Short term decisions and long-term responses of catchment systems

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2005 to 2010

Dissolved Organic Carbon as C

Nitrate as N

Total Phosphorus as P
1980 to 2010

Dissolved Organic Carbon as C

Nitrate as N

Total Phosphorus as P
1950 to 2010

Dissolved Organic Carbon as C

Nitrate as N

Total Phosphorus as P

Concentration (mg/l)

1950 to 2010
1920 to 2010
1860 to 2010

**Dissolved Organic Carbon as C**

**Nitrate as N**

**Total Phosphorus as P**
Changes in agriculture

Medieval Farming Methods
Changes in agriculture

Kimball’s Dairy Farmer Magazine, July 15th 1911
Changes in agriculture

21st Century Farming
River Thames Catchment

Londoners called 1858 "The Year of the Great Stink"

The Red Granite kerbstone marks the site of the historic BROAD STREET PUMP associated with Dr. John Snow's discovery in 1854 that Cholera is conveyed by water.

Welcome to London in the 'Great Stink' of 1858
Observation...
Annual land use records from 1867

- parish land use
- annual records (MAFF68)

Nitrogen Inputs

Farming for Water Quality: Balancing Food Security and Nitrate Pollution in UK River Basins

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Widespread pollution of groundwater by nitrates is an externality of modern, intensive agriculture. Rising nitrate concentrations in freshwater have been of concern throughout the developed world for several decades. Initial worries focused on human health, but more recently nitrate's role in eutrophication has also become a cause of concern. Because the impact on water quality often comes decades after land-use change, the challenge for science is to produce an integrated model of catchment hydrology and quality applicable to the long timescales involved and that can cope with the complexity of connectivity among land, aquifer, and river. This article discusses the balance between food production, and therefore food security, and protection of water resources. We use recent results from a catchmentscale model of the River Thames in the United Kingdom to demonstrate that the response time of catchments can be on the order of decades, given the delays induced by groundwater flow through aquifers. Historically, the main drivers for changes in N fluxes were massive land use change associated with wartime plowing of permanent pastures and postwar reclamation and intensification of agriculture, leading to the current quasi-steady state of N-dependent but leaky agriculture. It is clear that restoration of water quality to mid-twentieth-century levels would require very severe changes in land use and land management, significantly affecting UK food supply and security. Moreover, the potential timescales for recovery are well beyond those of normal political cycles. Failure to act will mean a continued high level of nitrogen transfer to rivers, estuaries, and oceans, with potentially serious ecological implications, and continued emissions greenhouse gases to the atmosphere. Nonwithstanding improved efficiency of agronomic methods, the situation is unlikely to change significantly without substantial shifts in legislation or farm management.

Nitrogen Model

Phosphorus Inputs

Phosphorus Inputs and Output

Sustainable Phosphorus Management and the Need for a Long-Term Perspective: The Legacy Hypothesis

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Global land and water security depend upon sustainable phosphorus management. This inter-disciplinary study provides an ideal set of tools for studying this, and analytical developments in-tandem measurements have been utilized in short-term (tempo) dynamics (e.g., ref 3). However, we argue that a potentially new and deeper understanding will arise from assessing the historical changes in the P budget at the catchment scale and even many years, with the need for a much longer-term perspective.

In many high-productivity intensively managed catchments, phosphorus inputs have accumulated over many years. Studies have shown that the build-up of P in the topsoil, and the complex release patterns in catchments and diffuse sources. However, we are currently unable to accurately quantify these effects. In response, we attempt to provide a solution, allowing for example, for long-term observations to inform a new framework for targeting hypotheses and quantitative research, to tidy over the scientific frontiers.

Further, we aim to evaluate at unprecedented rates following the United Nations World Water (UNWW), to extend the local dynamics of a rapidly growing population, with P as an essential component for agricultural productivity globally. With parallel mechanization and intensification of crop and livestock systems, regional P in agricultural land has developed with increasing rates of P surplus above local needs, leading to P impairment of active waters, and the areas of P deficit limiting production. Thus, to get a full understanding of the behavior of P in landscapes and catchments, we need to determine, over the long term, the magnitude of the accelerated P pool in catchments, and, equally, the magnitude of P export from the catchment. Deriving P flux input and output time series for extended periods will facilitate calculation of the accumulation or depletion of P within a catchment, from which we can estimate, for example, how long it may take, given current rates of P flux export, to draw down the accumulated legacy of P or, conversely, how long it may be before we see enhanced agricultural production in P-deficient areas. From this, long-term perspective, we can determine the P sustainability status of catchments. We also need to consider soil, plants, and catchment-scale processes in a better evaluation of mid-term (e.g., ref 3).

We show these example trajectories in long-term P flux time series for a globally important source, the Thames (U.K.) and

Conclusions... to date...

- **Nitrate**
  - animal, fertiliser and ploughing inputs important, and almost 60% of response controlled by long-term groundwater processes with a lag time of >30 years
  - if we reduce inputs by 50% now, the immediate effect would be a 20% reduction in outputs...

- **Phosphorus**
  - wastewater inputs have risen steadily and then declined after WWTD, but there is a large legacy store of P; diffuse inputs to land do not appear to have a fluvial impact?

- **Ongoing work: how do these results map to wider scales?**
National-Scale Models of N, C and P Export (1 km²)

Worrall et al. [2012] - STOTEN
Worrall et al. [2012] -JoH
Worrall et al. [in prep]

Nitrogen Inputs and Outputs