Can integrated modelling support catchment management? A case study of the River Dee, Scotland

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Peatlands are important water and carbon stores, support unique flora and fauna, and sustain a range of recreational activities. Restoring peatlands towards good condition is essential for climate regulation and protecting water supplies.

Careful management of the catchment's forestry is essential to minimise erosion and protect the river from sediment run off.

Farming is widespread, especially in the lower catchment. By practising sustainable management, farmers can help to improve water quality, reduce flood risk and provide important habitats for wildlife.

The Dee supplies domestic water for Aberdeen and over half of Aberdeenshire as well as bottled water and whisky businesses. These abstractions need to be managed to minimise stress on the river during low flows.

The mouth of the Dee forms Aberdeen harbour, one of the busiest in the UK, and home to a range of wildlife including otters and dolphins. Controls on noise, lighting and pollution enable migrating salmon to enter the river all year round.

The Dee is internationally famous for its salmon and sea trout fishery attracting large numbers of visitors each year. Managing the catchment sustainably is essential for a healthy fish population.

The River Dee is home to a wide range of flora and fauna, and is designated as a Special Area of Conservation for internationally important populations of freshwater pearl mussel, salmon and eel. Their survival depends on a healthy river system.

We depend on the Dee for waste water disposal. Treated effluent is usually discharged but during heavy rain untreated waste can enter the river directly. Septic tank inputs are also an issue.

The catchment's expanding population brings a demand for more housing. Associated construction works, sealed surfaces, drainflow and water demand can affect water quality and quantity, and its flow through the catchment.

Where are we?
It is an old story

- Greek mythology alludes to our problematic relationship with water

- REFRESH seeks to build new trans-disciplinary understanding of cost effective mitigation of water quality problems
Some of the practices on the Dee are not all that good for water quality!!!
What I intend to talk about

- How have water quality problems arisen?
- The three worlds of catchment management (regulatory, practical and theoretical)
- The modelling challenges
- The REFRESH approach to bio-economic modelling
- The need for (and challenge of) socially cost effective mitigation of water pollution
- The farm level marginal abatement challenge
- Some conclusions
How have water quality problems on the Dee arisen?

- The Water Framework Directive specifies a requirement for:
  
  Good Ecological Status including Good Morphological Status

- Both can be seen to be compromised on the Dee catchment to different degrees in different parts of the catchment. It is not all good

- Rural land use is implicated in diffuse pollution
  
  - Nitrates from fertilisers or ploughed pasture
  - Phosphates from fertiliser
  - Pesticide residues
  - Forestry ploughing and timber extraction
  - Cattle waterings
  - Lack of trees

- But some rural land use effects are more like mini-point pollution
  
  - Yard washings
  - Silage leachate ‘bree’
  - Food or timber processing plant leaks
The causes are not just farming and forestry practices

- Septic tanks are (or could be) an issue
- Acid deposition (nutrient enrichment and acidification)
- Climate change exacerbates the effects through extreme events
  - Temperature
  - Extreme weather events
- Fishing interests introduce morphological interventions
- Industry can cause pollution incidents
- Urbanisation can increase runoff & pollution incidents
- Open grouse moor and deer forest leads to water temperature rises
- Quarrying can increase sediment load
The modelling challenge

- **We must model**- either intuitively or formally in order to try and direct improvements to the system. This requires
  - Understanding the association and causation between land management practices, climate change and water ecological and morphological consequences, including the impact of extreme events
  - Understanding at a **scale** which can be translated into accurate specification of remedial practices
  - Understanding the diversity of farm economic situations, so that cost effectiveness and proportionality can be reasonably established/attributed
  - Understanding the non-market costs and benefits to feed into spatially explicit catchment models
  - Understanding both trickle and pulse effects
  - *This requires very good data and rather sophisticated bio-economic modelling with both geochemical and socio-economic elements*
The scale problem

CEA and PA in WP 6 depend on opportunity costs of mitigating action, normally based on sub-field level practices (fencing of watercourses & buffer strips).

Some actions are at field (e.g. no till cultivations) or even sub-catchment level (e.g. manure prescriptions in NVZs).

Data refinement allows downscaling to sub-catchments and even farms based on refinement of emission functions to different ‘land use’ types.

WP 5 operates at catchment scale-e.g. Thames based on modelled P and N emissions from major land use types and STWs.
Pulse vs trickle and hot spots

- The trickle of pollution from e.g. arable or grassland (esp nitrates)
- Pulses of extreme rainfall activity resulting in major erosion incidents and sediment delivery
- Hot spots – vulnerable parts of the land-water system often particular soil types and slopes with particular crops (e.g. potatoes) which are adjacent to water courses

Pulses of activity on hot spots can have major effects
Catchment management operates in two (or three) worlds

- The science of catchment management
  
  Objective research looking at the science challenges and making judgements (often based on models) as to what would be an appropriate course of action to improve the GES
  
  This can be seen as the ‘formal knowledge system’

- The practice of managing the land water interface
  
  Highly varied practices based on locally informed knowledge, mediated by regulation, almost always focussed on something other than water.
  
  This can be seen as lay knowledge

.....with a regulatory system behind it
If we want to address a WFD compliance problem we need to model holistically.
Part 1: Biogeochemical modelling scenarios – Tarland Burn

3 climate change simulations:

4 land use scenarios:

Tarland Burn is a transitional catchment where significant land use changes could occur. The impact of these appears greater than likely climate change impacts.
In this lowland catchment neither climate nor land use change scenarios have any significant effect on phosphorus; mitigation measures likely remain effective in the future.
Part 2: Identifying mitigation and adaptation measures

A Step-by-Step approach in CEA Modelling

<table>
<thead>
<tr>
<th>CEA STEPS</th>
<th>KEY QUESTIONS</th>
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<td>1. Identify the major pressures</td>
<td>What are the key pressures that compromise water quality?</td>
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<td>2. Identify sources of pressures</td>
<td>Where do these pressures come from? (Diffuse or point sources)?</td>
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<td>3. Determine environmental targets</td>
<td>What is the environmental target we aim to achieve?</td>
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<td>4. Identify measures</td>
<td>What is the potential set of mitigation or adaptation measures?</td>
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<td>5. Determine the scale or unit analysis</td>
<td>At what scale do cost and effectiveness data need to be generated?</td>
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<td>6. Assessment of the (likely) effectiveness of measures</td>
<td>How effective these measures are?</td>
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<td>7. Cost estimates of the various measures/actions</td>
<td>How much do these measures cost?</td>
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<td>8. Integrate cost and effectiveness data</td>
<td>How to integrate the effects and cost data? or model the CEA?</td>
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<tr>
<td>9. Rank measures</td>
<td>Identify cost-effective set of measures</td>
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Economic Modelling (CEA Results - Tarland)

Mitigation/adaptation measures

- cost-effect ratio (£/KG N) - Arable
- cost-effect ratio (£/kg N) - grassland
CEA Results-Loch of Skene (ranked measures)
Part 3: Engaging with stakeholders

- Building upon the solid roots of the Dee Catchment Partnership

- Designed as a two ways dialogue:
  - Gather local knowledge on the key pressures and their sources, available measures, barriers, sources of information for costs and benefits, etc.
  - *Ground-truthing* /validating modelling results

- Through a series of local workshops, personal interviews and follow-up contact with land owners and representatives of nature organizations, the environmental agency (SEPA), local councils, local estate, sailing clubs and Scottish Water
Summary: the basic requirement if we are to mitigate cost-effectively

- An understanding of the biophysical consequences of land management practices

- A farm/estate scale understanding of the current state of play: stocking rates; grazing regimes; watering; fencing, fertiliser applications, other inputs, drainage, yields

- An understanding of the opportunity costs of delivering improvements, changing fertiliser regimes – what income is foregone, what costs are saved

- An understanding of the capital costs of different actions (fencing, buffer strips, etc) and the effective life of that capital

- An understanding of other non-market values impacted (e.g. scenery or biodiversity)
A typical averaged MACC

1. No autumn N
2. Buffer strip with AEP
3. Better FYM management
4. Fencing watercourses
5. Buffer strips without AEP
6. Clover sub for N
7. Major reduction in ruminant livestock

These are win-win actions

The target level of pollution reduction

These are progressively more costly interventions

High cost

0

positive cost = profit
The proportionality principle

The economic value of pollution mitigation

These are win-win actions

These are progressively more costly interventions

The target level of pollution reduction

High cost

0

positive cost = profit
And the average MACC does not represent the situation of the individual land manager.

Should our example intensive dairy farmer continue to pollute with impunity?
Case Study A: Growing barley in the Leuchars burn sub-catchment

- Good Ecological/Morphological Status suggests that channel dredging is undesirable
- A small farmer’s arable fields abut one of the problematic and more polluted watercourses on the Dee
- Harvesting one field of spring barley was severely compromised by waterlogging 20% of the field nearest the stream
- This waterlogging will increase Nitrous Oxide emissions, decrease nitrates to water but add to Greenhouse gas emissions - pollution swapping.
- Does the ‘wellbeing’ of that water body really require that one of the only arable fields abutting the stream cannot have 300 metres of adjacent stream dredged? Are we being proportionate here?
- We are in danger of looking for a solution to one (maybe small) water environmental problem and causing another environmental problem and a negative income effect on the basis of weak evidence base.
Case study B Pulse vs trickle

- Extreme events can be hugely important in phosphate pollution
- Gully erosion and massive soil and phosphate losses into Loch of Skene (a shallow lake) in autumn 2010 and into the main A944 road which was blocked for many hours
- Most normal interventions reduce trickle effects (e.g. winter stubble), but the big pulses may cause a real problem with phosphates and normal remediation strategies may not work.
- We need more information on effectiveness of different measures under different conditions (e.g. does it matter what the slope is of a winter stubble or how close to a stream?)
Conclusions: we need three elements

First Element

- The biophysical model gives us a basic understanding of the biophysical processes and impacts

Second Element

- The economic model gives us optimisation under normal/average conditions
- But optimising to what?: a standard or an economically optimal level of pollution

Third Element

- The catchment walking and stakeholder engagement tell us about the actors on the ground and their understandings and likelihood of response
- We can link these in an iterative learning process
- We can refine our models and enhance our engagement processes
- But can in our modelling we handle the multiple nature of the WFD with its leanings both to regulatory logic, economic logic and stakeholder engagement?
We have made very considerable progress in building bridges between bio-geochemical and economic models on the Dee at sub-catchment scale.

Our understanding of causes of diffuse pollution (and climate change effects) and cost effective interventions is enhanced.

But we must ground interventions in an understanding of practice.

Thank you.