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RESEARCH SUMMARY

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The potential risks to water quality from diffuse pollution driven by future land use and climate change

Introduction

Land use, climate and water quality are inextricably linked. Furthermore, diffuse pollution, mainly from agricultural sources, is a significant pressure on the rural water environment in Scotland. A major initiative (The Rural Diffuse Pollution Plan for Scotland) is currently being successfully implemented to address this. However, given the likely future changes in land use and climate, there is a need to assess future risks so that water quality can be protected. This project makes an initial qualitative screening assessment of risk by:

- Developing a qualitative methodology that identifies whether the impacts of these changes are negative, positive or neutral for a range of pollutant loads under potential land use and climate change scenarios

- Producing Scotland-wide maps to identify where impacts might be greatest, where more detailed quantitative modelling would be required and where resources should be prioritised.

The starting point from which the impact of change is assessed is the present day under current climatic conditions and land use patterns. This work will feed into the forthcoming 'Current Condition and Challenges for the Future' document required by the European Commission for Water Framework Directive reporting.

Key Points

Land use and management are strongly related to water quality. The lowest pollutant losses occur from semi-natural habitats, through woodland, unimproved grassland to the highest losses generally being associated with improved grassland and arable. Whether pollutants are in dissolved form (e.g. nitrate) or particulate (e.g. suspended solids) strongly affects their response to future climate and land use change. Pollutants included in this report include nutrients, pesticides, suspended solids and faecal bacteria. The risk assessments presented for dissolved pollutants such as NO3 are valid for both surface and ground water whereas the risk from sediment borne pollutants only applies to surface waters. Two climate simulations (Figures 1 and 2) based on the medium emissions scenario were used in the analysis. These illustrate the potential range of changes in annual rainfall rather than the median; this was considered appropriate for a scoping project such as this.

Climate change in Scotland carries a high uncertainty, with a projected general increase in temperature and little change in annual rainfall. However, this masks a projected increase in winter rainfall, decrease in summer rainfall and uncertainty in the direction of change in autumn rainfall; all of these are significant in terms of water quality. Rainfall, runoff from land and changes in temperature strongly influence the processes controlling both the losses of pollutants from land and their transport to water. Predictions for Scotland include a small decrease in annual average runoff, although with increases in some regions of the country. However, high uncertainty in temporal and spatial patterns of precipitation means such predictions have low confidence; the contrasts between Figures 1 and 2 exemplify this. A potentially more important direct impact of climate change is changes in the magnitude and frequency of extreme events, linked to overall increases in autumn and winter precipitation. Although increases in temperatures might be expected to increase the decomposition of soil organic matter, changes in other processes of the carbon and nitrogen cycles may counteract this effect.

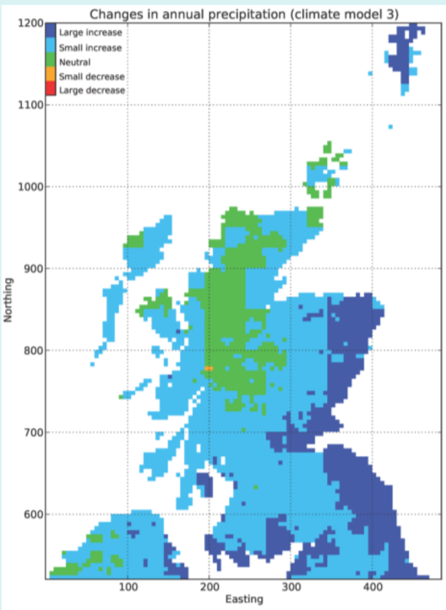

Figure 1: Changes in annual precipitation for model 3.

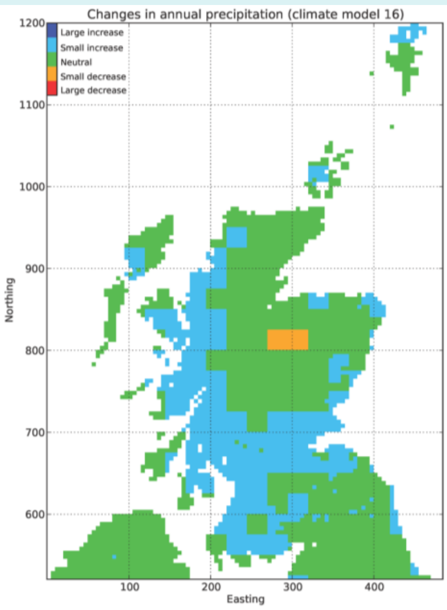

Figure 2: Changes in annual precipitation for model 16.

The impacts of the two climate simulations differ both in terms of scale, location and between **dissolved** and **particulate** phases. The 'wetter' simulation (Figure 1) consistently has greater predicted impacts for both **dissolved** (Figure 3) and **particulate** (Figure 5) phases compared to the 'drier' simulation (Figures 4 and 6, respectively). The impact of the wetter simulation is greatest in those parts of Eastern Scotland where agriculture is currently most intensive. If climate were to change in this direction then implications for water quality could potentially be serious. Areas where water quality is currently high may also be at risk from specific pollutants in specific locations, for example on the western seaboard.

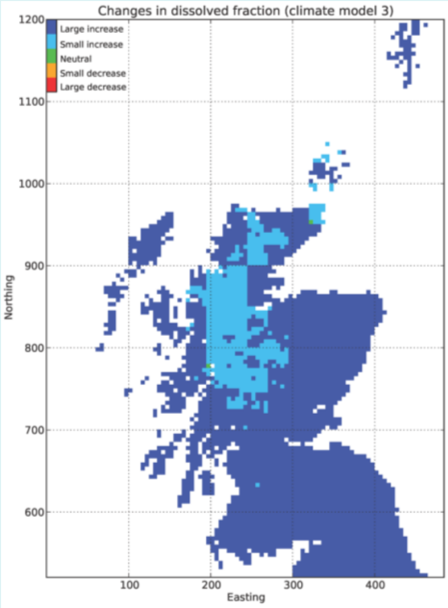

Figure 3: Changes in the dissolved fraction for model 3.

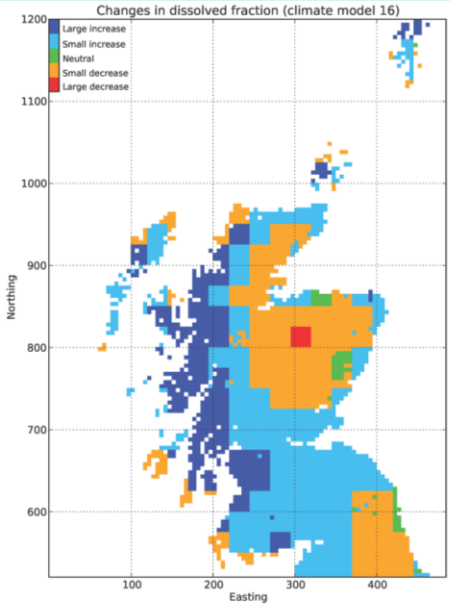

Figure 4: Changes in the dissolved fraction for model 16.

The differences in outputs between the two climate simulations are apparent across the board and highlight a difficulty in handling the uncertainty in climate change for Scotland, because predicted pollutant responses are in some cases in different directions and spatially highly variable. Although the 'drier' simulation can be viewed as a 'better case scenario', nevertheless the overall impact on water quality is deleterious, albeit in some areas, for example in the Central Highlands, there are predictions of small decreases in dissolved and particulate phases.

A summer decrease in net precipitation (precipitation minus evapotranspiration) will cause some reduction in summer river flows, but this will be less significant than the potential impact on soil moisture deficits which may lead to a delay in the autumn return to field capacity. This is a potential area of concern for agriculture with an increased propensity to drought conditions leading to an increase in irrigation demand, especially in the east of Scotland.

Land use is never constant. Over the next forty years the key projected directions of land use change are an increased area of arable land, linked to more favourable climatic conditions for agriculture, and an increased area of woodland as a planned mitigation response to climate change. Different policies, such as CAP reform, the Scotland Rural Development Programme and Planning, may also lead to land use changes. Figures 7 and 8 represent the current land use and an illustration of how it might change under these two land use changes. Although the future scenario is rather extreme with a large conversion of improved grassland to arable, it is useful in a scoping study such as this. An obvious feature is that much of the land remains the same and that both land use changes must be accommodated in a relatively constrained part of the Scottish landscape.

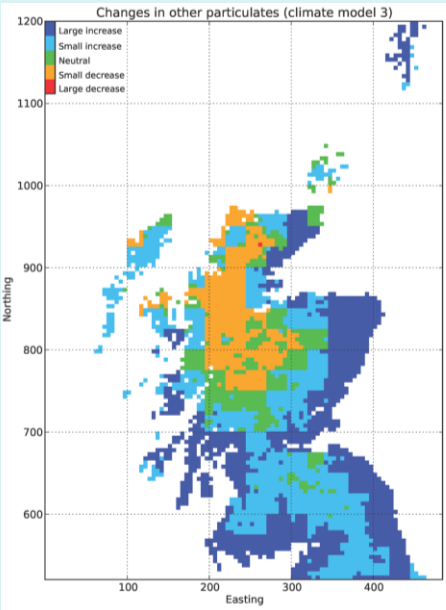

Figure 5: Changes in the particulate fraction for model 3.

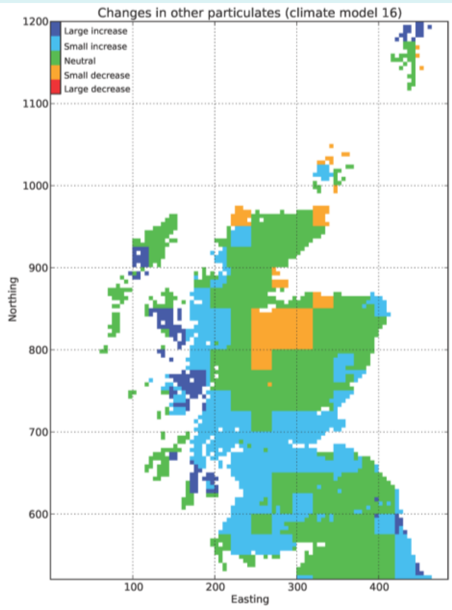

Figure 6: Changes in the particulate fraction for model 16.

The impact of these land use changes, which are reactive and planned responses to climate change, is restricted to those areas of land where a land use change has been imposed. Impacts vary depending on the pollutant of interest, for example a general increase in suspended sediments and particulate phosphate are predicted compared to a decrease in Faecal Indicator Organism export. All of these are due to a land use change from improved grassland to arable.

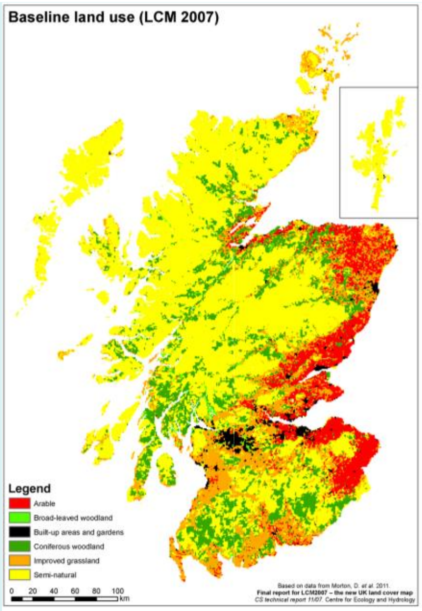

Figure 7: Baseline land use.

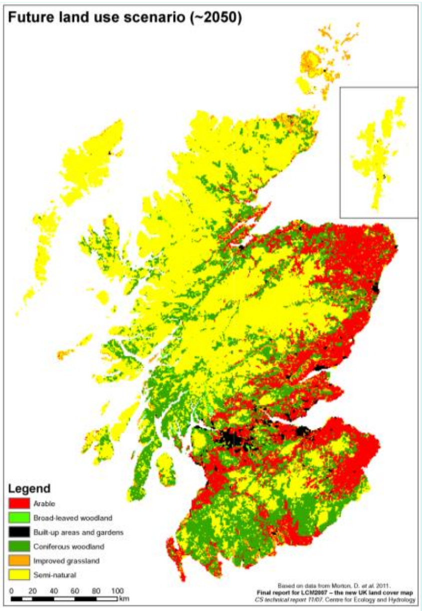

Figure 8: Future land use.

The **climate and land use change** simulations have been combined and a range of maps produced. In the 'wetter' simulation, both climate change and land use change are predicted to have an impact on water quality for most pollutants, including in locations such as the west coast where water quality is currently high. In contrast, in the 'drier' simulation, for a number of the pollutants the impact is neutral over much of Scotland except in those areas where rainfall is projected to increase.

The work has proved a very useful screening tool to assess the scale and location of predicted changes in water quality (as specific pollutant loads) due to climate and land use change. Catchments that face potential substantial changes in pollutant load have been identified by assigning cumulative pollutant scores to each catchment. Figures 9 and 10 illustrate the location of these for both climate simulations; clearly the 'drier' simulation has less potential impact than the wetter one. However, this should be treated with a little caution; here we are dealing with pollutant loads, while the 'drier' simulation might lead to higher concentrations in water which is itself a potential impact

Although the focus of the report is the losses of pollutants to surface waters and to groundwater for NO3 in rural areas, it is important that gaseous emissions are also considered in order that the whole system in terms of diffuse pollution production and pollution swapping are recognised.

Further work should include a similar assessment using a median climate simulation where more quantitative risk assessments are required, for example, the catchments identified in Figures 9 and 10. Additional work could also look at concentrations as well as loads.

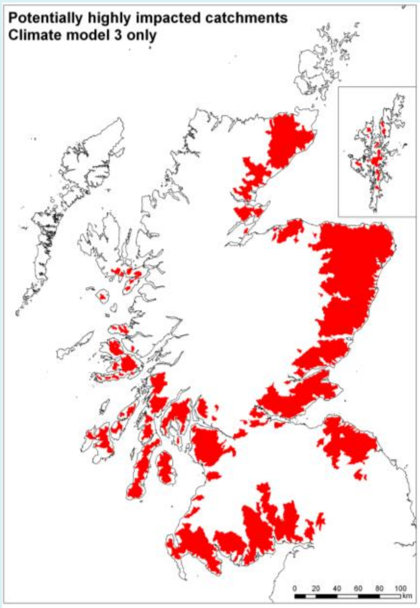

Figure 9: Potentially highly impacted catchments (model 3).

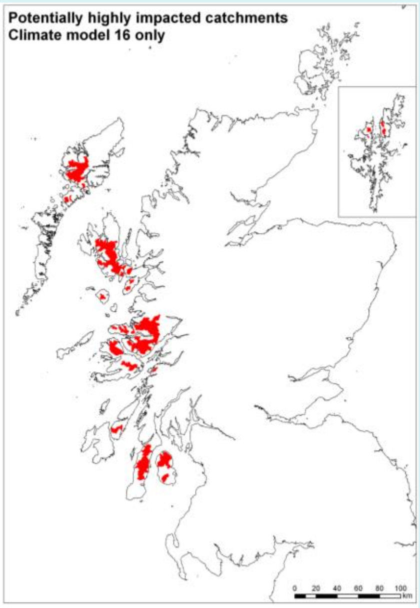

Figure 10: Potentially highly impacted catchments (model 16).

Research Undertaken

The project has undertaken a review of the sources, pathways and impacts of specific pollutants from four land cover types (semi-natural habitats, woodland, improved grassland and arable) and a review of the potential impacts of climate change and land use change on water quality until the middle of the 21st century. This was carried out by examining climate change, land use changes that might result because of climate change and land use change caused by other drivers.

A qualitative methodology for the spatial representation of future impacts of climate and land use change on water quality has been developed, based on the literature review, and a suite of maps have been produced to represent predicted changes in:

- Seasonal and annual rainfall and potential evapotranspiration changes
- Runoff
- Exported loads of specific pollutants to water, caused by climate change alone
- Exported loads of specific pollutants to water, caused by land use change alone (please see full report for details)
- Exported loads of specific pollutants to water, caused by climate change and land use change

Policy Implications

The findings of this report suggest, in general, increasing pressure on Scotland's water resources driven by both climate and land use change. The impact of the wetter simulation is greatest in those parts of eastern Scotland where agriculture is currently most intensive. If climate were to change in this direction then implications for water quality could potentially be serious. Areas where water quality is currently high may also be at risk from specific pollutants in specific locations, for example on the western seaboard. It is notable that even under the drier simulation, impacts are predicted to be deleterious in some areas. In addition, even though rainfall is predicted to increase in the dry scenario, increased evapotranspiration may increase the likelihood of drought conditions in eastern Scotland. However, further work is required to increase confidence in these predictions and to investigate a wider range of rainfall simulations.

Consideration should be given to designing and implementing measures to reduce these risks once more quantitative assessments are carried out in those areas identified as being at potential risk. The predicted increase in arable area, which is likely to increase sediment transport and its associated pollutants to water courses, provides opportunities to develop measures and incentives to encourage cultivation techniques aimed at minimising sediment export, perhaps for inclusion in the next Scotland Rural Development Programme. There are opportunities for creating synergies between different policy areas, for example, by targeting some new woodland planting to riparian zones along appropriate water courses to protect water quality from these future risks. Such planting would have added benefits in terms of biodiversity, landscape quality, amenity and water course shading and therefore directly achieving the aspiration of multiple benefits of land which is embedded in the Scottish Land Use Strategy.

The project provides an initial spatial assessment of critical source areas so that policy and funds may be targeted to higher risk catchments with land uses that have a disproportionate impact on water quality. There are also likely to be opportunities for developing and instigating measures that can provide mitigation against more than a single pollutant.

Research Team and Contacts

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