A pragmatic methodology for horizon scanning of water quality linked to future climate and land use scenarios

Willie Towers, Sarah Dunn, James Sample and Jannette McDonald

James Hutton Institute

The James Hutton Institute

CREW centre of expertise for waters

The Scottish Government Riaghaltas na h-Alba

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Outline of talk

- Introduction and Objectives
- Key drivers of changes to water quality
- Methodology
- Scenarios of change
- Results
- Concluding remarks.

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Introduction

- Under the WFD, the Scottish Environment Protection Agency (SEPA) is required to undertake River Basin Management Planning
  - Includes identifying 'Significant Water Management Issues (SWMI)'
  - Including forward look into the middle of the 21st century
- Pollutant modelling:
  - involves many pollutants with different behaviours, different effects and different policy goals
  - is therefore very complex
  - and 'data hungry'
- A more pragmatic qualitative approach is required

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Objectives

(i) To identify key drivers of water quality in terms of:

(a) broad characteristics of the climate that dominate hydro-chemical transport and

(b) qualitative relationships between different land uses and various pollutants.

(ii) To develop a qualitative spatial methodology to integrate these drivers.

(iii) To demonstrate the method by application of a simple set of climate and land use scenarios for Scotland to evaluate qualitative impacts on a range of key pollutants.

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What might drive changes in water quality?

- Climate
  - Important in the **transport** and **bioavailability** of different pollutants
  - Water storage and run-off
  - Nitrogen mineralisation
  - Seasonal shifts in rainfall important
  - Some effects may counterbalance each other e.g. increased temperature and modified water availability

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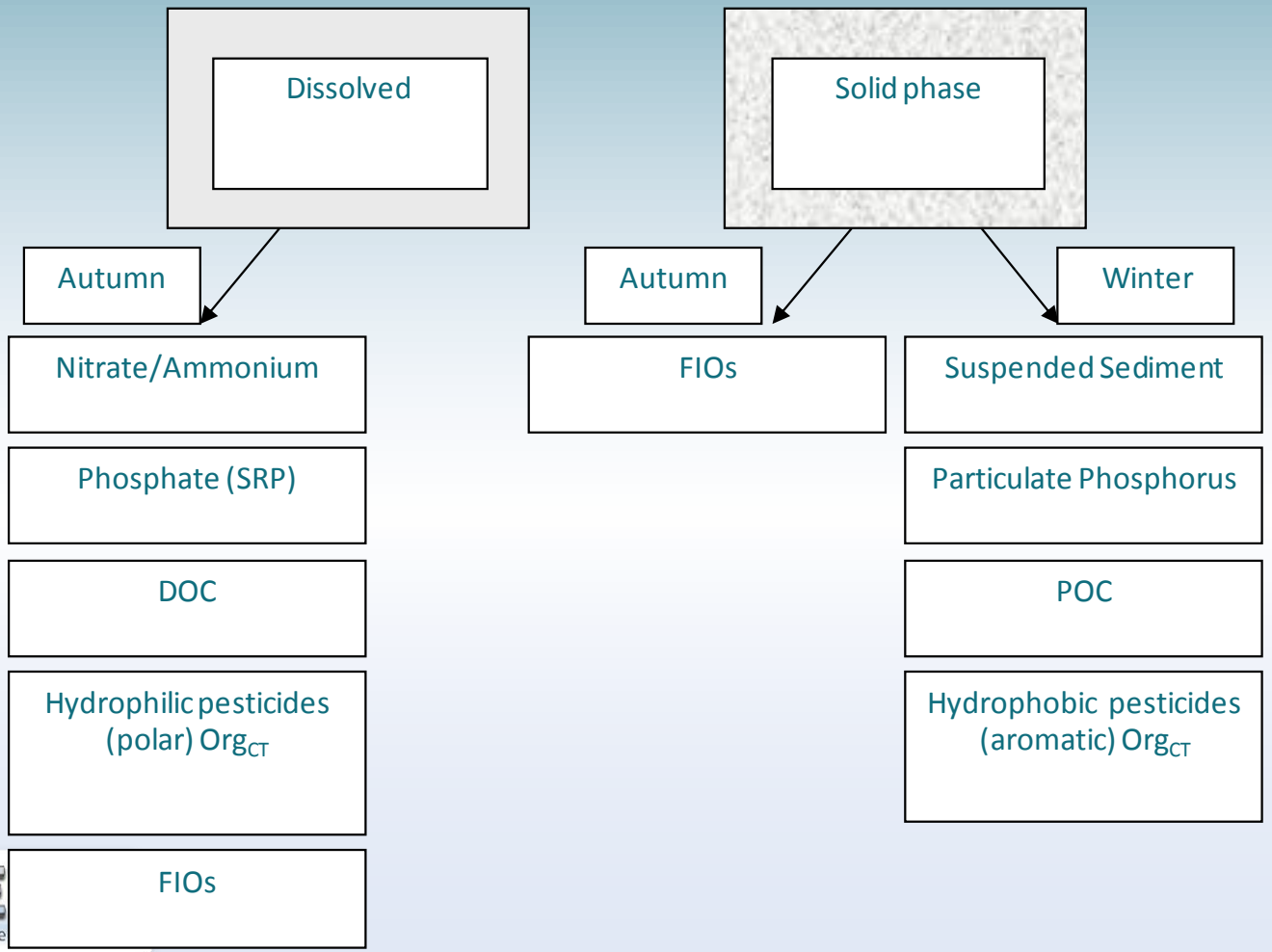
Simplified classification of climate change drivers for pollutant transport, based on phase (dissolved or solid) and time of year of dominant transport.



What might drive changes in water quality?

- Land Use Change
  - Important in the **sources** and **availability** of different pollutants
- Some changes can be positive
  - E.g. arable to woodland
- Others can be negative
  - E.g. Increase in arable cropping.
- **Not disconnected to climate change…this might be the driver for land use change**

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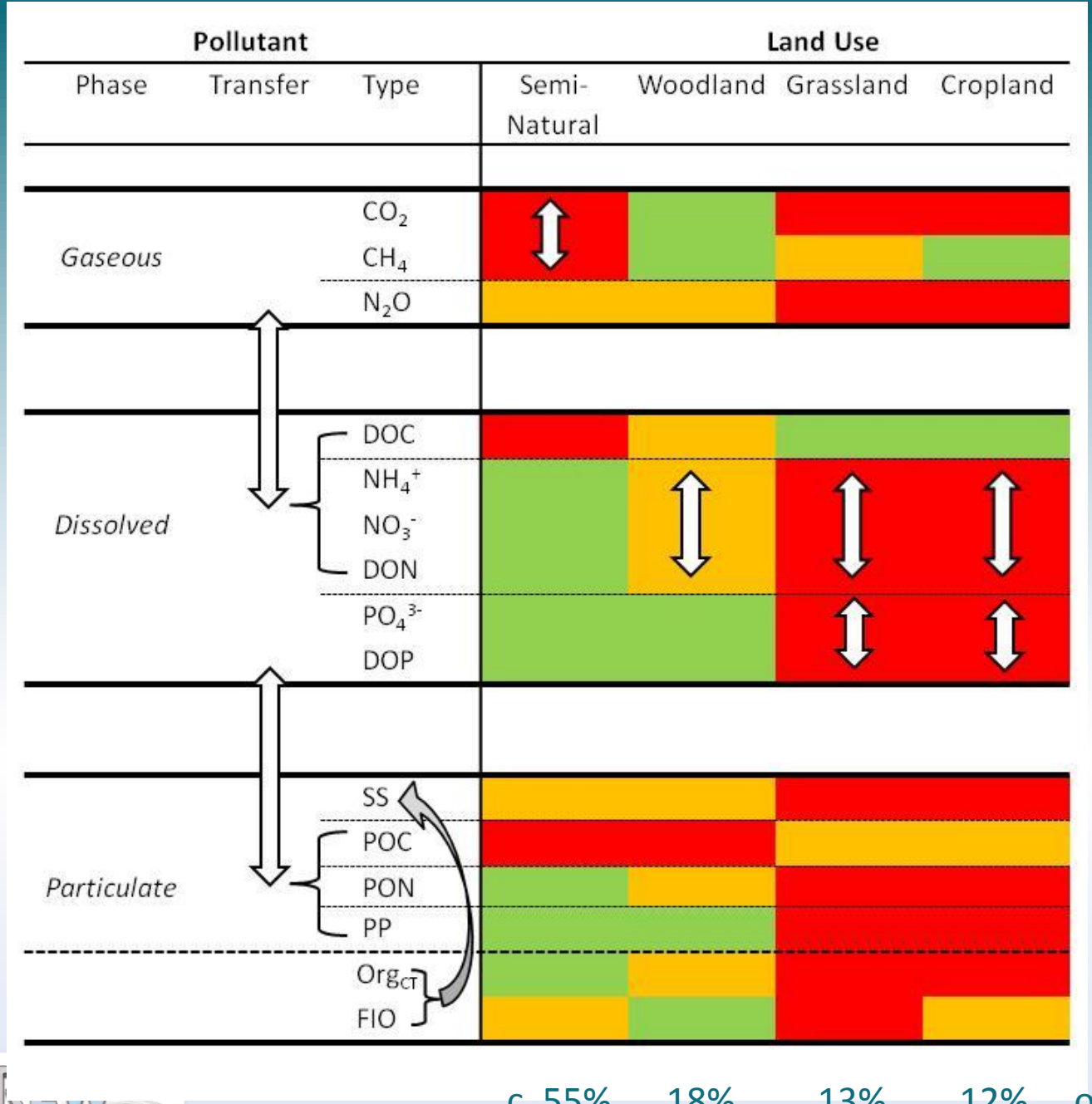
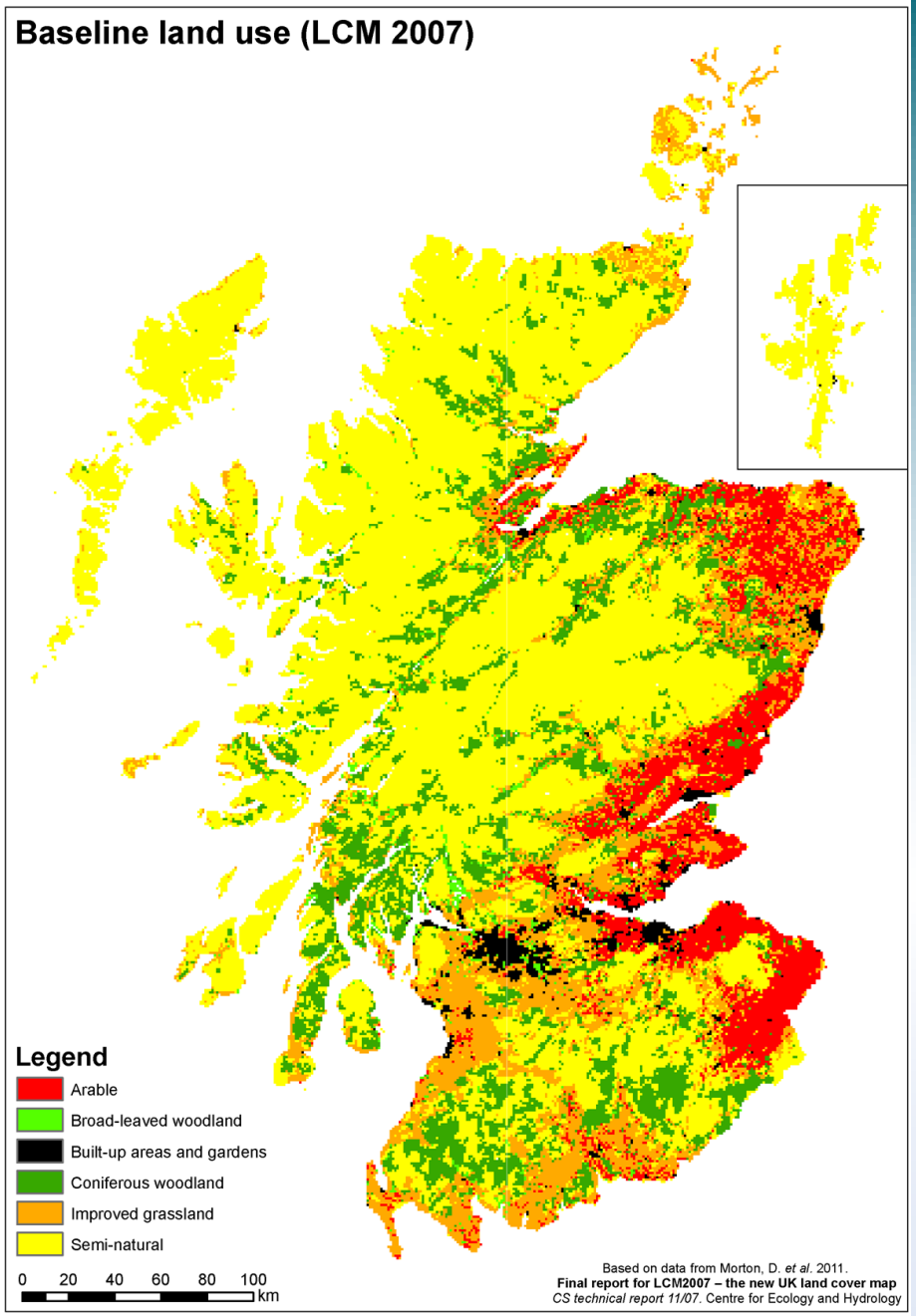


c. 55% 18% 13% 12% of Scotland

After Dawson and Smith 2010



All sectors have a very specific spatial distribution:

- Particularly arable and improved grassland
- Conditioned by climate, soil and topography
- 'Scotland has nine months of winter and three months of bad weather…..'

So how do we assess impacts of changes on water quality?

- We have developed a series of matrices to 'translate' these drivers into a set of pollutant responses
  - Key climate change drivers and expected pollutant responses
  - Impacts of changing land use on pollutant responses
  - The relative importance of climate change drivers versus land use change drivers on pollutant responses

All Matrices classified as follows:

- −2 refers to a large decrease in pollutant load

,

- −1 refers to a small decrease,
- 0 refers to neutral,
- +1 refers to a small increase,
- +2 refers to a large increase.

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Climate change driver: changes in run - off

	Precipitation Change class				
PET class	<-15 ("-2")	-15 - -5 ("-1")	-5 - 5 ("0")	5 - 15 ("1")	>15 ("2")
<-15 ("-2")	-1	0	1	2	2
-15 - -5 ("-1")	-1	-1	1	2	2
-5 - 5 ("0")	-2	-1	0	1	2
5 - 15 ("1")	-2	-2	-1	1	1
>15 ("2")	-2	-2	-1	0	1

Matrices developed for each pollutant group, e.g. particulates

Increase in rainfall and decrease in PET…leads to increase in run-off

Decrease in rainfall and increase in PET….leads to decrease in run-off

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Changes in Land Use

Baseline land use	Land use change: Arable	Imp grass	Conif forest	B-leaf forest	Semi-nat	Urban
Arable	0	0	-2	-2	-2	-1
Imp grass	0	0	-2	-2	-2	-1
Conif forest	2	2	0	0	0	1
B-leaf forest	2	2	0	0	0	1
Semi-nat	2	2	0	0	0	1
Urban	1	1	-1	-1	-1	0

For example, for dissolved pollutants:
Change from improved grassland to woodland……large decrease
Change from woodland to improved grassland…….large increase

Similar matrices developed for other pollutant groups.

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Climate change and Land Use change combined

Land use response class	Climate Response Class: -2	-1	0	1	2
-2	-2	-2	-1	-1	0
-1	-2	-1	-1	0	1
0	-1	-1	0	1	1
1	-1	0	1	1	2
2	0	1	1	2	2

For agriculturally sourced pollutants, land use is assumed to be more important

For some other pollutants, climate is given more or an equal weighting compared to land use e.g. suspended solids

All matrices were reviewed at a stakeholder workshop and where appropriate, changed. Some degree of 'peer review'

Scenario of change

- Using two contrasting Climate Change simulations
  - Based on UKCP09 projections
- Subsequently referred to as ‘Models 3 and 16’
- They can be viewed as at the extremes of the range of possibilities
    - Appropriate for a scoping study such as this.

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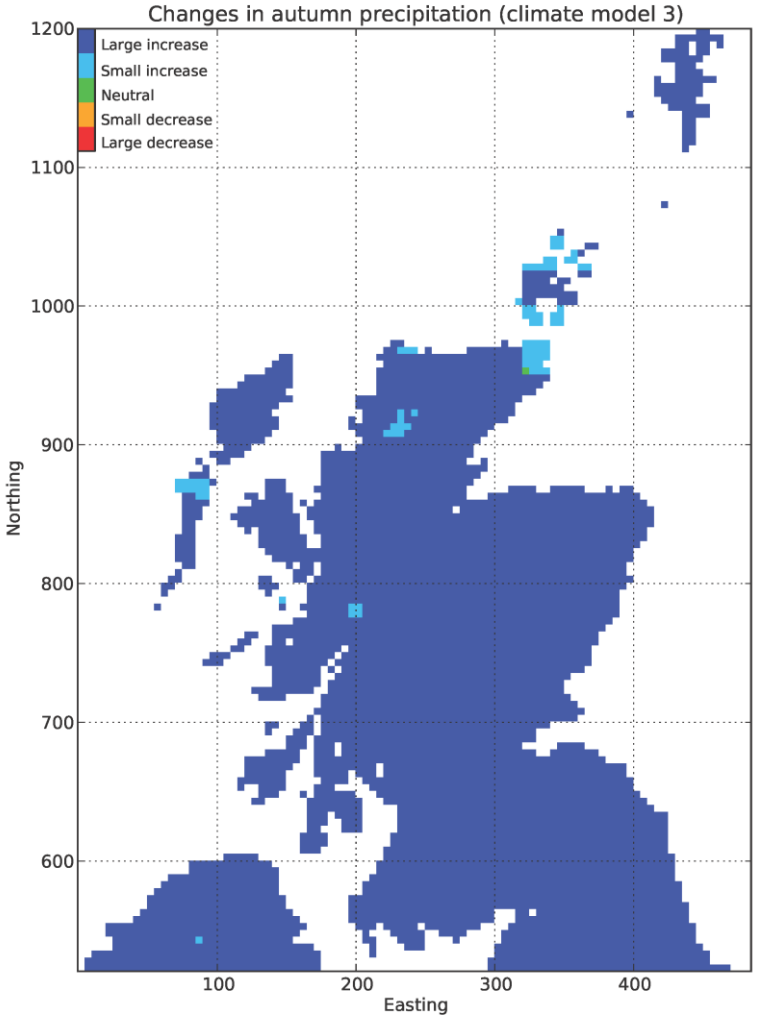
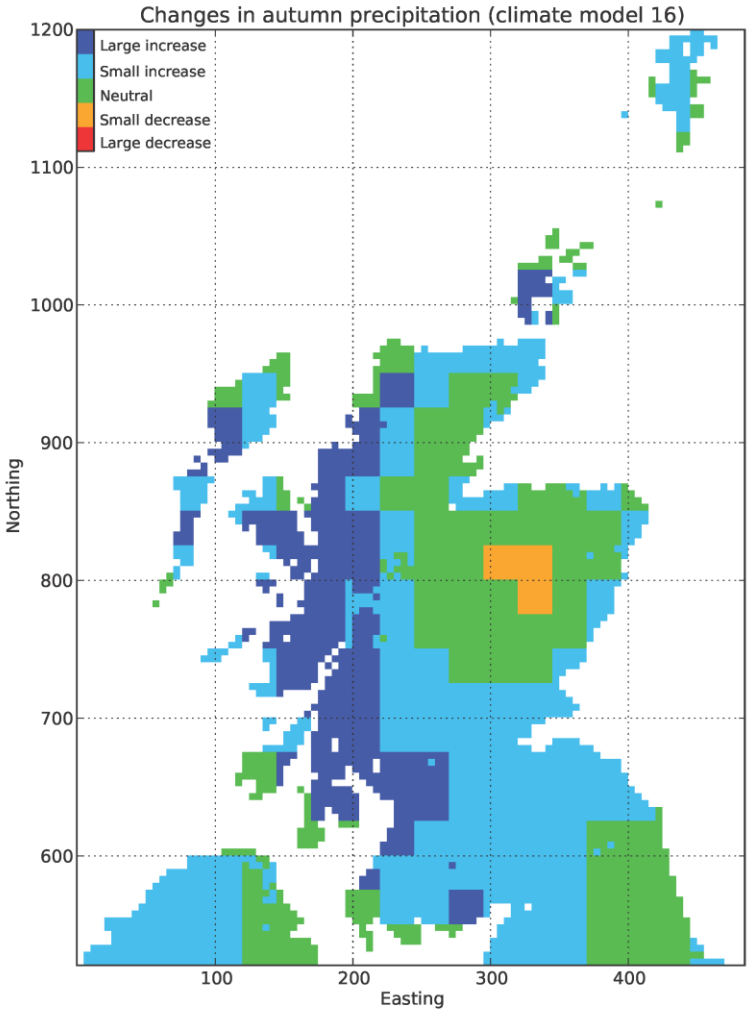
Map 2


Changes in autumn precipitation (climate model 3)
Large increase
Small increase
Neutral
Small decrease
Large decrease
1200
1100
1000
900
800
700
600
Northing
100
200
300
400
Easting

Map 6


Changes in autumn precipitation (climate model 16)
Large increase
Small increase
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1200
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Northing
100
200
300
400
Easting

Land use change – two key components

- Woodland Expansion target set by the Scottish Government's Land Use Strategy
  - Part of our CC mitigation strategy
- Potential increase in arable cropping due to temperature increase (Brown et al Climate Research, 2008)
- Scenario of change represents an extreme (and probably unrealistic) example
  - But appropriate for a scoping study such as this

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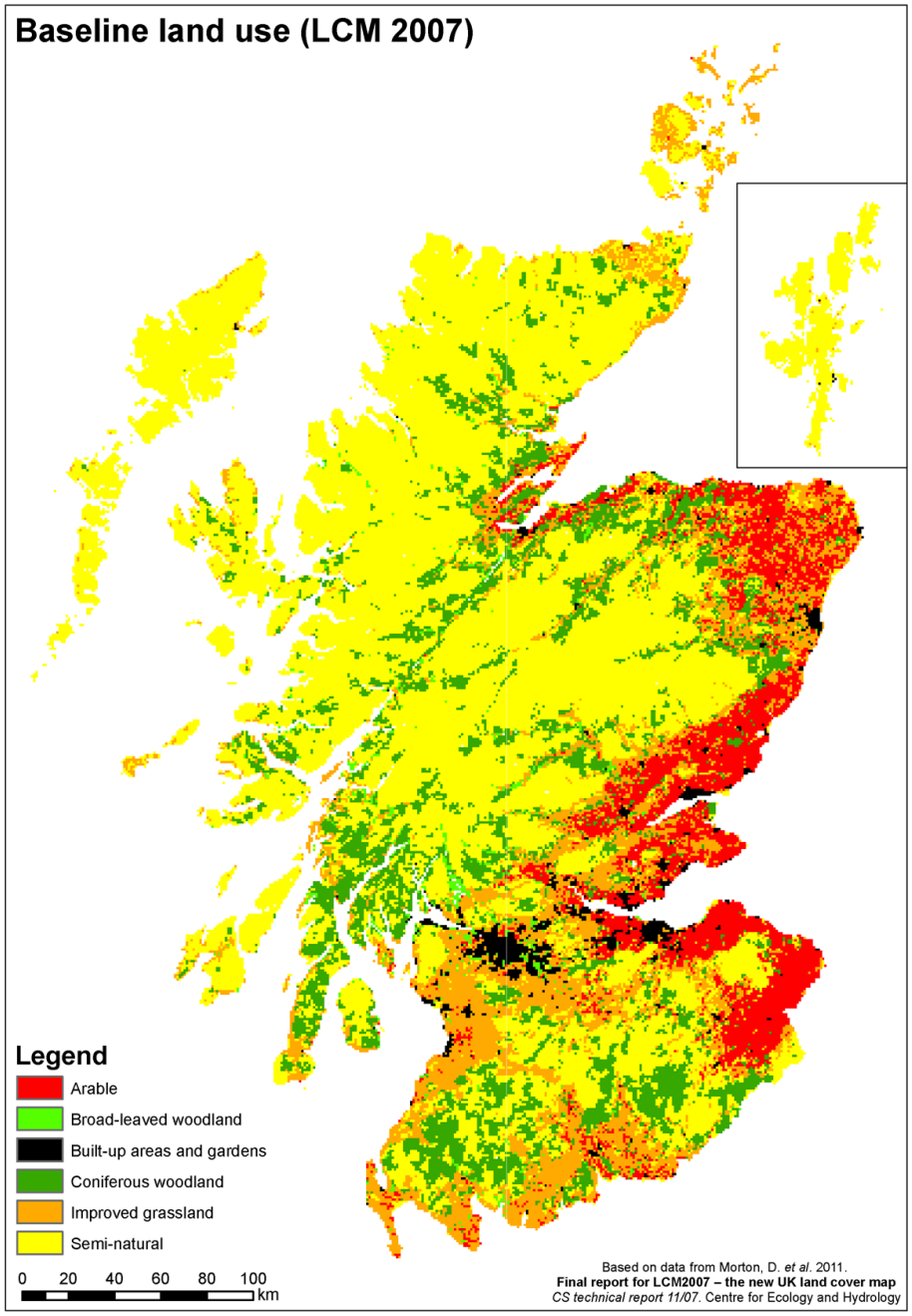
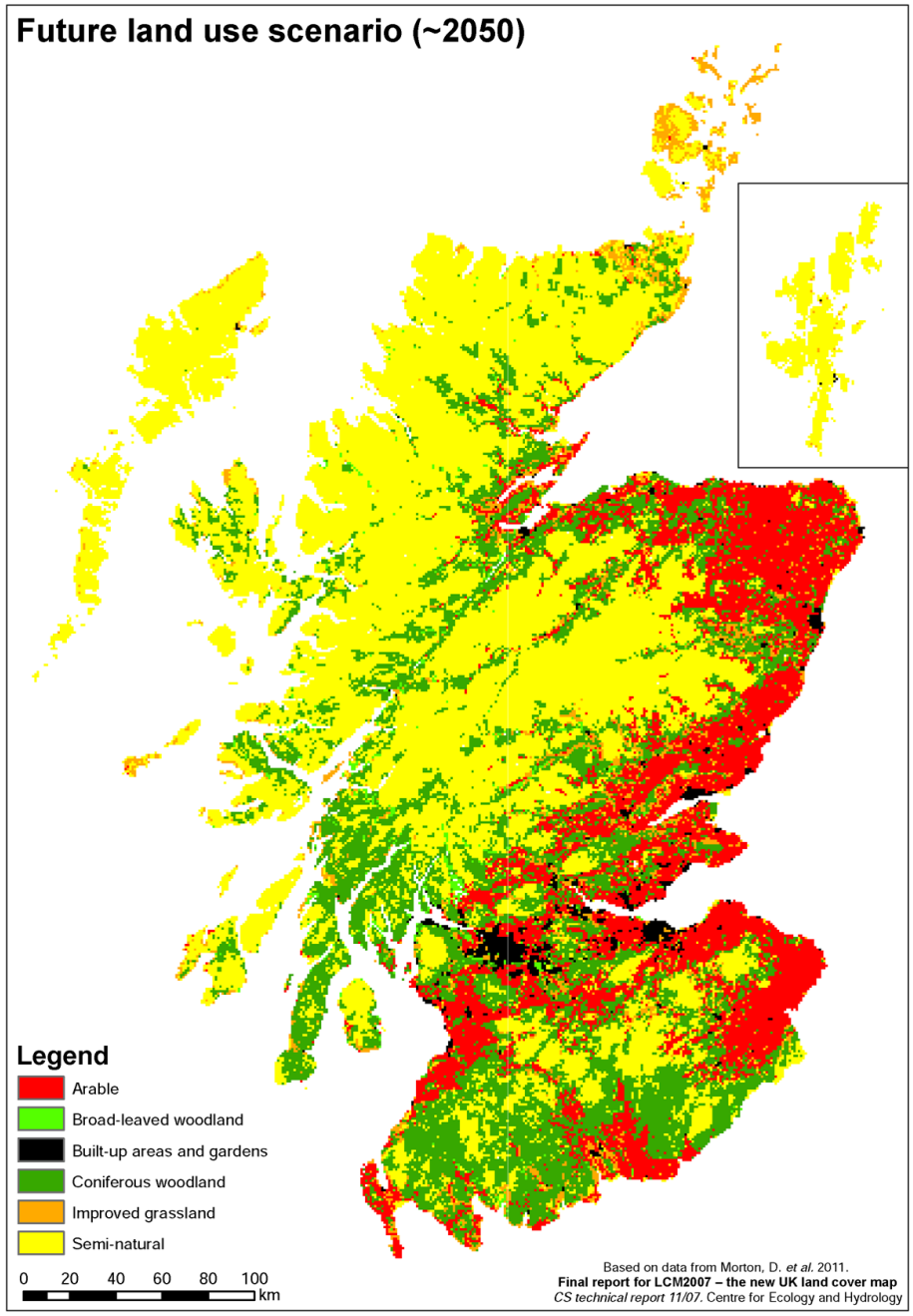
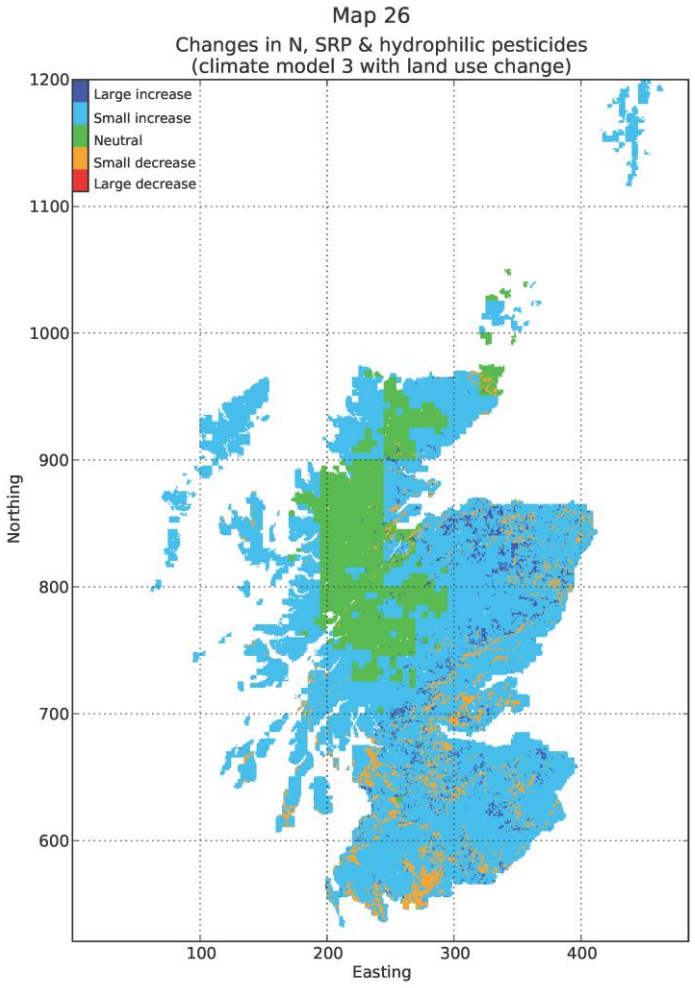
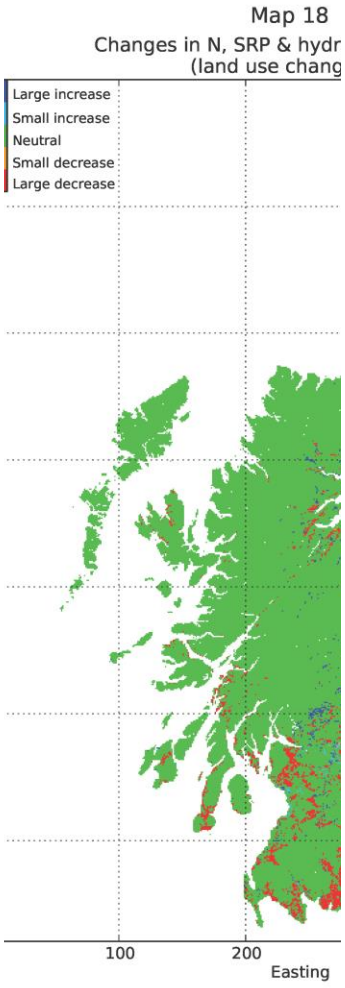
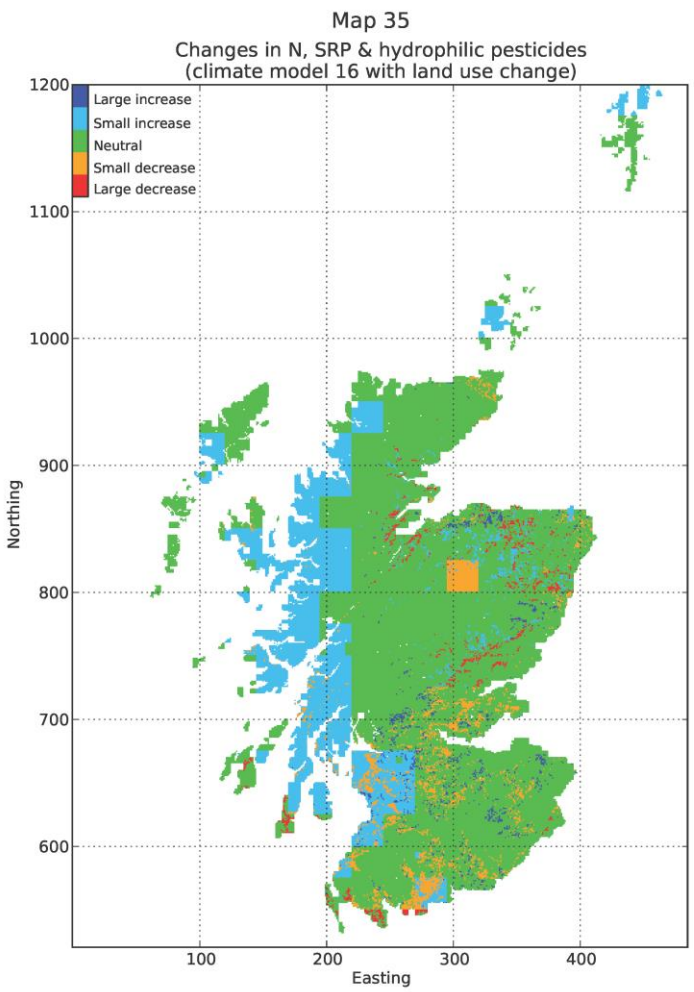

Baseline land use (LCM 2007)
Legend
Arable
Broad-leaved woodland
Built-up areas and gardens
Coniferous woodland
Improved grassland
Semi-natural
0 20 40 60 80 100
km
Based on data from Morton, D. et al. 2011.
Final report for LCM2007 – the new UK land cover map
CS technical report 11/07. Centre for Ecology and Hydrology


Future land use scenario (~2050)
Legend
Arable
Broad-leaved woodland
Built-up areas and gardens
Coniferous woodland
Improved grassland
Semi-natural
0 20 40 60 80 100
km
Based on data from Morton, D. et al. 2011.
Final report for LCM2007 – the new UK land cover map
CS technical report 11/07. Centre for Ecology and Hydrology

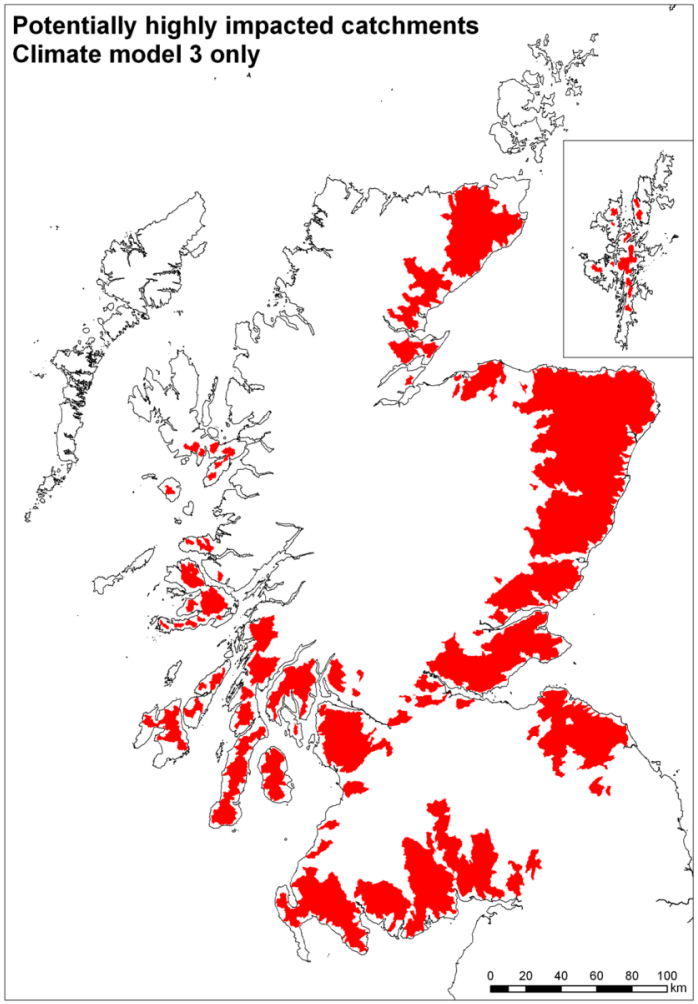
Taking dissolved pollutants as an example

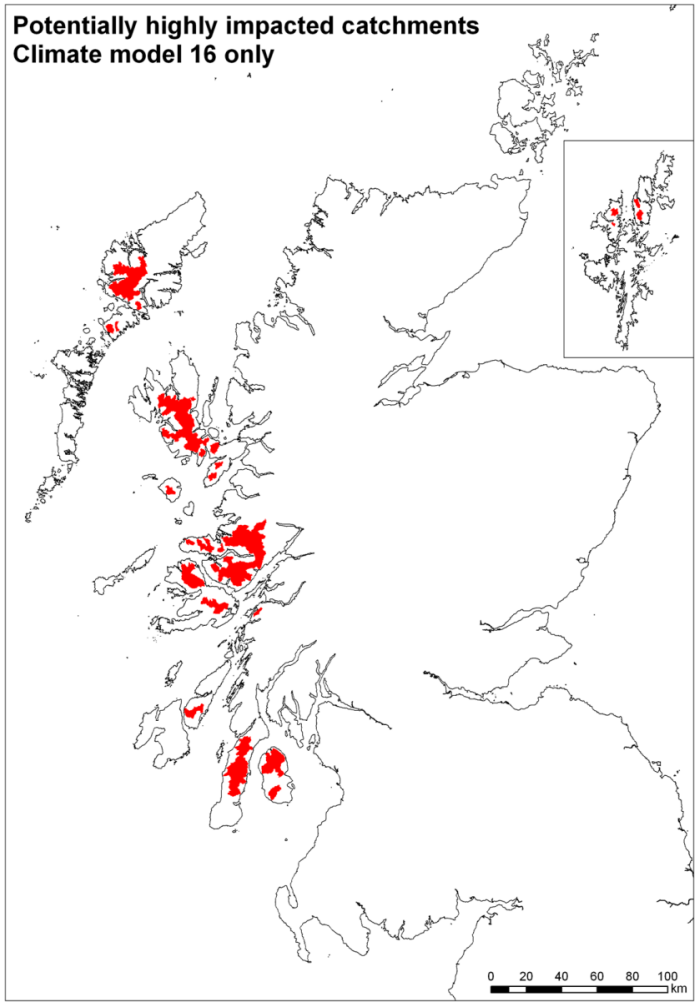






Vulnerable catchments: climate change alone





Based on cumulative matrix scores > 6

Land use change component has little effect:

- Different land uses are associated with different pollutants
- Different weightings for different quality objectives?

‘Observations’

Strengths:

- It is flexible and relatively straightforward
- The approach can explore a number of scenarios of change
- It provides a good method for stakeholder engagement
- Provides a point of entry for more detailed studies

Caution:

- The risk assessments are relative and qualitative in nature
- Maps can lead to a false sense of belief that they are correct
- All the pollutants are equally weighted; should they be?
- The approach deals with loads, not concentrations.

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Concluding remarks

- The approach provides a useful and flexible screening tool for more detailed focussed work
- Co-construction with stakeholders increased its usefulness
    - Has informed the SWMI report for which it was designed
- Further work is proposed that uses less extreme climate and land use change scenarios
- For more information please see Dunn *et al* Land Use Policy 44 (2015) 131-144 or

http://www.crew.ac.uk/publications/potential-risks-water-quality-diffuse-pollution-driven-future-land-use-and-climate-chan

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Acknowledgements

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This work, and subsequent publications and presentations, are dedicated to our colleague Dr Julian Dawson who was tragically killed in a road accident in March 2013.

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