Mitigation options for phosphorus and sediment (MOPS): tillage practices to reduce erosion from arable fields

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1. Introduction

Diffuse P pollution presents a serious problem in the UK, contributing to the eutrophication of surface waters. Losses of P from agriculture are of particular concern, as agricultural systems traditionally have high inputs of P applied in fertilisers and manures to enhance productivity. In the UK, the agricultural P surplus has been estimated to average around 16 kg ha^{-1} per year (Withers et al., 2001). Although there has been extensive research into effective treatments for reducing soil erosion from arable land (e.g. Quinton and Catt, 2004), less is known about the effectiveness of mitigation options for reducing P losses. To address this research gap, the Defra funded MOPS (Mitigation Options for Phosphorus and Sediment) project is investigating a range of tillage treatments with potential for mitigating P losses from arable land associated with combinable crops.

2. Methods

Field monitoring is being carried out at three field sites in the UK, each with contrasting soil types for which appropriate mitigation treatments have been selected and trialled (Figure 1). Fifty-two unbounded hillslope length plots are being monitored over three winters across the three sites, which allows replication of different treatments and combinations of treatments. Surface runoff is intercepted at the base of each hillslope plot by a 3 m collection trough, from which runoff is piped into a flow splitter and collection tank for sampling. After runoff events, samples are collected from each tank and refrigerated at 4 °C prior to analysis.

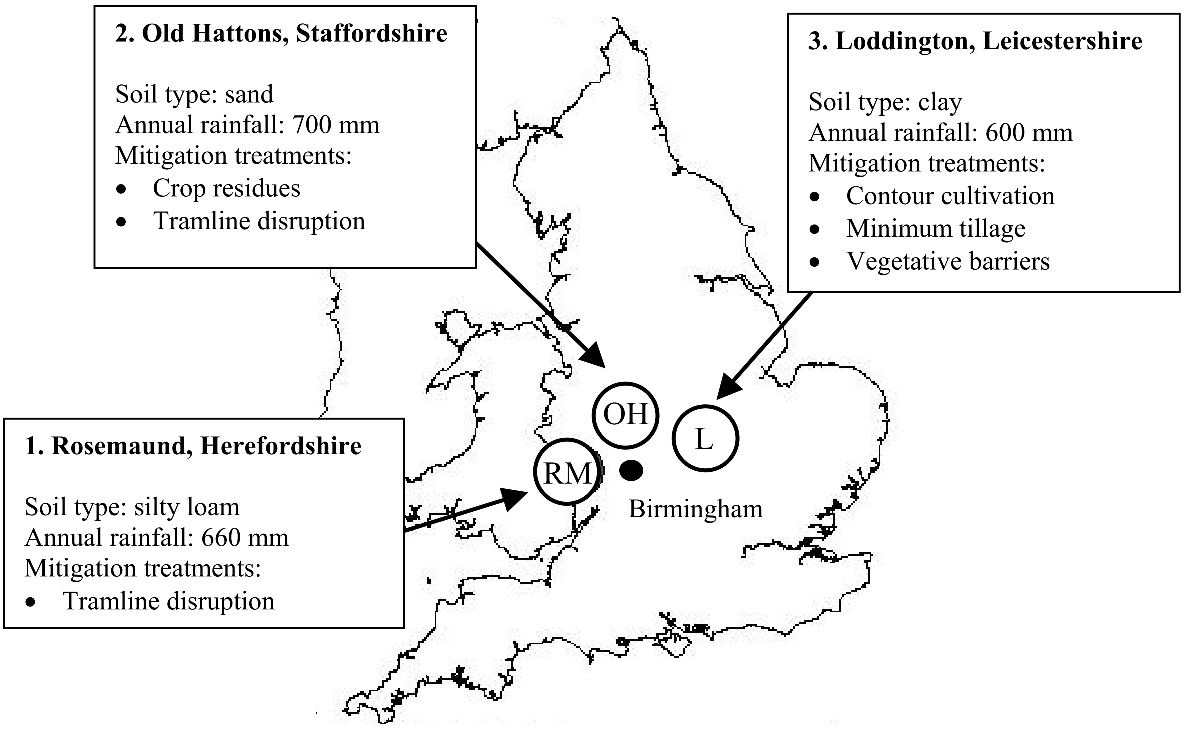

Figure 1 Location and characteristics of the three MOPS field sites

Samples were analysed for suspended sediment (SS), total P (TP) and total dissolved P (TDP). Suspended sediment was analysed by determining the mass of sediment evaporated from a 200 ml runoff sample at 105 °C. Samples for TDP were filtered through 0.45 µm cellulose nitrate filters within 24 hours of collection, and P concentrations were determined colorimetrically (Murphy and Riley, 1962) using flow injection analysis after persulphate digestion. All samples were analysed within one week of collection. Particulate P (PP) was determined by difference (PP = TP - TDP).

3. Results

The results from the first two field seasons show that P losses at all three sites are principally particulate (>76 %). Results from two of the three sites (RM and OH) indicate that tramlines (unseeded lines compacted by tractor wheels) are the main route of P and sediment transfer from arable fields, with losses of runoff, SS and P from plots containing tramlines (T) at least an order of magnitude higher than losses from plots without tramlines (NT) (Table 1). However, the results also showed that it was possible to reduce runoff by disrupting tramlines using a ducksfoot tine (DT). Runoff, SS and P losses from disrupted tramline plots were reduced to levels comparable to non-tramline areas at the silty loam site (RM).

Table 1 Aggregate over-winter yields for the first winter of monitoring at Rosemaund (RM) and Old Hattons (OH). NT = no tramline, T = tramline, DT = disrupted tramline, B = straw baled and removed, C = straw chopped and spread

Site	Treatment	Runoff (m^3 ha^{-1})	SS (kg ha^{-1})	TP (kg ha^{-1})
RM	NT	3	3	0.01
	T	58	357	1.32
	DT	3	6	0.02
OH	B, NT	4	21	0.06
	B, T	84	499	1.52
	C, NT	2	12	0.03
	C, T	64	298	0.99

Results from the sandy site (OH) indicated that crop residue treatments can reduce runoff, SS and P losses from arable land. Chopping and spreading straw (C), instead of baling and removing it (B) significantly reduced losses from arable land, typically by 30-60 % (Table 1). However, the losses from non-tramline areas were small compared to losses from tramline areas. In the second winter, tramline treatments were trialled at both the sandy and silty loam sites. The results indicate that at both sites, disrupting tramlines could reduce runoff, SS and P losses to levels from non-tramline areas (Table 2).

Table 2 Aggregate over-winter yields for the second winter of monitoring. OT = offset tramline

Treatment	Runoff (m^3 ha^{-1})		SS (kg ha^{-1})		TP (kg ha^{-1})	
	OH	RM	OH	RM	OH	RM
NT	27	20	24	21	0.1	0.0
T	153	778	275	4776	0.8	2.9
DT	50	27	72	40	0.2	0.0

Results of the mitigation treatments trialled on clay soils at Loddington (L) in 2005-2006 and 2006-2007 are presented in Figure 2. Both minimum tillage (MT) and cultivation on the contour (C) reduced runoff, SS and P losses compared to conventional tillage and up-and-down slope cultivation (P) at this site, although with high variability between replicate treatments. On average, minimum tillage reduced TP losses by 0.02 kg ha^{-1} compared to the plough treatments, and TP losses were reduced by 0.03 kg ha^{-1} for contour cultivation compared to up-and-down slope cultivation. The vegetative barrier (BB) was also effective in reducing TP loads; losses were reduced by a further 0.03 kg ha^{-1} for contour treatments containing the vegetative barrier.

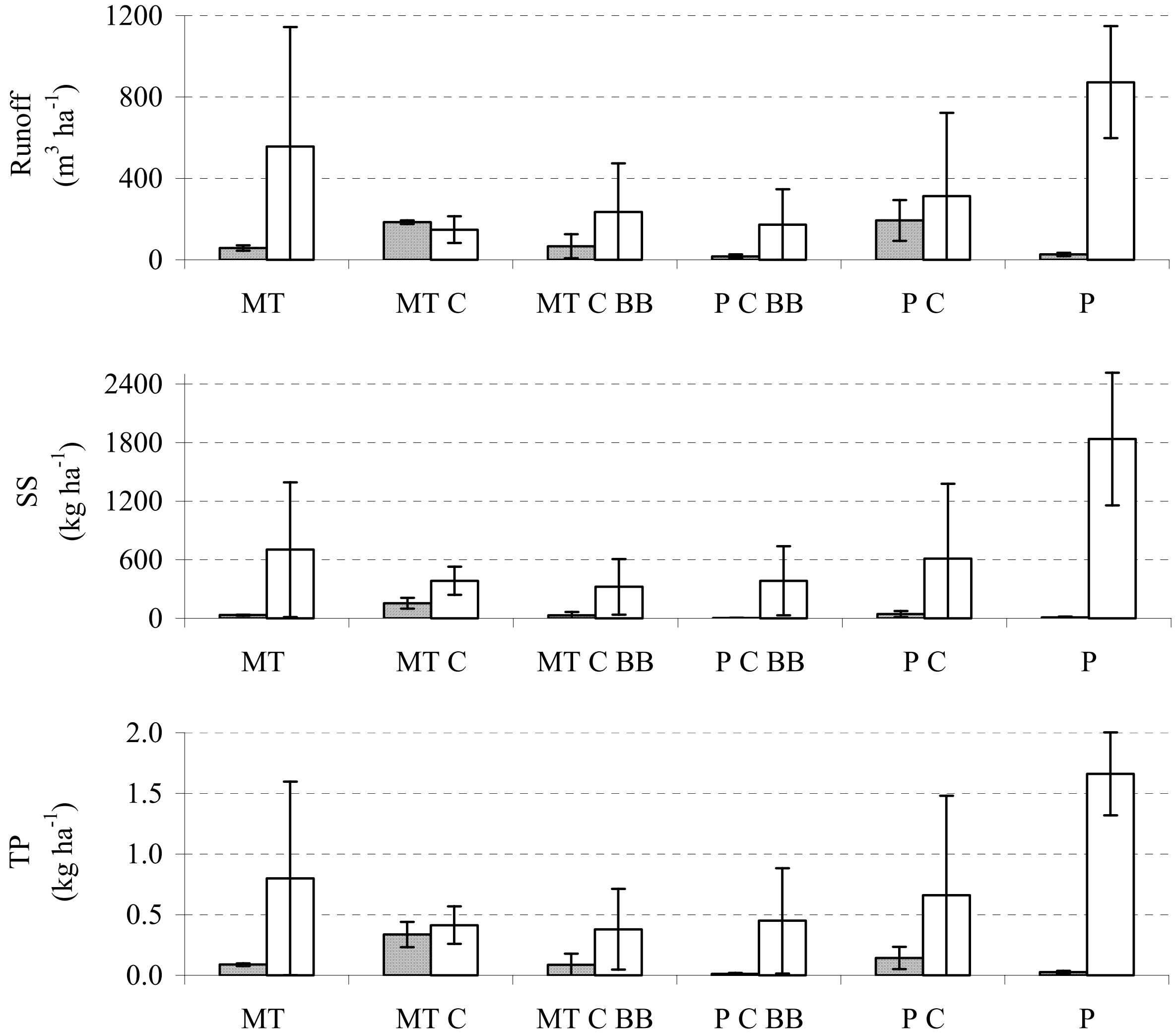

Figure 2 Aggregate over-winter yields for events monitored in 2005-2006 and 2006-2007, at Loddington (L). MT = minimum tillage, C = contour cultivation, BB = beetle bank, P = plough.

4. Discussion

Results from three field sites on different soil types have indicated that losses of P from arable land are principally particulate, therefore treatments which reduce erosion, either by reducing runoff and particulate carrying capacity, or by trapping particulate material on the hillslope, have potential for reducing P losses. Tramlines are a principal pathway for runoff and transfer of eroded material on arable hillslopes, and hence tramline disruption treatments, which allow water to infiltrate, have been shown to be effective at reducing SS and P losses. However, as tramline disruption is associated with decreased operating margins (-£11 ha^{-1}) (see Bailey et al. 2007), it is unlikely to be widely adopted as a mitigation treatment until the disruption mechanism can be incorporated into standard field management activities. Incorporation of crop residues, which is an effective treatment in non-tramline areas, is also associated with decreased operating margins (-£19 ha^{-1}). Treatments such as minimum tillage and contour cultivation, which are likely to involve cost savings, are more likely to be adopted. Bailey et al. (2007) suggest that minimum tillage could involve considerable cost savings (+£48 ha^{-1}) because of reduced mechanisation and labour costs, although this treatment may be less effective at reducing SS and P losses than alternative treatments. Cultivation on the contour rather than up-and-down slope may have no effect on operating margins, although this is dependent on the field size and slope characteristics. In-field vegetative barriers, although effective, are associated with small cost increases (-£2 ha^{-1}), and are difficult to cultivate around. In addition, as they need to be applied on the contour, substantial benefits may be achieved almost as easily and at lower cost by converting to contour cultivation.

The treatment which has the greatest impact on SS and P losses, tramline disruption, is successful because it breaks up compacted soil surfaces and allows rainfall to infiltrate where it would previously have run off. Surface erosion and transport processes are therefore reduced. It is unclear whether the water which would have flowed down the tramlines is stored in the soil, or whether it is transferred to the stream by an alternative subsurface pathway, but as concentrations of SS and P in subsurface runoff are usually lower than in surface runoff (e.g. Dils and Heathwaite 1996), treatments which displace runoff from surface to subsurface pathways can still be considered beneficial mitigation options. Of more concern is the effect of controlling sediment and P losses on other pollutants, which may be positive or negative. In a review of pollution swapping in agricultural systems, Stevens et al. (in press) report that the use of crop-residue treatments may increase leaching losses of N, P and C, and increase emissions of N_2O and CO_2. Evidence discussed in the same review suggests that minimum tillage is likely to be a beneficial treatment not only for surface losses of SS and P, but also for N, C and pesticides, with little effect on gaseous emissions.

The MOPS project is currently in its third year, and the results from the 2007-2008 field season are expected to provide further evidence to support the effectiveness of tramline treatments, minimum tillage and contour cultivation in reducing P losses from arable land.

Acknowledgements

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