

ABSTRACT

The aim of this study was to compare the nutrient and sediment releases from 5 Irish tillage soils, inclined at 10 and 15 degree slopes, under a simulated rainfall intensity of 30 mm hr⁻¹ in the laboratory. Using the relationship between soil test phosphorus (STP) level in the 5 soils and dissolved reactive P (DRP) in surface runoff from them, a P loss risk indicator (PLRI) was developed to identify the STP level above which there is a threat to surface water quality. The results are in agreement with the Nitrates Directive as they indicate that tillage soils with STP values higher than 10 mg L⁻¹ have the potential to degrade surface water quality.

INTRODUCTION

Increased P concentrations in surface waters can contribute to algal blooms and subsequent eutrophication resulting in depletion of dissolved oxygen (DO) and potential fish kills. In erosion events, nutrients can be transported from soils in surface runoff or on soil particles that are detached during erosion (Figure 1). Tillage soils are particularly susceptible to erosion due to long periods without crop cover. Research has shown that regressions of DRP in runoff and STP were consistent between field plots and soil packed boxes. Laboratory flume studies on soil slabs using a rainfall simulator provide excellent controlled conditions in which nutrient and sediment releases from soils can be examined and quantified.

METHODS

A rotating-disc type rainfall simulator was constructed and calibrated to produce a rainfall intensity of 30 mm hr⁻¹. For each soil investigated, the top 5 cm of the soil profile was collected, air-dried, sieved (<5 mm), thoroughly mixed and then packed in 200 cm-long by 22.5 cm-wide by 7.5 cm-deep laboratory flumes to a bulk density of 1.4 g cm⁻³ (Figure 2). The packed soil was then saturated using the rainfall simulator and left to drain for 24 hrs until field capacity was achieved.



Figure 1 - Runoff on a tillage field in Co. Wexford following heavy rainfall.



Figure 2 - Laboratory flume set-up.

Selected soil chemical and physical properties are shown in Table 1. Each rainfall simulation comprised 3 successive 1-hr rainfall events at time intervals of 1hr and 24 hrs to determine the effect of storm interval on surface runoff. Each soil was examined at 10 and 15 degree slopes and subjected to a rainfall intensity of 30 mm hr⁻¹. Each rainfall simulation experiment was replicated (n=2). Surface runoff samples were collected during each event and were analysed for suspended sediment (SS), total phosphorus (TP), total reactive phosphorus (TRP), and DRP. A generalized linear mixed model (GLMM) was fitted to test whether the effect of soil type on surface runoff responses depends on slope and rainfall event. Stepwise linear regression was used to identify the soil parameters having the greatest impact on runoff water quality.

RESULTS

Soils with high levels of STP and water extractable P (WEP) had the highest concentration of DRP in surface runoff (Figure 3). The basic soil textural class ranged from loam to sandy loam, with sandy loam dominating. Generally, the highest SS and nutrient concentrations occurred within 10 minutes of the commencement of surface runoff. Across the 5 soils tested as STP increased DRP in surface runoff increased exponentially (Figure 4).

A stepwise linear regression analysis identified WEP as the most important parameter to test for in the soils in order to accurately predict DRP in runoff. A WEP level > 5 mg kg⁻¹ in the soils tested resulted in a surface runoff DRP concentration > 30 µg L⁻¹, which may be potentially harmful to aquatic life according to the Water Framework Directive (WFD).

Table 1. – Soil physical and chemical properties.

Location	STP mg L ⁻¹	WEP mg kg ⁻¹	%			
			Sand	Silt	Clay	
Tullow, Carlow	17.5	11.5	4.9	57.9	26.7	15.4
Clonmel, Tipperary	15.8	6.6	4.2	52.8	30.6	16.7
Bunclody, Wexford	7.1	3.5	7.1	41	38.7	20.3
Letterkenny, Donegal	4.8	2.8	5.5	49.1	39.5	11.4
Fermoy, Cork	2.8	2.3	5.1	56.9	28.6	14.5

STP = soil test phosphorus (Morgans method); WEP = water extractable phosphorus; OM = organic matter

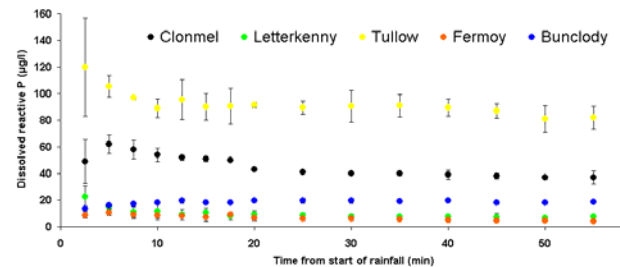


Figure 3 - DRP concentrations in surface runoff during first rainfall event at a 10 degree slope.

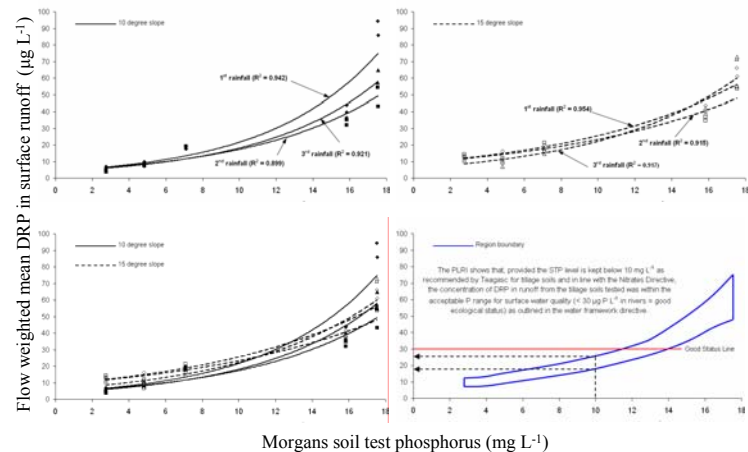


Figure 4 – PLRI across 5 tillage soils

CONCLUSIONS

The PLRI developed shows that even at steep slopes under heavy rainfall provided the STP level is kept below 10 mg L⁻¹ as recommended by Teagasc for tillage soils and in line with the Nitrates Directive, the DRP concentration in runoff from the tillage soils tested was within the acceptable P range for surface water quality (< 30 µg P L⁻¹ in rivers). In the case of the Tullow soil, where fertiliser in excess of crop requirements was applied over time raising the STP level above 17.5 mg L⁻¹, the concentration of DRP in runoff is more than twice the acceptable level for surface water quality under the WFD. This work facilitates the ranking of tillage soils based on erodibility and identifies soils with a high pollution risk.

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