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Spatial variability of phosphorus on a field with a long-term history of livestock manure application

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Phosphorus is an essential element to maintain profitable agriculture. Application of livestock manure to agricultural fields has been shown to increase crop growth and improve the soil capacity to hold water and nutrients. However, in agricultural areas with high cattle manure and/or slurry inputs over a period of several years, soil P can accumulate to levels in excess of crop needs. Phosphate overloading in soil has the potential to enrich surface runoff causing eutrophication of water bodies. The accelerated nutrient enrichment or eutrophication of surface water by runoff, and that of groundwater by leaching from the profile has become a significant environment problem in many developed countries and agriculture has been identified as a significant P source. This is also the case in the Atlantic temperate humid region of Galicia, north-western of Spain. Various extraction methods are used to measure available P in soils. Differences in soil phosphorus (P) concentrations measured by various techniques may have implications for agronomic and environmental testing. The aims of this study were: 1) to compare available and total P concentrations measured by various methods and 2) to assess variability of excessive P accumulated on a field with a long-term history of manure application. Forty soil samples were taken at the 0-30 cm depth on a 6 ha field with a mean slope of 2 %, located in Castro de Ribeira de Lea, Lugo province, Spain. The study soil had hydromorphic features and was classified as a gleyic Cambisol. Available soil P was extracted by anion-exchange resin (AER) and by Mehlich 3 (M3). Moreover, two determination methods of P contents extracted by Mehlich 3, namely molybdic acid colorimetric standard procedure (M3-COL) and inductively coupled plasma emission spectroscopy or ICP-MS (M3-ICP) were compared. Total P was determined after extraction with nitric acid combined with microwave digestion, following USEPA method 3051, and determined by ICP-MS. Mean values for AER-P, M3-COL-P, M3-ICP-P and total-P, in mg kg^{-1}, were 160.0, 397.6, 498.2 and 1080.9 respectively. Therefore, a marked accumulation of P in the top soil layer occurred following long-term manure application. Linear correlations coefficients between the four P forms analyzed were highly significant; however a two-straight-line model or a quadratic relationship was more adequate for describing the dependence between the two determination procedures after M3 extraction, i.e. M3-COL-P and M3-ICP-P. Coefficients of variation varied from 25 to 54 % and ranked as M3-COL-P $<$ Total P $<$ M3-ICP-P $<$ AER-P, indicating medium to high variability of the P concentrations in the experimental field. Geostatistical analysis showed spatial dependence of all the four studied P forms, characterized by semivariograms with small nugget effect and ranges of spatial dependence from 60 to 140 m. Kriging maps showed the highest P accumulations at the lowest border of the field, suggesting sheet erosion and tillage erosion as main factors responsible for P spatial distribution in this field. Most overload patches within the field exhibited three to four times more P concentrations than those with the lowest accumulation. This study confirms that Mehlich 3 soil tests are a rapid and effective means for evaluating the phosphorus status of agricultural soils with excess levels and high inputs of organic fertilizers. Both, colorimetric and ICP-MS determination methods were capable to evaluate excessive soil P at the topsoil. Site specific information provided by geoestatistics has been found to be useful to design strategies for reducing soil P concentrations by plant removal.