LM0308: Catchment Management for Water Quality

Case Study 4: Effectiveness of pollution control measures under scenarios of future climate and land cover change at the catchment scale.

Lead: Andrew Wade (University of Reading); Leah Jackson-Blake (James Hutton Institute)

Purpose: To demonstrate the effectiveness of measures given future projections of climate and land cover change at the catchment scale.

Policy driver(s)	Water Framework Directive, New Environmental Land Measures Scheme, Scotland Rural Development Plan, Land Use Strategy for Scotland, Water Environment Fund
Enduser(s)	River Basin Management Planners, Catchment Based Hosts (CaBa)
Pollutant(s)	Suspended sediment, Total Phosphorus, Total Dissolved Phosphorus, Nitrate
Measures	Large scale catchment measures: targeted interventions including reduction in fertiliser and manure application to arable and improved pasture, reduction in Sewage Treatment Works final effluent concentration, and re-afforestation.
Scenario if appropriate	Climate: 3 GCM/RCM combinations from EU FP6 Ensembles (baseline: 1981-2010; future: 2031-2060). The Ensembles data is available free of charge for research, education and commercial work. The data policy is available at http://www.ensembles-eu.org/ and notes that appropriate acknowledgement must be given to the data source. The climate model runs have been biased corrected by the James Hutton Institute. Existing land use scenarios for the 2050s: these are consistent with the Land Use Strategy for Scotland (2011) targets, all scenarios incorporated an increase in woodland cover and two included an increase in arable land area. Four scenarios have been developed, broadly corresponding to the quadrants of the IPCC SRES scenarios representing “World Market” (A1), “National Enterprise” (A2), “Global Sustainability” (B1) and “Local Stewardship” (B2).

Outcome / output	Projections of streamwater suspended sediment, total phosphorus, total dissolved phosphorus and nitrate concentrations for: baseline, baseline + measures, future climate and land cover, future climate and land cover + effective measures.
Scale / Location	The Tarland tributary (74 km^2) drains the most westerly area of intensive agriculture in the River Dee catchment. In 2008, the Tarland Burn was classified as being at 'Moderate' ecological status, primarily due to morphological alterations, namely channel straightening and resultant loss or degradation of habitat. Water quality is also of concern, primarily due to diffuse inputs of nutrients and sediments from agriculture which comprises a mosaic of grassland and arable including beef cattle, sheep, barley and small areas of other crops.
Scale / Location	The village of Tarland has a wastewater treatment works (600 person input). The Tarland sub-catchment has been the focus of the Tarland Catchment Initiative since 2000, which aims to provide a scientific assessment of the efficacy of measures used to improve the aquatic and riparian habitats, in addition to building relationships with land owners and the local community.
Risks	For future applications to all UK catchments, the following datasets must be available as a minimum: mean daily flows, EA, SEPA, NEIA water chemistry data, land cover map, final effluent concentration data, daily precipitation and air temperature. For this specific case study then, for repeatability, the ENSEMBLES data and the JHI mapped projections of 2031-2060 need to be made available or accessible. The model used to generate the estimate of the hydrologically available rainfall and soil moisture deficit needs to be available.

Background / Narrative:

Compliance with the Water Framework Directive is required by 2015 and during the second (2021) and third management cycles (2027) and beyond (Directive 2000/60/EC, Articles 4 and 13). Future population growth, climate change, changes in nutrient supply, agricultural intensification and other land use changes may cause deterioration of water quality in some areas; other areas may see an improvement. Models can be used to quantify how future trends may affect water quality, taking into account uncertainty in future conditions. Models may also be used to assess whether measures put in place to achieve compliance with environmental objectives today are likely to remain effective in the future, thereby helping River Basin Management Planners 'future proof' measures.

Basic approach:

The novelty in this case study is to demonstrate if measures selected to improve the chemical status under the Water Framework Directive are 'future proof', namely if measures implemented to lower streamwater suspended sediment, total phosphorus, total dissolved phosphorus and nitrate concentrations today will still improve the water quality in the 2050s, based on integrated climate projections and land use change scenarios.

The dynamic (daily) response of three pollutants (suspended sediment, phosphorus as total phosphorus and total dissolved phosphorus, and nitrate) will be assessed for a baseline (1981-2010) period and compared to model-based projections for: the effects of measures (fertiliser application reduction, reduced final effluent concentrations); climate and land cover change; climate and land cover change plus those measures identified as effective for the baseline period runs. The assessment of multiple pollutants will be done by using INCA-P and INCA-N.

The baseline + measures case, when run with a phased in measure, can be used to look at the time lag between the introduction of a measure and catchment response, and whether compliance is achieved within a certain (e.g. 20 year) period.

Models to be used:

- Hydrological model to generate soil moisture deficit and hydrologically effective rainfall for input to INCA models
- INCA-P
- INCA-N

Data to be used:

Model	Input	Output and model testing
SMD and HER generator	Daily temperature and precipitation timeseries (source: Met Office for baseline, three RCM/GCM model combinations from the EU FP6 ENSEMBLES project for future scenarios; format: csv)	Timeseries of soil moisture deficit and hydrologically effective rainfall (format: csvs)
INCA-P and INCA-N	Timeseries of soil moisture deficit and hydrologically effective rainfall (source: SMD and HER generator; format: text file) Parameter values (source: various; format: text file) Nutrient budget: annual fertiliser and manure nutrient loads for different crops, timing of application (British Survey of Fertiliser Practice; Agricultural Census data); annual plant uptake rates and growing season dates	As below
INCA-P and INCA-N	Annual N and P atmospheric deposition fluxes DEM-derived data (50m): sub-catchment area, sub-catchment and reach slope, reach length. Also for defining sub-catchments (in combination with stream network data) Land use: Derived from the Land Cover Map of Scotland (2008) for the baseline; future scenarios: (2007)four storylines, linked to the four quadrats of the IPCC SRES scenarios, all consistent with the Land Use Strategy for Scotland (2011) targets (source: James Hutton Institute; format: part of parameter text file).	As below
INCA-N	Sewage effluent inputs (mean annual flow, nitrate, ammonium concentration), abstraction data Data to constrain model parameters (ideal but not essential): groundwater nitrate and ammoninum concentrations, baseflow index, soil nitrogen process fluxes. Data for model calibration and evaluation: mean gauged daily flow, in-stream NO_3^- concentration and fluxes (text file)	Daily timeseries of discharge and in-stream nitrate concentration and fluxes (text file)

Model	Input	Output and model testing
INCA-P	Sewage effluent inputs (mean annual flow, TDP, PP and SS concentration), abstraction data Data to constrain model parameters (ideal but not essential): groundwater phosphorus concentrations, soil properties (texture, nutrient content), phosphorus sorption characteristics (terrestrial and in-stream), average reach width, relationship between stream discharge and velocity, parameterisation of Freundlich P sorption isotherm (terrestrial and in-stream), in-stream sediment texture, baseflow index. Data for model calibration and evaluation: Mean gauged daily flow, observed in-stream concentrations (e.g. TP, TDP, PP, SRP, SS) (text file)	Daily timeseries of discharge and in-stream concentrations and fluxes of TDP, SRP, SS, PP and TP at the outflow from each sub-catchment (text file)

Abbreviations: P (phosphorus), TDP (total dissolved phosphorus), PP (particulate phosphorus), TP (total phosphorus), SS (suspended sediment), RCM/GCM (Regional Climate Model/Global Climate Model)

Other requirements:

None

Workplan:

Description of Model Run	Run Exists?
INCA-P calibration and testing	Y
INCA-P baseline run for 1981-2010	Y
INCA-P run to assess effectiveness of measures on stream water phosphorus concentrations.	N
INCA-P run to assess effects of climate and land cover change on stream water phosphorus concentrations.	Y
INCA-P run to assess effectiveness of measures on stream water phosphorus concentrations under scenarios of climate and land cover change.	N
INCA-N calibration and testing	N
INCA-N baseline run for 1981-2010	N
INCA-N run to assess effectiveness of measures on stream water nitrate concentrations.	N
INCA-N run to assess effects of climate and land cover change on stream water nitrate concentrations.	N
INCA-N run to assess effectiveness of measures on stream water nitrate concentrations under scenarios of climate and land cover change.	N

Milestones:

- Scope out Case Study (Feb 2015)
- Develop model documentation for the Platform (March 2015)
- Start conditioning and ingestion of data and models with documentation into Platform including model input and outputs (June 2015)
- Completion of first model application outputs and testing with Community Forum (Nov 2015)
- Start conditioning and ingestion of external data and models into Platform (June 2016)
- Iteration to identify benefits of model coupling (Nov 2016)
- Final report (Mar 2017)

Link to Enduser Questions:

Future pressures and extrapolation of impacts

- Potential effects of future trends such as population growth, climate change; land-use change, food security and nutrient supply need to be better quantified.
- What are the implications of climate change and agricultural intensification for water quality?
- Future proofing – climate change and other impacts
- How will future land use and climate change affect pressures e.g. N, P, Sediment in water

Evidence of outcome

- Can models help to target measures and provide an estimate of the level of confidence that they will work? No point in investing customers money if uncertainty high

Uncertainty, confidence and communication

- What is the uncertainty associated with modelling the different effectiveness of measures?