

Phosphorus stocks in Scottish soils



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Introduction

- Modern agriculture places a demand for phosphorus (P) that cannot be met by the weathering of minerals and turnover of soil organic matter, and soils are fertilised with P to maintain production.

- There are concerns related to the long-term security of supply of P fertilisers and a need to understand and monitor the P-stocks in soils.

- The 1st National Soil Inventory of Scotland (NSIS1) started in 1978 was based on a 10-km grid spacing (707 locations). The 2nd National Soils Inventory of Scotland (NSIS2) started in 2007 was based on a 20-km grid (182 locations). In both inventories pits with a target depth of 1-m were excavated and soil taken from the centre of the genetic horizons.

- We have compared the P concentrations in paired soil samples from NSIS1 and NSIS2 and investigate possible changes in P status over the intervening period of 3 decades.

Soil analysis

Archived NSIS1 and the more recently sampled NSIS2 soil-samples were analysed together to eliminate analytical bias.

- Total P was measured by fusion with NaOH.
- Aqua regia extractable P was measured by a reflux method.
- Available P (Olsen) was determined by extraction with 0.5 M NaHCO₃ at pH 8.5.
- Bulk density (BD) of soil was determined by drying cores. BD measured by drying was not available for NSIS1 and some NSIS2 samples. To provide a complete and comparable dataset we used values predicted from their IR spectra (J. Robertson, unpublished).
- The amount of P in individual soil horizons (P m⁻²) was determined by multiplying the volume of soil × bulk density × P concentration and the stock in the profile calculated by summing the amount in each horizon down to a maximum of 1 m. The volume of stones was taken into account.

Data selection

- The comparison of P concentration made between NSIS1 and NSIS2 samples relates to 444 pairs of samples representing 163 of the 182 possible 20-km grid sites.
- The set was restricted because many of the samples of NSIS1 soils for analysis were not available, especially for surface horizons where only 74 pairs were available.
- There were 34 pairs of samples of ploughed soil (Ap horizons) available for comparison of Olsen P.

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Results

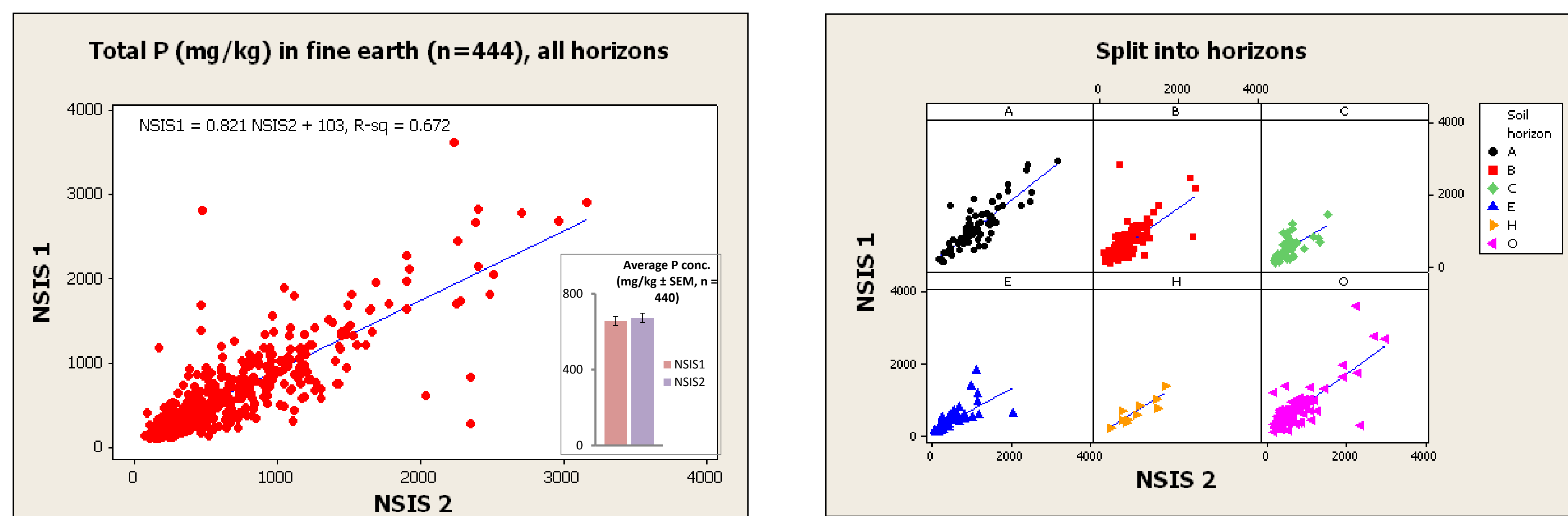


Fig. 1 shows the concentration of total P in paired NSIS1 and NSIS2 soil samples. The paired t-test with untransformed or log transformed data shows that the overall mean difference between the two groups was not significantly different from zero ($p=0.05$, see inset). For individual horizons, only the H-horizons showed an overall difference between the means that was significantly different from zero ($p=0.010$).

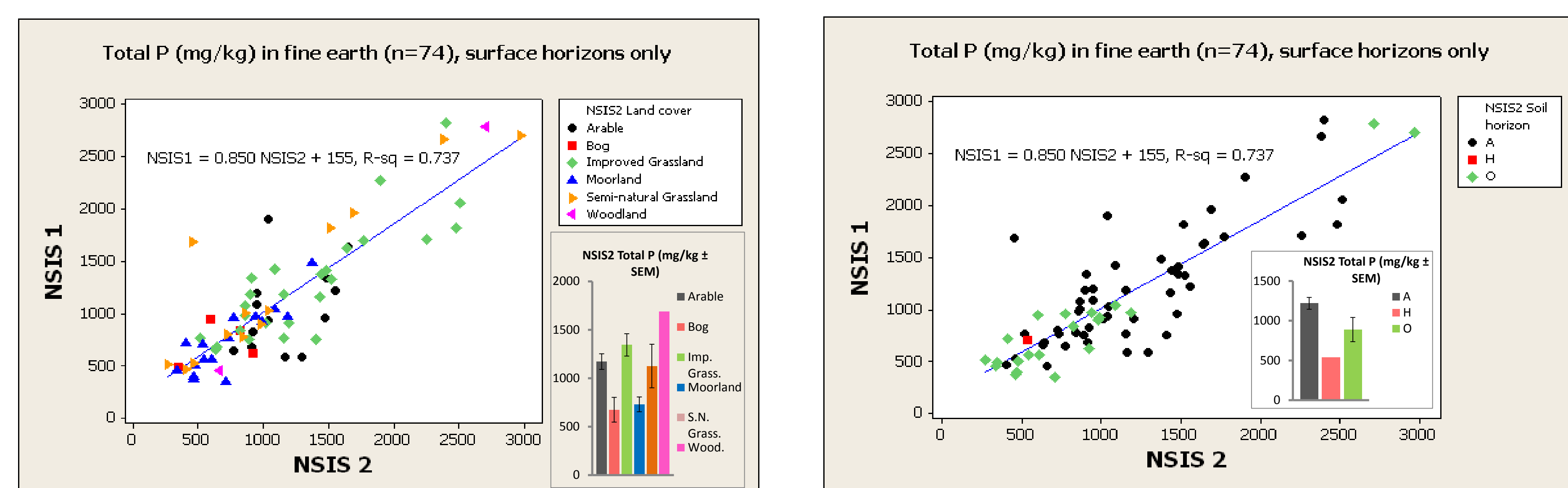


Fig. 2 shows the concentration of P in paired samples from the first major horizon sampled (which may be expected to be the most influenced by management). The P concentration in organic soils tends to less than in mineral soils and the difference on an area basis is accentuated when bulk density is considered. The paired t-test showed that the overall mean difference between the NSIS1 and NSIS2 groups was not significantly different from zero ($p=0.05$).

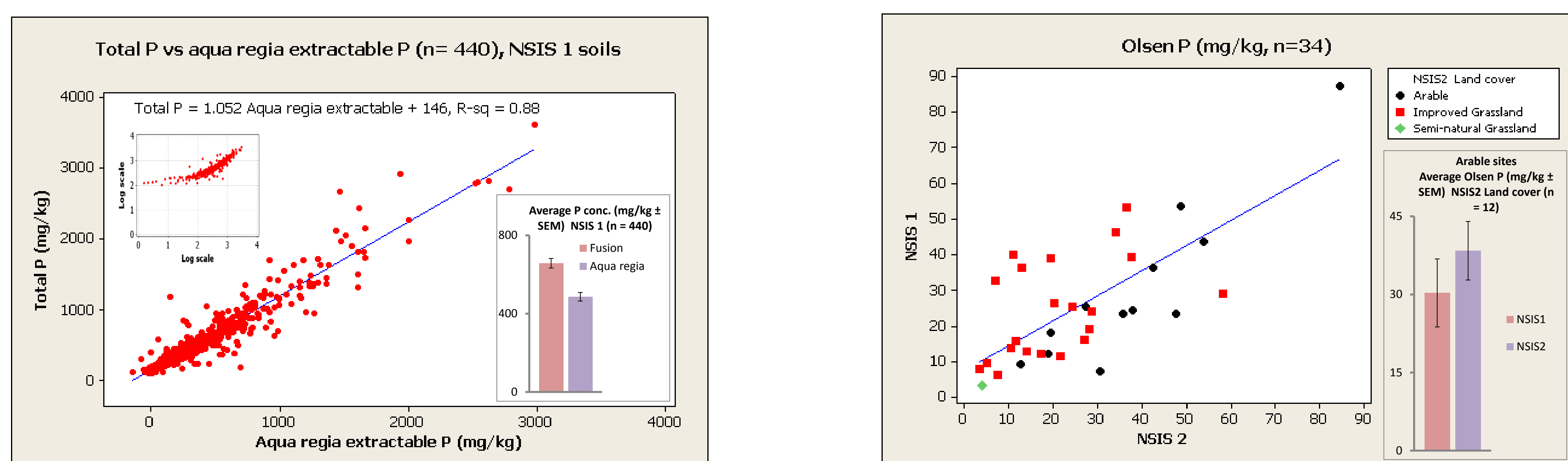


Fig. 3 shows the relationship between total P determined by fusion and P extractable by boiling aqua regia for the NSIS1 sample set. The paired t-test showed that the overall mean difference between the two groups was significantly different from zero ($p = 0.000$). Overall aqua regia solubilised 74% of the total P. However, inspection of the log₁₀ transformed data (inset) reveals that for soils with a relatively low P content aqua regia extraction is less efficient.

Fig. 4 shows the concentration of Olsen P in 34 paired soil samples from NSIS1 and NSIS2. For soils classified as arable in NSIS2, the paired t-test showed that the overall mean difference between the two groups was significantly different from zero ($p = 0.011$). For soils classified as improved grassland in NSIS2, the paired t-test showed that the overall mean was not significantly different from zero ($p = 0.235$). Similar data (not shown) is available for extraction with 0.43 M acetic acid and modified Morgan's reagent, which are agronomic extractants often used by soil testing laboratories in Scotland.

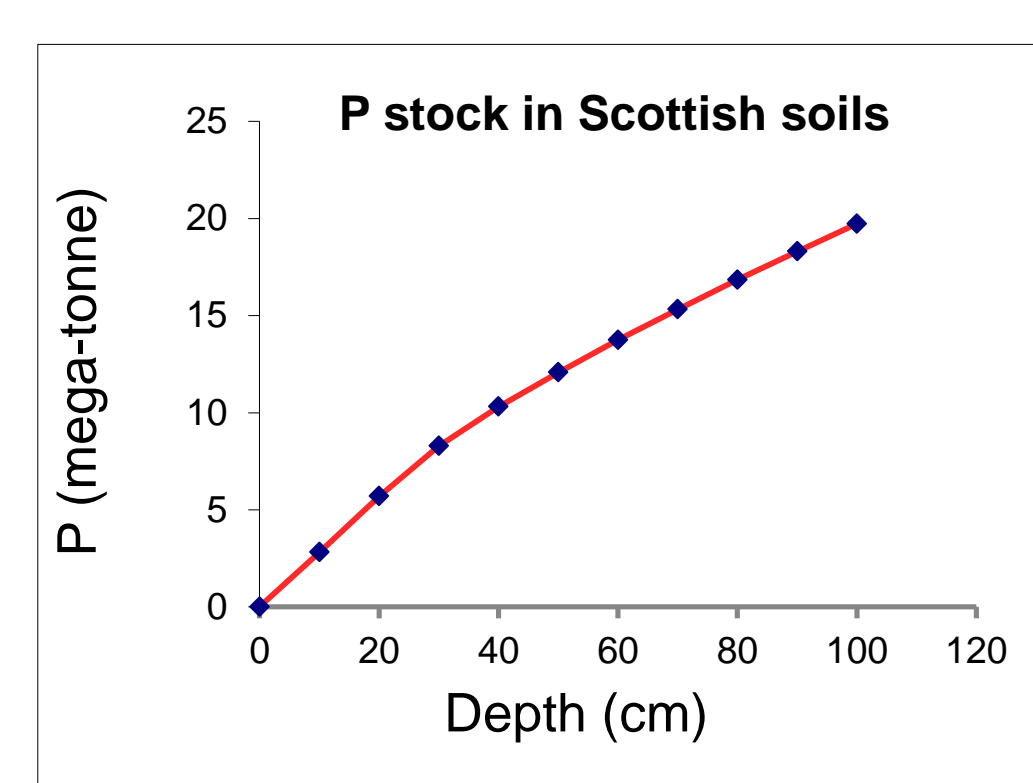


Fig. 5 shows the estimated P stock (cumulative) in Scottish soils and the changes with depth in the profile. The estimate was made by multiplying the average areal amount of P in the NSIS2 profiles by the land area of Scotland.

Conclusions

- There was no detectable change (paired t-test, $p = 0.05$) in the overall average total P concentration in soil in the period of three decades between NSIS1 and NSIS2 sampling.
- On average aqua regia solubilised around 74 % of the total P in soils but the efficiency was poorer in soils with a low P content.
- For a limited number of arable soil-pairs the overall average values for Olsen P was significantly greater (paired t-test, $p=0.05$) in NSIS2 samples.