6.9	15.5
2002	76	7.2	0.37	2.1	6.7	21.7
2003	98	9.2	0.85	2.0	6.7	63.2
2004	72	7.4	0.26	3.8	7.0	12.7
2005	55	8.4	0.66	1.8	7.3	30.0
2006	44	11.3	1.63	3.0	8.2	71.5
2007	105	8.1	0.71	2.4	7.1	79.6
2008	12	12.4	1.43	4.0	13.6	20.1
2009	83	8.6	0.58	3.0	7.4	44.3
2010	4	8.3	1.65	5.5	7.5	12.9

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	24			5.1	5.8	7.0
1997	79			3.8	5.7	7.0
1998	381			3.6	5.8	8.1
1999	256			3.3	5.9	8.0
2000	74			5.0	5.9	7.3
2001	36			4.6	5.7	6.4
2002	76			3.3	6.0	8.4
2003	98			3.5	6.1	8.4
2004	72			4.6	5.8	8.1
2005	55			4.0	6.1	7.5
2006	44			3.5	5.6	6.7
2007	105			5.2	6.1	7.6
2008	12			5.1	5.4	5.5
2009	83			3.6	5.8	8.0
2010	4			5.5	5.6	5.7

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of samples were collected prior to grass with some winter and spring sown arable crops.

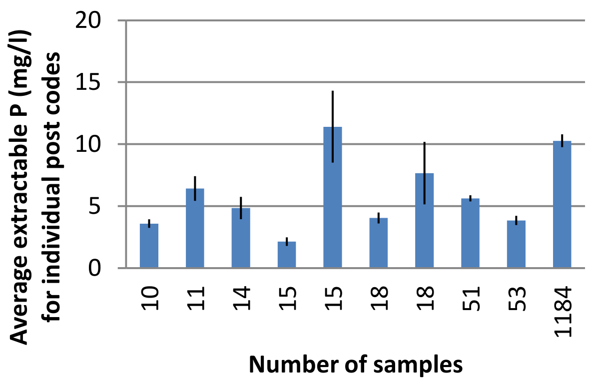
North Ayrshire Coastal	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	22	0	1	0	1	0	183
L	0	0	0	76	0	9	0	7	2	310
M-	0	0	0	96	0	7	0	14	2	308
M+	0	0	0	33	0	9	0	5	0	83
H	0	0	0	28	0	1	0	4	2	121
VH	0	0	0	1	0	0	0	0	2	71
All	0	0	0	256	0	27	0	31	8	1076

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from one post code area

North Ayrshire Coastal						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
KA1	52	5.413	0.932	0.7	3.75	41.7
KA2	10	3.59	0.345	2.5	3.2	6
KA20	15	2.133	0.345	0.6	1.6	5.2
KA21	53	3.842	0.372	1.2	2.8	12.8
KA22	15	11.41	2.9	2.4	9.3	49.1
KA5	11	6.418	0.995	2	6.7	11
KA6	1240	10.054	0.495	0	5.7	259.3
KA9	3	8.5	3.76	3.3	6.4	15.8

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – Galloway Coast (80)

The total number of soil samples collected from within the Galloway Coastal area catchment was 905 with a maximum of 104 collected during the calendar year 1997 and a minimum of 25 during 2006. Median pH, DOM and extractable P were 5.8, 10.9 and 7.7, respectively. The proportion (%) of samples falling within each P class was 2, 22, 38, 18, 15, 5, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	92	7.9	0.65	1.1	6.7	47.1
1997	104	18.3	3.30	0.9	9.0	198.0
1998	95	13.0	2.25	1.6	8.3	198.0
1999	37	10.3	3.45	1.7	6.2	132.6
2000	44	12.2	1.46	2.3	9.5	50.7
2001	70	12.6	1.27	2.9	8.3	51.0
2002	26	9.6	0.94	2.3	9.5	22.7
2003	50	5.2	0.55	1.1	3.9	23.2
2004	28	12.1	2.85	2.0	6.0	70.7
2005	51	10.9	1.55	1.6	7.1	51.5
2006	25	14.8	2.96	2.2	10.9	63.3
2007	52	9.8	0.62	1.9	10.1	19.4
2008	92	10.0	0.61	1.8	8.8	24.5
2009	86	8.3	0.71	2.0	7.3	45.8
2010	53	6.9	0.57	1.1	5.8	17.2

DOM

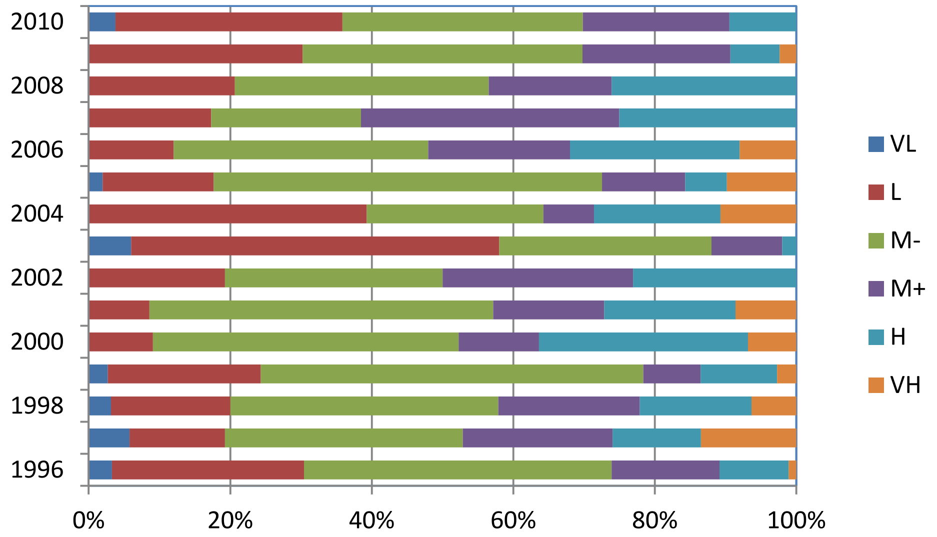
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	92	9.4	0.30	3.3	9.0	17.6
1997	104	9.2	0.40	2.9	8.4	24.0
1998	95	9.3	0.26	3.9	9.1	16.5
1999	37	8.1	0.38	2.1	8.4	12.4

2000	44	8.5	0.46	4.5	8.0	20.6
2001	70	9.4	0.49	4.0	7.9	20.7
2002	26	8.6	0.62	2.7	7.7	14.7
2003	50	9.8	0.35	6.2	9.2	18.7
2004	28	7.6	0.68	1.8	7.6	18.3
2005	51	9.0	0.54	3.9	8.4	18.8
2006	25	8.5	0.81	4.0	7.0	16.5
2007	52	9.3	0.36	4.2	9.3	20.9
2008	92	7.3	0.41	4.0	5.9	17.9
2009	86	10.6	0.65	3.0	9.3	41.2
2010	53	10.1	0.72	3.5	8.5	24.8

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	92			4.8	5.7	7.0
1997	104			4.8	5.7	6.8
1998	95			5.0	5.9	6.7
1999	37			4.7	5.8	6.3
2000	44			4.9	5.9	6.5
2001	70			4.7	5.9	6.6
2002	26			5.0	5.9	6.5
2003	50			5.2	6.0	6.5
2004	28			5.3	6.2	8.2
2005	51			4.8	5.9	6.8
2006	25			4.8	6.0	6.4
2007	52			5.3	5.8	6.5
2008	92			5.0	5.8	6.7
2009	86			4.5	5.8	6.5
2010	53			5.3	6.1	6.5

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of soil samples were collected prior to grass with the next most significant being spring and winter sown crops.

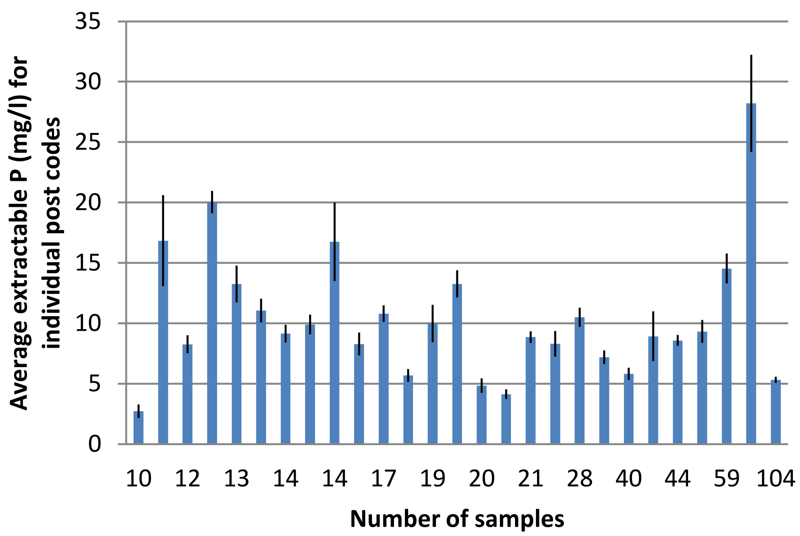
Galloway Coastal	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	1	12	0	2	0	0	1	3
L	0	2	2	119	1	20	0	9	8	36
M-	0	1	3	213	6	56	1	24	5	38
M+	0	0	2	89	2	33	0	18	4	15
H	0	0	1	74	3	31	2	11	3	11
VH	0	0	0	13	0	18	0	1	1	10
All	0	3	9	520	12	160	3	63	22	113

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

Two post code area dominated the number of samples being collected.

Galloway Coastal						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
DG6	34	6.397	0.652	1.5	6.2	17.3
DG7	21	7.776	0.772	1.7	8.3	13
DG8	460	10.943	0.817	0.9	6.5	198
DG9	390	11.634	0.766	1.1	9.6	198

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – Buchan Coast (31)

The total number of soil samples collected from within the Buchan Coast catchment was 2693 with a maximum of 448 collected during the calendar year 2008 and a minimum of 61 during 2000. Median pH, DOM and extractable P were 5.9, 7.3 and 6.3, respectively. The proportion (%) of samples falling within each P class was 2, 24, 48, 15, 9, 1, for the VL, L, M-, M+, H, VH.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	80	7.5	0.90	1.8	5.5	55.9
1997	102	8.3	0.51	1.5	6.9	31.3
1998	85	7.6	0.42	1.8	6.4	22.7
1999	124	7.7	0.41	2.4	7.0	44.3
2000	61	6.7	0.35	1.9	6.4	14.5
2001	186	7.5	0.27	0.9	7.2	22.3
2002	150	5.6	0.21	0.5	6.0	13.1
2003	272	6.4	0.29	0.7	5.3	43.2
2004	245	7.6	0.29	1.8	6.6	34.4
2005	216	8.0	0.32	0.8	7.0	38.1
2006	211	6.9	0.29	1.2	5.7	23.6
2007	216	10.1	1.06	0.3	7.3	162.5
2008	448	9.7	0.30	0.9	8.3	35.5
2009	139	8.9	0.57	1.8	6.8	42.4
2010	158	5.9	0.31	0.8	5.1	30.2

DOM

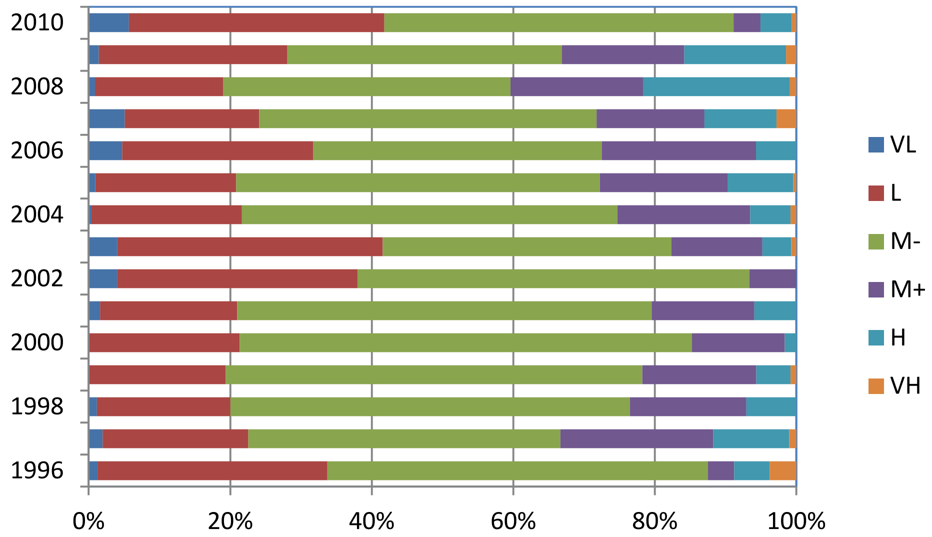
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	80	7.1	0.18	2.5	7.1	11.8
1997	102	7.0	0.20	2.8	7.1	16.0
1998	85	7.0	0.24	4.0	6.6	16.4
1999	124	7.7	0.19	3.4	7.8	21.1
2000	61	6.7	0.19	4.3	6.5	13.1

2001	186	7.4	0.08	3.9	7.5	10.5
2002	150	6.9	0.11	3.4	7.0	9.8
2003	272	7.2	0.15	2.1	7.0	25.9
2004	245	6.1	0.11	2.1	6.2	13.4
2005	216	6.4	0.14	2.6	6.3	17.5
2006	211	7.3	0.16	2.8	7.2	12.9
2007	216	6.4	0.16	2.1	6.4	13.3
2008	448	6.4	0.11	2.0	6.4	15.6
2009	139	7.2	0.20	1.3	7.3	18.2
2010	158	7.0	0.20	3.1	6.6	16.7

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	80			5.0	5.9	7.5
1997	102			5.0	5.9	6.9
1998	85			5.3	5.9	7.1
1999	124			5.2	6.1	7.7
2000	61			5.4	5.9	6.8
2001	186			4.9	6.0	7.2
2002	150			5.3	6.0	7.8
2003	272			5.1	5.9	6.6
2004	245			5.0	5.9	7.1
2005	216			4.8	5.9	7.3
2006	211			5.0	5.8	6.6
2007	216			5.0	5.8	7.4
2008	448			4.7	5.9	7.3
2009	139			4.7	5.8	7.4
2010	158			4.8	5.9	7.1

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The majority of soil samples were collected prior to a spring sown crop, but the mixed nature of the agriculture is well demonstrated by the large number taken prior to grass.

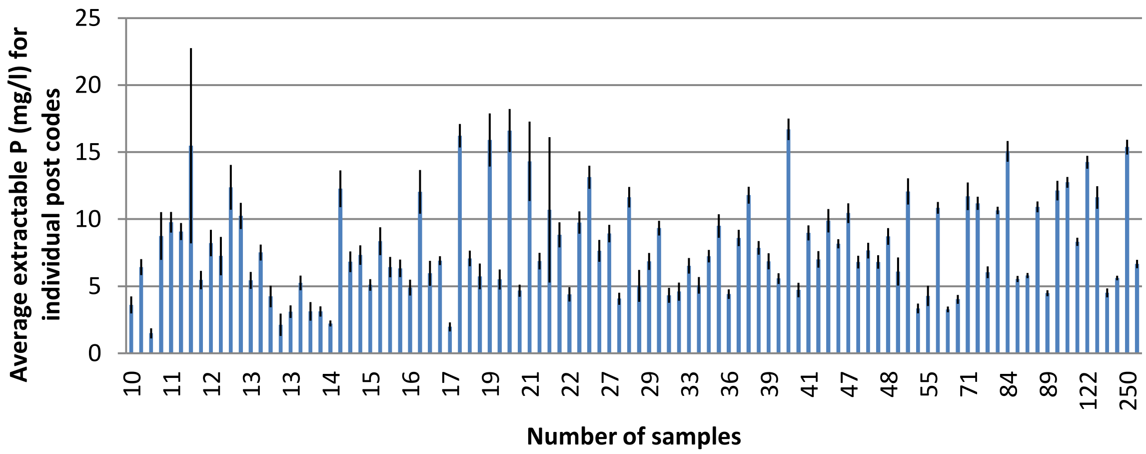
Buchan Coastal	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	42	1	10	0	0	6	4
L	0	0	9	291	2	223	1	51	40	40
M-	0	1	5	326	10	539	0	292	38	84
M+	0	0	5	75	12	174	0	121	14	16
H	0	0	1	55	5	75	0	92	5	5
VH	0	0	1	8	1	6	0	4	1	2
All	0	1	21	797	31	1027	1	560	104	151

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

Buchan Coastal						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
AB21	803	7.71	0.143	0.8	7	34.4
AB23	253	6.077	0.17	0.7	5.9	22.3
AB41	960	6.89	0.152	0.3	5.8	35.5
AB42	205	7.781	0.283	1.5	7.1	24.4
AB43	472	11.132	0.568	0.9	8.1	162.5

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.



Catchment summary – Lunan water (42)

The total number of soil samples collected from within the Lunan Water catchment was 447 with a maximum of 130 collected during the calendar year 1997 and a minimum of 7 during 2005. Median pH, DOM and extractable P were 6.0, 5.3 and 8.6, respectively. The proportion (%) of samples falling within each P class was 1, 8, 53, 28, 10, for the VL, L, M-, M+, H.

Extractable P (mg P/l)

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	24	7.9	0.50	4.6	7.5	15.6
1997	130	8.4	0.32	1.3	8.2	22.9
1998	11	8.1	0.89	4.3	7.3	12.9
1999	21	9.0	0.67	5.1	7.8	16.5
2000	34	11.3	1.14	2.8	9.5	27.2
2001	9	9.3	1.04	5.5	8.9	16.3
2002	8	11.2	2.26	1.0	12.7	19.3
2003	24	10.3	0.67	5.2	10.2	17.7
2004	11	8.2	0.81	3.8	8.6	12.5
2005	7	9.2	1.79	4.3	8.2	17.8
2006	17	8.5	0.76	4.9	7.1	16.4
2007	56	9.0	0.38	1.6	9.2	14.5
2008	27	11.2	1.01	2.8	10.3	24.6
2009	38	8.2	0.49	1.9	7.4	15.6
2010	30	7.9	0.39	4.4	8.2	12.9

DOM

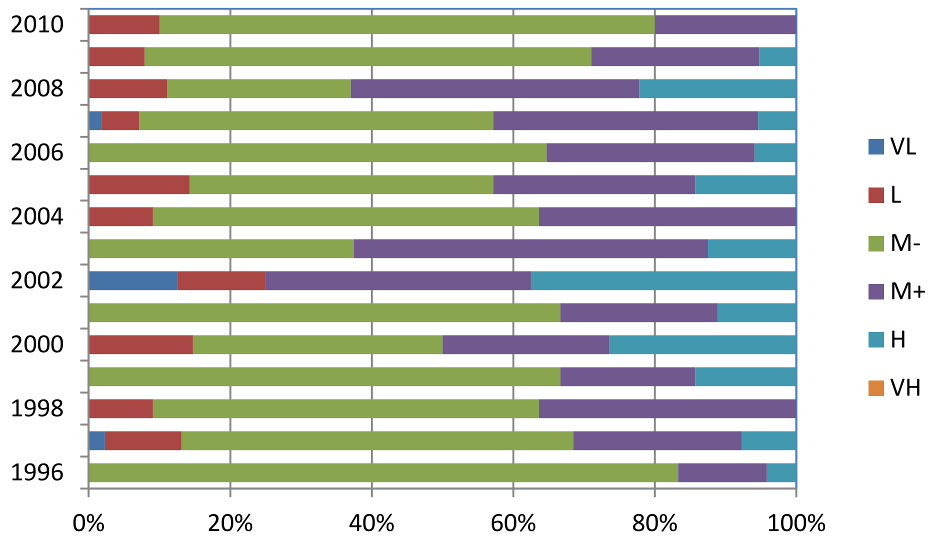
Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	24	6.7	0.32	3.7	7.2	8.6
1997	130	5.8	0.15	3.5	5.3	11.8
1998	11	5.9	0.45	4.4	5.7	9.5
1999	21	5.3	0.19	3.2	5.2	7.0

2000	34	5.6	0.26	2.8	5.5	9.2
2001	9	5.2	0.21	4.1	5.2	6.0
2002	8	6.6	0.84	4.7	5.8	11.2
2003	24	5.3	0.16	3.9	5.2	6.7
2004	11	4.8	0.23	3.6	4.8	6.0
2005	7	5.0	0.19	4.4	4.8	5.7
2006	17	5.2	0.15	4.0	5.2	6.2
2007	56	5.7	0.23	4.0	5.3	13.4
2008	27	5.1	0.16	3.4	5.0	7.3
2009	38	5.2	0.12	4.1	5.2	7.5
2010	30	5.8	0.28	3.8	5.4	10.3

pH

Year	Count	Mean	SE Mean	Minimum	Median	Maximum
1996	24			5.6	6.0	6.7
1997	130			4.5	6.0	7.0
1998	11			6.0	6.2	6.6
1999	21			5.8	6.2	6.7
2000	34			4.3	6.0	6.9
2001	9			5.8	6.1	6.4
2002	8			5.2	5.5	6.0
2003	24			5.8	6.2	6.7
2004	11			5.5	5.9	6.1
2005	7			5.8	6.4	6.4
2006	17			5.5	6.1	6.4
2007	56			5.3	5.8	6.2
2008	27			5.7	6.0	6.7
2009	38			5.2	5.9	6.8
2010	30			5.5	6.0	6.7

P status



A summary of the distribution by soil P status for samples collected prior to next crop.

The largest number of samples was collected prior to potatoes and no samples had a very high P status.

Lunan Water	B	E	F	G	P	S	V	W	X	Missing
VL	0	0	0	0	0	0	0	0	0	5
L	0	0	0	1	4	0	0	0	0	30
M-	0	0	0	4	38	15	0	10	2	170
M+	0	0	0	1	20	11	0	1	0	92
H	0	0	0	1	8	3	4	1	0	26
VH	0	0	0	0	0	0	0	0	0	0
All	0	0	0	7	70	29	4	12	2	323

X – set-aside/fallow, W – winter sown crops, V - vegetables, S – spring sown crops, P – all potatoes, G – all grass, F – all fodder, E - peas , B – berries.

The majority of samples originated from two post code areas

Lunan Water						
POCODE	Count	Mean	SE	Minimum	Median	Maximum
DD10	42	9.219	0.516	4.6	9.05	22.9
DD11	116	9.633	0.393	3.1	8.8	27.2
DD8	289	8.715	0.224	1	8.6	24.6

A summary of averaged extractable P (mg/l) for individual full postcodes where 10 or more samples have been collected, showing the SE.