Cost-effectiveness of mitigation of sources of P pollution in the Lunan Water catchment: a note on effect of including point sources and internal loch sources of phosphorus along with diffuse sources

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Introduction

The purpose of this note is to assess the impact of including point sources and internal loch sources of P in the analysis of cost-effectiveness of measures to achieve reductions in P pollution loads to the Lunan Water. The Lunan water catchment is a mixed arable farmland catchment that drains an area of 134 km^2 from its source near the town of Forfar to the North Sea at Lunan Bay, in Angus, Eastern Scotland. The main crops grown in the catchment are spring and winter barley (26% of cultivated area in 2005), winter wheat (12%), potatoes (7%) and winter oil seed rape (7%) and grassland (15%). The cultivated area is 96% of the catchment. The remainder of the non-arable land use is mainly grassland and forestry with only a few small settlements within the catchment. Average annual rainfall is around 820 mm and is quite uniformly distributed throughout the year. Estimated annual evapotranspiration is around 400 mm. Based on discharge and water chemistry data for the SEPA gauging station at Kirkton Mill, annual loads and flow weighted concentrations of soluble P for the period 1987-2010 were estimated as 3894 ± 2025 kg P and 78±30 ug P/L (Dunn et al. 2014) respectively. As part of a current Scottish Government (RESAS) funded project (Vinten et al., 2018) it is useful to consider the impact of mitigating point (septic tank and sewage treatment works) and internal loch sources (from Balgavies and Rescobie Lochs, situated in the upper part of the catchment) on these costs. We have done this by considering potential mitigation of sewage treatment works in the catchment (about 500 kg P/year, based on data provided by SEPA), septic tanks (estimated to be about 100 kg P/year – see Balana et al., 2012) and internal loch sources of P (these vary from year to year but may be up to 200 kg P/year). We carried out a sensitivity analysis on price of mitigation of such point sources.

Methods

The cost-effectiveness of six edge-of-field measures for mitigating diffuse pollution from sediment bound phosphorus (P) runoff from temperate arable farmland were previously analysed at catchment/field scales across 1634 riparian and non-riparian fields (Vinten et al. 2017). These measures were: buffer strips, permanent grassland in the lowest 7% of arable fields, dry detention bunds, wetlands, and temporary barriers such as sediment fences. Baseline field P export was estimated using export coefficients (low risk crops) or a modified Universal Soil Loss Equation (high risk crops). The impact of measures was estimated using simple equations. Costs were estimated from gross margin losses or local data on grants. Costs minimisation for target impact was done using PuLP, a linear programming module for Python. With all measures in place, average cost-effectiveness increases from £9 to £48/kg P as target P mitigation increases from 500 to 2500 kg P across the catchment.mTo assess the impact on these costs of including mitigation of point and internal sources of P, we included additional increments of potential P mitigation, at a range of potential fixed cost-effectiveness values from £5 to £35/kg P mitigated, in the analysis framework previously described (Vinten et al., 2017) and reran the analysis.

Results

Figure 1 shows the effect on the cost-effectiveness analysis for mitigation of P loads, of including mitigation of point and internal sources at a range of fixed values for cost-effectiveness. Mitigation of these sources only reduces annual mitigation costs when their combined cost is below 25/kg P and when the overall P mitigation target is above about 400 kg/ year. If the costs are as low as £5/kg P, mitigation of point sources and in loch sources substitute nearly completely for mitigation of diffuse sources. At prices for mitigation of point and internal sources of between £5/kg P and £25/kg P, the costs should be borne by a combination of diffuse and point/internal source mitigation.

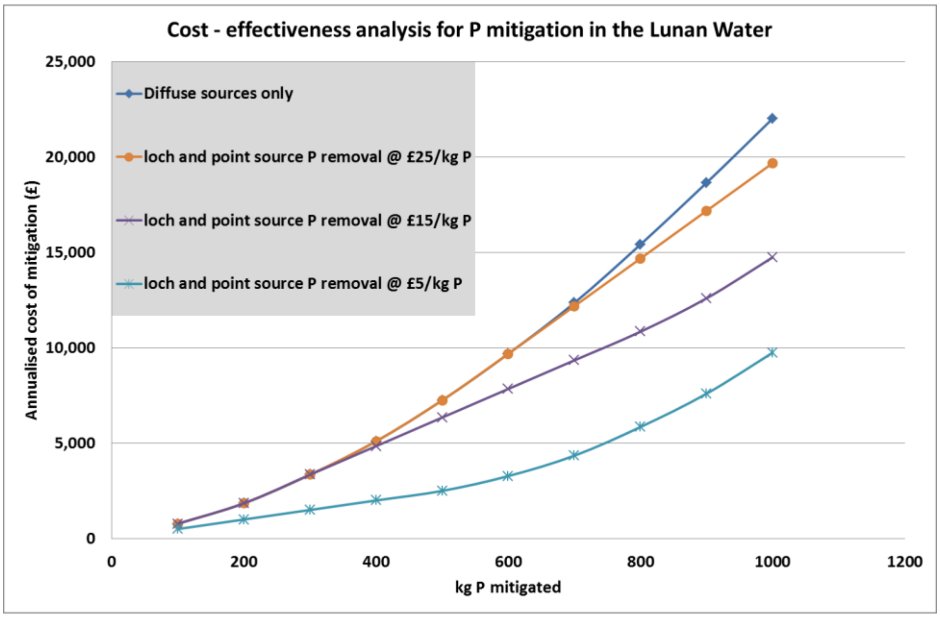

Figure 1. Estimation of costs of mitigation of P loading to the Lunan Water – effect of including point source P mitigation in the analysis.

Discussion

Table 1 summarises information from the literature on assumed costs of mitigation for various point and internal sources. Based on these figures, mitigation of septic tank sources is likely to be difficult to justify on economic grounds, but mitigation of sewage treatment works sources is justified, alongside the previously assessed diffuse sources in the catchment, if the benefits are high, as will be the case in many catchments containing standing waters (see Balana et al., 2012; Vinten et al., 2012).

With respect to reducing annual P load, mitigation of internal P sources cannot be justified as a primary measure on grounds of cost-efficiency alone, compared with diffuse sources. However, it should be noted that this source is unique here in that the release of P from bed sediments in lakes may increase following a reduction in catchment P load as a result of re-equilibration of P between the water column and the sediment P stocks. This has been evident in other lakes following catchment management, for example, Loch Leven (Sharpley et al., 2013). This re-equilibration period can extend decades following catchment management (Jeppesen et al., 2005). If diffuse pollution alone is sufficient to raise the water column P concentration causing an increase in phytoplankton, then controlling internal loading instead of diffuse pollution will have little effect on water quality. This has been aptly demonstrated by Huser et al (2016) and Hupfer et al. (2016) who demonstrate that cost-effectiveness of the control of in-lake P sources increases as catchment load increases. In some instances, where catchment load is difficult or very costly to control, topical measures for the reduction of in-lake P may become more cost-effective. What is important here, is to first identify the target TP concentration of the lake to reflect desirable water quality conditions, and then apportion responsible and effective P sources and mitigation measures to meet this target. Moreover, it should be borne in mind that P from septic tank sources are often prevalent at times of the year when stream flow is low (Stutter et al., 2014) increasing the relative significance of such sources and the benefits of mitigation.

Source to be mitigated	Region/Country	Cost ($/kg P) (median used if ranges available)*	Raw data for cost/cost range (units given)	Reference
Agriculture mitigation	EU	$5	3–5 (£/kg P)	(Haygarth et al. 2009)
Sewage treatment works	EU	$19	15 (£/kg P)	(Vinten et al. 2012)
Urban diffuse	EU	Data not available	n/a	n/a
Septic tank	EU	$43	35 (£/kg P)	(Vinten et al. 2012)
Combined sewer overflows	EU	$2,480	2000 (£/kg P)	(Hjerppe and Väisänen 2015)
Bank erosion	EU	$310	250 (£/kg P)	(Hjerppe and Väisänen 2015)
In-lake P capping	EU	$310	200 (£/kg P)	(Vinten et al. 2012)

Table 1. Examples of P mitigation costs from selected literature.

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