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Short communication

Degree of Phosphorous Saturation in Intensively Cultivated Soils in Sri Lanka

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ABSTRACT. *The loss of Phosphorous (P) from intensively cultivated soil is one of the major causes of reducing water quality. The Degree of Phosphorous Saturation (DPS) which relates the extractable P of a soil to its P adsorption capacity is a good indicator of the soils potential to release P. Therefore, the objective of this research was to determine the DPS in intensively cultivated soils in Nuwara Eliya region of Sri Lanka and to predict P losses with runoff water. Twenty seven surface soil samples from intensively cultivated fields were analyzed for pH, water extractable P (P_{H20}) and Mehlich 3 extractable P. Single point adsorption study was conducted to determine the P adsorption capacity of soil (P_{150}). The Degree of Phosphorous Saturation was calculated as the percentage ratio between Mehlich-3 extractable P and single point adsorption capacity. The runoff potential of P from soils was evaluated using P_{H20}, where 20% DPS was considered as the cutoff point for runoff losses. The studied soils were acidic to strongly acidic in reaction. Very high Mehlich -3 extractable P levels ranging from 17.3 to 298.4 mg/kg P with the mean of 155.5 mg/kg P were observed. Phosphorous adsorption capacities were also high in soils with a mean of 664.7 mg/kg P. Calculated DPS values ranged from 1.7 to 80.4% with mean of 27.7%, while, 55.6% of soils had DPS values higher than 20%. DPS showed a considerably strong relationship (r^2 = 0.67) with P_{H20} and the corresponding P_{H20} at 20% DPS was 8.8 mg/kg P. Along with high DPS values, 59.3% of the studied soils were observed to exceed critical P_{H20} content and thereby they were at a risk of losing P from soil due to runoff.*

Key words: *Degree of Phosphorous Saturation (DPS), Mehlich 3 extractable P, Water extractable P (P_{H20}).*

INTRODUCTION

Phosphorus is an essential plant nutrient which leads to optimum crop growth and production (He *et al*., 2004). It is less water soluble and thus the by availability for plants is very low, seldom exceeding about 0.01% of the total P in the soil (Brady and Ray, 1996). Therefore, the fertilization with P is necessary to achieve optimum level of crop production (Allen and Mallarino, 2006).

Long term continuous application of P fertilizers and other P sources, such as organic wastes and manure cause P accumulation in surface horizon due to low crop use efficiency (<25%). Fertilizer addition without considering crop removal may also cause excess P in soil (Zhang, *et al*., 2004). It is reported that, the majority of Sri Lankan farmers apply higher than recommended quantity of fertilizer (National Science Foundation, 2000) aiming for higher economical benefits. Therefore, in agricultural soils when high quantities of P are received, available P content exceeds the critical P for fertilizer response (Saavendra, *et al*., 2006). In

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this situation, soil P has become more of an environmental concern than an agronomic one in areas with intensive cropping and livestock production (Central Environment Authority, 1995; Sharpley *et al*., 1995).

The Degree of phosphorus saturation (DPS) is an environmental index to assess the potential of soil for the release of P to runoff and leaching (Allen and Mallarino, 2006). DPS provides a reliable and unifying criterion for making environmentally acceptable and agronomically efficient fertilizer P recommendations for sustaining crop production (Khiari *et al*., 2000). Therefore, the objective of this research was to determine the DPS in intensively cultivated soils in Sri Lanka and to predict P losses with runoff water.

MATERIALS AND METHODS

For this study, 27 representative surface soil samples were collected from some intensively cultivated vegetable fields from WU3 and WU2a agro-ecological zones in *Nuwara Eliya* district (Table 1). The samples were air dried, gently crushed and passed through a 2 mm sieve to remove coarse fragments and then stored in tightly sealed plastic bottles until analysis were conducted.

Table 1. pH (1:2.5 soil: KCl), Mehlich- 3 extractable phosphorus (P_{M3}) values and adsorption capacity, P_{150} values of studied soils

Location	Agro-ecological zone	pH	P_{M3} in soil (mg/ kg)	P_{150} (mg/ kg)
Sandathenna	WU3	5.2	207	608
Palagolla	WU2a	5.5	17	1005
Sandathenna	WU3	5.0	219	572
Sandathenna	WU3	3.9	260	654
Sandathenna	WU3	4.9	232	437
Kudaoya	WU3	5.9	77	681
Kudaoya	WU2a	5.2	230	617
Labukele	WU2a	5.5	298	371
Kandapola	WU3	4.5	249	708
Kanadapola	WU3	3.9	107	915
Meepilimana	WU3	4.6	171	690
Hawaeliya	WU3	5.8	111	500
Seethaeliya	WU3	5.5	128	599
Lalukele	WU3	5.2	88	635
Magastota	WU3	5.8	227	185
Sanadathenna	WU3	4.4	211	1059
Ruwaneliya	WU3	6.4	91	771
Kalukele	WU3	5.8	63	608
Ruwaneliya	WU3	4.2	91	1167
Ruwaneliya	WU3	5.2	173	482
Hawaeliya	WU3	5.7	206	419
Topass	WU3	5.2	219	500
Meepilimana	WU3	5.1	34	1041
Meepilimana	WU3	5.5	124	509
Magastota	WU3	4.2	116	753
Kandapola	WU3	5.7	175	906
Kandapola	WU3	4.4	76	554
Minimum		**3.9**	**17**	**185**
Maximum		**6.4**	**298**	**1167**
Mean		**5.1**	**151**	**676**

The soil pH was measured by the glass electrode pH meter using a soil to solution ratio of 1:2.5 in distilled water and in 0.1 M KCl solutions (Rowell, 1994). Water and Mehlich-3 extractable P (PM_3) was determined by the Molibdate blue color method. For the determination of water extractable phosphorus (P_{H2O}), 20 mL of distilled water was added to 2 grams of soil (< 2 mm) which was in a plastic bottle and shaken for 30 minutes in a reciprocal shaker. They were then filtered through Whatman no. 42 filter paper. The filtrate was used to measure the water extractable P (Kuo, 1996). Mehlich-3 extractable phosphorus (P_{M3}) was determined by equilibrating 25 mL of Mehlich-3 solution with 2.5 g of soil in a plastic vial (Mehlich, 1984). It was shaken for 5 minutes in a reciprocal shaker and then filtered through Whatman no 42 filter paper. Phosphorus concentration of the aliquot was measured by spectrophotomettrically at 680 nm.

Single point adsorption study was conducted as described by Ige *et al*. (2005) using a P concentration of 150 mg P/L. Two grams of air dried, sieved soil was weighed into plastic vials and 20 mL of solution containing 150 mg P/L in 0.001 M KCl was added. The suspension was placed in a shaker and shaken for 24 h. at room temperature. The samples were filtered through Whatman number 1 filter paper and the remaining P of the filtrate was determined calorimetrically using molibdate blue method. The amount of P adsorbed, P_{150} , was determined by the difference between the amount of P added to the soil and the equilibrium P solution concentration. Then, DPS was calculated using P_{150} as the denominator and Mehlich-3 extractable P as the numerator.

Relationships were developed between calculated DPS and water extractable P which is used as an index of P in runoff losses in this study. The runoff potential of P from soils was evaluated using (P_{H20}), where 20% DPS (Ige *et al*., 2005) was considered as the cutoff point for runoff losses.

RESULTS AND DISCUSSION

General soil properties

The studied soils of intensively cultivated fields of *Nuwara Eliya* area were acidic to strongly acidic in reaction; pH ranged from 3.9 to 6.4 with a mean of 5.1 (Fig. 1) by proving general pH values of the area (Withana and Kumaragamage, 1993). Acidic pH of the soils is a norm in up country wet zone due to heavy rainfall. The upward trend of pH in some soils may be due to application of liming materials and poultry manure to the fields.

Mehlich -3 extractable P was very high and ranged from 17 to 298 mg/kg with a mean of 156 mg/kg (Table 1) indicating the availability of high extractable P (Sims *et al*., 2002). In general, the need of Olsen extractable P for optimum crop production is less than 30 mg/kg while it has been proved that some plants perform well under higher P contents (48 mg/kg) (Keerthisinghe *et al.,* 2007) . Twenty five soils, out of 27 soils studied (92.6%) showed exceeding P concentrations higher than 48 mg/kg which were extracted by Mehlich 3 solution (Table 1).

Phosphorus sorption properties of soils

The single point adsorption capacity, P_{150}, of soils ranged 185 and 1167 mg/kg with a mean value of 665 mg/kg (Table 1) indicating the very high adsorption capacities of the studied soils. The lower the pH, the more available are the metallic ions, especially Mn, Fe and Al which subsequently combine with soluble P and form insoluble compounds (Soon, 1991).

Calculation of degree of phosphorus saturation (DPS)

The estimated adsorption capacity, ES_{max} represents the actual capacity of soil to adsorb P while being a time consuming and costly procedure (Pautler and Sims, 2000). The single point adsorption capacity, P_{150} can be considered as an index representing the P retention capacity of soil due to its good correlation with ES_{max} ($p < 0.001$) (Ige *et al*., 2005).

$$DPS = \frac{P_{M3}}{P_{150}} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Calculated DPS values using above equation, ranged from 1.7 to 80.4% with mean of 27.7%. Researchers have used 20% DPS as cut off point for loss (Fig.1) of P due to runoff (Khiari *et a*l., 2000; Sims *et al*., 2002 and Ige *et al*., 2005). Of the soils studied, 55.6% showed higher DPS values than 20% indicating severe risk of P loss from soil to water, whereas the rest showed less potential for runoff P loss. These low values were due to the higher values obtained for adsorption capacity of these soils which confirm earlier studies reported for the area (Withana and Kumaragamage, 1993; Indraratne *et al*., 2009).

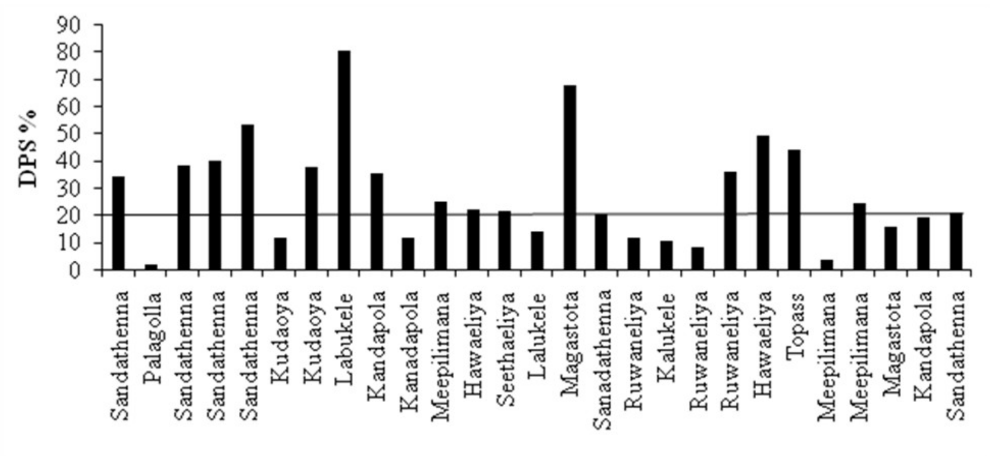

Fig. 1. Distribution of calculated DPS of studied soils

Evaluation of the calculated degree of P saturation

Water extractable P (P_{H2O}) was used as the index of soil P to evaluate runoff losses in many studies (Pote *et al*., 1996, Davis *et al*., 2005 and Ige *et al*., 2005). P_{H2O} of the studied soils were ranged between 0.93 and 58.74 mg/kg and the mean value was 14.63 mg/kg. A strong relationship ($r^2 = 0.677$, p=0.001 (n=27)) was observed between P_{H20} and calculated DPS (Fig. 2). At 20% DPS, the corresponding P_{H2O} was calculated as 8.8 mg/kg using the above relationship. Therefore, if P_{H2O} in a soil exceeds this threshold P concentration, it can be concluded as that soil has a high risk of runoff losses of P. Sixteen of twenty seven (59.3%) soils studied have shown exceeding P_{H2O} levels having greater risk of P loss.

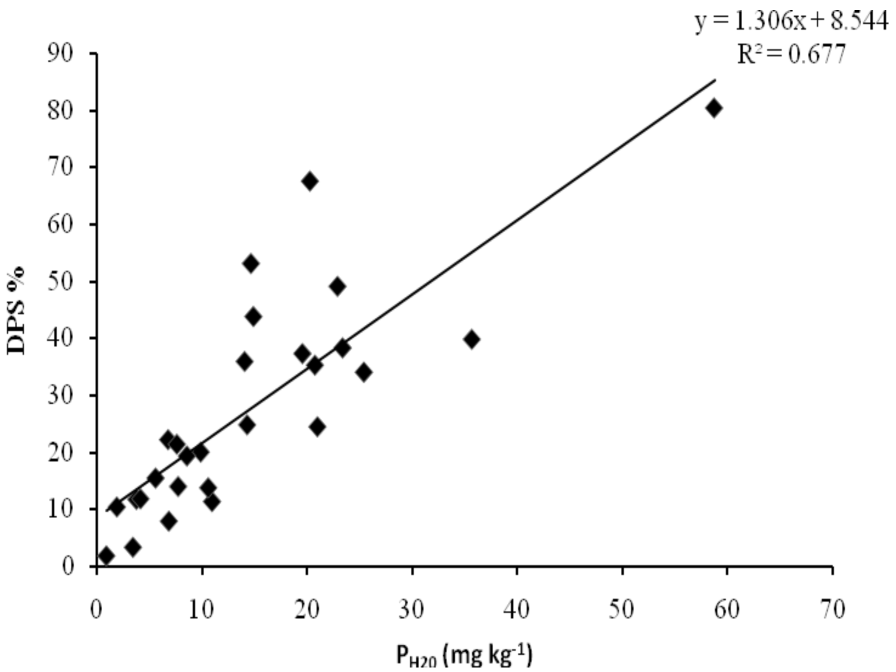

Fig. 2. Relationship between water extractable P and calculated DPS

CONCLUSION

Intensively cultivated soils in *Nuwara Eliya* exhibit very high available P concentrations in surface layer posing negative impacts on water quality in the area. On the other hand, the soils also have considerably high P adsorption capacities. However, 55.6% of studied soils showed higher DPS values than 20% indicating the risk of P loss from soil to water. Degree of Phosphorous Saturation calculating methods using Mehlich 3 P as the numerator and P_{150} as denominator gave significant and positive relationship with water extractable P. This study provides the preliminary P indexing for P runoff losses for intensively cultivated fields in Sri Lanka which requires field validations in future studies.

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