A cost:benefit evaluation of *in situ* high temporal resolution stream nutrient monitoring

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INTRODUCTION

Technologies that enable automated, *in situ*, sub-hourly sampling and analysis of key water quality parameters are increasingly being used to measure catchment nutrient transfers in streams (e.g. Jordan *et al.* 2012). These 'bankside analysis' technologies are supplementing or replacing the traditional approaches such as using automated stream sample collection technologies coupled with laboratory analysis of water. This study compares the costs and (known) benefits of bankside analysis with a traditional approach.

METHODS

Bankside analysis technology

- Deployed by the Agricultural Catchments Programme in Ireland to monitor five streams and a spring draining agricultural catchments (3.4 to 12.1 km^2) (Wall *et al*. 2011).
- Unfiltered stream water was continuously supplied by a submersible pump to an enclosed header tank on the stream bank (Fig. 1).
- A Dr Lange suite of spectrophotometric instruments analysed total digested P (TP) and total molybdate-reactive P (TRP) concentrations, total oxidised nitrogen (TON) concentrations, turbidity, electrical conductivity and temperature (Fig. 2). Between 2 and 6 measures per hour of each analyte were logged continuously.
- Data were transferred by a GPRS data-push system to a web-enabled SQL server (Dexdyne Ltd.) for real-time and historic data visualisation. System fault alerts were sent to mobile phones. The bankside analysis technology required 230V AC power.

Traditional sampling and analysis technology

- Discrete water samples collected using a battery-powered 24-bottle autosampler followed by analysis of samples in a laboratory (Fig. 3).
- Two sampling protocols assessed; a) '24/7': sampling every 7 hours and collection and analysis weekly (considered optimum for this technology for stream P load estimation by Jordan and Cassidy (2011)) and, b) 'weekday hourly': hourly sampling and daily collection and analysis 5 days/week to mimic the temporal frequency of the bankside analysis.

Costs for each technology and protocol were calculated or estimated for the purchase and commissioning of instruments and associated training, for maintenance and quality control and for consumables required per site. Frequency of failure of the bankside analysers to measure at least one analyte for at least one hour was also assessed.

Fig. 1. Stream water was continuously supplied by a submersible pump

Fig. 2. Bankside analysis provides sub-hourly measures of stream TP, TRP, TON, conductivity, temperature and turbidity

Fig. 3. Traditional autosamplers are usefully deployed in difficult to access streams

RESULTS

The **total capital cost** of deployment for the bankside technology was 10 times that of the traditional technology (Table 1). **Maintenance and consumable costs** were, however, similar to the traditional technology '24/7' protocol and six times lower than the 'weekday hourly' protocol. Bankside analyser maintenance required approximately 0.45 **Full Time Equivalents** per year (FTE/yr) for the furthest and most problematic catchment and approximately 0.32 FTE/yr for the closest and least problematic catchment. Less time (0.29 FTE/yr) was estimated as required using the traditional technology '24/7' protocol, but increased to 1.44 FTE/yr for the 'weekday hourly' protocol.

The **minimum data captured** for phosphorus (P) over 12 months was 85%, with at least three sites capturing greater than 90% of hourly records. Data capture for other analytes exceeded 85%. Between one and 27 data capture failures occurred per year per site. The main reason for **failure** was blockages in the sample supply system, which occurred more frequently in the catchments with higher sediment loads and leaf debris. Other causes of failure included; the P sampler stopping after temporary interruption to the water sample delivery, worn seals on the P sampler, and submersible pump electrical fault. On one occasion failure was caused by circuit board fault, sensor fault, biofoul or insufficient reagent volume.

Non-monetary benefits of bankside analysis technology include; improved accuracy and precision in nutrient load estimation, the potential to reveal sub-hourly nutrient dynamics in streams due to both storms and point sources, and real-time patterns of reactive N and P fractions (Fig. 4), which would otherwise be subject to transformations during sample storage. Further to this, process information that is new to catchment science is likely to emerge from these high frequency instantaneous and continuous data.

Table 1. Comparison of costs and observation frequencies for bankside analysis vs traditional sampling and analysis of TP, TRP, TON, conductivity and turbidity.

	Bankside analysis	Traditional analysis '24/7'	Traditional analysis 'weekday hourly'
	Number of observations		
All analytes per year	205344	4067	19314
TRP per year	22320	156	261
	Annual cost (€) per site (rounded to nearest €1000)		
Capital (Year 1 only)	52000	5000	5000
Maintenance & consumables	27000	31000	187000
	Cost (€) per observation		
Year 1	0.34	8.78	9.91
Year 2	0.13	7.65	9.68

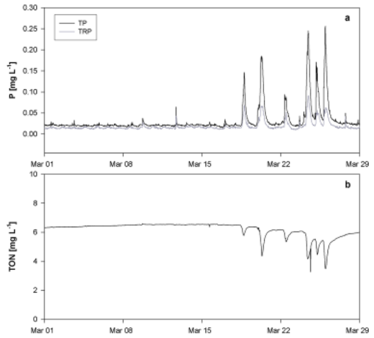

Fig. 4. Dynamic patterns of a) P fractions and b) TON concentrations in streamflow captured by bankside analysis

DISCUSSION AND CONCLUSIONS

The high capital cost of bankside analysis is likely to limit its widespread deployment and the technology is not suitable in environments with difficult access or no mains power available. However, the post-deployment costs and technician time were comparable with, or lower than, the traditional technologies considered. Data management costs and time also need consideration. Given the significant non-monetary, knowledge building benefits, targeted investment into bankside analysis is likely to be warranted, particularly in hydrologically dynamic catchments, to assess water quality impacts of land management policies that have significant social and financial implications.

REFERENCES

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