Modelling, GIS and remote sensing

Part 2 – Opportunities from remote sensing
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(with slides from Colin Neal, CEH Wallingford, UK)
Introduction

- Need for scenario projections
- Reminder of uncertainties in models
- SCIMAP
- New opportunities
  - Digimap
  - Digital elevation data (LIDAR)
  - Land cover
  - Soil moisture
  - High frequency water quality data
- New approaches based on new data
  - New process understanding
  - New calibration methods
- Summary
Kennet and Lambourn

Upper Kennet Catchment

Sewage Treatment Works

Input from livestock
Equifinality in model structure and parameters

Temperature changes 1960-2100 for A2 and B2 scenarios for 3 GCMs Hadley, CSIRO and CGCM2

Percentage Change in Flows for 20s, 50s and 80s for A2 and B2 Scenarios for 3 GCMs: Hadley, CSIRO and CGCM2
Climate scenario A2; CGCM2

Flow in-river

Nitrate concentrations in-river

Red = observation
Blue = calibration to observation
Green = P removal to 1 mg P/L in final effluent
Uncertainty

GCMs
- Scenarios
- Precipitation
- Temperature

Other Input Data
- Land management
- Point sources

Observations
- Grab samples
- Analytical error

Hydro-chemical models
- Structure
- Parameters

Oreskes et al. 1994.
Uncertainty

GCMs
Scenarios
Precipitation
Temperature

Hydro-chemical models
Structure
Parameters

Other Input Data
Land management
Point sources

Observations
Grab samples
Analytical error

Monte Carlo + Sensitivity/Uncertainty Analysis

?
Dealing with uncertainty

- GIS-based risk approach
  - The Sensitive Catchment Integrated Modelling Analysis Platform (SCIMAP)
- Remotely-sensed data
  - Land cover
  - Digital Elevation Model
  - Soil moisture
  - Water chemistry
Phosphorus

Upper Kennet Catchment

Input from livestock

Sewage Treatment Works
SCIMAP

• The Sensitive Catchment Integrated Modelling Analysis Platform (SCIMAP)
• Risk-based assessment technique
• Sediment and nutrient loss
• Uses GIS data
  – DTM
  – Land cover
• Lane, S. 2006. Journal of Agricultural Economics, 57(2): 239-257
• www.scimap.org.uk
• Universities of Durham and Lancaster
Figure 1. Ure location and land cover map.
SCIMAP – data requirement

Digital elevation data

Legend
- Intensive pasture
- Extensive pasture
- Montane
- Blanket peat
- Urban
- Lakes
- Agriculture
- Woodland

0 2.5 5 10 15 20 Kilometres

Land cover
SCIMAP – data requirement

Risk of sediment or nutrient loss

Saturation Index
Surface ponding in the Kennet catchment

Maize grown in the River Kennet catchment
SCIMAP – limitations

- Uncertainty in identification of Critical Source Areas
  - Land cover changes
  - Local barriers to flow movement
  - Groundwater-dominated catchments
  - Large river-catchments
    - Instream processes
    - Multiple source areas
    - History of P in sediment
  - Farming techniques
GIS and remotely sensed data: state of the art

- Easy to access information in GIS - Digimap
- Centre for Ecology and Hydrology
  Land Cover Survey 2007
- LIDAR
- SMOS
- Water chemistry
Digimap

- Ordnance Survey digital map collection
- Web-based, GIS based, data resource
- EDINA (National Academic Data Centre at U. Edinburgh)
- 10 m Digital Elevation Model
- 1:10 000 field boundaries
- Long-term changes in land cover – 1931
- Agcensus
- OS Mastermap
River Lambourn at Lambourn
Image of 1:50 000 mapping

Not to scale: both images have been resized

River Lambourn at Lambourn
Image of 1:10 000 mapping
CEH Land Cover Survey 2000

- LANDSAT data
- 1km cell, 25 m available gridded from land parcels
- New release 2007
  - Linked to OS MasterMap
  - Better structural quality
LIDAR

- Light Detection and Ranging
- Airbourne mapping technique
- LASER based, measures distance to ground from aircraft
- Very high resolution mapping
- 2m DTM
- Height differences in centimetres
- Used for flood inundation estimation by UK Environment Agency
SMOS

- ESA Soil Moisture and Ocean Salinity
- 2-D interferometric radiometer
- Measure microwave radiation emitted from the Earth’s surface at L-band (1.4 GHz)
- Moisture effects emissivity
- 50 km cell
High frequency water quality data

- Total phosphorus, Northern Ireland
- New data from Plynlimon, Wales
Fig. 1. (a) Ireland and the location of the three study catchments; the Dripsey (Co. Cork) and Clarianna (Co. Tipperary), Republic of Ireland and the Oona Water (Co. Tyrone), Northern Ireland. (b) The Dripsey, Oona Water and Clarianna study catchments showing hydrometeorological and water quality monitoring stations.

Monitoring Total Phosphorus

- Oona Water (96 km²)
- Northern Ireland

Acoustic Doppler Channel Profiler
Phil Jordan, University of Ulster

Continuous TP analyser
Phil Jordan, University of Ulster
Model comparison

- Nasr et al., 2007. Water Research 41: 1065-1073
- Oona Water (96 km²)
- Clarianna (23 km²)
- Dripsey (15 km²)
- SWAT
- HSPF
- SHETRAN/Grid Orientated Phosphorus Component
Fig. 3 – Oona water catchment: results of the three models: (a) flow and (b) total phosphorus load.
Plynlimon, Wales

Prof. Colin Neal
Centre for Ecology and Hydrology
Chloride

Rainfall  Upper Hafren  Lower Hafren

Cl (mg/l) vs Day number (day 1 = 01/03/2007)
Sulphate

SO₄ (mg/l)

Rainfall  Upper Hafren  Lower Hafren

Day number (day 1 = 01/03/2007)
Cl concentration spectra

Rain

Hafren stream

Spectral power

Wavelength (years)

3 years of daily data

14 years of weekly data

1/f^0.97

Kirchner, Feng and Neal, 2000. Nature 403:524-526
Simulated and observed DOC concentration power spectra - Dickie Stream, Canada

Courtesy of Martyn Futter, Macaulay Institute
High frequency data
Where will it lead us?

• Better load estimates
• Better understanding of diurnal cycles
  – Biology
  – Evaporation
  – Catchment functioning; timing of inputs
• Better model calibration or model rejection
• New models
Summary

• Integrated catchment nutrient models
  – Needed for future projections
  – Data intensive

• Uncertainty

• Opportunities from remotely sensed data in a GIS framework
  – Land cover
  – Digital elevation data
  – Soil moisture
  – High frequency chemistry
SCIMAP – link with Mastermap

Ordnance Survey data from EDINA Digimap
SCIMAP – data requirements

Model structure

www.scimap.org.uk
Management

• Model output
  – Learn about possible catchment response
  – Models with estimates of uncertainty

• Other environmental factors
  – Water quality
  – Residence time
  – Solar radiation

• Socio-Economics and Politics

*Catchment management decisions made by politicians not scientists*