Making a connection - modelling hydrological connectivity across landscapes

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What is Landscape Connectivity?

“The probability that a certain point in the landscape is capable of transmitting material to another point”
Why is it Important?

- Catchment storm response
- Diffuse pollution
- The ‘missing link’ in hydrology?
The Network Index Approach to Hydrological Connectivity
Real World Example of Connected and Disconnected Areas
Testing the Connectivity Index
Testing the Network Index against Modelled Data: Research Approach

1. Define conditions for connectivity
2. Predict patterns of soil moisture
3. Calculate landscape connectivity
4. Derive statistics
5. Compare to Network Index
Approach to Determining Surface Flow Connectivity

• For a point to be considered connected, it must be
  • Generating runoff
  • Every downslope cell must be capable of transmitting the flow

• Therefore, points may be generating flow but disconnected from the river channel
Generation of soil moisture patterns - CAS-HYDRO

- A tightly integrated hydrological and water quality model

- Physically based process representation

- Based on a grid structure with multiple flow path routing

- Simulation of
  - Catchment hydrology
  - Water quality
  - River flows
  - Anthropogenic features
Upper River Rye, North Yorkshire, England
CAS-HYDRO Model Performance Assessment
Processing of Model Output

- Soil moisture maps at each model iteration
- Processed to a map of connected areas
- Statistics are derived from the stack of maps
Description of Connectivity Statistics

- Percentage of time a point is connected to the river channel
- Number of Connection - Disconnection Cycles per Year
Testing the Network Index for Hydrological Connectivity Summary

- Rapid to calculate
- Network Index performs well against the physically based hydrological model
- Good insight into the catchment connectivity
Climate Change Impacts

- Predicted climate change could alter the surface flow connectivity
- Changes in storm structure
- Changes in land management
Research Approach

- Define conditions for surface flow connectivity
- Generate predicted patterns of soil moisture
  - Baseline
  - 2080’s
- Calculate landscape connectivity
- Derive statistics
Distribution functions of changing connectivity

- Current Climate
- 2080’s Medium High Climate
Percentage of Time a Point is Connected to the River Channels
Number of Connection - Disconnection Cycles per Year
Implications of Results

- New source locations for diffuse pollution
- Changing in the timing of delivery
- Different processes will be effected in different ways
However, not all doom and gloom...

- The new areas may be of low risk
- The pollutant may be source limited
Climate Change and Connectivity
Conclusions

- Large increase in the area exporting risk to receiving waters
- Large increase in the number of connection - disconnection cycles
Application of Connectivity to Diffuse Pollution: The SCIMAP Framework
What to do where?
Diffuse pollution has some special characteristics.
Risk * Connection = Problem
Application of SCIMAP - Fine Sediment
The River Eden Catchment
Calculation of a Fine Sediment Risk Map

- DEM
- Rainfall Pattern
- Land Cover
- Slope
- Upslope Area
- Stream Power
- Channels
- Classical Wetness Index
- Erodability
- Surface Flow Index (Connection Risk)
- Point Scale Risk
- Route risk through catchment (connect and dilute)
- Risk Map

Legend
Landcover based erosion risk
0.0 0.9 1.0
0 2 4 6 8 10 12 16 Kilometres
Field scale problem identification
Testing of the SCIMAP approach

- Electrofishing
- Spatial water quality sampling
Electro Fishing Results

Salmonid fry Density Classification 2003

ERT
- A (excellent) 86
- B (good) 74
- C (fair) 42
- D (poor) 49
- E (absent) 25

EA
- A (excellent) 15
- B (good) 12
- C (fair) 21
- D (poor) 12
- E (absent) 5

Acknowledgement: Eden Rivers Trust
Fry and Risk

[Graph showing salmonid fry counts across different connectivity bands with error bars, comparing connectivity plus fine sediment risk and connectivity only.]
Salmon fry abundance
Letting the Fish tell us what makes them (hydrologically) happy

- Inverse modelling of land cover risk weightings
- Assessed for fish and NO$_3$
Uncertainty results presentation

- Determine an objective function
- Find the best values
- Add in next best OF
- Shows evolution of goodness of fit
Land use weightings for salmonid fry
Land use weightings for water quality (nitrate)
Expression of uncertainty in the risk maps

- The fittest 0.1% parameter sets used for the uncertainty analysis
- Uncertainty expressed on maps
- Colour determined by the mean risk
- Size related to the variation in the sample results
Thin green lines = low risk but low certainty

Wide red lines = high risk and high certainty

Legend

Fine sediment risk
- > 2.83 Std. Dev.
- 2.50 - 2.83 Std. Dev.
- 2.17 - 2.50 Std. Dev.
- 1.50 - 1.83 Std. Dev.
- 1.17 - 1.50 Std. Dev.
- 0.83 - 1.17 Std. Dev.
- 0.50 - 0.83 Std. Dev.
- 0.17 - 0.50 Std. Dev.
- -0.17 - 0.17 Std. Dev.
- -0.50 - 0.17 Std. Dev.
- -0.03 - 0.50 Std. Dev.
- -1.17 - 0.83 Std. Dev.
- <= -1.17 Std. Dev.
SCIMAP Summary

- SCIMAP offers a risk mapping framework
- Field scale targeting of diffuse pollution measures
- Currently being tested
- Being expanded to consider N and P
Presentation Summary

- Connectivity provides the links both within a landscape and between the landscape and rivers
- Landscape hydrological connectivity can be described using the Network Index
- Connectivity plays a key role in the transmission of diffuse pollution
- SCIMAP Risk Mapping Framework couples connectivity and inverse modelling to make spatial predictions of risk source zones
This work is part of the SCIMAP project

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SCIMAP Risk Mapping Framework

Welcome

Polluted water is a problem if we have to drink it. However, it can also be a problem for the plants, insects and fish that require clean water to survive. Traditionally, we accepted that water can become polluted because we discharge waste into it. Now, we also know that water can be polluted because of waste produced from across whole landscapes (excess fertilizers, animal manure or set). This type of waste comes from a large number of places (e.g. fields) but in small amounts. It becomes a problem because it gets funnelled into our rivers where the concentrations can be very high. This is called diffuse pollution. Across the world we are trying to improve our rivers and streams for the living creatures that are being impacted upon by diffuse pollution. How can we make our rivers and streams clean again?

To make our rivers and streams clean again, we need to be able to work out where the pollution is coming from. Not all fields will be polluting. Two things make a field a problem:

1. A field that produces lots of pollutants
2. A field that is easily connected to rivers, lakes, or groundwater.

To identify the locations that are a problem, we have developed SCIMAP, a joint project between Durham and Lancaster Universities. SCIMAP is supported by the UK’s Natural Environment Research Council.