Implications of Climate Change for Northern Ireland: Informing Strategy Development

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This study has been commissioned by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) to improve understanding of climate change impacts in Northern Ireland and to assist the Department of the Environment in formulating appropriate policy responses.

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Consortium Members

Queen's University Belfast

Napier University, Edinburgh

Centre for the Study of Environmental Change and Sustainability, University of Edinburgh

Editors

Prof. Austin Smyth	Transport Research Institute, Napier University
Prof. W. Ian Montgomery	School of Biology and Biochemistry, Queen’s University Belfast
Dr David Favis-Mortlock	School of Geography, Queen’s University Belfast
Simon Allen	Centre for the Study of Environmental Change and Sustainability, University of Edinburgh

Authors/Task Managers

Task managers are marked*

Dr Roy Anderson*	DARDNI Newforge/School of Agriculture, Queen’s University Belfast
Dr William Beattie*	Electrical and Electronic Engineering, Queen’s University Belfast
Dr Nicholas L. Betts*	School of Geography, Queen’s University Belfast
Dr Brenda Boardman	Environmental Change Institute, University of Oxford
Dr Vivienne Crawford*	School of Medicine, Queen’s University Belfast
Dr David Favis-Mortlock*	School of Geography, Queen’s University Belfast
Dr David Hughes*	Department of Civil Engineering, Queen’s University Belfast
Prof. Bob Kalin*	School of Civil Engineering, Queen’s University Belfast
Dr Jim McAdam*	DARDNI Newforge/School of Agriculture, Queen’s University Belfast
Dr Loraine McFadden	School of Geography, Queen’s University Belfast
Simon Allen*	Centre for the Study of Environmental Change and Sustainability, University of Edinburgh
Prof. W. Ian Montgomery*	School of Biology and Biochemistry, Queen’s University Belfast
Prof. Julian Orford*	School of Geography, Queen’s University Belfast
Dr Dai Roberts*	School of Biology and Biochemistry, Queen’s University Belfast
Dr Alastair Ruffell*	School of Geography, Queen’s University Belfast
Prof. Austin Smyth	Transport Research Institute, Napier University
Dr Jude Stephens*	Gibson Institute, Queen’s University Belfast
Dr Christopher Tweed*	School of Architecture, Queen's University Belfast
Prof. W. Brian Whalley	School of Geography, Queen’s University Belfast

STEERING GROUP MEMBERS

Jennifer Hamilton	SNIFFER
Dr Penny Bramwell	Department for Environment, Food and Rural Affairs
Dr Caroline Fish	Department for Environment, Food and Rural Affairs
Dr Richenda Connell	UKCIP
Dr Sue Christie	Northern Ireland Environment Link
Andy McCrea	NIE Supply, representing CBI Northern Ireland
Rodger Lightbody	Environmental Policy Division, Department of the Environment
Clifford Henry	Environment and Heritage Service, Department of the Environment
Dr Howard Platt	Environment and Heritage Service, Department of the Environment
Nigel McMahon	Environment and Heritage Service, Department of the Environment
John C Clarke	Rivers Agency, Department of Agriculture and Rural Development

Executive Summary

1. The objectives of this study were to investigate — in broad terms — the likely impacts of climate change on the environment, economy, and natural resources of Northern Ireland; and to assess levels of awareness of climate change, to consider the possibilities of adapting to climate change and to assess policies for mitigating emission of greenhouse gases. Publications were reviewed and organisations and individuals (stakeholders) from the public and private sectors were interviewed. The scenarios of climate change published in 1998 for the UK Climate Impacts Programme were the primary source of information on possible future climates. These were used to guide discussion with stakeholders.

2. Predicted climate changes for Northern Ireland are characterised by warming, rise in precipitation and potential evapotranspiration, but seasonal and annual effects are inconsistent and year-to-year variation may confound overall trends. Overall winter gale frequency may decline, although very severe winter gales may increase. Improved models and estimates of the spatial and temporal patterns of climate change will provide more detail of changes. Particular attention must be directed to the repercussions of inter-annual variability and climate extremes.

3. Estimates of sea level change by the 2050s range between 13 cm and 74 cm. The coastal zone will experience rapid change over the next century but stakeholders are largely unaware of how this will affect society in coastal areas. Fisheries are vulnerable to the predicted effects of climate change because seasonal cycles of reproduction in most aquatic species are temperature dependent and sensitive to small changes in temperature over relatively short time scales. Fishing communities in coastal areas and those dependent on sport angling will be most affected. The predicted increase in overall precipitation, particularly winter precipitation and its intensity, will have effects on river basins: in particular on water quality, flooding, and the stability of exposed slopes.

4. Impacts of climate change on the biodiversity of the species-poor but unique ecological communities of Northern Ireland could be considerable, although these may be unnoticed by the general public. Invasion of more southerly, warmth-loving species replacing cold-adapted species at the southernmost edge of their ranges, may occur at different rates depending on habitats and types of species. Such changes are likely to be severely compounded by other impacts of human activity such as habitat fragmentation, agricultural change, invasion by alien species and eutrophication. Sympathetic interpretation and implementation of agricultural policies in, for example, the management of freshwaters or creation of salt marshes would help reduce the impacts of climate change on biodiversity. Impacts on the biodiversity of NI’s raised bogs and blanket bogs are, however, unlikely to be severe.

5. Agriculture is Northern Ireland’s most important industry. Under the predicted climate changes most land will remain in pasture or silage production although increased warmth may encourage a more mixed agriculture including spring-sown cereals. Milder winters may require increased applications of pesticides. Farming in the west may become more marginal as wetter winters adversely affect agricultural activities such as silage/turf cutting, and hay-making. Forestry and agri-forestry may however

benefit from climate change, offering opportunities to improve the landscape in a continuation of the current shift from upland conifer planting to broad-leaved planting on land displaced from agriculture, and by introduction of trees into farmed landscapes by more novel means. This would help correct a major imbalance in the trade in timber. Recent livestock disease epidemics have led to a questioning of agricultural intensification and to an exploration of possible alternative strategies: the implications of climate change should also inform this debate.

6. Poverty, social inequality, deprivation and social and health policy drive the health sector. Climate change may impact on any or all of these and hence will certainly impact upon health; the complex interrelationships between climate and health are however still not well understood. Climate change may bring both benefits and threats to the health of Northern Ireland, and the balance of harmful and beneficial effects (e.g. a reduction in metabolic bone disease with increased sunlight, offset by an increase in skin malignancy) is currently unknown. Issues of particular concern are the entry of new diseases into Northern Ireland (since increased rain and relative humidity favour the transmission of infection), and a possible increase in rodent-borne diseases.

7. Awareness of climate change in the construction, infrastructure and transport sectors is low, reflecting a reactive approach to climatic variation, such as flooding or drought, rather than a planned long-term strategy. Relevant expertise within the construction industry will need to be developed with respect to adaptation and mitigation technologies.

8. As a region which is isolated with respect to its location in the United Kingdom and Europe, the economy of Northern Ireland is heavily dependent on its transport links, and is therefore uniquely vulnerable to increased disruption or costs. The impacts of climate change on transport are complicated by interactions between different transport modes and operators. Consequences of weather-related airport closures include diversion to other airports and bussing of passengers: these result in significant inconvenience and increased costs for business and individuals. Development of seaports must take into account vulnerability to changes in prevailing wind direction, wind force and mean sea levels. Some modern high-speed vessels cannot operate in conditions as severe as those accommodated by more traditional heavy displacement ferries. More severe winter weather conditions, even if they occur less frequently than at present, will have an impact upon ferry timetables.

9. The built environment is affected by shifts in climate and is responsible for many of the emissions implicated in climate change. If rainfall increases, with heavier downpours, flooding may become more frequent with resultant damage to buildings and their contents. This is likely to be more critical in the west. Increased rainfall may also reduce days available for outdoor construction work, causing more interruptions. Some land may become unsuitable for development because of a greater risk of subsidence. Increased humidity will affect condensation in housing: this is already an acknowledged problem that, combined with higher temperatures, will create conditions more attractive to fungal attack on building materials. Predicted change in light levels due to increased cloudiness requires a review of lighting regulations.

10. Northern Ireland has significant energy problems due to its near complete reliance on imported fossil fuels and high levels of fuel poverty in the population, but climate change is not likely to have a major, additional effect. Cleaner energy sources that produce lower carbon dioxide emissions should be supported e.g. gas and combined heat and power. Renewable energy sources are relatively more cost-effective in Northern Ireland given the existing high fuel prices compared to other regions of the UK. Opportunities exist for increased use of renewables.

11. Interviewees in the sports sector were unfamiliar with thinking about the impacts of climate change as a strategic issue, but were concerned about mitigation policies that might increase the cost of fuel and transport in general.

12. The local political situation is the most important factor affecting tourism. Indirect impacts, such as the effect of the weather on visitors' perceptions of the region as a destination and the 'visitor experience', are also important. Direct impacts of climate change on tourist attractions and infrastructure were not considered significant by interviewees. Increased transport costs are seen as undesirable, since it is already more expensive for overseas visitors to travel to Northern Ireland than to competing destinations.

13. An apparent increase in weather-related insurance losses globally has increased the insurance industry's concern over climate change. Recent localised flooding in Belfast, though not as serious as in England and Wales, has reinforced the perception of a changing climate for the insurance sector in Northern Ireland. Changes in rainfall, temperature, wind regime and sea level increase the risk of losses in almost every category of insurance business, but the risk of more frequent and severe flooding of vulnerable areas of Belfast and Londonderry are the main concern. Measures designed to increase public awareness of climate change and weather-related risks would be helpful to the insurance industry. Stronger partnerships with the public sector, for instance in the design of flood defences, would also benefit the industry.

14. Effects of climate change in one sector are likely to affect another. Similarly, it was clear from discussions with stakeholders that climate change impacts often interact with other environmental, socio-economic and political changes. Three multidimensional themes emerged in the consideration of interactions among the sectors and other pressures from changing environment, socio-economic and political conditions; *water*, *rural environment* and *energy*. These themes arise from a mix of factors unique to Northern Ireland: the greater importance of freshwaters coupled with high rainfall; continued reliance on pastoral agriculture; and a high dependency on non-renewable, expensive energy sources. An evaluation of cross-sector and multifactor effects shows that they are generally negative from the perspective of human interests.

15. Northern Ireland shares a land boundary with The Republic of Ireland. It also shares many attributes of both the physical and human environment with its southern neighbour. This makes it highly desirable to explicitly consider the North-South dimension in any study of climate change and Northern Ireland. There is clear benefit from promoting awareness of the impacts of climate change in both jurisdictions, as

well as benefits arising from a joint research strategy, and joint development of adaptation and mitigation measures.

16. Communicating the impacts of climate change and the requirement for adaptation and mitigation measures to individuals and organisations requires a combination of raising awareness about the issues generally among the population, instilling concern and the need for action, provision of targeted information about particular sectors, and dissemination of regulatory, financial and design guidelines by responsible authorities and other bodies. In Northern Ireland, society has not shown much interest in, or apparent concern for, environmental issues in general even if occasionally displaying strong reaction to individual isolated or local events.

17. There is generally a low state of awareness and concern about climate change and its impacts across all sectors in Northern Ireland. The Province thus lags behind the rest of the UK in the development of adaptation strategies. No stakeholder identified or anticipated any acute impact of climate change. Impacts are generally negative, and expected to be chronic and cumulative; however there are some potential benefits e.g. in energy generation and agriculture. A comprehensive survey of awareness and concern about climate change would provide a starting point for development of a focused education and awareness drive for the general population and for key sectors.

Summary of impacts by sector

Minerals and other natural resources

- increased problems associated with elevated water tables and seasonality

Water resources

- lower river flow levels in summer and turbulent flows after heavy rainfall will have an adverse impact upon water quality
- increased frequency of intense precipitation events exceeding the capacities of wastewater treatment plants, sewer systems and flood defences
- weather patterns may require changes to discharge consents to rivers and seas

Coastal and flood defence

- loss of intertidal areas of open coasts
- intertidal zones in estuaries will see a decrease in the areas of protected habitats and a loss of marsh with an associated loss of biodiversity
- dune coasts will suffer non-sustainable beach and front-of-dune erosion

Other natural processes

- increase in overall precipitation, particularly winter precipitation, and its intensity will have effects on river basins, flooding, land use and the stability of exposed slopes

Biodiversity

- invasion of more southerly, warmth-loving species replacing cold-adapted species at the southernmost edge of their ranges
- loss of unique communities and assemblages of plants and animals
- climate change will compound effects of other negative factors e.g. eutrophication
- impacts on migrant species that might occur in other parts of species' ranges

Agriculture, horticulture and forestry

- more mixed agriculture with spring-sown cereals making a comeback in the East of region
- farming in the West may become more economically marginal
- enhanced survival of pest insects could result in increased applications of pesticides with increased opportunity only in the East
- forestry and especially agri-forestry offer additional opportunities in the face of climatic change enhancing biodiversity and the balance of trade in timber

Fisheries

- fisheries are vulnerable to predicted climate change because seasonal reproductive cycles of commercial species are temperature dependent and sensitive to small changes in temperature over relatively short time scales
- some cultured shellfish that currently do not spawn may do so in the future allowing them to colonise with unpredictable effects on local biodiversity
- changes in marine primary productivity will lead to corresponding changes in catch sizes, whereas changes in the boundaries of species distribution are only likely to lead to changes in the composition of fish catches
- rural communities, particularly those in coastal areas or dependent on angling and tourism, will be most affected

Landscape and cultural heritage

- climate change is anticipated to degrade designated conservation sites

Health

- new diseases from warmer countries may arrive
- increase in rodent borne diseases
- increased rain and relative humidity may promote infectious disease transmission
- the number of injuries resulting from road accidents may increase in more frequent storms and wet weather

Construction, infrastructure and transportation

- climate change will have a major effect on the spend in construction through increased commissioning of construction projects such as flood prevention schemes, improvements to water treatment plants to improve quality of water discharge, drainage schemes, coastal defences and ports and harbour works
- modes of transport interact with effects in one having consequences for others
- air services and seaports, crucial travel links for Northern Ireland may become less reliable due to increased disruption by severe weather

Buildings

- with increased rainfall and heavier downpours, flooding will become more frequent with damage resulting to buildings and their contents especially in the West
- increased rainfall may also reduce the number of days available for outdoor construction work and so cause more interruptions
- higher rainfall may render some land unsuitable for development because of a greater risk of subsidence in the soil
- higher rainfall and flooding could adversely affect the operation of some septic tanks

- changes in the water table may lead to localised soil subsidence and shrinkage, especially in soils with significant clay content
- increase in humidity will promote condensation, particularly in housing, which then becomes more prone to fungal and insect attack
- increased wind loadings on buildings and driving rain could lead to more structural damage

Energy

- increased use of cleaner energy sources that produce lower carbon emissions
- improved energy efficiency and greater development of renewables, as these are relatively more cost-effective given the region's existing high fuel prices

Waste

- increased temperatures slightly increase the rate of biodegradation of wastewater or refuse
- major impact due to increased emission of greenhouse gases (GHG) during waste handling/treatment activities
- waste industry could provide an overall reduction in energy use through efficient recycling of materials

Sport and recreation

- increased cost of fuel and transport in general

Tourism

- potential impacts of climate change on tourism seem to be mainly beneficial
- mitigation measures may increase transport costs reducing Northern Ireland's ability to compete with other destinations

Insurance

- changes in rainfall, temperature, wind regime and sea level appear to increase the risk of losses in almost every category of insurance business
- more frequent and severe flooding of rivers and coastal inundation are the main concerns

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Acknowledgements

We are indebted to many colleagues in Belfast, Edinburgh and Napier who informed and illuminated our discussions at all stages of the work. Staff in the Northern Ireland Department of the Environment, SNIFFER, UKCIP and the members of the Steering Group appointed to monitor progress of the study have stimulated and promoted the work throughout. We are grateful for their input. Numerous colleagues have read one or more sections of the report in draft form. We thank these reviewers especially Dr Richenda Connell (UKCIP), Dr Pam Berry (Environmental Change Institute, University of Oxford), Dr Roy Tomlinson (Geography, Queen's University Belfast) and Jenny Hamilton (SNIFFER). Finally, we are deeply indebted to Emma Muise who collated much of the material and worked tirelessly with Task Managers to ensure timely delivery. Without Emma's tactful and polite reminders this report would not have been finished: thank you.

Chapter 1. Project overview

Austin Smyth
Transport Research Institute, Napier University

Summary
The main objective of the study was provision of an overview of existing information (including reviews, research and monitoring studies) on the impacts of future climate change in Northern Ireland, focusing on environment, economy, and natural resources. A central component was soliciting the views of stakeholders.

The six-stage programme of research was driven by one or more task managers per sector. Stakeholder opinions were obtained following distribution of briefing packs by means of a combination of face-to-face semi-structured interviews, telephone interviews, and a survey. Work commenced in February 2001 and was completed the following September.

1.1 Introduction

The objectives for this study, as set out in the bid, were:

- provision of an overview of the existing information on the impacts of the climate change scenarios on the environment, economy, and natural resources based on existing reviews, research and monitoring studies
- generation of an overview of the best current information on the likely climate scenarios for Northern Ireland
- identification of key stakeholders who will be most affected by climate change and assess the views of stakeholders on the likely impacts on their interests. Report on how they expect to respond, including any plans for adaptation and mitigation
- assessment of stakeholder views on the local impact of Government emission targets and mitigation measures
- cross-sectoral analysis of the impacts of climate change
- identification of vulnerabilities and adaptation opportunities for different sectors, activities and sub-regions in Northern Ireland
- presentation of adaptation options for the region for the 2020s, 2050s and 2080s
- identification of key information gaps and uncertainties in assessing the impacts and identifying adaptation options and recommend ways to respond
- review of current and desirable levels of public awareness of climate change issues
- assessment of the implications of climate change for the strategic planning and decision-making process in Northern Ireland
- identification of priorities for research and information collection
- production of final report.

1.2 Work programme

A six-stage work programme was devised with the aim of achieving these objectives. (The original version is listed on the study's website, http://boris.qub.ac.uk/sniffer/.)

Analysis of climate change scenarios and the development of a protocol of critical issues was carried out during stages 2 and 3. These were used, along with a set of key questions identified by means of a literature review (stage 1), in discussions with sectoral and disciplinary experts (stage 4) and stakeholders (stage 5) during telephone and face-to-face interviews, and during a workshop.

Stage 1: Review of literature, expertise and policy

A first task was a literature review of past and on-going research on climate change impacts, adaptation and mitigation strategies in Northern Ireland, and (to an extent) the wider UK. National and international programmes as well as Northern Ireland Executive Departmental and EU-funded programmes were reviewed, with UK Climate Impacts Programme (UKCIP) sources and experience found to be especially relevant. This stage also included a preliminary identification of appropriate expertise within Northern Ireland and the Republic of Ireland, as well as a review of policy initiatives in Northern Ireland (subsequently supplemented by information derived from stakeholders).

Stage 2: Analysis of regional climate change scenarios

A central requirement of all UKCIP Regional Assessment Studies, including the present study, is to base all assumptions regarding future climate upon a standardised set of scenarios for the 2020s, 2050s and 2080s for the whole of the UK. These were constructed for the UKCIP in 1998 (see Chapter 3). During stage 2, we extracted information from these scenarios relating to climate change in Northern Ireland. Four scenarios were developed, for use as a benchmark during subsequent discussions with sector experts and stakeholders. The robustness of these scenarios, both in representing the regional climate of Northern Ireland, and with respect to known scientific limitations in simulating future climate, was also assessed during this stage. This information was incorporated into a briefing pack, for use in stage 5.

Stage 3: Development of critical issues protocol

Here we focused on the design of a protocol to guide the workshops and interviews with experts and stakeholders. Its development derives from previous work by members of the project team; in particular, lessons learned from the Scottish study (Kerr *et al.*, 1999). The aim was to create a structure which would uncover the key climate-related issues during discussions with the experts or stakeholders, and which would provide a consistent means of assessing the quality and coverage of prediction and mitigation mechanisms of climate change.

Stage 4: Expert assessment and elicitation

The critical issues protocol was to be used, in conjunction with the analysis of climate change scenarios, to examine each sector. This was done by supplementing the expertise of the project team with that drawn from key expert advisors and representatives of stakeholders. With each of the advisors and stakeholder representatives, members of the project team discussed the available predictions of future climate in NI, as well as adaptation to, and mitigation of, climate change impacts. Information from the expert advisors was used to supplement the information in briefing packs, distributed to stakeholders prior to their participation in discussions and workshops during stage 5.

Stage 5: Stakeholders' assessments

Stakeholder groups affected by different climate change issues in Northern Ireland were approached to elicit their expertise and opinion on the quality and coverage of predicted impacts and the mitigation of climate change in their sector. (See Appendix 1 for a list of stakeholders who were consulted).

This process was introduced to elicit sector- and disciplinary-specific expertise. The critical issues protocol and the analysis of regional climate change scenarios were used to focus the discussions. Stakeholder opinions were obtained following distribution of briefing packs by means of a combination of face-to-face semi-structured interviews, telephone interviews, and a survey. In addition to the protocol questions (stage 3) stakeholders were asked the following questions:

- What climate change policy exists already in your organisation, if any?
- What climate change policy might emerge in response to the impacts and responses discussed above?
- Is climate change (and policy responses to it) always perceived negatively? In what ways is it perceived positively?
- What are your reflections on the significance of climate change impacts as an issue for Northern Ireland?
- What level of interest would your organisation have in a broader-scale research initiative on climate change impacts in Northern Ireland? What should be the focus of such a study?

Additionally, a workshop for selected stakeholders was hosted by Queen's University Belfast in June 2001: this had the aim of enhancing understanding of cross-sectoral issues.

Stage 6: Synthesis, analysis and writing of final report

This final stage comprised a synthesis of all information gained from the experts and stakeholders together with assessments by the project team for each sector and landscape element. In July 2001, a meeting of task managers was held at Queen's to review progress and to discuss cross-sectoral issues. Further discussion regarding particular points took place in August.

1.3 Project management and staffing

These are reviewed and updates in Appendix 2. The main 'milestones' of the project are listed in Table 1-1. In conjunction with an overall study-wide briefing and individual consultations, a guidance document was prepared to assist task managers (Appendix 3). In addition, an outline questionnaire, together with some notes regarding interview procedure from UKCIP, was provided for task managers to consider and comment upon before implementing the survey programme (Appendix 4).

Table 1.1. Main 'milestones' of the project.

January 2001	First job for Task Mangers was to produce a list of stakeholders.
February 2001	Task Managers draw up questionnaires/decide on interview structures.
12th April 2001	500 word preliminary statement of envisaged impacts from each Task Manager
23rd April 2001	Project delivers an interim progress report to DoENI/SNIFFER
1st June 2001	Task Managers produce first 2000 word drafts

30th August 2001	Draft report to DoENI/SNIFFER
5th October 2001	Final report to DoENI/SNIFFER

The wide range of issues required for consideration in this study demanded an equally wide range of expertise. However, there was also a need to maintain tight control over project delivery with respect to deadlines and budgets. Thus, a small Consortium Management Group (Prof. Austin Smith, Prof. Ian Montgomery, Dr Simon Allen, Dr David Favis-Mortlock) was set up to coordinate execution of the main work programme. The Consortium Management Group brought together all consortium members to take advantage of the skills and expertise available within the partner institutions. The Project Director also had access to support from the Project Advisor who brought expertise from the successful Scottish study. The Management Group and Task Managers were assisted by the Project Assistant appointed in April 2001.

Chapter 2. The regional geography of Northern Ireland

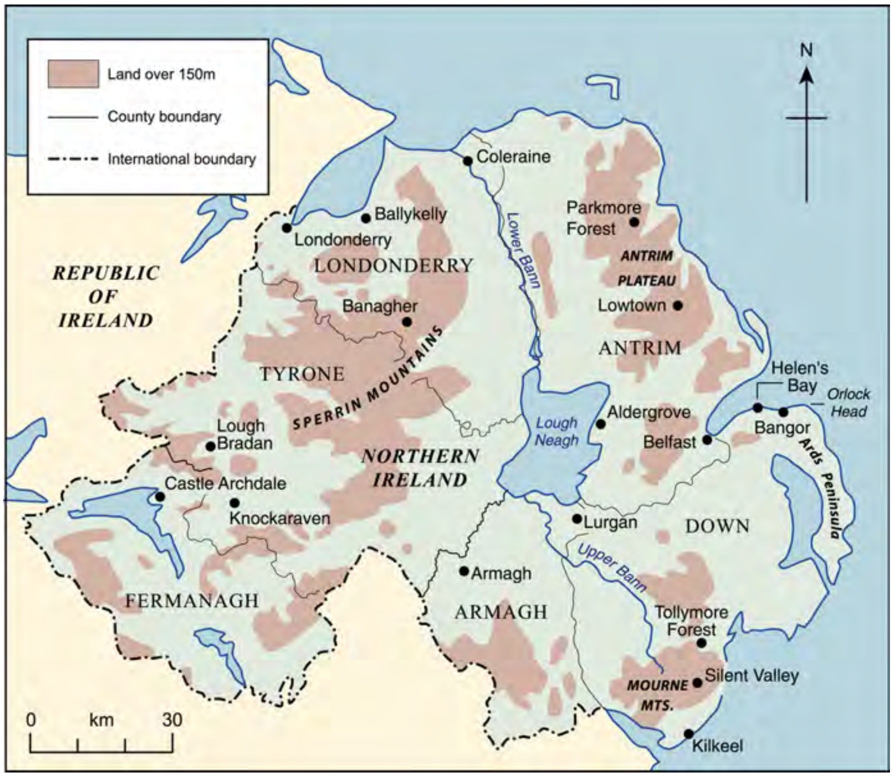
Austin Smyth[1], Nicholas L. Betts[2] and **W. Ian Montgomery**[3]
[1]Transport Research Institute, Napier University
[2]School of Geography, Queen's University Belfast
[3]School of Biology and Biochemistry, Queen's University Belfast

Summary
Northern Ireland is a very distinctive region of the United Kingdom that is part of a distinct biogeographical unit and which is largely unfamiliar to people living on the mainland. Here we describe briefly the natural physical and biological environment, and its demography, infrastructure, economic and commercial activity, history and politics. Finally, we give some general conclusions regarding environmental quality.

2.1 Natural environment

The land area of Northern Ireland (Figure 2-1) is approximately 14,000 km^2, which is approximately one sixth of the area of the whole island. The province of Northern Ireland is roughly the same size as the county of Yorkshire. Within this modest area, however, it contains a wide variety of relief and structure. This diversity is also true of its soils: there are 308 distinctively different soil series in Northern Ireland (Cruickshank, 1997), compared with the c. 700 found in England and Wales, an area approximately 11 times greater.

FIGURE 2-1: The main landscape regions of Northern Ireland, with principal place-names used in the text. *© 2001, School of Geography, Queen's University Belfast.*



2.1.1 Landscape and topography

Northern Ireland's relief closely reflects the underlying geological structure. The region's geology is notably diverse with most geological periods represented. The land surface of the Province is mostly lowland, with approximately 75% of its total area lying below 150m. Much of this forms an extensive saucer-shaped lowland around Lough Neagh. Coastal lowland extends along the north coast westward into the Foyle estuary. In the south, corridors of lowland connect to the basin of the Upper and Lower Lough Erne in County Fermanagh and also eastwards into the Lagan Valley, through Belfast and ultimately to the Ards Peninsula beyond Strangford Lough. Much of the lowland is underlain by clay-rich glacial deposits of low permeability, and with stream gradients often being very gentle in lower courses, it is inevitable that poor land drainage restricts land use unless artificial improvements have been made. Potential for flooding and subsidence is widespread in lowland areas particularly in the interior while much of the coastline of Antrim and Down is rocky and rises steeply from sea level. Areas around the Foyle, the sand dunes of the north coast, Larne Lough, Belfast Lough, Strangford Lough and Dundrum Bay, in contrast are low lying and vulnerable to rising sea level.

In Northern Ireland there are few mountains but often they have striking appearance in the landscape by virtue of their isolated position. Only 6% of the total land area is above 300m, but the mountains are distributed in isolated blocks peripheral to the central lowland, giving them dominance over the surrounding landscape that belies their area. The location of the Mountains of Mourne and the cliffs of the Antrim Plateau adjacent to the coastline means these mountains rise sharply above the shore, providing steep rocky slopes and shallow ranker soils.

There are four main uplands in Northern Ireland. Two are visible from Belfast, from where both near and distant skylines are made from young and tough igneous rocks. To the north, the skyline of three summits (Divis at 477m, Black Mountain 375m, and Cave Hill 358m) is part of the Tertiary basalt plateau of County Antrim and beyond. From north Belfast, the extruded sheets of basalt lava extend some 80 km to the cliff coastline of the spectacular Giant's Causeway in north Antrim, with the main plateau surface being between 300 and 400m above sea level. From Belfast, south across 50 km, the distant skyline of the Mourne Mountains is built up of hard Tertiary granites; in between, the lower upland of Slieve Croob in mid-Down was formed of much older 'Newry' granite. Towering above the coastal town of Newcastle, Slieve Donard at 847m is the highest summit in the Mournes, indeed in the whole of Northern Ireland. The Mournes are small in area (only 187 km^2), but have fifteen summits above 600m and a further thirty above 300m. As a result, over 80% of the soils are shallow rankers, or peat podzols in mixes with rankers. The steeply-sloping topography restricts the areas of peat development. To the west of the Lough Neagh basin, the more extensive Sperrin Mountains, running about 30 km east to west, are formed from metamorphosed sediments, in the form of relatively resistant mica-schist rock. The main summits of the Sperrins are above 600m, the highest being Sawel at 683m, and only just stand out above rounded ridges and gentle slopes. Ice sheets of the Pleistocene swept over and smoothed the outlines of the Sperrins, while valley glaciers cut deep into the Mournes producing many more summits in a smaller area. The fourth upland forms the western border of the Province. A table-land of hard Carboniferous limestone capped with grits, its cliff-line edge just over 300m, makes a striking feature west of the Lough Erne basin in County Fermanagh. The highest peak is Cuilcagh at 670m, rising above the area of the Marble Arch caves and an extensive peat complex on a plateau at 300 – 350m.

There are other mountains over 300m in Northern Ireland but these are even more restricted in area. There is the isolated peak of Slieve Gullion at 574m, with a few other hills in ring formation close by in south Armagh. Again, these are formed from a mixture of hard, acid igneous rocks produced from multiple volcanic activity. In County Tyrone there are rolling uplands of Old Red Sandstone where a few peaks just break through 300m, but are extensively peat-covered. The upland structure of the Province is also controlled by major fault lines, the most important of which is the Southern Uplands of Scotland fault which enters by Belfast Lough and fashions the hill slopes on the south of the city. The Scottish Highland Boundary fault plays a less obvious role in the landscape, being buried below the Antrim basalts, but it does delimit the south-eastern slopes of the Sperrins. Of greatest scale is the internal and relatively recent Tertiary down-faulting of the basalts which takes those lava sheets down 800m below sea level under Lough Neagh. The down-faulting of the central lowlands contributes in some measure to the relative prominence of the surrounding uplands, and has much affected the drainage pattern.

The most notable feature of the drainage pattern in the Province is that so much appears to feed inward and pass through Lough Neagh. This inward drainage is now represented by the catchment of the River Bann and its tributaries, which drains 39% of the land area of Northern Ireland, and which may have been more extensive in the past, when the basalt was more extensive.

This outline of the main structures of the Province has indicated how relief is interconnected with geology. The interconnections between relief and climate (section 2.1.3) are just as important, explaining the distribution of some soil profile types, and specifically that of peat. This covers 14% of Northern Ireland and provides a good example of topography encouraging the accumulation of peat, given surface wetness of the site. Lowland, nutrient-rich peat (also called basin or fen peat) is fed initially by groundwater but later may develop a mossy dome and become a ‘raised bog’. These bogs have been developing since the end of glaciation about 10,000 years ago. The development of upland blanket peat, usually above 300m in the east and above 150m in the west, also requires a level surface and site wetness. Good examples can be found on the Antrim Plateau, the Sperrins, and plateau surfaces in west Fermanagh.

2.1.2 The living environment

The biota of Northern Ireland must be considered in the context of Ireland as a whole although there are differences north to south reflecting differences in temperature and post-glacial history with latitude. The plant and animal communities of Northern Ireland are shaped by a combination of glacial history and how this has affected sea level and land contact with Britain and the rest of Europe, post-glacial climate and human influences. These influences have produced a species poor fauna and flora with few species or sub-species unique to the region, northern species relict of a colder climate and a growing list of introduced species some of which are probably responsible for major alterations of native biological communities.

The complicated and contentious story of the present Irish fauna and flora commences with the final retreat of ice around 13,000 ybp (Mitchell and Ryan, 1997). At this time, open ground denuded of soils or featuring glacial till and small hills or drumlins, was dominated by grasses. These rapidly gave way to low scrub and heath communities, firstly comprising willow and then juniper and birch. A cold spell around 11,500 to 10,500 ybp due to a southerly movement of Arctic waters brought this to an end and Ireland reverted to tundra and alpine scrub. Once again the climate warmed and Ireland rapidly became wooded almost in its entirety (over 80%) to around 5,500 ybp. Hazel, oak, wych elm and alder dominated at this time with yew and ash in limestone areas and pine on upper slopes (V. Hall, personal communication, 2001). Ireland, however, was not fully an island throughout this period. Wingfield (1995) following earlier authors has proposed a ‘fore-bulge’ theory of land bridge formation between Ireland and Britain. As the depression of land by ice eased a land bridge is thought to have moved northwards from south of Pembrokeshire (11,000 ybp) to just south of the Isle of Man (9,700 ybp). Hence, until other factors intervened, the Irish biota comprised terrestrial and freshwater species incapable of aerial dispersal or powered flight but tolerant of the conditions prevailing in Ireland and crossing the land bridge before the latter date. Similarly, Britain enjoyed a temporary land bridge with mainland Europe (possibly as late as 7,000 ybp but certainly later than the latest British-Irish land bridge; Yalden, 1999). Despite the lack of hard evidence of land bridges it is difficult to envisage how the fauna and flora of both Ireland and Britain might otherwise have emerged from the final glacial period. Many taxa show a progressive decline in numbers of species from mainland Europe to Britain to Ireland; for example, there are approximately 20 native or possibly native Irish mammals, 42 British and 134 in Europe west of Russia (Corbet and Harris, 1991). Impoverished, the Irish flora and fauna also contain relict Arctic, ‘lusitanian’ and montane species, and, hence, is composed of different species assemblages and is not merely a subset of that of Britain. While both lusitanian and montane relict species are important components of the extreme west and south of Ireland, Arctic relicts are present in Northern Ireland.

Ireland, particularly the north of Ireland, has long been accessible to people. Mesolithic and then Neolithic settlements were well established with migrations, temporary or otherwise, frequent across the northern part of the Irish Sea. The influence of people in Ireland has compounded the impoverishment of the island’s fauna and flora. By 5,500 ybp early agriculture commenced the clearance of forest on south facing slopes and better soils. Major forest depletion took place in the Bronze Age (4,000 ybp) such that by the Early Christian period a major part of the primary or climax woodland had gone (V. Hall, personal communication, 2001). Species poor scrub and secondary woodland persisted to the mid 17th century. Not surprisingly, Ireland in general and Northern Ireland, in particular, have the unenviable reputation of being the least forested areas of temperate Europe. Deforestation during the Bronze Age, was accompanied by cooling and dampening of an already cool damp climate. This led to the accumulation of substantial areas of blanket peat characteristic of Irish uplands and the lower ground to the west. Raised bog also accumulated in shallow depressions in lower ground creating major reserves, now sadly depleted in, for example, the valley of the River Bann and around Lough Neagh. In the absence of wood, peat constituted a readily available high quality fuel and latterly a soil conditioner for horticulture. The migrations of people were and remain accompanied by alien plants and animals. Accidental and deliberate introductions of species into Ireland continue to create species assemblages that are less unique than those formerly present. Ironically, much of the woodland acquired since the mid 17th century is comprised of exotic species ranging from the eucalyptus of Australia to the Sitka spruce of Canada.

All influences in the history of the Irish and Northern Irish flora and fauna are illustrated by a single taxonomic group, the mammals (Box 1). These species and their biology are familiar to many non-biologists and illustrate much of the complexity and uncertainty surrounding the origin of the plants and animals of Ireland.

BOX 1

Case Study 1. The origin of the Irish terrestrial mammals (source: Yalden, 1999).

The postglacial, climatic condition of Ireland dominated by broadleaved woodland presented sufficient area and diversity of habitats to support most of the species in Britain at the time. However, the Mole, Common shrew, Water shrew, Weasel, Polecat, Roe deer, Field Vole, Water vole and Common dormouse were absent in Ireland having failed the land bridge test. Apart from bats, the Irish 'native' mammal fauna, comprises three endemic subspecies of Mountain hare, Stoat and Otter, and Wolf (extinct by end of the 18th century), Red fox, Badger, Pine marten, Pygmy shrew and Red deer. In addition, it is likely from fossil evidence that Wild boar, Brown bear, Wild cat and Lynx were in Ireland around 9,000 ybp to early Christian times. Bat species regarded as native to Ireland are Pipistrelle (both Common and Soprano sibling species), Leisler's, Brown long-eared, Daubenton's, Natterer's, Whiskered and Lesser Horseshoe (not Northern Ireland). There are a number of notable absentee bat species that are present in Britain and the larger population density of Leisler's bat in Ireland than Britain, for example, has been attributed to the absence of the Noctule bat in the former. Recently, Nathusius' pipistrelle has been found breeding in Ireland and probably has been a member of the Irish fauna as a migrant for some time. Whether it should be regarded as a native species, having got to Ireland unaided, is a moot point. Regardless, both volant (flying) and non-volant native Irish mammal communities constituted unique assemblages that were distinct from anything found elsewhere. As is the case elsewhere, native species especially endemic forms are vulnerable and the Irish (Mountain hare) potentially will follow the fate of the native Red squirrels and Otter that possibly became extinct in historical times to be replaced by conspecifics from Britain and mainland Europe.

Deliberate and accidental anthropogenic introductions of mammals to Ireland can be classed as so early as to be inseparable from the native fauna or late such that they remain to be fully assimilated into the mammal community. The former are exemplified by the Wood mouse (possible native or very early introduction) and Hedgehog (probably introduced about 1700 AD). The latter include Rabbit, Fallow deer, Sika deer, Grey Squirrel, Mink and Brown hare. Grazers and browsers have a considerable effect on vegetation and it is likely that the first three species have had more than just local effect. The Sika deer has also hybridised with Red deer further impoverishing Ireland's unique mammal fauna. As in Britain the Grey squirrel is replacing the Red squirrel in deciduous woodland. Finally, the Bank vole was probably introduced into Ireland around 1950 and has spread from its original distribution in south-west Ireland at roughly 3 km per year. It is unlikely to trouble Northern Irish mammalogy for 60 years. Reviewing the composition of introduced mammal species in comparison to Britain, Ireland remains species poor, but several of these introduced species have had and will continue to have a detrimental effect on native species and their environment.

2.1.3 Present climate (WMO standard period 1961-1990)

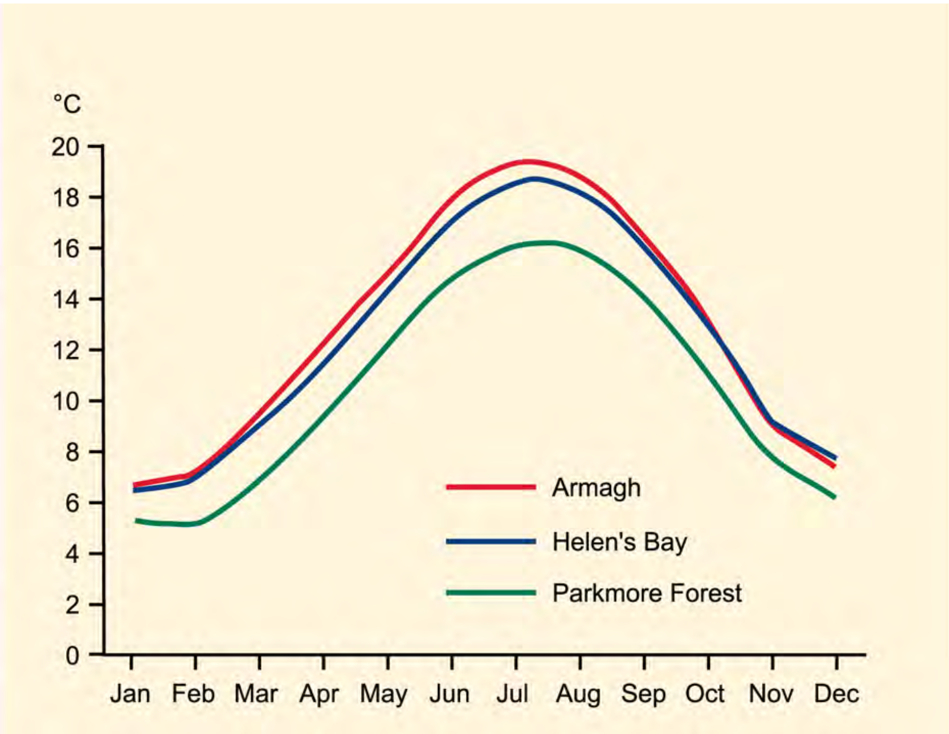
The climate of Northern Ireland owes much to its mid-latitude oceanic position on a western side of a landmass (Betts, 1997). Heat transfers from the relatively warm surface waters of the North Atlantic Drift to the overlying atmosphere enhance maritime influences. The climate of an individual period of the year is determined by the fluctuating upper atmospheric pattern shifting between zonal (west – east) and meridional (north – south and south – north) airflow. Resultant frequency fluctuations in terms of westerly circulation have implications in respect of climate change.

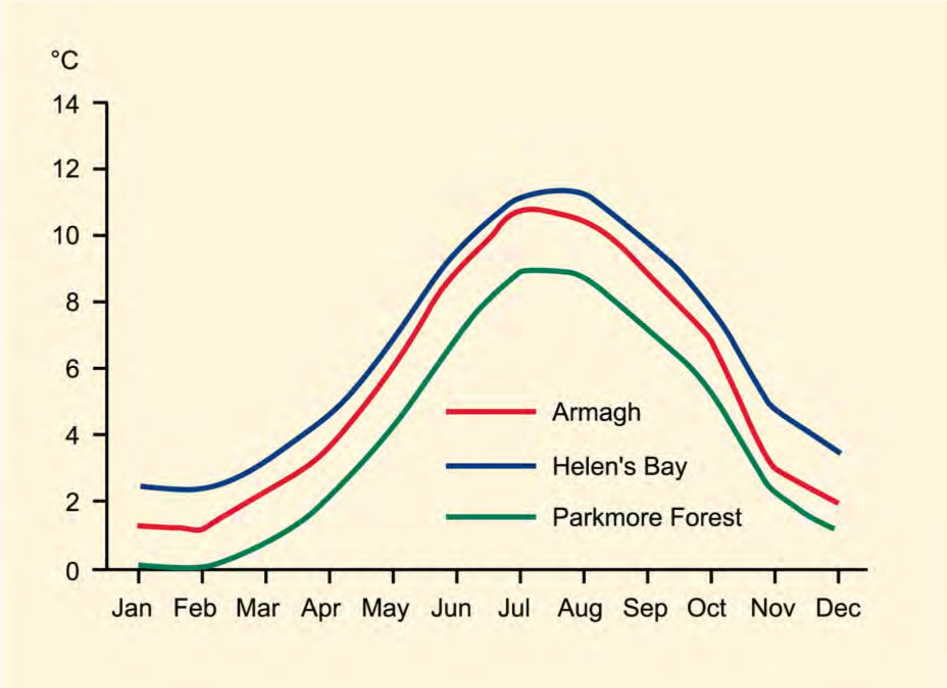
Temperature

Northern Ireland's extremely oceanic climate regime means that temperature extremes are rare. Mean air temperature fluctuates within narrow limits, with a 10% probability of a departure more than 0.5°C from the 1961-1990 mean. At low altitudes, mean annual temperatures range from 8.5°C to 9.5°C, with the higher values occurring in coastal areas. Mean annual temperature decreases by approximately 0.5°C per 100 metres.

With surface temperature of the surrounding sea at a minimum in late February and March, coastal locations are coldest in February, but inland January and February are equally cold (Figure 2-2). Average daily maximum temperatures in February range from about 7°C at coastal sites, to around 5°C over the highest upland. Along coasts mean minimum temperature is 2.5°C, decreasing inland to less than 0°C over upland summits. Cold air drainage results in extreme minimum temperature as low as -17.5°C on inland valley floors. Coastal areas do not experience such cold nights; as an example, the lowest temperature recorded at Helen's Bay, County Down in the period 1961-1990 was -5.4°C.

FIGURE 2-2: Mean daily maximum and minimum temperatures for representative inland (Armagh), coastal (Helen's Bay) and upland (Parkmore Forest) sites in Northern Ireland, 1961-90. *© 2001, School of Geography, Queen's University Belfast*



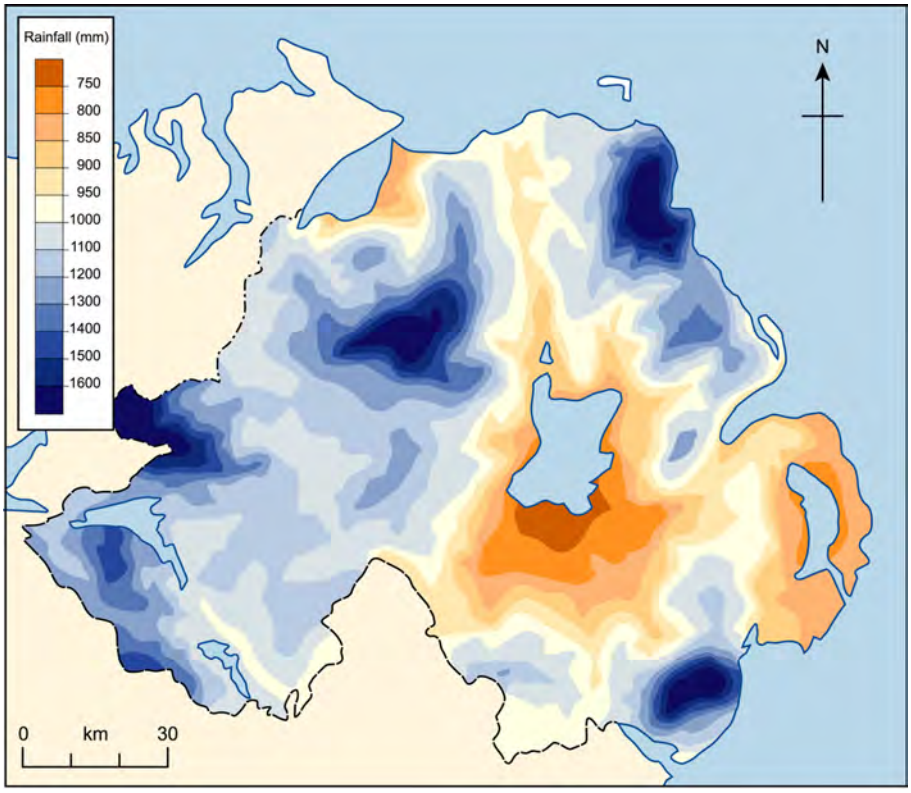


July is the warmest month, with mean daily maximum temperatures between 18°C and 19°C inland at low altitude, 17°C to 18°C along coasts and less than 17°C over uplands (Figure 2-2). The maximum temperature ever recorded in Northern Ireland is 30.8°C at Knockarevan in County Fermanagh in June 1976 and at Shaw's Bridge, Belfast in July 1983. This is in marked contrast with central and southern England stations, some of which have experienced temperatures exceeding 35°C in June, July and August during the period 1961-1990.

Precipitation

A general west-east trend of decreasing precipitation is complicated by topography. Highest areas of upland receive annual precipitation in excess of 1600 mm. In contrast, parts of the Ards peninsula receive less than 800 mm and the driest areas are the upper Bann - Lough Neagh lowlands with annual totals less than 750 mm (Figure 2-3).

FIGURE 2-3: Mean annual precipitation (mm) for Northern Ireland, 1961-90 (derived from data supplied by Belfast Climate Office). *© 2001, School of Geography, Queen's University Belfast*



Seasonal variation of precipitation in Northern Ireland is not large, but the wettest months are between August and January. Away from the lowlands, particularly in the west, a winter precipitation maximum is more pronounced, associated with the most intense depressions at this season. Upland stations have in excess of 10 mm in each month between August and January, and some sites especially in the west, experience this amount in all months. The general enhancement of autumn/winter precipitation implies the operation of an external control. Betts (1989) has indicated the roles of the Atlantic Ocean and Irish Sea as important influences upon the precipitation regime through the transference of latent energy to the atmosphere and to cyclonic (low pressure) systems at these seasons.

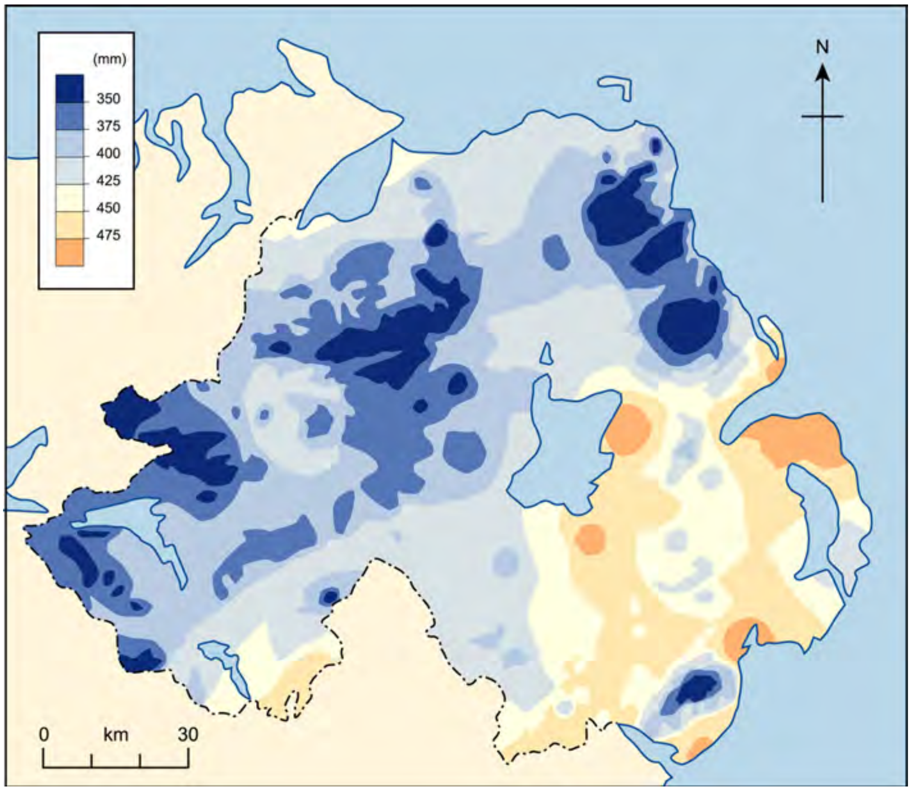
'Wet days' (daily precipitation ≥1mm) range from 150 days in the east to 200 days in the west and uplands. At Armagh daily falls in excess of 25 mm do not occur each year, and rarely on more than two occasions in a given year. Daily falls exceeding 100 mm occur over upland, but falls greater than 125 mm are rare and absent from lowland sites (Betts, 1990b; 1999; 2000). The maximum 24-hour precipitation recorded was 158.9 mm at Tullymore Forest, County Down in October 1968. Precipitation amounts of more than 16 mm in 60 minutes have a return period of five years, as do 48-hour totals of 50 mm over lowland, 75 mm in the Sperrins and Antrim Plateau, and 100 mm in the Mournes (Logue, 1995). Infrequency of heavy falls is due to the relatively low topography and limited severe convectional activity in summer. At Armagh, thunder occurs on average less than four days a year, compared with 15 to 20 days at many places in England. Only in a few locations, mainly away from coasts, does the frequency of thunder exceed five days annually.

Snow is comparatively rare, averaging 10 days annually near the east coast and over 30 days in upland areas. Snowfall occurrence is highly variable from year to year, and rarely persists on lowland before December and after March. In some winters snowfall does not occur, but exceeded 30 days during the winters of 1962/63 and 1981/2. Even coastal locations experienced prolonged snow cover during these two winters.

Water balance

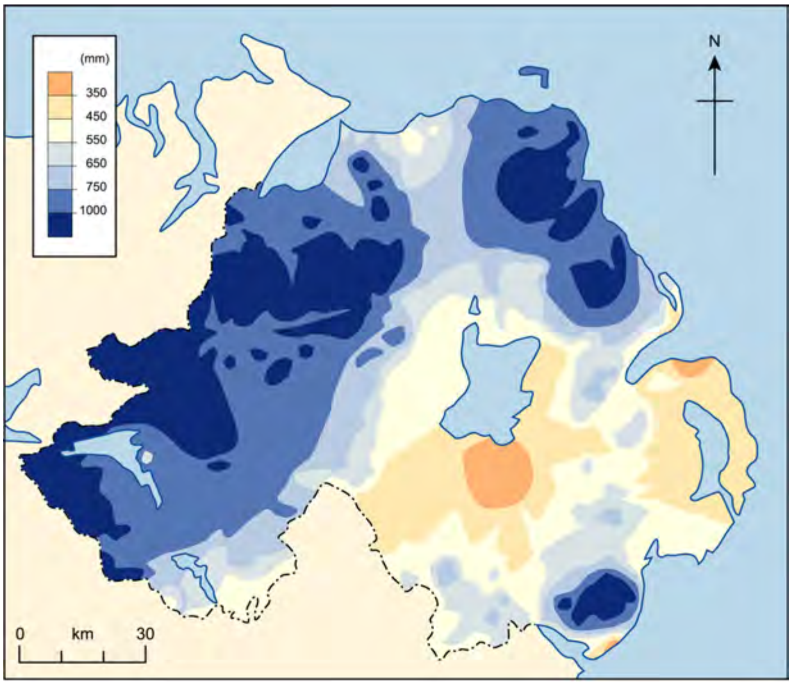
Mean annual potential evapotranspiration (PET) is greatest in the east and on exposed coasts, and lower in the west and upland areas (Figure 2-4). Annual PET at Aldergrove averages 504 mm, 568mm at the coastal site of Bangor, and 339 mm at the upland station, Lowtown.

FIGURE 2-4: Mean annual potential evapotranspiration (PET) in mm for Northern Ireland, 1969-94 (source: Betts, 1997). *© 2001, School of Geography, Queen's University Belfast*



In terms of the annual potential water balance, precipitation (P) minus PET, P greatly exceeds PET, especially in the west and north (Figure 2-5). Two areas where the differences are significantly reduced are the Lurgan area with P exceeding PET by 300 mm, and in parts of north Down and the Ards peninsula where P exceeds PET by less than 350 mm. In contrast, over much upland, P exceeds PET by more than 1000 mm annually (Betts, 1997).

FIGURE 2-5: Mean annual moisture excess, precipitation (P) - potential evapotranspiration (PET) for Northern Ireland, 1969-94 (source: Betts, 1997). *© 2001, School of Geography, Queen's University Belfast*



Monthly data show that the excess P over PET during winter is reversed from late spring onwards (Figure 2-6). With PET exceeding P, a soil moisture deficit (SMD) develops to an average July value of 50 mm generally for Northern Ireland. In the Lough Neagh basin and in coastal areas during a dry summer, SMDs of more than 100 mm will occur. Soils normally return to field capacity in September.

FIGURE 2-6: Mean monthly values for precipitation (P) and potential evapotranspiration (PET) at selected climatological stations in Northern Ireland, 1969-94 (source: Betts, 1997).
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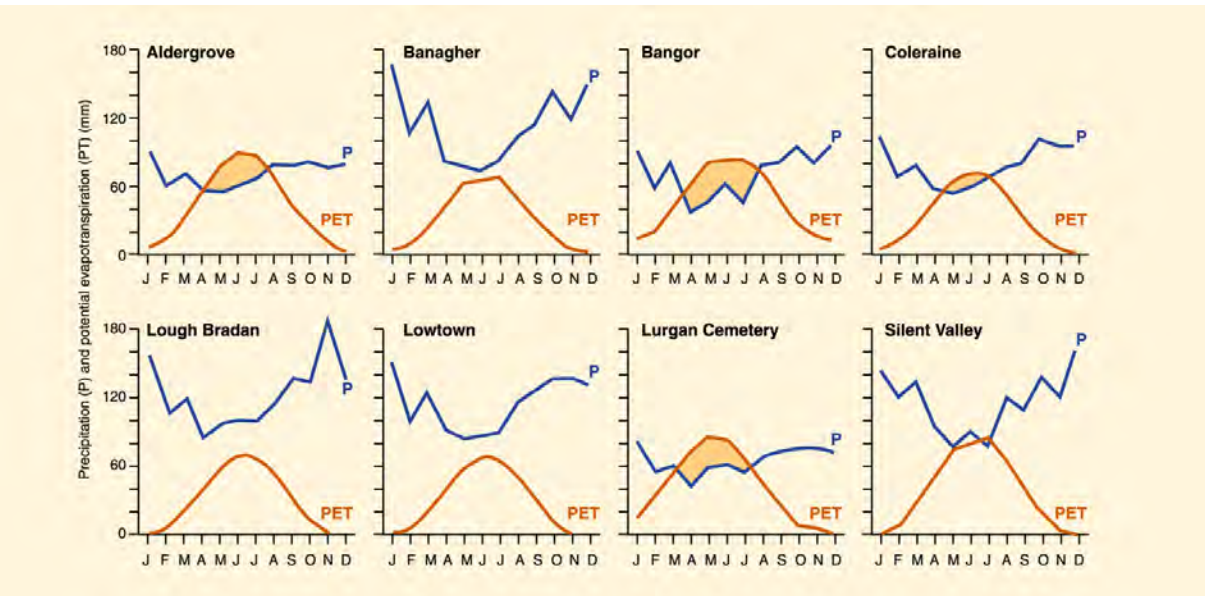
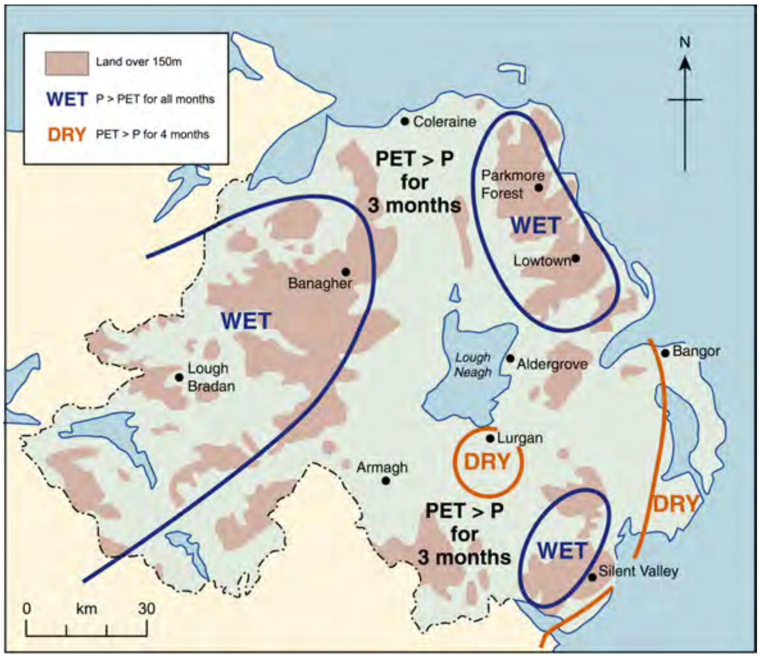


The moisture balance at altitude and in the west remains in surplus throughout the year (Figure 2-7). One exception is the Silent Valley in the Mournes (Figure 2-6), where a sheltered, south facing aspect results in PET marginally exceeding P during July.

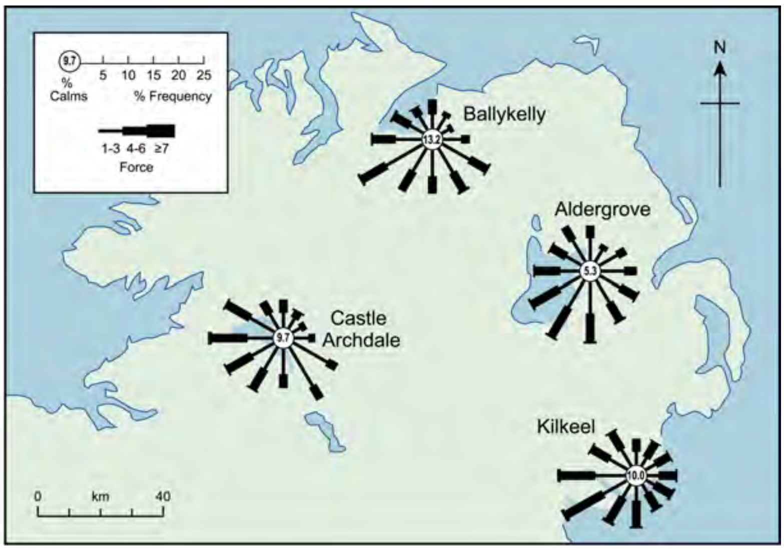
FIGURE 2-7: Generalised distribution of the mean number of months in the year when soil moisture deficit (PET > P) prevails under Northern Ireland's present climate regime (source: Betts, 1997). *© 2001, School of Geography, Queen's University Belfast*



Wind

Predominant wind directions are between 200°-280° (approximately SSW to WNW), although surface airflow is greatly modified by topography (Figure 2-8).

FIGURE 2-8: Annual percentage frequency of the force (Beaufort scale) and direction of wind at selected stations under Northern Ireland's present climate regime (source: Betts, 1997). *© 2001, School of Geography, Queen's University Belfast*



The close proximity of Northern Ireland to depression tracks over the Atlantic results in stronger winds than experienced by southern areas of the British Isles. Afforded protection by the rest of Ireland and adjacent parts of Scotland, however, coastal areas are not as exposed as western Scotland and the extreme south-west of England.

Annual mean wind speed ranges from in excess of 6.7 m s^{-1} on the North Antrim coast to less than 4.1 m s^{-1} at sheltered inland sites. Maximum velocities occur between November and March. Coasts of Antrim and Down experience an annual average of 15 days with gale (mean wind speed attaining 17.2 m s^{-1} or more for 10 minutes in 24 hours); inland the mean is 5 days. The maximum recorded lowland gust speed is 55.6 m s^{-1} at Kilkeel, County Down in January 1974, and the highest hourly mean wind speed recorded is 28.8 m s^{-1} at Orlock Head, County Down in January 1978. There are no wind-recording stations at high altitudes in Northern Ireland.

2.2 Society

The complexity of the issues linked to climate change and the cross sector interactions of many of the impacts demand a wide-ranging response from society in terms of adaptation and mitigation. Society's response will be dependent to a marked extent on its history and circumstances. In this section we set out the demographic, economic and lifestyle characteristics of Northern Ireland as a context for review of the various impacts, adaptation and mitigation measures of central or potential relevance to the region. In some cases these differed significantly from other regions of the UK. This overview draws on information from various sources including the Northern Ireland Abstract of Statistics, the North South Statistical Profile and Regional Trends (Table 2-1).

2.2.1 Demographic characteristics

The estimated population of Northern Ireland in mid 1999 was 1,691,800, a 0.2% increase on the 1998 estimate. While broadly reflecting demographic trends in the rest of the UK and the Republic of Ireland, there are some disparities. Spatial variation in demographic features within Northern Ireland is more notable. Within the region the population density was highest in Belfast district at over 2,600 people per sq km and lowest in Moyle at only 31 people per sq km. Around two fifths of the people living in NI households were aged 30-64 and a further quarter were aged under 16 suggesting a lower age structure than the rest of the UK. Hence, future health provision requirements in Northern Ireland may differ from those in, for example, the south east of England.

Table 2.1. Key demographic and economic statistics for Northern Ireland, compared with the wider United Kingdom.

	Northern Ireland	United Kingdom
Population, 1998 (thousands)	1,688.6	59,236.5
Percentage under 16	24.5	20.4
Percentage pension age or over[1]	15.2	18.1
Standardised mortality ratio (UK=100), 1998	101	100
Infant mortality rate[2], 1998	5.06	5.8
Percentage of pupils achieving 5 or more grades A* to C at GCSE level, 1998/99	56.0	49.1

Economic activity rate[3], Spring 1999 (percentages)	71.9	78.4
Employment rate[3], Spring 1999 (percentages)	66.6	73.6
ILO unemployment rate Spring 1999 (percentages)	7.2	6.0
Average gross weekly earnings: males in full-time employment April 1999 (£)	377	441
Average gross weekly earnings: females in full-time employment, April 1999 (£)	295	326
Gross domestic product, 1998 (£ million)	15,966	747,544
Gross domestic product per head index, 1998 (UK=100)	75.8	100.0
Total business sites, 1999 (thousands)	76.2	2,508.0
Motor cars currently licensed, 1998 (thousands)	585	23,878
Fatal and serious accidents on roads, 1998 (rate per 100,000 population)	74	66
Average weekly household income, 1996-1999 (£)[4]	347	430
Average weekly household income expenditure, 1996-1999 (£)[4]	301	333

[1]Males aged 65 or over, females aged 60 or over
[2]Deaths of infants under 12 years of age per 1,000 live births
[3]For people of working age, males aged 16 to 64, females aged 16 to 59
[4]Combined years 1996-97, 1997-98 and 1998-99

There were approximately 23,000 resident births in Northern Ireland in 1999. Between 1998 and 1999, the NI birth rate per thousand decreased slightly from 14 to 13.6. In 1999, Northern Ireland had an overall Total Period Fertility Rate of 1.9. In 1999, there were around 16,000 registered deaths in Northern Ireland. Between 1998 and 1999, the region's crude death rate increased from 8.9 to 9.3 deaths per thousand population. Overall the region has a slightly higher Standardised Mortality Ratio than the UK as a whole at 101 in 1998 (UK =100). Within Northern Ireland this ranged from 86 in Cookstown to 117 in Derry. The Infant Mortality rate for 1998 for Northern Ireland was around the same as the UK rate for 1997-99 (5.6 and 5.8 deaths of infants under 1 year old per 1,000 live births, respectively); within the region it ranged between 4.2 for the Eastern Health and Social Services Board area and 8.1 for the Western area. Life expectancy for those born during 1997-99 is 74 years for males and 80 years for females. In 1998-99 approximately 25% of males and females reported that they had a long standing illness that limited their activities. In 1998-99, Northern Ireland's net outward migration was more than 2,800, the highest net outward migration since 1989-90. Households in Northern Ireland tend to be larger than those in the rest of the United Kingdom. In 1998-99, the average NI household comprised 2.71 persons, the average GB household, 2.36.

In 1841, shortly before the Famine, the population of what is now the Republic of Ireland was approximately 6.5 million, almost four times the population of the future Northern Ireland *(1.65* million). Subsequently, there was a marked population decrease in both parts of Ireland reflecting the impact of the famine and a high rate of emigration. Between 1841 and 1901, total population declined by around 50% in the future Republic of Ireland and by 25% in what is now Northern Ireland. For what is now the Republic of Ireland, the 1996 Census total of 3.6 million was around 45% lower than that recorded for 1841. In Northern Ireland, population increased throughout the 1900s, rising by more than a third between 1901 and 1996. Nonetheless, the NI population estimate for 1996 (1.7 million) was only slightly higher than the corresponding figure for 1841.

Between 1970 and 1998, the Republic of Ireland's birth rate decreased from 21.9 births per thousand to 14.5. Over the same period, the corresponding NI rate declined from 21.1 births per thousand to 14.0. Life expectancy is broadly comparable in both Northern Ireland and the Republic of Ireland. Female life expectancy at birth is 79 in both parts of Ireland; male life expectancy at birth is 73 in the Republic of Ireland and 74 in Northern Ireland. Just under 28% of the NI population are aged 50 or more compared with around 25% in the Republic. In 1997, households in the Republic of Ireland were, on average, slightly larger than NI households. Twenty% of households in the Republic comprised five people or more compared with 14% in Northern Ireland.

2.2.2 Economy

The Gross Domestic Product (GDP) estimate for Northern Ireland for 1998 was £15,966 million. This represented a GDP per capita of £9,438, more than 25% less than the UK average. Between 1990 and 1998, the nominal value of GDP per capita doubled in the Republic of Ireland and increased by more than 50% in Northern Ireland.

In 1997, the industries making the largest contribution were manufacturing (20% of the total); wholesale and retail trade (13%); real estate, renting and business activity (11%); and public administration and defence (10%). In 1999, 65.5% of the value of direct export trade from Northern Ireland was to the EU, higher than the UK rate of nearly 61%. Imports from the EU accounted for over 43% of the value of direct import trade to Northern Ireland, below the UK average of 51.5%. Sales of electricity increased by 31% between 1989-90 and 1999-2000. Between 1989 and 1999, all shipments of coal and other solid fuels into Northern Ireland increased by 2% to 2.2 million tonnes. In 1999, electricity production accounted for 60% for all shipments of coal and solid fuels.

Over the period 1995 to 1999, NI manufacturing output (seasonally adjusted annual average) increased by 19%. The biggest sectoral increase over this period was in engineering and allied industries (an increase of 37%). The largest decrease (approximately 11%) occurred in the leather, textile and textile products industry. Services and retail businesses are dominant in urban areas while agriculture dominates the economy in rural and border areas. Between 1998 and 1999, Total Income from Farming (TIFF) fell by 22% (23% real terms) to £70.9 million. This followed a 54% decrease in 1998 and took TIFF to its lowest level in real terms since 1980. Moreover gross value added from the agriculture sector fell by 6% in 1999 to £425 million. Net value added (gross value added less consumption of fixed capital plus subsidies) declined by 11%, to £210 million.

In both parts of Ireland, livestock and livestock products accounted for about 90% of the total value of agricultural output in each of the years 1994 to 1998. Crops, fruit and horticulture account for the remaining 10% of the total value. Cattle and milk products account for more than three quarters of the total value of livestock and livestock products in the Republic of Ireland and for around two thirds of the total value in Northern Ireland. Sheep, poultry and eggs account for a higher proportion of the total value of Northern Ireland's output for livestock and livestock products (25% compared with 12% for the Republic of Ireland).

The number of cattle recorded on farms at June 1999 (1.7 million) was 3% lower than at June 1998. Total sheep numbers (2.9 million) were also 3% lower. The problems in the pig sector were reflected in a 25% decline in total pig numbers between June 1998 and 1999 and at

490,000 was the lowest figure for 50 years. The commercial laying flock, (2.1 million birds) was 16% lower in June 1999 than the year before. Between 1998 and 1999, the total area of land used for cereals decreased by 6% to 42,000 hectares whilst the area used for potatoes remained unchanged at 7,500 hectares. The total area under grass increased by 1% to 838,000 hectares. A higher proportion of land under crop and horticulture is dedicated to fruit (3%) potatoes (13%) in Northern Ireland than Republic of Ireland (fruit 0.3%; potatoes 4%). In 1999-2000 there were 83,000 hectares of forested area in Northern Ireland: 74% state forests and 26% privately owned. Timber production from state forests was valued at approximately £4.1 million.

In 1998, the external sales of Northern Ireland’s food and drinks processing sectors were approximately £1,100 million. More than 65% of these external sales were accounted for by three processing sectors: milk and milk products; beef and sheep meat; and poultry meat.

Around 25,000 tonnes of fish were landed in Northern Ireland in 1998, 95% of which was landed by Northern Ireland boats. The value of all fish landed in Northern Ireland was approximately £20.2 million. Between 1996 and 1998, the total volume sea fish landed in the Republic of Ireland fell by 2% but the nominal value of the total catch increased by 15%. In Northern Ireland, the same period saw a 10% fall in volume and a 4% rise in the nominal value.

Revenue generated from visitor tourism in 1999 showed a nominal increase of 22% compared with 1998 (19% in real terms). More than 500,000 home holidays were taken in Northern Ireland in 1999, a decrease of 6% on the 1998 total. Between 1994 and 1999, there was a 65% increase in the number of visits to the Republic of Ireland and a 28% increase in the number of visits to Northern Ireland. In the Republic, the totals for leisure/recreation and business visits each increased by more than 80%. In Northern Ireland, there was an 11% increase in holiday and visits and a 29% increase in business visits.

2.2.3 Employment

There were an estimated 680,000 people in employment in Northern Ireland in Spring 2000 (Labour Force Survey). Of these, 85% were employees, 13% were self-employed and 1% on Government employment and training programmes. At June 2000, the Quarterly Employment Survey indicated that there were 635,740 employee jobs in Northern Ireland, 52,320 (9%) more than at June 1995. Part-time jobs accounted for more than half of this increase. Between June 1995 and June 2000, there were marked increases in the number of employee jobs in the service sector (11%) and in female part-time employment (16%). In Northern Ireland, manufacturing industry accounted for some 20.1% of the region’s GDP in 1997, compared to 21.3% for the UK as a whole. Agriculture, forestry and fishing accounted for 4.8% of the region’s GDP in 1997, compared to 1.5% for the UK. The total agricultural labour force including part time and casual labour in 1999 (59,200) was 3% lower than in 1998. Between 1994 and 2000, agricultural employment as a proportion of total Republic of Ireland employment fell from 12% to 8%.

The International Labour Office’s (ILO) unemployment rate in Northern Ireland for Spring 2000 (7.0%) was equal to that of London and was the third highest of all UK regions and 1.5 percentage points lower than the EU average. Between 1989 and 1999, the seasonally adjusted figure for NI claimant count unemployment fell by 52,200 (50.7%). At June 2000, the Travel to Work Areas with the highest rates of unemployment were Strabane (9.4%) and

Londonderry (8.6%). In Spring 2000, 533,000 people in Northern Ireland were economically inactive (i.e. neither employed nor ILO unemployed). This represented an increase of 24,000 since March-May 1999.

2.2.4 Incomes and expenditure patterns

In UK terms Northern Ireland is a region of high unemployment, although now lower than in the recent past, and low incomes per household but again there is much variation within the region. In 1999 average weekly earnings for people in the region were the lowest in the UK; £344.90 compared with the UK average of £398.70. However, while NI household income and expenditure is lower than the UK average it exhibits a similar pattern when controlled for household composition and housing tenure. Household incomes in Belfast (£348) and in the west of the region tend to be below the NI average. Household income in the east of the region (£382) is slightly higher than the NI average (£355). In 1998-99, approximately 60% of household income in Northern Ireland was derived from wages and salaries. NI households derive a markedly higher proportion of their income from social security benefits and a markedly lower proportion from wages and salaries compared with Great Britain.

The average gross weekly wage in Northern Ireland at April 1999 was £344.90, around 4% higher that at April 1998. Average gross weekly earnings were highest in education and were higher in the public sector than in the private sector. This represents reversal in the relative positions of public sector and private sector salaries and wages obtaining in the remainder of the UK. Between 1998 and 1999, public sector earnings increased by 2.8%, private sector earnings by 4.1%. In 1999, average NI earnings for both men and women in manual occupations were the lowest of all UK regions. For non-manual occupations, NI average male earnings were the lowest of all UK regions aside from Wales and the North East whilst NI female earnings were the sixth lowest.

In 1998-99, NI households spent 21% of their average weekly expenditure on food, 14% on motoring and 11% on leisure services. The region’s households spent a higher proportion of average weekly expenditure on food and a lower proportion on housing compared with households in the rest of the United Kingdom. The average price of new houses sold by National House Building Council (NHBC) registered builders in 1999-2000 was £75,000, 6% higher than in 1998-99. Some 68% of houses in Northern Ireland are either owned outright or owned with a mortgage, whilst close to a quarter are rented from the Northern Ireland Housing Executive (NIHE). Private rentals account for a lower proportion of NI than GB tenures.

2.2.5 Housing patterns

In 1998-99, more than 90% of all NI households were in detached, semi-detached or terraced housing. Only 6% of the region’s households were in purpose-built flats or maisonettes. Detached houses made up more than half of all NI homes owned outright. Terraced houses accounted for close to three quarters of the region’s public sector rentals. More than half of the region’s households were in housing built after 1965. In 1999-2000, more than 10,000 new dwellings were completed in Northern Ireland, an increase of 13% on 1995-96. The private sector accounted for around 90% of these completions. Between 1994 and 1999, the average price of a new house in the Republic of Ireland more than doubled. Over the period 1995-1999, the NI average house price increased by 21%.

Table 2.2. Method of travel to work, 1996.

Method of Travel	*Republic of Ireland* Number	%	*Northern Ireland* Number	%
Car, van, mini-bus	766,900	67.6	451,000	79.8
Motorbike, moped, scooter	12,200	1.1	*	*
Bicycle	46,400	4.1	*	*
Bus, coach	98,300	8.7	36,000	6.4
Train	22,600	2.0	*	*
Walk	148,400	13.1	64,000	11.3
Other method (including not stated)	40,600	3.6	*	*
Total	1,135,400	100.0	565,000	100.0

Sources: Republic of Ireland: Central Statistics Office
Northern Ireland: Department of Enterprise, Trade and Investment

Note: Figures are based on those in employment who travel to work and therefore exclude those working from home. Figures for the Republic of Ireland are from the Census '96. Figures for Northern Ireland are from the Labour Force Survey Autumn 1996.

2.2.6 Cars and consumer durables

Between 1998 and 1999, the number of NI licensed vehicles increased by around 4%. Over the ten-year period from 1990 to 1999, the NI licensed vehicle stock increased by 33% compared with 20% in Scotland and 15% in both England and Wales. Although similar proportions of NI and GB households are car or van owners (70% and 72% respectively), 28% of households in Great Britain own more than one car, compared with just 22% in Northern Ireland (cf. Table 2-2). Ownership of the main consumer durables (washing machine, telephone, etc.) is broadly similar for NI and GB households. In 1998, there were more than 138,500 new car registrations in the Republic of Ireland, two thirds more than in 1990. In Northern Ireland, there were more than 62,000 new registrations, just under a fifth more than in 1990.

2.2.7 Environmental quality

A fifth of the total area of Northern Ireland is designated as Areas of Outstanding Natural Beauty; just under a sixth is Green Belt land. Acid deposition from acid rain is a widespread problem for soils in Northern Ireland: Jordan and Hall (1997) found that the 'critical load' of acidity was exceeded in 54.5% of 1 km square samples covering the Province. Exceedance was greatest in the extreme north-east, north-west and south-west. However, the chemical water quality of around 56% of the 2,426 km of river monitored between 1997 and 1999 was 'very good or 'good'. This compares with 48% of the 1,970 km of river waters monitored between 1990 and 1992. In the period 1997-99, just over 4% of the river length tested was 'poor' or 'bad' compared with around 6% between 1990 and 1992. Hence there are reasons for both concern and optimism with respect to freshwater water quality of the region's rivers. The major lakes of Lough Neagh and Lower Lough Erne have been degraded by input of phosphate hitherto from domestic sources but more recently from agricultural fertilisers.

Air quality in Northern Ireland is generally good, although under stagnant meteorological conditions pollution from domestic heating, transport and industrial sources may promote the development of intense pollution episodes. The problem is particularly apparent in winter when anticyclonic (high pressure) conditions and associated atmospheric subsidence induces a temperature inversion that prevents the upward dispersion of pollutants. In summer, persistent anticyclonic circulation may also lead to significant reductions in air quality. The situation is enhanced by local topography trapping pollutants in natural basins.

Such a location is epitomised by the Belfast urban area occupying lowland between the Antrim plateau escarpment to the west and the County Down hills to the east and south-east. Black Mountain rises to over 300 metres while the Craigantlet and Castlereagh hills exceed 150 metres. Steep slopes lead from these surrounding hills towards the low-lying and almost flat areas adjacent to the river Lagan occupied by Belfast CBD, and less than 5 metres above sea-level. As the primary city of Northern Ireland by a considerable margin, Belfast experiences the most significant atmospheric pollution within the Province and has a history of chronic air pollution continuing up to the present-day.

The Lagan valley, provides a natural corridor for pollution dispersal from Belfast by prevailing south-westerly winds. This ventilation is enhanced by higher mean wind speeds than experienced in southern areas of the British Isles. Anticyclonic weather, however, when accompanied by easterly or southerly airflow, may result in pollutants not only being trapped beneath an inversion, but also hindered from horizontal dispersion by banking up against the Antrim plateau. Under such meteorological conditions, Belfast has considerable difficulty in complying with air quality standards particularly in relation to sulphur dioxide and fine particles.

Less heavily-industrialised than many other cities in the British Isles, the problem of high atmospheric pollution episodes in Belfast has persisted long after initial introduction of clean air controls in 1964. Particularly in winter, the chronic problem of both gaseous and particulate pollution stems from poor enforcement of clean air legislation and the continued use of coal and oil for domestic fuel as availability of piped-natural gas is still limited. In September 1998 regulations were made which ban the sale of unauthorised fuels in Smoke Control Areas, and set a maximum 2 per cent limit on the sulphur content of solid domestic fuel. It remains to be seen the degree by which these new controls will drive down levels of sulphur dioxide and particulates still further.

Persistent anticyclonic weather in summer can also result in high atmospheric pollution levels in the form of photochemical pollution, although with the lower vehicular traffic levels and less intense solar radiation receipt, the scale of the problem is less severe than in London or Birmingham and markedly reduced in comparison with Los Angeles, Mexico City or Athens. Nevertheless, with the introduction of policies to further reduce domestic pollution emissions, other sources , including road traffic, are now being examined more closely.

Air quality monitoring in Northern Ireland is the responsibility of Environment and Heritage Service, an Executive Agency of the Northern Ireland Department of the Environment (DoENI) and district councils. The DoENI multi-pollutant station monitoring sulphur dioxide, carbon monoxide, ozone, nitrogen oxides and particulates (PM_{10}) in Belfast, is complemented by a hydrocarbon unit and a sulphur dioxide site in the city. The Department's rural site at Lough Navar, County Fermanagh, monitors ozone and particulates (PM_{10}).

DoENI monitors for the heavy metals lead, cadmium, arsenic, nickel, zinc and mercury has been established in Belfast, Londonderry, and Carrickfergus. Monitoring of poly-aromatic hydrocarbons (PaHs) occurs in Lisburn.

In addition to the DoENI sites, several councils measure smoke, sulphur dioxide and nitrogen dioxide. Belfast City Council has installed a particulate matter (PM_{10}) monitor in East Belfast, and a multi-pollutant site, similar to the DoENI station in Belfast, is operated by Derry City Council.

Chapter 3. Climate change in Northern Ireland

Nicholas L. Betts
School of Geography, Queen's University Belfast

Summary
Four climate change scenarios for Northern Ireland are derived from the GCM-based UKCIP98 scenarios, each relating to variation in sensitivity of the climate system to changing concentrations of greenhouse gases. Climate changes are presented for three future thirty-year periods centred on the 2020s, 2050s and 2080s. The climate changes for each period are calculated as the changes in respect to the 1961-90 average. Dependent on scenario, from a 1961-90 mean of 334 ppmv, atmospheric carbon dioxide concentration is estimated to fall within the range 498 ppmv to 697 ppmv by the 2080s. As a result, increases in mean annual temperature of between 1°C and 2.8°C are anticipated by the 2080s. Enhancement of mean temperature in winter of up to 2.9°C and 2.5°C in summer is also possible. Inter-annual variability of winter temperature decreases, with very cold winters becoming rarer. In contrast, summer variability increases with greater frequencies of hot summers. Changes in precipitation are less consistent between seasons and scenarios than those for temperature. By the 2080s mean annual precipitation increases by up to 13%, with winter enhancement of up to 22% and similar increases in autumn. Summer precipitation is estimated to decline by up to 7%. Inter-annual variability in precipitation increases in all seasons and is greatest in autumn. Daily precipitation intensities are expected to increase in both summer and winter. Overall gale frequency declines, but very severe winter storms are expected to increase. These climate change scenarios are anticipated to result from greenhouse gas forcing of the climate system. It is important to note that natural climate variability will affect this human-induced climate change.

3.1 Introduction

A set of national climate change scenarios for the UK were commissioned by the DETR for the UK Climate Impacts Programme (Hulme and Jenkins, 1998). These scenarios — the 'UKCIP98 climate scenarios' — are national in their purpose, but subsequently have been used as a starting point in a number of impacts and adaptation applications, including scoping studies of climate change impacts at the regional level within the UK.

In this report, a brief synopsis compares recent trends in Northern Ireland climate with those of global climate change. The National UKCIP98 scenarios are then taken and interpreted where possible for the Northern Ireland climate. The UKCIP98 scenarios of future climate change are measured with respect to the 1961-90 mean climate of the region. This baseline is not necessarily representative of the long-term climate, but it is the thirty-year period for which observed data is best available, and is the current World Meteorological Organisation (WMO) reference period against which climate change is assessed.

3.2 Global climate change

Climate can be viewed as a series of energy transformations and exchanges within and between the atmosphere and the underlying surface. In association with the radiative properties of the Earth's atmosphere, these exchanges and transformations act in such a way as to distribute energy over the globe and maintain the Earth's temperature within a range conducive to the support of life. The climate system varies naturally in response to variations in solar output, land surface processes, oscillations within the ocean-atmosphere system and the orbital characteristics of the Earth. Climate change throughout the Earth's history has also been induced by proportional variation in atmospheric constituents that control its radiative properties.

During the 20th century the global-averaged surface temperature increased by 0.6°C +/- 0.2°C with most of the warming occurring during two periods, 1910 to 1945 and 1976 to 2000. In the Northern Hemisphere, the 1990s probably represented the warmest decade and 1998 the warmest year during the past 1,000 years. It is also very likely that precipitation increased by 0.5 to 1% per decade in the 20th century over most middle and high latitudes of the Northern hemisphere continents, with a 2 to 4% increase in the frequency of heavy precipitation events (Houghton *et al*., 2001).

The balance of evidence suggests the existence of a discernible human influence on global climate, with most of the observed warming over the last 50 years likely to have been due to the increase in anthropogenic emissions of greenhouse gases (Houghton *et al*., 2001). It is expected that relative to the year 2000, global mean radiative forcing due to greenhouse gases will continue to increase through the 21st century, with the proportion due to carbon dioxide projected to increase from slightly more than half to about three quarters.

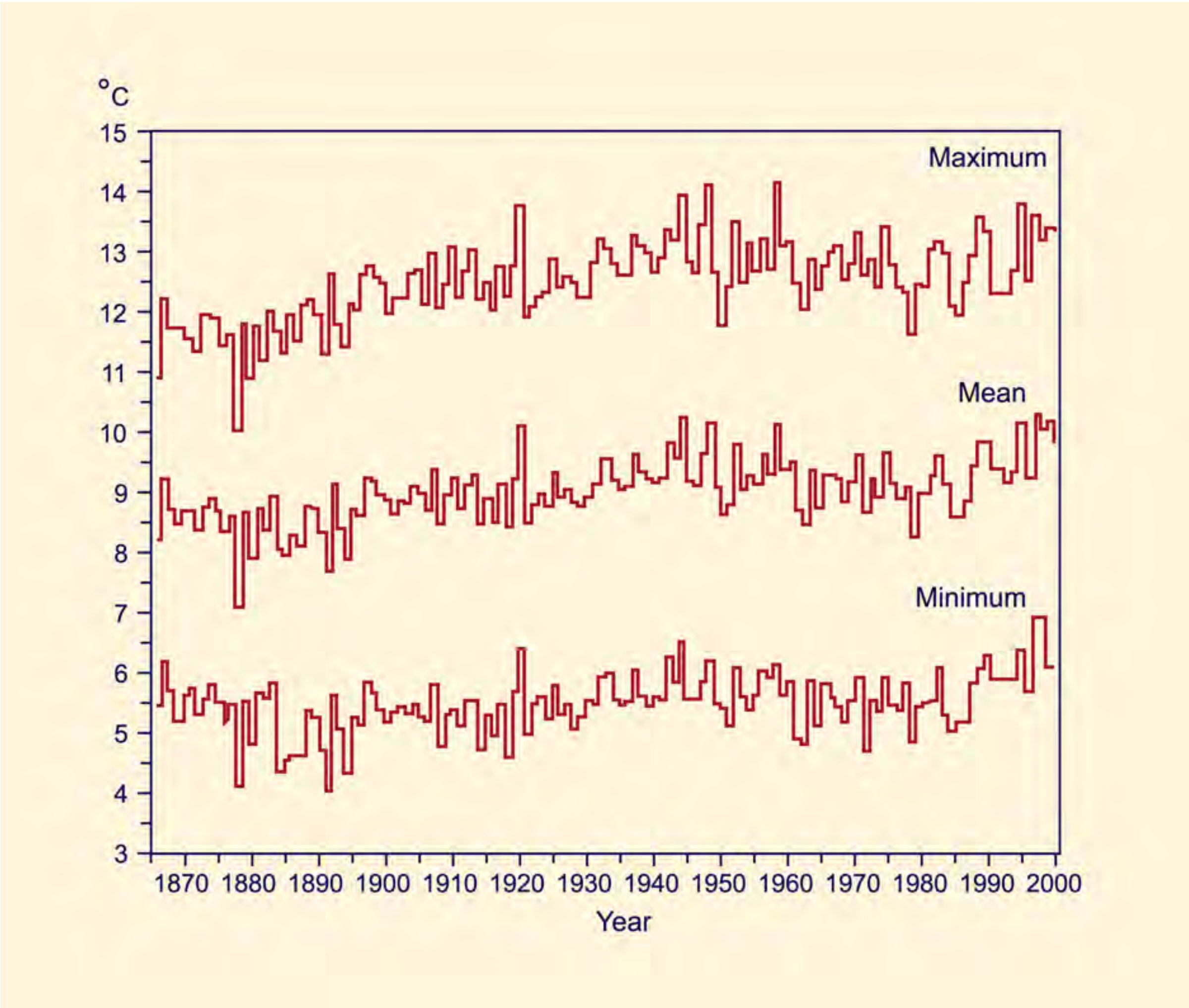
3.3 Recent trends in the climate of Northern Ireland

Against the background of global climate fluctuations over the past century, it is of interest to consider recent climate changes in Northern Ireland. This will also be useful in placing in context discussion of future changes.

3.3.1 Temperature

The meteorological station at Armagh Observatory (Figure 3-1) where observations have been carried out since 1795, possesses the longest continuous series of records in Northern Ireland, dating back to 1844. Butler (1994) has demonstrated that the site in experiencing little environmental change, provides data that reflects the general lowland temperature variations experienced in the Province since the mid 19th century. Figure 3-1 presents the annual mean maximum, annual mean minimum and annual mean temperature at Armagh Observatory for the period 1866-2000, data corrected for thermometer errors. The amplitude of the variation in minimum temperature is less than that in maximum temperature, but the long-term variations in maximum and minimum temperatures have the same general behaviour. A colder than average period is evident in the second half of the 19th century, a significantly warmer period around 1950, a fall in temperature during the decades of the 1960s and 1970s and subsequent rise from the 1980s. The latter rise is reflected in the work of Werner *et al.* (2000), who identify the decade 1981-1990 as the onset of climate change in the North Atlantic/European sector.

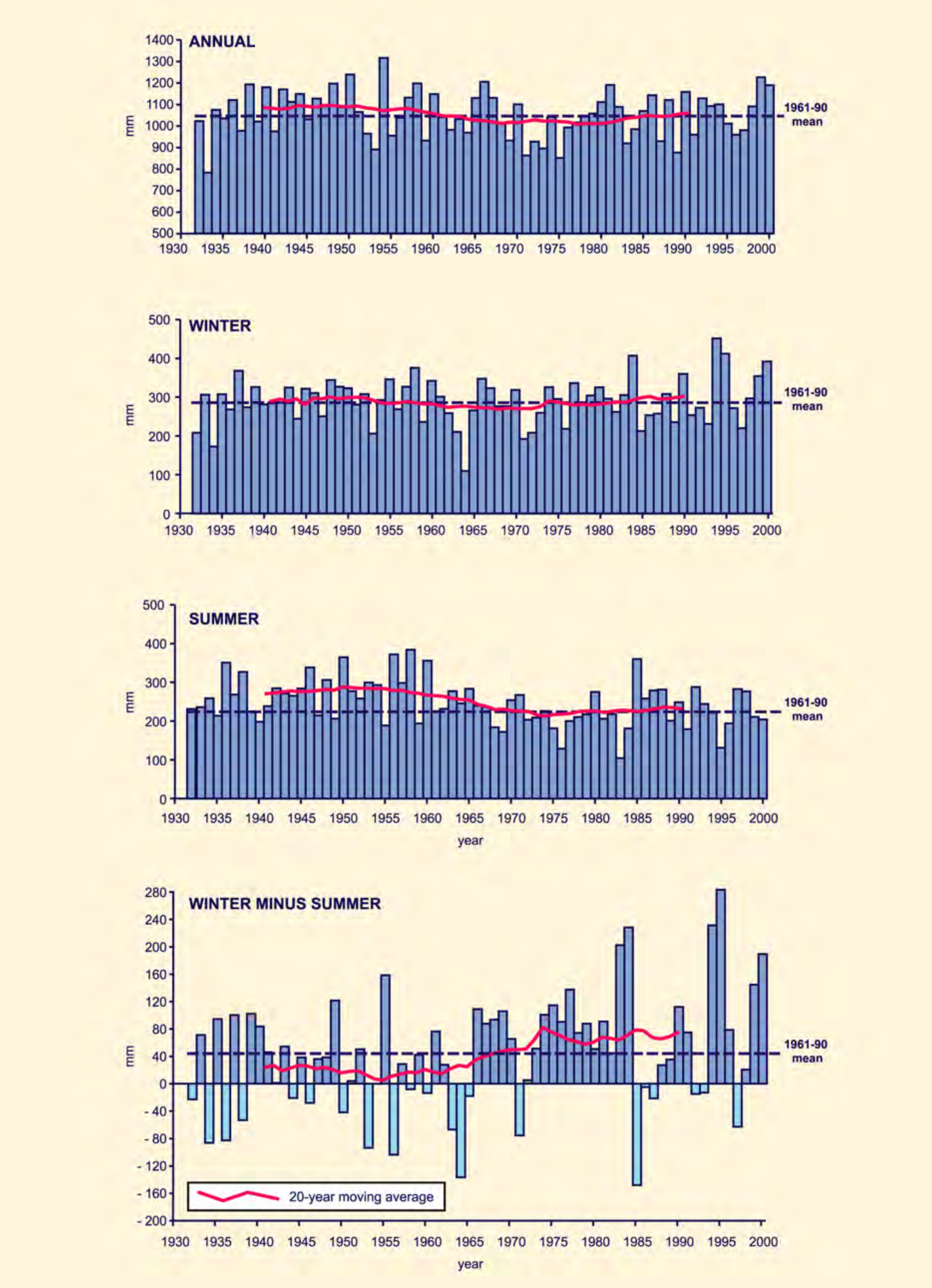
FIGURE 3-1: The annual mean maximum, annual mean minimum and annual mean temperature at Armagh Observatory, 1866-2000 (derived from Butler, 1994).



3.3.2 Precipitation

Recent precipitation trends can be ascertained using area-average data obtained from the updated homogeneous series of monthly rainfall for the spatially coherent precipitation region of Northern Ireland (Gregory *et al.*, 1991; Jones and Conway, 1997). Figure 3-2 shows the annual, winter, summer and winter minus summer precipitation totals for the period 1931-2000.

FIGURE 3-2: Annual, winter and summer precipitation totals (mm) for Northern Ireland, 1931-2000. The bottom panel shows the difference between winter and summer precipitation (derived from Gregory *et al*., 1991; Jones and Conway, 1997).



From an annual perspective, no statistically significant long-term trend is evident. Variability from year-to-year is greatest in winter (December-February). No statistically significant trends are evident in winter precipitation, although the recent winters of 1999-2000, 1994-1995, 1993-1994 and 1983-1984 were the wettest of the Northern Ireland series. Over the past three decades, summers (June-August) generally, have been drier than earlier in the period. In particular, the summers of 1976, 1983 and 1995 experienced markedly anomalous low precipitation. The lower panel in Figure 3.2 depicts the difference between winter and summer precipitation in Northern Ireland. An increasing trend towards contrasting behaviour of winter and summer precipitation is apparent. This change is consistent with expectations under the UKCIP98 scenarios discussed in section 3.5.2.

Osborn *et al.* (2000) indicate that over Northern Ireland during the period 1961-95, the slight upward trend in mean winter precipitation has been manifested by a combination of more frequent wet days and more precipitation on those wet days. This has coincided with an upward trend in the winter North Atlantic Oscillation from the 1960s to the early 1990s (Hurrell, 1995) that is associated with stronger and more frequent westerly and south-westerly airflow. Such weather patterns cause more frequent heavy rainfall events and it is likely that the winter circulation changes have contributed to the increase in the proportion of precipitation provided by heavy events. Increases in mean intensities are also apparent in the autumn (September-November), but weaker in the spring (March-May). Conversely, in summer there has been a slight decline in mean intensities.

Climatic variation is an important source of year-to-year variation in flood series. In relation to recent precipitation fluctuations, however, no statistically significant evidence is available to show that climate change has affected Northern Ireland flood behaviour (Robson *et al.*, 1998).

3.3.3 Storminess

Studies of storminess in the Atlantic/European sector present contradictory evidence of fluctuations in storm incidence. Lamb (1991) suggested increased storm frequency in the eastern Atlantic since 1950, and Schinke (1993) identified a marked increase in occurrence over the period 1931-1990. A sequence of very intense depressions affected Northern Ireland in the late 1980s and early 1990s (Betts, 1990b; 1991), a period characterised by a very high North Atlantic Oscillation index (Zveryaev, 1999). Since the early 1990s, however, there is an indication of a return to less intense storm activity. Over the past century the storm record shows no significant trend, events falling within the range of ‘random’ fluctuations to be expected in the long-term wind climate of Northern Ireland (Betts, 1994).

3.4 Climate change scenarios for the 21st century

Atmospheric concentrations of greenhouse gases have risen markedly over the past 200 years. The atmospheric concentration of carbon dioxide, the gas most heavily implicated in the enhanced greenhouse effect, has increased by 30% over pre-industrial levels. Pre-industrial carbon dioxide concentrations were approximately 275 ppmv, and the average 1961-90 concentration was about 334 ppmv. Over the past two decades the rate of increase of atmospheric carbon dioxide concentration has been 0.4% per year. During the 1990s the year to year increase varied from 0.2 to 0.8%, a large part of this variability being due to the effects of climate variability (e.g. El Niño events) on carbon dioxide uptake and release by land and oceans (Houghton *et al*., 2001).

3.4.1 Climate change models

Much of the information relating to the potential effects of greenhouse gases on global warming is derived from climate change models. These models, mathematical representations of the atmosphere and oceans, have usually, but not exclusively, a global focus. The models can be run for a variety of different rates of increased concentrations of greenhouse gases and for different sensitivities of the climate system to the effects of greenhouse gases. The results of these experiments take the form of future climate change scenarios. The methods of deriving climate scenarios from Global Climate Model (GCM) experiments have been reviewed comprehensively in the literature (Conway, 1998).

This report is based upon climate scenarios developed by the Hadley Centre of the Meteorological Office and the Climatic Research Unit, University of East Anglia for the UKCIP. These were derived from the results of a coupled ocean-atmosphere GCM called HadCM2. The spatial resolution of the model over the British Isles comprises grid boxes corresponding to about 300 km by 350km. Four boxes cover most of Great Britain and one box incorporates much of Eire, but excludes the North of Ireland. The grid box incorporating Northern Ireland possesses a large ocean/land ratio and effectively exists only as 'ocean' in the GCM. This presents a problem of appropriateness of model output within this box for application to future climate scenarios for the region.

The Hadley Centre for Climate Prediction and Research (Geoff Jenkins, personal communication, March 2001) advised the climate change for Northern Ireland be determined by averaging the output from the Northern England and Eire grid boxes. It was considered inappropriate to apply a weighted average to the grid squares adjacent to Northern Ireland, as the spatial resolution of the data does not merit this. Furthermore, it is important not to over-emphasise the detail of the climate changes from the GCM, but to consider also the importance of natural variability, which in turn, may increase under a changing climate.

3.4.2 UKCIP98 scenarios

The UKCIP98 scenarios comprise four alternative future climate outcomes termed **Low**, **Medium-low**, **Medium-high** and **High**. The **Low** and **Medium-low** scenarios assume a relatively slow increase of around 0.5% per annum in future greenhouse gas concentrations. In contrast, the **Medium-high** and **High** scenarios assume an increase in future concentrations of approximately 1% per annum.

The difference between the **High**, **Medium-high**, **Medium-low** and **Low** UKCIP98 scenarios originates from the sensitivity of the climate system to changing concentrations of greenhouse gases (Hulme and Jenkins, 1998). The **High** scenario assumes the highest likely sensitivity and the Low the lowest likely sensitivity, with the **Medium-high** and **Medium-low** scenarios lying between the extremes.

The scenarios do not incorporate consideration of sulphate aerosol influences upon climate forcing. Furthermore, these scenarios are not to be used as forecasts of what might happen, rather they should be viewed as possible outcomes each of which is equally likely.

3.5 UKCIP98 Climate Scenarios – interpreted for Northern Ireland

The possible future climate changes for Northern Ireland presented here relate to three future thirty-year periods centred on the 2020s, the 2050s and the 2080s. The climate changes for each of these periods are calculated as the change in thirty-year mean climates with respect to the 1961-90 average. The 2020s are representative of the period 2010-2039, the 2050s of 2040-2069 and the 2080s of 2070-2099.

The results presented here relate mainly to the **Medium-high** scenario, but this does not imply that this is the most likely outcome. It is simply that more information is available for this scenario. This scenario suggests changes of significant magnitude and thereby represents a useful framework to measure the impact of climate change on various elements of the physical and human environments of Northern Ireland. Since the other three scenarios are equally likely to occur, and it is important to be aware of the differences between them, a summary of data from the UKCIP98 scenarios relating to the Province is provided in Table 3-1.

Table 3.1. Climate changes during the 21st century associated with the four UKCIP98 scenarios. Values presented in the order: **Low, Medium-low, Medium-high** and **High** scenarios (source: Hulme and Jenkins, 1998).

Temperature (change °C)

	2020s				2050s				2080s			
Summer	0.5	0.9	1.2	1.3	0.8	1.3	1.8	2.1	1.1	1.9	2.2	2.5
Winter	0.4	0.7	1.1	1.2	0.8	1.3	1.7	2.0	1.0	1.6	2.6	2.9
Annual	0.5	0.8	1.1	1.2	0.8	1.3	1.7	2.0	1.0	1.6	2.5	2.8

Diurnal temperature range (change °C)

	2020s				2050s				2080s			
Summer	0	0	0	0	0	0	0	0	0	0.1	-0.2	-0.3
Winter	0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.1	-0.2	-0.2	-0.3
Annual	0	0	-0.1	-0.1	0	-0.1	-0.1	-0.1	0	0	-0.1	-0.2

Precipitation (percentage change)

	2020s				2050s				2080s			
Summer	0	1	1	1	0	0	-7	-8	-4	-7	-2	-3
Winter	4	8	10	11	6	11	11	13	7	12	20	22
Annual	2	4	5	6	3	5	4	4	2	4	12	13

Vapour pressure (change hPa)

	2020s				2050s				2080s			
Summer	0.5	0.8	1.1	1.2	0.7	1.2	1.5	1.7	0.9	1.6	2.2	2.4
Winter	0.3	0.4	0.7	0.8	0.5	0.8	1.1	1.3	0.7	1.1	1.7	1.9
Annual	0.4	0.6	0.8	0.9	0.6	0.9	1.3	1.5	0.7	1.2	1.9	2.2

Cloud cover (change in percentage of the sky covered)

	2020s				2050s				2080s			
Summer	-1	-1	-1	-1	-1	-1	-1	-1	-1	-2	0	0
Winter	0	0	0	0	0	0	0	0	0	0	1	1
Annual	0	0	0	0	0	0	0	0	0	0	0	0

Mean wind speed (speed change in m s^{-1})

	2020s				2050s				2080s			
Summer	0	0	0	0	0	0	0	0	0	0	1	2
Winter	0	0	1	1	1	1	-1	-1	0	0	0	0
Annual	0	0	0	0	0	0	0	0	0	0	1	1

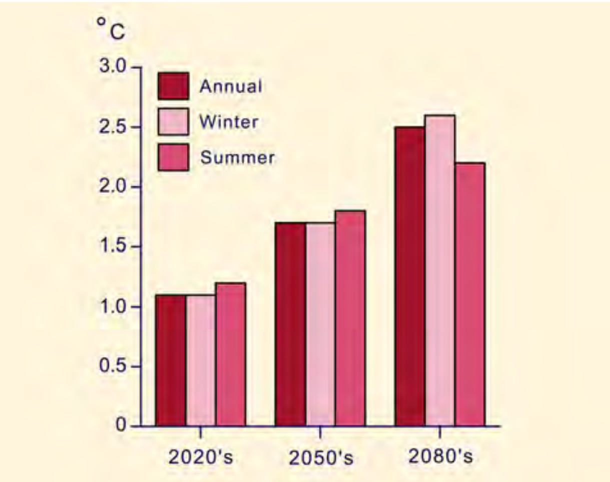
Potential evapotranspiration (percentage change)

	2020s				2050s				2080s			
Summer	2	3	4	5	2	4	7	8	5	9	6	7
Winter	-7	-12	0	0	6	-12	-4	-4	-7	-12	-12	13
Annual	2	3	4	5	3	5	7	8	5	8	7	8

3.5.1 Temperature

The rate of future climate warming in Northern Ireland for the four scenarios ranges from 1.0°C per century for the Low scenario to 2.8°C for the High scenario. For comparison, mean annual temperature at Armagh increased by about 0.4°C over the 20th century (Butler, 1994). Changes in mean annual, winter and summer temperatures in Northern Ireland associated with the Medium-high scenario for the three future thirty-year periods centred on the 2020s, the 2050s and the 2080s are shown in Figure 3-3. Changes are expressed in comparison with the 1961-90 mean. Warming is slightly greater in summer than winter until the 2050s. Thereafter the opposite applies, culminating in winter warming of 2.6°C and summer warming of 2.3°C by the 2080s.

FIGURE 3-3: Changes in mean annual, winter and summer temperature over Northern Ireland with respect to the 1961-90 mean for thirty-year periods centred on the 2020s, 2050s and 2080s under the UKCIP98 Medium-high scenario.



By the 2080s under the Medium-high scenario, the diurnal temperature range with respect to the 1961-90 mean reduces by 0.3°C in winter and summer, although the greatest reduction is in spring (-0.4°C). These diurnal temperature changes are consistent with the anticipated increase in cloud cover (1%). Winter, summer and spring also experience incident short-wave radiation decreases of between 1 and 2 Wm^{-2}. In contrast, Autumn experiences an increase in the diurnal temperature range of almost 0.2°C. This is paralleled by an increase of incident short-wave radiation of more than 3 Wm^{-2} and reduced cloud cover (2%).

The year-to-year variability in seasonal temperatures also changes. It is evident from Table 3-2 that winter variability decreases in all three periods, indicative of very cold winters becoming more rare. Conversely, summer variability increases, with the more frequent occurrence of hot summers. Notwithstanding this, the oceanic influence upon the Northern Ireland climate manifests itself in the rarity of marked daily temperature extremes.

Table 3.2. Changes in the inter-annual variability (per cent) in mean annual and seasonal temperatures of Northern Ireland with respect to the 1961-90 mean for thirty-year periods centred on the 2020s, 2050s and 2080s, under the **Medium-high** scenario. Changes are from pooled results of four HadCM2 ensemble experiments, and are calculated as the per cent change in the standard deviation (source: Hulme and Jenkins, 1998).

Season	2020s	2050s	2080s
Winter	-5	- 17	-16
Spring	-1	+12	+8
Summer	+6	+42	+16
Autumn	+6	+4	+15
Annual	+1	+11	+4

Armagh has the highest continentality index value (i.e. has a local climate which is least moderated by oceanic proximity) relating to temperature within the Northern Ireland climatological station network (Betts, 1997), yet a summer incorporating a ‘hot’ day with a maximum temperature above 25°C has a return period of approximately 2 years in the present climate regime. In the last 25 years, however, four summers have recorded over 13 ‘hot’ days each – 1976, 1983, 1989 and 1995. Under the Medium-high scenario, however, the annual mean number of degree-days for a maximum daily temperature above 25°C for Northern Ireland more than trebles by the 2080s. Furthermore, the summer warmth of 1995 with an anomaly of 1.9°C above the 1961-90 average at Armagh, equates to the average summer warmth to be expected by the 2080s under the UKCIP98 Medium-low scenario.

In consideration of the frequency of ‘cold’ winter nights, the 1961-90 seasonal mean of days with frost in Northern Ireland ranges from around 40 days along coasts up to a maximum of 58 nights inland. Under the Medium-high scenario the number of degree-days for a minimum temperature below 0°C decreases more than 75% by the 2080s. Indeed, the winter of 1988/89 with an anomaly of 2.5°C above the 1961-90 mean approaches the average winter warmth expected for Northern Ireland by the 2080s under the Medium-high scenario. Some individual winters will not reflect this trend to milder conditions, while others might be at least 4.5°C milder than the 1961-90 average, and 2°C milder than the prevailing 2080s climate.

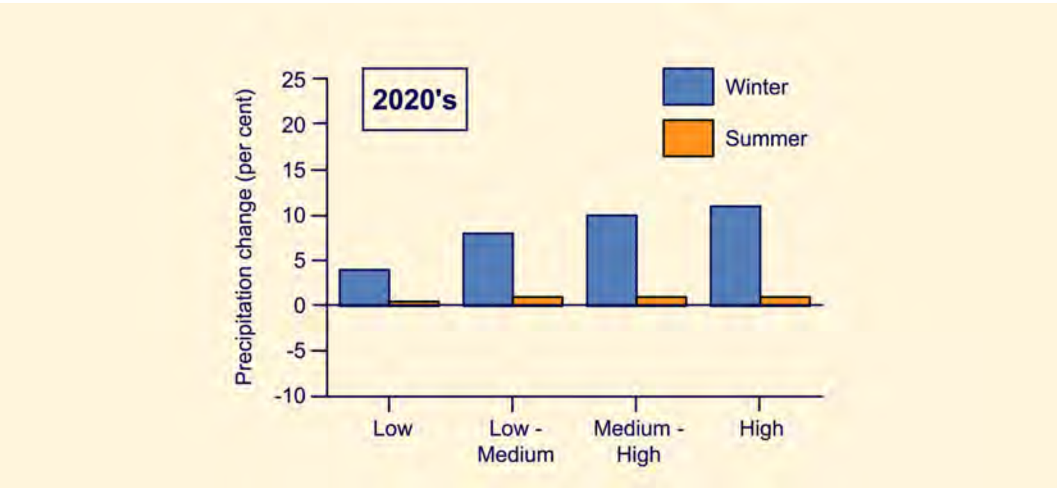
Accumulated degree-days for mean temperatures above 5.5°C (indicative of the intensity of the plant-growing season) increase by more than 5% per decade over the 21st century under the Medium-high scenario.

3.5.2 Precipitation

While the UKCIP98 precipitation scenarios are expressed in comparison with the 1961-90 mean, considerable variation in 30-year averaged precipitation totals arise naturally. For example, the Northern Ireland regional precipitation mean for the 1951-80 period was more than 6% less than the 1941-70 mean. Seasonal 30-year means can vary by even more substantial margins and such natural variability may have, for example, as great an impact upon water resource management as human-induced changes outlined below.

Changes in precipitation from the 1961-90 means for the four UKCIP98 scenarios are less consistent between seasons and scenarios than those for temperature. Annual precipitation over Northern Ireland increases in all four scenarios, by between 3 and 5% by the 2050s, but this is made up of precipitation increases in autumn and winter, decreases in summer and little change in spring. Winter precipitation increases by between 6 and 13% by the 2050s, whereas summer precipitation remains unchanged or decreases by up to 8% by the same period. By the 2080s, annual precipitation increases by between 2 and 13%, with winter enhancement of between 7 and 22% and similar increases in autumn. Summer decreases with respect to the 1961-90 average, dependent upon scenario, are between 2 and 7%. The winter and summer precipitation changes for Northern Ireland are shown in Figure 3-4 for the 2020s, 2050s and 2080s.

FIGURE 3-4: Changes in mean winter and summer precipitation (per cent) over Northern Ireland with respect to the 1961-90 mean for the thirty-year periods centred on the 2020s, 2050s and 2080s under each of the four UKCIP98 scenarios.



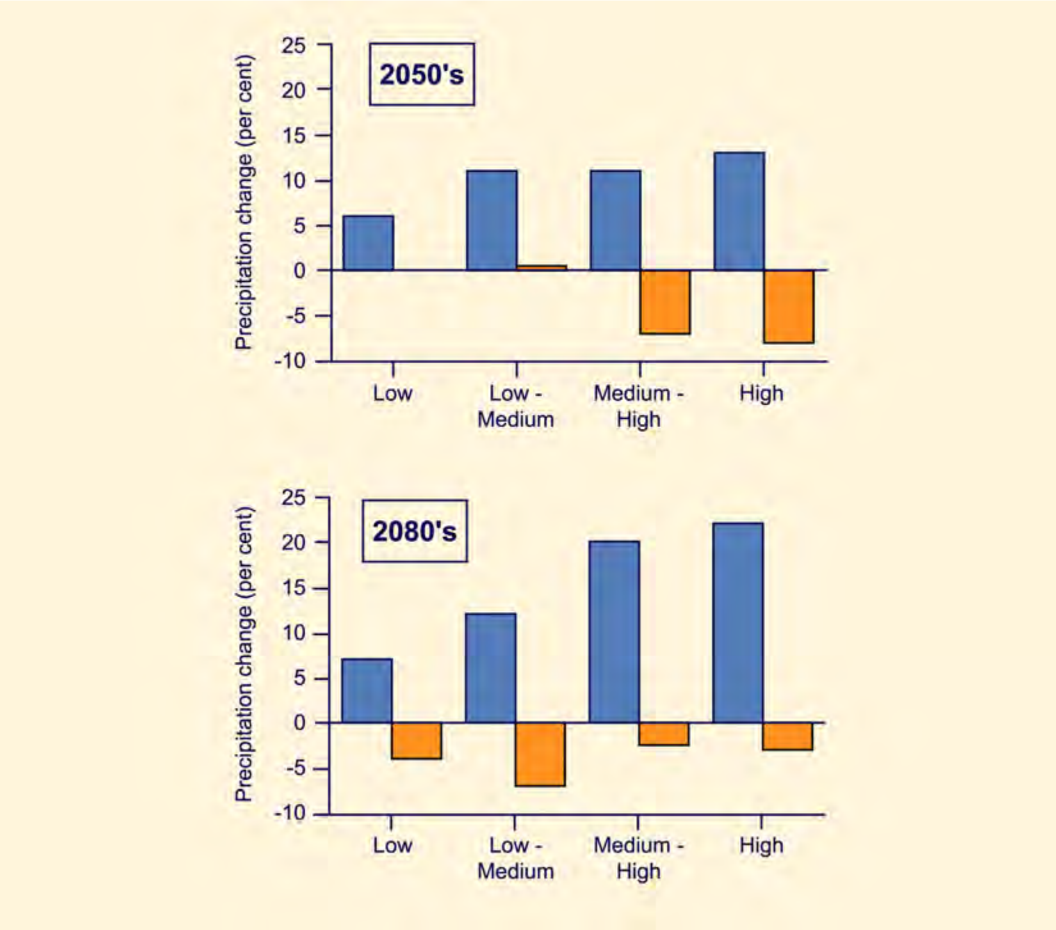


Table 3.3. Estimates of winter means of area-average precipitation for Northern Ireland in the thirty-year periods centred on the 2050s and 2080s under the four UKCIP 98 scenarios (sources: Gregory *et al.*, 1991; Jones and Conway, 1997; Hulme and Jenkins, 1998).

Scenario	Average winter precipitation (mm)
Mean 1961-90 climate	296
Wet winter (1954/55)	346
Mean 2050s climate	
Low	315
Medium-low	330
Medium-high	330
High	336
Mean 2080s climate	
Low	317
Medium-low	332
Medium-high	355
High	361

It is possible to estimate future precipitation totals by applying the seasonal changes of the UKCIP98 scenarios to the Northern Ireland area-average precipitation series (Gregory *et al.*, 1991; Jones and Conway, 1997). As indicated in Table 3-3, over the period 1931-2000 the 10th wettest winter, 1954/55, was more extreme than the respective average winter conditions in the 2050s under all four scenarios. By the 2080s, however, average winter precipitation under both the **Medium-high** and **High** scenarios, exceeds the wetness of the 1954/55 winter. In contrast, summer 1996, the 10th driest in the last 70 years, was more extreme than the average summer conditions of the 2050s and 2080s under all four UKCIP98 scenarios (Table 3-4).

Table 3.4. Estimates of summer means of area-average precipitation for Northern Ireland in the thirty-year periods centred on the 2050s and 2080s under the four UKCIP98 scenarios (sources: Gregory *et al*., 1991; Jones and Conway, 1997; Hulme and Jenkins, 1998).

Scenario	Average summer precipitation (mm)
Mean 1961-90 climate	228
Dry summer (1996)	194
Mean 2050s climate	
Low	228
Medium-low	227
Medium-high	212
High	210
Mean climate 2080s	
Low	219
Medium-low	212
Medium-high	222
High	221

Inter-annual variability in precipitation also changes. Variability increases in all seasons, resulting in less reliable precipitation totals. Under the **Medium-high** scenario annual precipitation increases by 8% come the 2050s and 16% by the 2080s. Precipitation variability increases by 19% in winter and 17% in summer by the 2080s, but variability is greatest in autumn with an increase of 25% (Table 3-5).

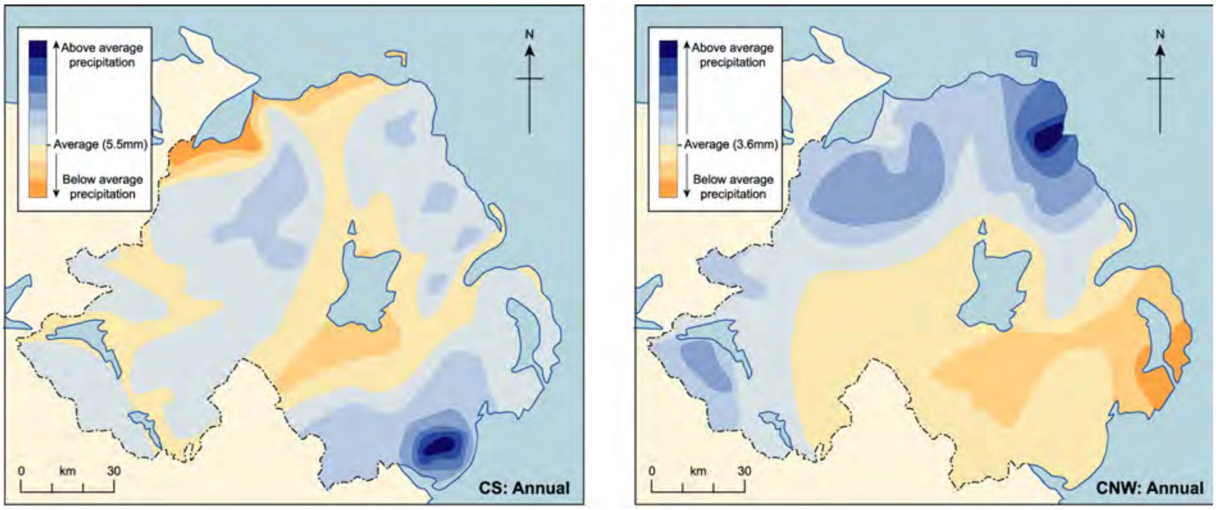
Table 3.5. Changes in inter-annual variability in mean annual and seasonal precipitation of Northern Ireland with respect to the 1961-90 mean for thirty-year periods centred on the 2020s, 2050s and 2080s, under the **Medium-high** scenario. Changes are from pooled results of four HadCM2 ensemble experiments, and are calculated as the per cent change in the standard deviation (source: Hulme and Jenkins, 1998).

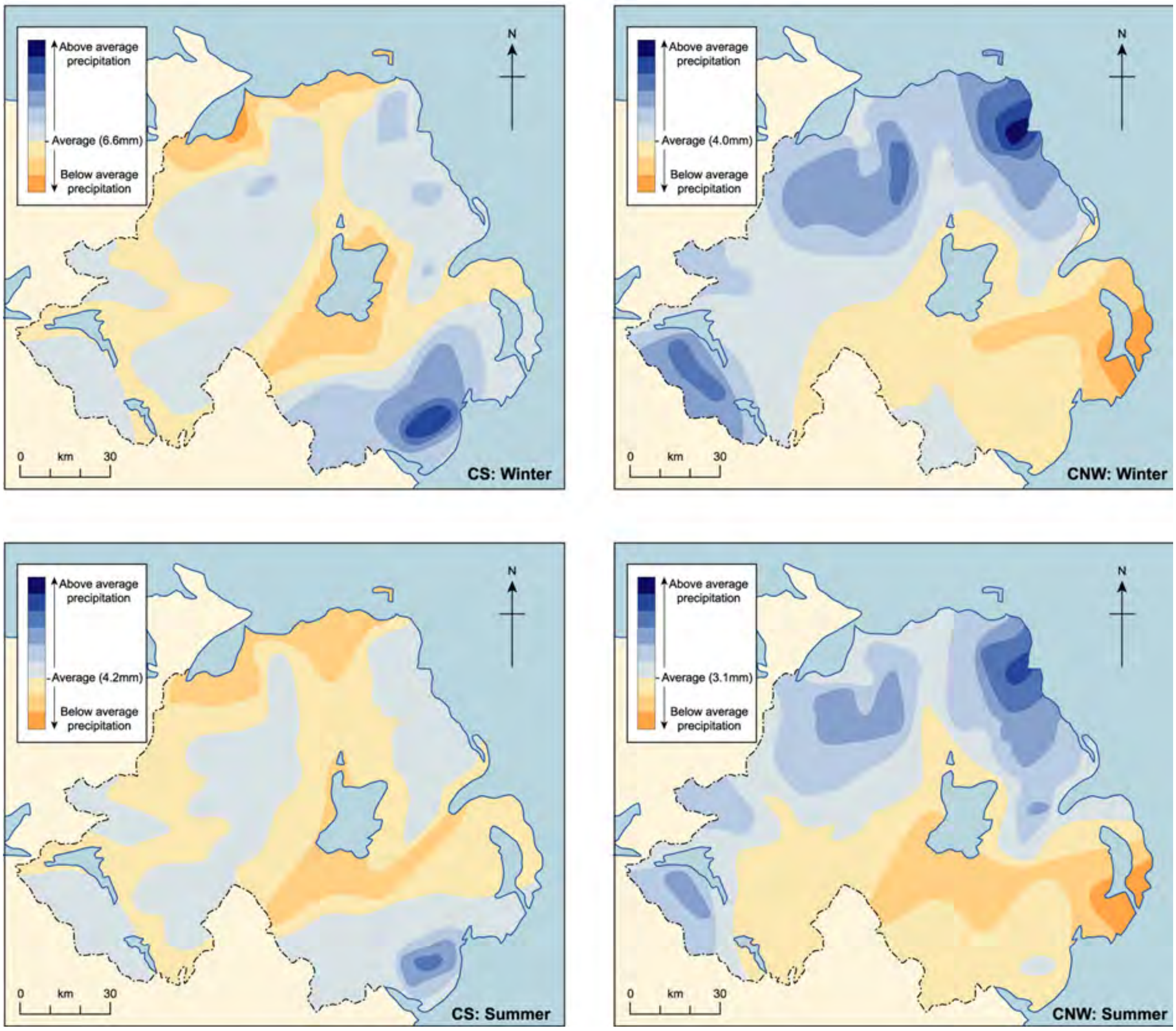
Season	2020s	2050s	2080s
Annual	+5	+8	+16
Winter	0	+4	+19
Spring	+4	+2	+7
Summer	+11	+21	+17
Autumn	+18	+13	+25

Changes in the overall amount of precipitation will be accompanied by changes in the number and intensity of precipitation events. Reference was made earlier to suggestions of recent upward trends in Northern Ireland winter daily precipitation intensities (Osborn *et al.*, 2000), and the UKCIP98 scenarios suggest that daily precipitation intensities will increase in both winter and summer over the northern UK. The most intense events are expected to occur several times more frequently than at present, thereby enhancing the flood hazard.

Precipitation distributions over a region are closely linked to the broader near-surface atmospheric circulation (Sumner, 1996). Changes in frequency of occurrence of synoptic circulation types (i.e. large-scale weather patterns) will impact upon precipitation patterns across Northern Ireland. As an example, Figure 3-5 shows annual and seasonal precipitation activity over Northern Ireland in the form of discrete daily precipitation patterns associated with two wet synoptic circulation types, Cyclonic Southerly and Cyclonic North-westerly airflow. The patterns relate to daily values standardised with reference to the daily areal mean precipitation (1961-90) over the region for that individual airflow (Betts, 1989). The two synoptic types display marked contrasts of gradient in precipitation activity, and emphasise the pronounced geographical variation of precipitation receipt associated with differing airflow.

FIGURE 3-5: Annual, winter (December-February) and summer (June-August) precipitation 'activity' associated with Cyclonic Southerly and Cyclonic Northwesterly airflows over Northern Ireland, 1961-90. Variations in precipitation 'activity' relate to values standardised with reference to annual and seasonal averages of daily aerial precipitation over Northern Ireland for each airflow type. *© 2001, School of Geography, Queen's University Belfast*





Changes in the frequency of individual circulation types will alter the proportion of precipitation received from particular circulation types over time, with possible ramifications for long-term trends at some locations over and above those indicated by the UKCIP98 scenarios. Under the **Medium-high** scenario, analysis suggests a tendency for autumns to experience a reduction in northerly and easterly flow and an increase in south-westerly and westerly flow. Summers become marginally more anticyclonic in character with more westerly and north-westerly flow, while winter and spring become a little less anticyclonic (Hulme and Jenkins, 1998). The effects could have particularly significant implications upon water resources (see section 4.1.2).

3.5.3 Evaporation and humidity

Evaporation in Northern Ireland increases under all scenarios and in all seasons. Under the **Medium-high** scenario potential evapotranspiration (PET) increases by up to 12% in winter by the 2080s, mostly during the last decades of the century. Spring shows a 5% increase and summer 6%, but it is in autumn that the rise in potential evapotranspiration is greatest. The 2080s are to expect an autumn increase of 18%, with an 11% rise as early as the 2020s. This upturn is consistent with enhanced wind speeds, increases in incident short-wave radiation and reduced cloud cover at this season under the **Medium-high** scenario.

Vapour pressure also increases in all scenarios and seasons. By the 2080s, the **Medium-high** scenario sees increases of 1.7 hPa in winter and spring and 2.2 hPa in summer and autumn. With increasing temperatures, however, relative humidity changes little, with spring and summer alone showing marginal increases of between 0.5 and 1%.

3.5.4 Wind

In winter and spring there is little change in mean wind speed over Northern Ireland by the 2080s. Rises of 1.5% in summer and 4% in autumn are apparent under the **Medium-high** scenario by the 2080s. In winter there exists a possibility that overall gale frequency declines in future, although very severe winter gales increase (Devoy and Lozano, 2000). With summer gales being so rare, any frequency changes will be modest and amount to approximately a 10% increase.

3.5.5 Sea level rise

Changes in storminess create concern in relation to their interaction with tidal surge and sea level rise. Estimates of the change in mean sea level around Northern Ireland coasts by the 2050s resulting from global climate change range between 13 cm and 74 cm, dependent upon scenario. These values, however, must be modified in relation to natural vertical movements resulting from isostatic adjustments (see section 4.1.3). Clearly, such rises in sea level have implications for the sensitivity of coastal environments to storminess activity.

3.5.6 Airflow characteristics and air pollution

Anticipated changes in airflow characteristics over Northern Ireland, including summers becoming slightly more anticyclonic, winter and spring slightly less anticyclonic and increased windiness in autumn, may impact upon air pollution levels in urban areas.

There will be a reduction in frequency of cold stagnant winter weather (see Section 3.5.1), typically associated with winter air pollution episodes. A reduction in the emissions of particles, oxides of nitrogen and sulphur dioxide is also expected (Anderson *et al.*, 2001). This will result in a decrease in mean annual and episodic winter ambient concentrations of particles, nitrogen dioxide and sulphur dioxide, the latter showing the largest fall.

Occasionally, during warm, sunny anticyclonic conditions in summer, elevated ozone concentrations occur over Northern Ireland as regionally-polluted airstreams drift westward from continental Europe. Despite the expected future increase in occurrence of hot sunny summer days, with the anticipated reduction in emissions of ozone precursors including nitrogen dioxide, and a reduction in concentrations of particulates, there is likely to be a only a small net increase in ozone episodes (Anderson *et al.*, 2001).

3.6 Natural climate variability

The climate change scenarios stated here, are those anticipated to result from greenhouse gas forcing of the climate system. It is important to note, however, that natural climate variability will affect this human-induced climate change (Hulme and Jenkins, 1998). Failure to appreciate this fact may result in impact assessments attributing the effects on social or environmental indicators of both human-induced climate change and natural climate variability as if they were the effects of human-induced climate change alone.

Hulme and Jenkins (1998) examining intra-ensemble differences within the HadCM2 experiments, define a range of 30-year mean climate changes that could actually be experienced under the **Medium-high** scenario after allowing for the contribution that natural climate variability may make. Where there exists little variation between ensemble members most of the change can be considered as human induced; large variations between members indicates a more significant role for natural climate variability.

Table 3.6. The range of mean annual and seasonal temperature change (°C) with respect to the 1961-90 mean that could be experienced in Northern Ireland during the thirty-year period centred on the 2050s under the **Medium-high** scenario (source: Hulme and Jenkins, 1998).

Season	Temperature change (°C)	
	Mean	Range
Annual	+1.7	+1.3 to +1.9
Winter	+1.7	+1.1 to +2.2
Spring	+1.6	+1.2 to +1.8
Summer	+1.8	+1.5 to +2.3
Autumn	+1.9	+1.5 to +2.0

Table 3.7. The range of mean annual and seasonal precipitation change (per cent) with respect to the 1961-90 mean that could be experienced in Northern Ireland during the thirty-year period centred on the 2050s under the **Medium-high** scenario (source: Hulme and Jenkins, 1998).

Season	Precipitation change (per cent)	
	Mean	Range
Annual	+4	-2 to +15
Winter	+11	+6 to +21
Spring	0	-7 to +6
Summer	-7	-13 to +3
Autumn	+11	+3 to +28

Table 3-6 presents the annual and seasonal mean temperature changes for the 2050s under the **Medium-high** scenario along with the intra-ensemble range. Similar data for precipitation are displayed in Table 3-7. The **Medium-high** seasonal temperature changes are due largely to human-induced climate change rather than to natural climate variability. For example, annual warming over Northern Ireland by the 2050s is +1.7°C, but any single realisation of climate change by this period may lie between +1.3°C and +1.9°C. In contrast, for precipitation the intra-ensemble range exceeds the mean change. This suggests a large proportion of seasonal-mean precipitation change in the **Medium-high** scenario is due to natural climate variability rather than human-induced climate change. In autumn for example, mean precipitation change over Northern Ireland by the 2050s is +11%, but any single realisation of climate may result in seasonal changes between +3% and +28%.

It is apparent that an appreciation of the full range of multi-decadal natural climate variability is necessary with respect to climate impacts assessments.

BOX 2

The thermohaline circulation and climate cooling over maritime north-west Europe

The thermohaline circulation (THC) comprises strong ocean currents that transport large amounts of heat around the world in a manner often described as a ‘conveyor belt’. There exists considerable interest in how stable ocean thermohaline circulation will remain faced with future rises in greenhouse gas concentrations. Concern has existed for some time (Broecker, 1987) that a collapse of the THC in the North Atlantic and southwards movement of the Gulf Stream would leave north-west Europe exposed to a cooler climate. It is believed that this last occurred in the Younger Dryas period, 11,000 years ago, which interrupted the progressive warming coming out of the last ice age.

Most global climate models show a gradual weakening of the THC throughout the present century as greenhouse gas concentrations increase (Wood *et al*., 1999). This slowdown decreases the magnitude of heat transported into maritime north-west Europe, but is more than offset by direct greenhouse warming, so that temperatures will still rise.

None of the most comprehensive modelling experiments indicate a sudden, dramatic collapse of the THC. Some studies using intermediate climate models suggest, however, with continued increased atmospheric concentrations of greenhouse gases, the THC would continue to weaken over future centuries leading to a European climate colder than at present (Rahmstorf and Ganopolski, 1990). It therefore seems unlikely that over the 21st century, changes in the THC will be sufficient to offset more than a small proportion of the anticipated climate warming over Northern Ireland.

Chapter 4. Impacts of climate change in Northern Ireland: sectoral analyses

4.1 The physical environment

4.1.1 Minerals and other natural resources

Alastair Ruffell
School of Geography, Queen’s University Belfast

Summary
While impacts of climate change upon the mineral extraction industry in Northern Ireland are unlikely to be major, there is some concern regarding increased problems associated with elevated water tables and seasonality. The industry is poorly prepared to meet the challenges that climate change will bring.

Background

This section focuses on three categories of site: mines, quarries and boreholes. The situation in Northern Ireland is unusual by comparison with other areas of the UK, since many of these sites, features or constructions extend across the border into the Republic of Ireland. However, regardless of location, they all share one thing in common: they are either totally located below regional mean ground elevation or have a substantial part below ground surface.

Climate change impacts

The responses of stakeholders (Appendix 1) to questions regarding climate change impacts are summarised in Table 4-1.

Table 4.1. Responses of stakeholders involved in mineral extraction in Northern Ireland regarding the impacts of climate change.

Question	*Stakeholder response*
What are the key socio-economic drivers and pressures on your sector?	Cost effectiveness, profitability, maintenance of position in the marketplace. Pressures from Planning Service and obligations to the Department of Trade and Industry.
What are the attributes of your particular sector that may be affected by climate change?	Issues concerning the water table, almost exclusively.
On what time and space scales is climate likely to have an effect?	Planned on the long term, increasingly becoming short-term.

What is the sensitivity of your sector to specific elements of climate change?	In the quarry industry there is some sensitivity (changes in demand for materials, monitoring, pollution). The mining sector sees great sensitivity in terms of water table issues and in some cases, the market place for products such as salt de-icer.
What are opportunities and benefits presented by climate change for the sector?	Opportunities include the specialised extraction of materials that will be more durable under wetter/drier conditions. Benefits include quicker turn-around in market, thus allowing faster response for those that can achieve it.
Why does the potential impact matter and to whom does it matter?	It affects profit and will affect everyone from producer to consumer.
Can the attributes in your sector that are sensitive to the climate be substituted with other attributes?	No answers given.
What are the key uncertainties in your assessment of climate change impacts on the sector and what data would be required for greater certainty?	Climate variability and lack of precise predictions for small areas.

Building upon these responses, Table 4-2 lists the potential impacts of climate change on mines and quarries in Northern Ireland.

Table 4.2. Potential impacts of climate change on mines and quarries.

	Flooding	**Drought**	**Storms**	**Seasonality**	**Temperature increase**	**Sea-level rise**	**Biota**
Mines	Elevated water tables will require more pumping and the dispersal of water-borne pollutants. Discharge increase	Drying out will promote rock and soil shrinkage and collapse. Pollutants can be concentrated	Damage to infrastructure, rapid flooding requiring continuous monitoring and rapid remediation	Rapid and unpredictable changes from dry to wet, cold to warm require rapid remediation	Better air circulation, storage of temperature-sensitive materials affected	Marine flooding, raised water tables, marine shipping affected	-
Quarries	Elevated water tables will require increased pumping and greater potential connectivity of leachates from land-fill to water table	Rock shrinkage and collapse, increased dust	Damage to surface structures, continuous monitoring of flooding, damage	Rapid remediation of changes from wet to dry, hot to cold	Acceleration of drought-induced dust production. Rock degradation accelerated under humid conditions. Working conditions deteriorate	Marine flooding, raised water tables, distribution of pollutants	Different plants for stabilisation of slopes will have to be planted.

This includes primary, secondary and tertiary (or later) effects. For instance, in times of drought, rocks and soils will dry out (primary effect). This may destabilise rock faces and buildings (secondary effect). Cracks may open in rocks, requiring less explosive to be used in blasting (tertiary effect). Over-use of explosive or rock hammering may increase dust levels (tertiary effect). Another example could be sea-level rise. This may flood mines or quarries close to sea-level (primary effect), but may also raise base level, causing silting-up of freshwater courses far above marine base level, causing an effect far away from sea-level (primary effect). Both will require increased pumping of water and slurry, with larger pumps, requiring more fuel and creating more noise, chemical and particulate emissions (secondary effect).

Responses of stakeholders to questions regarding adaptation and mitigation are given in Tables 4-3 and 4-4.

Table 4.3. Responses of stakeholders involved in mineral extraction in Northern Ireland regarding adaptation to climate change.

Question	***Stakeholder response***
What adaptation strategies can you envisage that would moderate the impact of climate change on your sector in the short, medium and long term?	Better monitoring, faster response times.
What are the likely costs of such responses?	Very high: indeed, many small companies will either have to consolidate operations or seek governmental aid in order to avoid simply reacting to problems instead of predicting them and possibly preventing.
What are the environmental and social impacts of such responses?	Huge. Changes in labour, transport, noise from different extractive techniques.
What are the barriers to the uptake of such responses: technical, economic, social, cultural, political and institutional? How might such barriers be overcome?	Largely financial. You have to appreciate that most extractive industries run on a profit and return basis. If a quarry can sell a product, its life is extended; if not, it closes down. There is little long-term financial planning beyond predicting the operation of the market place. Only the hydrocarbon industry is an exception.
What are the key uncertainties?	As above. Prediction.
What are the resulting management implications for the sector?	Advice on what prevention is required, pooling of information.
What will be the public perception of changes to the sector?	Negligible apart from aspects such as increased noise in some cases (e.g. higher pumping rates in mines)

Table 4.4. Responses of stakeholders involved in mineral extraction in Northern Ireland regarding mitigation of climate change.

Question	*Stakeholder response*
What approaches could be used to reduce the emissions of greenhouse gases from your sector?	Introduction of LPG vehicles; tax breaks for such changes; reduction in oil-fired power station use and concomitant increase in use of natural gas.
What is the likely cost?	Not answered.
How will Government mitigation strategies affect the sector: e.g. taxes, regulatory framework?	Taxes.
What opportunities are available to maximise the benefits of proposed strategies e.g. carbon trading?	Few on a local scale.

Approaches to adaptation and mitigation

Possible adaptation and mitigation strategies are summarised in Table 4-5.

Table 4.5. Possible adaptation/mitigation strategies for mines, quarries and boreholes.

Impact	*Time scale*	*Adaptation*
Floods	S	More pumps. High-resolution, continuous monitoring. Rapid response
Drought	S – M	Reverse pumps from water store. Rock and soil stabilisation. High-resolution, continuous monitoring. Rapid response
Storms	S	Storm-resistant construction of quarry and mine faces and buildings. High-resolution, continuous monitoring. Rapid response.
Seasonality	S – M	Continuous and recorded monitoring with analysis and GCM, RCM prediction
Temperature	M – L	Construction of shade, air circulation pathways, air-conditioning. Continuous and recorded monitoring with analysis and GCM, RCM prediction
Sea-level rise	M – L	More pumps, high-resolution monitoring. Modelling of effects using ancient analogues.
Biota	S – M – L	Research into appropriate planting of spoil heaps and quarry faces. Effect of mine and quarry waste and dust on crops.

Preliminary conclusions

Water is a major issue, mostly in terms of groundwater. Clearly in the eyes of the stakeholders involved in extraction, profits relative to investment is another major issue. The local economy is not conducive to dealing well with and adjusting to climate change, albeit everyone approached was aware of the problem and well informed regarding the impacts. The economic pressures on the industry make conducting any sensible inquiry such as this very difficult: for example, the key personnel at the Whitemountain Group currently work 9-10 hour days, 6 or 7 days per week. The extraction industry thus needs help in identifying and addressing the effects of climate change that will impact on their activities.

4.1.2 Water resources

Nicholas L. Betts
School of Geography, Queen's University Belfast

Summary
From a resource management viewpoint, Northern Ireland is relatively well-endowed with water, with one-third more water being discharged per km^2 than in England and Wales. Furthermore, a markedly lower population density promotes a correspondingly lower demand for water. Despite this adequacy in terms of the water balance equation, pressures exerted by continued urban expansion and prolonged dry periods create water supply problems in summer. Traditional reliance on surface water supplies and the usually plentiful precipitation have meant that groundwater as a resource has not been a high priority, and this will continue in the foreseeable future. The main features of the UKCIP98 climate change scenarios for Northern Ireland indicate that the water industry will operate within a more testing environment in attempts to meet both customer demand and maintain environmental obligations. A need exists to reduce domestic demand through behavioural change in patterns of water consumption. Management policy must continue action to reduce leakage from the distribution system. Anticipated lower river flow levels in summer will have an adverse impact upon water quality, as will turbulent flows after heavy rainfall, both scenarios probably requiring enhanced water treatment. Increased frequency of intense precipitation events might also necessitate enhanced capacities of wastewater treatment plants and sewer systems. Needs may also exist to upgrade flood defences and to review land use development of flood plains. It is essential that there is a long-term commitment from Government, or future private organisations, to regular reviews of best practice in sustaining supplies of the highest quality water throughout the year in Northern Ireland, despite environmental change.

Introduction

From a resource management viewpoint, Northern Ireland is over-endowed with water, with one-third more water being discharged per km^2 than in England and Wales (Wilcock, 1997). Furthermore, a markedly lower population density promotes a correspondingly lower demand for water. Despite this adequacy in terms of the water balance equation (see section 2.1.3), pressures exerted by continued urban expansion and prolonged dry periods create water supply problems in summer.

Unlike England and Wales, Northern Ireland has not experienced privatisation of the water industry. Instead, three Government agencies have discrete responsibilities for the water resources of the Province. Each agency has to meet statutory obligations, primarily derived from demanding quality and environmental standards required by EC Directives. These Directives are transposed into local legislation through Regulations and other national legislation, in particular the Water (Northern Ireland) Order 1999, which replaced the Water Act (NI) 1972 on 24 August 2001.

The Water Service (WS) within the Department for Regional Development (DRD), is responsible for the maintenance and operation of the water supply and sewerage infrastructures, and also monitors the quality of water abstracted for drinking water under the EC Surface Water Directive. The Agency supplies approximately 710 million litres of water daily to a Northern Ireland population of 1.7 million (over 98.5% have a public water supply). About 8% of the water in the public supply system is drawn directly from boreholes and springs, and additional supplies are taken from private groundwater sources for industrial, agricultural or domestic use. Groundwater storage contributes baseflow to surface streams, rivers and lakes, abstractions from which, amount to a further 52% of the total public water supply. The remaining 40% is drawn from upland sources such as reservoirs (Environment and Heritage Service, 2000). The reliance on surface water supplies and the usually plentiful precipitation have meant that, historically, groundwater as a resource has not been a high priority.

The Environment and Heritage Service (EHS), aims to promote the conservation and cleanliness of water resources in Northern Ireland and to facilitate their sustainable use. It is committed to biological monitoring of watercourses and the monitoring and management of groundwater resources. The Department of Agriculture and Rural Development of NI (DARDNI) also monitors minor tributaries within the catchments of the Upper Bann and Colebrooke to determine the impact of agricultural activities upon water quality, with particular reference to fisheries (Environment and Heritage Service, 2001a).

An excellent network of streamflow gauging stations, installed and maintained jointly by Rivers Agency (DARDNI) and EHS, provides accurate information on Northern Ireland rivers. Large catchments are well represented in the network, but small upland catchments, often the source of damaging flood flows (Betts, 1999), and catchments in urban areas, are not particularly well represented (Wilcock, 1997). Rivers Agency is responsible for drainage and flood defence in Northern Ireland, including preserving the productive potential of agricultural land and regulation and control of the water levels in Lough Neagh and Lough Erne within specified limits as far as climatic conditions permit.

The main features of the UKCIP98 climate change scenarios for Northern Ireland that will impact upon water resources during the present century include, a significant increase in mean autumn and winter precipitation and a decrease in mean summer precipitation (Hulme and Jenkins, 1998). These changes may be accompanied by increased daily precipitation intensities in autumn, winter and summer, and greater inter-annual variability of precipitation in these seasons. Rises in potential evapotranspiration are also anticipated, most pronounced in autumn and winter, but evident also in summer (see sections 3.5.2 and 3.5.3).

The water industry will operate within a more testing future environment in attempts to meet both customer demand and maintain environmental obligations. A problem in responding to climate change, however, is the considerable uncertainty associated with the scenarios of change. Changes in climate variability and occurrence of extreme events provide the greatest uncertainty, and are the aspects of climate change to which the water industry is most vulnerable. Indeed, summer precipitation decline might be two to three times greater than the mean change estimated for the UKCIP98 scenarios. Similarly, autumn and winter precipitation increases may exceed mean estimates of change by up to 75% and 40% respectively (see sections 3.5.2 and 3.5.6).

Raw water resources

Arnell (1996) has demonstrated that small, unconnected reservoirs are far more sensitive to climate change than inter-connected reservoir systems or an individual large source. Greatest sensitivity is found in relation to abstraction from rivers.

Present situation

Despite a normal adequacy of precipitation in Northern Ireland, from the 1970s occurrences of prolonged dry summers created serious water supply problems, occasionally exacerbated by insufficient winter precipitation recharge (Betts, 1978). An inflexible water supply system, in which transfers between areas of temporary surplus and shortage were difficult, was the principal cause of these shortages.

With further dry spells in the 1980s, a strategy evolved to increase flexibility within the supply system, and promote more effective management and maximisation of water resources. Over the last two decades this has been exemplified by increased abstraction of water from Lough Neagh, thereby alleviating demand upon upland catchments. Improved linkages have been made between smaller supply sources, and in the overall ability to transfer water within the supply network. Furthermore, greater exploitation of groundwater has occurred in the Lagan Valley, although this is only a minor source of supply. WS considers surface sources are sufficient to meet demand, and that spatial variability of groundwater quantity and quality, makes it an uneconomic source for further development at present.

Lessons learned from the droughts of the 1970s and 1980s reduced the impact of the 1995 drought, the third driest summer in the period 1931-2000 (see section 3.3.2 and Fig.3.2). Indeed, WS is confident of meeting the demands of future droughts similar to that of 1995, when precipitation during July and August 1995 was only 61% of the norm. Drought impact however, was cushioned by precipitation receipt between November 1994 and October 1995 being only 3% below average.

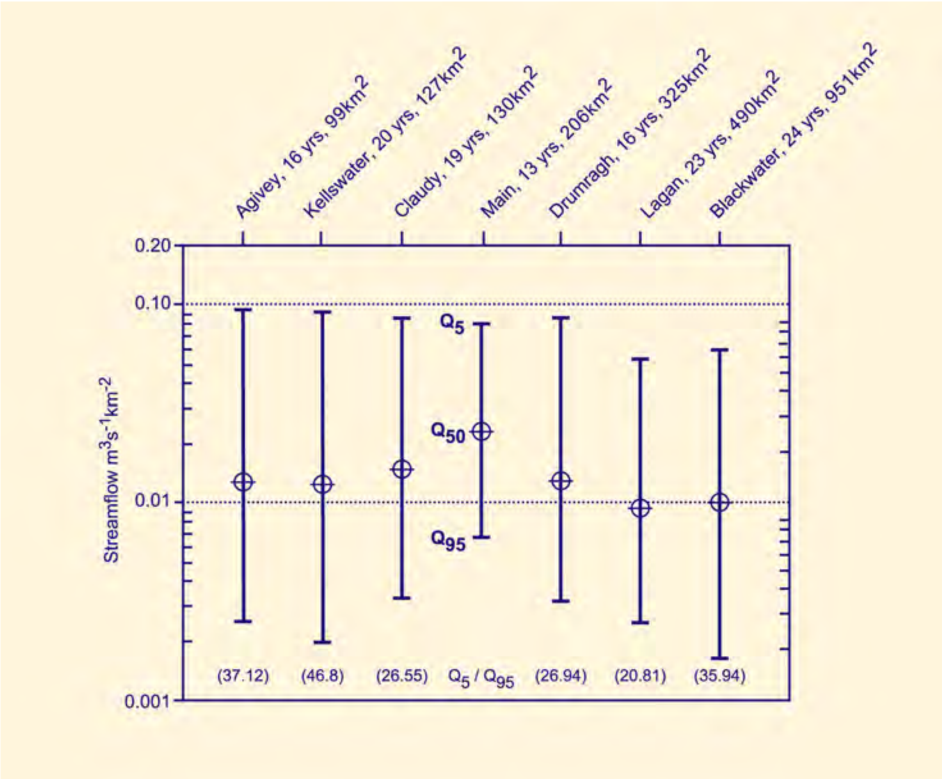
At present in Northern Ireland, leakage amounts to some 25% loss of water supply before reaching the consumer (Water Service, June 2001, personal communication,). This is high in comparison with the water industry in England and Wales, where privatisation has demanded solutions to the problem of leakage. A Water Efficiency Plan aims to achieve a substantial reduction in leakage losses over the next 3 years, to be achieved by improved metering, extending pressure system management and prioritising leakage detection and repair operations (Water Service, 2000).

WS does not view climate change as the driving force of its water resources strategy. Crucial to strategy development, is the availability of capital funds over a specified period. At present the Agency is undertaking a review of the Water Resources Strategy, with availability of capital expenditure remaining the prime driving force. Climate change is part of the review, but establishing the efficiency of the existing system in relation to the water-balance equation, must precede consideration of climate change impacts.

Climate change impacts upon raw water resources

The primary impact of climate change upon the water industry will be in water quantity. The historical pattern of river flows, surface reservoir yields and groundwater supply, around which the existing infrastructure is designed and managed, will be vulnerable to change.

FIGURE 4-1: Mean annual $\mathbf{Q}_{5,}$ $\mathbf{Q}_{50,}$ and $\mathbf{Q}_{95}$ flows for selected gauging stations in Northern Ireland. The $\mathbf{Q}_5$ flow is the flow equalled or exceeded 5 per cent of the time. This is a high flow but would not normally fill the channel. The $\mathbf{Q}_{95}$ flow is the flow equalled or exceeded 95 per cent of the time. This is a low flow and provides little dilution of effluents. Also shown are the $\mathbf{Q}_5$ /$\mathbf{Q}_{95}$ ratios. Only general comparisons between drainage basins can be made, as flow data period is not common to all rivers (source: Rivers Agency, Department of Agriculture and Rural Development). *© 2001, School of Geography, Queen's University Belfast*



Wilcock and Hanna (1987) indicate the general impermeability of Northern Ireland catchments. In terms of streamflow and groundwater recharge regimes, on the basis of $\mathbf{Q}_5$ /$\mathbf{Q}_{95}$ ratios, Wilcock (1997) suggests seasonal groundwater transfer is small in Northern Ireland (Figure 4-1). Generally, nearly all winter precipitation between December and March immediately becomes streamflow, very high water tables and very wet soils limiting sub-surface storage. In summer, streamflow is principally maintained by groundwater flow, although the absolute volume of groundwater flow in summer is quite small. There is little evidence that large amounts of groundwater are stored in winter for gradual release into the rivers in summer (Wilcock, 1982).

Recent studies, including those within the UKCIP programme, indicate that historical meteorological and hydrological statistics do not necessarily provide a realistic description of future conditions. Water resources strategies must also consider underlying changes in meteorology and hydrology resulting from climate change (Arnell *et al*., 1997).

Future higher amounts and intensities of autumn and winter precipitation may lead to increased volumes of surface run-off over short periods, and enhanced 'flashy' stream discharge. Attempts to store winter runoff in the form of impoundment meet with problems of acceptability to public opinion, as exemplified by the Kinnahalla Inquiry of 1980 (Common, 1982).

At present, winter precipitation in Northern Ireland normally sustains public water supply reservoirs at full capacity during this season. Unlike in some areas of the United Kingdom, future increased winter precipitation will not be of significance in sustaining reservoirs at full capacity throughout this season. Nevertheless, effectiveness of precipitation will be reduced by higher potential evapotranspiration rates associated with higher temperatures.

Anticipated change in future Northern Ireland summer precipitation is less marked than that of winter. Estimated reduction is less than conditions that prevailed during the 10th ranked dry summer, 1996 (see section 3.5.2.). Increased inter-annual variability of summer precipitation, however, may result in more frequent sequences of dry summers (see section 3.5.2.and Fig 3.2). This will impact upon the recovery period required of water resources to return to normal conditions, particularly when a dry summer is followed by below-average autumn and winter precipitation, a reflection of general increased inter-annual variability.

Lower summer precipitation, accompanied by longer periods of high temperatures and increased potential evapotranspiration, will extend the period when soil moisture deficits develop. This will lengthen the period of no groundwater recharge, and lessen surface runoff, a situation that will be magnified during dry years when catchments are already stressed. Furthermore, dependent upon the magnitude of future summer precipitation decline, water abstraction from rivers such as the Bann and Faughan might be curtailed, their low-flows reducing the dilution of effluent discharge.

Envisaged future climate change promoting reduced river discharge in summer and proposals to increase abstraction from Lough Neagh, may, during prolonged dry spells, result in a slight fall in the Lough's level, with possible adverse effects upon natural habitats around its margins.

Future strategies and climate change

WS strategy is guided by the fact that an *approximate* water balance for Northern Ireland shows a large excess of available supply over demand. Maximisation of existing supplies through flexibility and efficiency measures, is considered as being sufficient to meet pressures upon demand exerted by future climate change in Northern Ireland as envisaged by the UKCIP98 scenarios. Strategies will be subject to regular review.

To enable the system to meet demand at all seasons, the aims are to reduce the number of sources of water supply and improve linkages and flexibility between larger sources. This includes, on economic grounds, a move away from the use of small-scale groundwater sources, their future re-exploitation being possible if required.

Cross-border linkages will be maintained, with transfer of water to the Republic of Ireland, and abstraction of shared resources in the South Armagh region.

By the 2050s, mean summer precipitation is expected to have declined by 7% with reference to the 1961-90 period, although a reduction of up to 13% is possible under the **Medium-high** scenario. WS envisages the potential to increase abstraction from Lough Neagh will satisfy demand under the mean changes anticipated under the UKCIP98 scenarios, and possibly the extreme estimate (see section 3.6).

Despite future general increases in annual precipitation, accompanying inter-annual variability of mean annual and seasonal precipitation may alter the frequency of dry years and the occurrence of ‘back to back’ droughts. Such events will impact upon water resources.

WS has some headroom within resource zones to cope with future uncertainties in short-term supply/demand balance. Adequacy of this headroom is uncertain in view of difficulties in quantifying the influence of climate change on water supply and demand. Application of available methodologies for converting uncertainties outside the direct control of water companies into an estimate of target headroom will be used within a planning framework (UK Water Industry Research Limited and Environment Agency, 1998).

Water demand

While the major impact of climate change upon water resources is in terms of available quantity, assessment of adequacy to maintain supplies throughout this century, however, depends on reliable estimates of water demand.

Present position

Domestic demand for water is the component of public water supply most sensitive to climate change. More than 80% of average domestic water consumption comprises essential uses of sanitary systems, personal washing, clothes washing and dishwashing.

In Northern Ireland, industrial, commercial and agricultural customers are billed direct for metered water supplies, but unlike the drier South and East of England, domestic metering has not penetrated the community, and is unlikely to become an issue in the foreseeable future.

Public perception of the water industry depends upon its ability to meet demand. In reality, a negative perception prevails, with the public only taking note of the water industry when a crisis occurs.

The fact that the water industry in Northern Ireland is public sector based, in contrast to the privatised nature of the industry in England and Wales, restricts ability to raise funds and carry out new initiatives (Water Service, 2000).

Climate change impacts upon water demand

In Great Britain, micro-components analyses of changes in demand for water due to climate change suggest increases will come from household demand, especially gardening and greater uptake of household appliances (Gill and Wood, 2000). Future water demand in Northern Ireland is expected to follow a similar pattern.

Expectations are that higher temperatures will increase water consumption through personal hygiene and clothes washing, but technological advances may alleviate this through improved water efficiency of household appliances.

Water consumption of certain sectors of manufacturing, including drinks and ice cream, is sensitive to the weather (Agnew and Palutikof, 1997). In Northern Ireland, however, it is thought that increased water consumption imposed upon manufacturing by future climate change will not impact significantly upon water resources.

Future strategies and climate change

In line with water companies in Great Britain, WS is currently reviewing its ability to forecast for future domestic demand (Gill and Wood, 2000).

Future demand management policy will include promotion of greater public awareness about water conservation, particularly as the higher summer temperature and reduced precipitation impacts of climate change become more apparent. Attitudinal change will be required in re-evaluation of water as a resource. Initially, societal resistance may prevail.

Past funding has been insufficient to enable WS to meet statutory obligations, with the Agency forced to prioritise in its capital investment programme to achieve maximum benefit from the resources available (Water Service, 2000).

Lord Dubs, when addressing the newly appointed Northern Ireland Water Council in November 1999, stated that:

> “Substantial investment in our water and sewage infrastructure is required to meet the needs of our society and to comply with internationally accepted standards”.

Over the next decade more than £500 million is available for expenditure on water-related projects (Department of Regional Development Press Statement, 29th June 2000). Nevertheless, greater recognition is required of the importance to fund this sector of the Northern Ireland economy.

Water quality

A potential combination of increased temperatures and incident solar radiation along with decreased precipitation during summer, and increased incidence of heavy falls in winter and summer, raises concern over impact of climate change upon water quality. Quality problems will extend to reservoirs, lakes, rivers, groundwater resources and wastewater collection and treatment.

Present position

Management of water quality and quantity in all surface and groundwaters in Northern Ireland is becoming increasingly important under the EC Water Framework Directive (2000/60/EEC). This Directive promotes an integrated approach to groundwater and surface water protection within river basins. River basin management plans will be established and reviewed every six years. Member States will have to generally achieve the objective of good water status by 2015. Good surface water status is defined as the status achieved by the surface water body when both its ecological status and chemical status are at least good. Good groundwater status is defined by groundwater chemistry and also by quantity. Dates are also given for the repeal of a number of earlier Directives.

The water framework Directive also requires Member States to establish a register of areas designated as requiring special protection under specific community legislation, or for the conservation of habitats or species directly depending on water. This Directive will thereby integrate the requirements of other Directives such as the nitrates (91/676/EEC), Urban Waste Water Treatment (91/271/EEC), Bathing Water (76/160/EEC) Surface Water (75/440/EEC), Birds (79/409/EEC) and habitats (92/43/EEC) Directives. Member States must also achieve compliance with any standards and objectives relating to these Protected Areas 15 years after adoption unless otherwise specified in other Community legislation.

It is EHS policy:

> "To maintain or improve quality in surface waters and waters in underground strata as required by national policy, EC Directives and international agreements, and to generally manage river, estuarine and coastal waters to be at least 'Good' under the adopted classification schemes with no downward movement between classes" (Environment and Heritage Service, 2001b).

EHS carries out a number of monitoring programmes for rivers, lakes, groundwaters, coastal and estuarine waters in Northern Ireland (Environment and Heritage Service, 2000; 2001a; 2001c; in press). A co-ordinated programme of routine chemical monitoring of rivers in Northern Ireland began in the early 1970s and has been complemented by biological monitoring since 1990. EHS carries out these river monitoring programmes for a range of reasons, including general quality assessment under nationally adopted classification schemes and compliance with EC Directives and international agreements. In 1999 EHS reviewed the monitoring network and extended it, particularly into more upland waters, from approximately 2,400 km to over 5000 km.

In 2000, under the General Quality Assessment scheme, 96% of rivers of the 2403 km classified were of 'Very Good' to 'Fair' chemical quality, and 97% of the 5173 km classified were of 'Very Good' to 'Fair' biological quality (Environment and Heritage Service, 2001, personal communication).

Under the EC Urban Waste Water Treatment and Nitrates Directives, Member States must identify areas 'sensitive' to pollution from urban waste water and 'vulnerable' to agriculturally derived nitrate pollution respectively. Concern for water quality in Northern Ireland's lakes has principally focused on Lough Neagh and the upper and lower Lough Erne. The Erne catchment has been identified as sensitive to eutrophication and phosphorus removal is in place at the larger sewage treatment work in the catchment. Lough Neagh became very eutrophic during the 20th century, with urban point sources of phosphorus identified as the major problem. In the early 1980s, tertiary sewage treatment, to remove phosphorus, was implemented at the main population centres in the Lough Neagh basin and initially appeared to improve the phosphorus loadings on the Lough (Wilcock, 1997). Unfortunately, the beneficial effect of this has since been offset by increased inputs of phosphorous from diffuse agricultural sources. The catchments of Lough Neagh and Lough Erne were identified as sensitive to eutrophication under the terms of the Urban Waste Water Treatment Directive in 1994. Indeed, monitoring of the impacts of eutrophication during the 1990s indicates that rivers in Northern Ireland are for the most part enriched (Environment and Heritage Service, 2001c).

There is evidence of acidification in Northern Ireland (Jordan and Hall, 1997). Some areas, including the western Sperrin Mountains, the Mournes and north-east Antrim are vulnerable because of the poor buffering capacity of the associated types of underlying rock (Environment and Heritage Service, 2001c).

In the late 1990s, EHS published proposals for water quality management strategies for the Foyle, Erne and Lagan catchments. These strategies were funded through initiatives under the European Regional Development Fund and, in the case of the Erne and Foyle projects, were overseen by cross-border steering committees. In these strategies, the catchment is seen as the natural management unit for the integration of the work programme of all government agencies relating to water quality, water resources and ecosystem management. This is the underlying approach of the Water Framework Directive. The Directive requires individual river basins (including estuaries and groundwaters) to be identified and assigned to river basin districts by December 2003. The Directive also provides that, where a river basin covers the territory of more than one Member State, the river basin must be assigned to an international river basin district. EHS is working in close partnership with counterparts in the Republic of Ireland to further develop these cross-border catchment strategies to meet the needs of this Directive (Environment and Heritage Service, 2001d).

Over-abstraction from coastal aquifers can impact upon groundwater quality by saline water into circulation. Aquifers and the groundwater they contain are also vulnerable to the pollution activities of humans, and do not have an infinite capacity for absorbing and neutralising wastes. Once an aquifer is polluted, remedial treatment is expensive and may not even be feasible. EHS has developed a groundwater monitoring strategy for Northern Ireland, to meet the needs of a baseline surveillance-monitoring programme for the EC Water Framework Directive. (Environment and Heritage Service, 2000).

In provision of safe drinking water, the Water Service monitors compliance against the requirements of the EC Drinking Water Directive, achieved by an extensive water- sampling programme throughout the supply and distribution systems. Overall, drinking water quality achieves almost 99% compliance with regulatory standards (Water Service, 2000).

Approximately 83% of households are served by the public sewerage system. WS is responsible for effective treatment of wastewater and its safe disposal. EHS is responsible for setting standards against which compliance is measured. EHS aims to develop environmental needs standards for all discharges from Water Service installations by 2005, in line with the requirements of the Urban Waste Water Treatment Directive. Water Service aim to achieve 90% compliance with the requirements of the Urban Waste Water Treatment Regulations (1995), by 2005.

EHS also regulates discharges from trade premises under the Water (NI) Order 1999, and has set targets for improving compliance with discharges consent conditions. The current target is to achieve a 10% improvement by 2002 in comparison with a 2000 baseline.

Climate change impacts upon water quality

(i) Surface water resources A future rise in temperature will raise river temperatures and affect the rate of bio-chemical processes that determine water quality. This will impact upon existing levels of dissolved oxygen, biochemical oxygen demand and ammonia in the water,

to the detriment of indigenous flora and fauna. In nutrient rich water bodies, increased temperatures and incident solar radiation will enhance algal growth, further exacerbating the pollution problem.

Drier summers will increase periods of low river flows, resulting in a reduced capacity to dilute discharged effluent. There will exist a greater need for the maintenance of high quality standards, because the impact of poor quality effluent discharges to the receiving watercourse will be more severe, and the risk to the environment heightened.

Climate change impact upon reservoir water quality will relate to increased risk of stratification in spring and summer resulting from higher air temperatures and incident solar radiation, and slightly reduced wind driven mixing in spring (see section 2.6.). Reduction in mixing may also encourage algal growth, and as with rivers and lakes, increased water temperatures may result in adverse changes in both physico-chemical and biological criteria that determine water quality.

With vegetation cover so extensive and almost permanent, agriculture pastoral rather than arable, and precipitation rarely intensive, sediment loads in Northern Ireland rivers are relatively small. Future increases in autumn and winter precipitation intensities will raise the risk of physical damage to river channels. Resultant soil erosion and sedimentation may have significant environmental impact, including damage to invertebrate and fish populations.

Combined Sewer Overflows (CSOs) which are currently the subject of drainage area plans, urban pollution management studies, and upgrade programmes in agreement with EHS, may operate more frequently due to increased heavy precipitation events, and transport more highly polluted sewer sediments deposited during longer intervening dry spells. Fish kills following severe thunderstorms may become more frequent.

Changes in the quality of raw water will tend to exacerbate problems at water treatment works that already show symptoms of stress. Poorer water quality may require more expensive water treatment (Gill and Wood, 2000).

(ii) Groundwater resources Groundwater supplies most vulnerable to pollution from such sources as farms, industry and landfill sites occur where soils with a high leaching potential overlie highly permeable geological formations. Northern Ireland’s groundwaters most vulnerable to pollution include supplies in the Lagan valley and a discontinuous belt west of Lough Neagh, aligned north-south from Moneymore and Cookstown to Armagh. Triassic Sandstones underlie both these areas. Groundwater vulnerability also exists in lowland Fermanagh adjoining Upper and Lower Lough Erne, and underlain by Carboniferous Limestones (British Geological Survey and Department of the Environment for Northern Ireland, 1994).

Groundwater, however, occurs throughout Northern Ireland and local variation in soil and subsoil conditions can make it vulnerable to impact from anthropogenic pollutants.

Increased inter-annual variability of future mean precipitation implies that pollution infiltration will have serious implications for lowered groundwater tables resulting from future drier summers occurring in individual, or runs of dry years. Even soils of low permeability may pose a pollution threat, for in very dry weather clay soils may crack, and surface water, perhaps containing pesticides, might move down to groundwater. Increased wetness in autumn and winter may enhance the leaching process and threaten pollution of vulnerable groundwater. Furthermore, saturation of a soil's ability to absorb pollutants can also be reached, and the soil may be converted from a sink to a source of pollutants, with subsequent implications for underlying groundwater.

With the possibility of more frequent very severe winter gales (see section 3.5.4), aquifers close to the sea may deteriorate in quality from overtopping of low-lying ground by associated storm surges. A risk of saline intrusion already exists, and will be further exacerbated by a future rise in sea level (see section 4.1.3).

(iii) Wastewater collection and treatment Future changes of temperature, precipitation and potential evapotranspiration may have an impact upon wastewater collection and treatment systems. The effects are likely to be as significant as those regarding water supply and demand.

In terms of wastewater collection, reduction of volume and velocity of sewer base flows in dry periods may result in sedimentation accumulation and blockages, the former being highly polluted and harmful to treatment processes and receiving waters.

Future increased autumn and winter wetness will also exert pressure upon wastewater collection systems. Present drainage infrastructure is designed on the basis of historical data. Future precipitation regimes may fall outside present design boundaries, increasing the flood hazard and increasing the risk of spill from CSOs.

Potential loss of base flow during summers drier than at present may lead to reduced dilution of effluent from sewage treatment works, and an increased risk of septicity. Reduced dilution may lead to the need for reviewed standards for both sewage treatment works and industrial discharges.

Future strategies and climate change

WS, EHS and Rivers Agency are aware of potential climate change impact upon water quality, but considerable uncertainty lies in predictions of future water quality.

The key driver in future water quality will be the EC Water Framework Directive which will require all waters to be of good ecological quality by 2015, and a prime requirement is provision of data providing accurate flow characteristics of Northern Ireland rivers. Expansion of the hydrometric network is underway, with monitoring emphasis on groundwater-surface water interaction. Rivers Agency and EHS using the Hydrology of Soil Types (HOST) methodology (Higgins, 1997; Wilcock, 1997) are undertaking a scoping study of low-flow estimation. Such developments will result in data sets that provide an accurate baseline from which to obtain more accurate estimates of climate change impact on river flows and groundwater recharge.

There exists a need to review strategy in relation to abstraction control and to ensure maintenance of acceptable groundwater base flow and river flow. Unlike in England and Wales, there is no system of abstraction licensing in Northern Ireland, although EHS can oppose new developments of abstraction under the planning process. Evidence of a move towards establishing a control mechanism is in the Water (NI) Order 1999, whereby the Department has been given powers to create regulations to control water abstraction (Environment and Heritage Service, 2001c). Indeed, the EC Water Framework Directive requires Member States to manage water quantity and quality in the interests of good ecological quality.

Maskell (2000) has established that few river and reservoir water quality models for predicting effects of climate change exist for Northern Ireland. Most are mass balance models, although some SIMCAT consent models exist, but in their present form are unsuitable for climate change study. Clearly, encouragement should be given to the development of models suitable for predicting effects of climate change upon water quality in Northern Ireland.

Inland flooding

Northern Ireland has one of the largest runoff per unit area figures in the British Isles, soils are of widespread low permeability and stream gradients are often very gentle in their lower courses. Consequently, land drainage and flood alleviation have been long-standing and widespread problems. The history of arterial and land drainage in Northern Ireland has been described by Wilcock (1979; 1997).

Rivers Agency, on behalf of DARDNI, is responsible for drainage and flood defence in Northern Ireland, and much of the following information was obtained from stakeholder representatives (Appendix 1) at a meeting held in Belfast in June 2001.

Present position

In Northern Ireland, flooding is principally an autumn and winter phenomenon, with mean peak streamflow occurring between mid-November and mid-December. Summer flow is sufficiently reduced to cause few flood events, occurrences normally being small-scale urban effects associated with convective storms. Urban flooding more usually results from blockage rather than volume of flow.

Traditionally, management of flooding problems in Northern Ireland has focused upon capital works rather than flood warning schemes.

Despite the scale of flood problems being less prominent than in other areas of the United Kingdom, Rivers Agency is aware of Northern Ireland public consciousness of flood risk, a situation brought about by the magnitude of widespread flooding in central and southern England during the autumn and winter of 2000-2001.

The major rivers all have stretches vulnerable to flooding following heavy precipitation events. These events can cause serious disruption, and their scale of impact can be best demonstrated by reference to a case study (Box 3).

BOX 3

Case Study 2. The Strabane Flood, October 1987

Background
The town of Strabane is situated on the River Mourne, just upstream of the confluence with the River Finn (Figure Box 3-1). These low-gradient rivers are part of a network draining upland catchments of low permeability. Heavy and/or prolonged precipitation events can have a dramatic impact upon streamflow.

FIGURE BOX 3-1: Location map in relation to the Strabane flood, October 1987.
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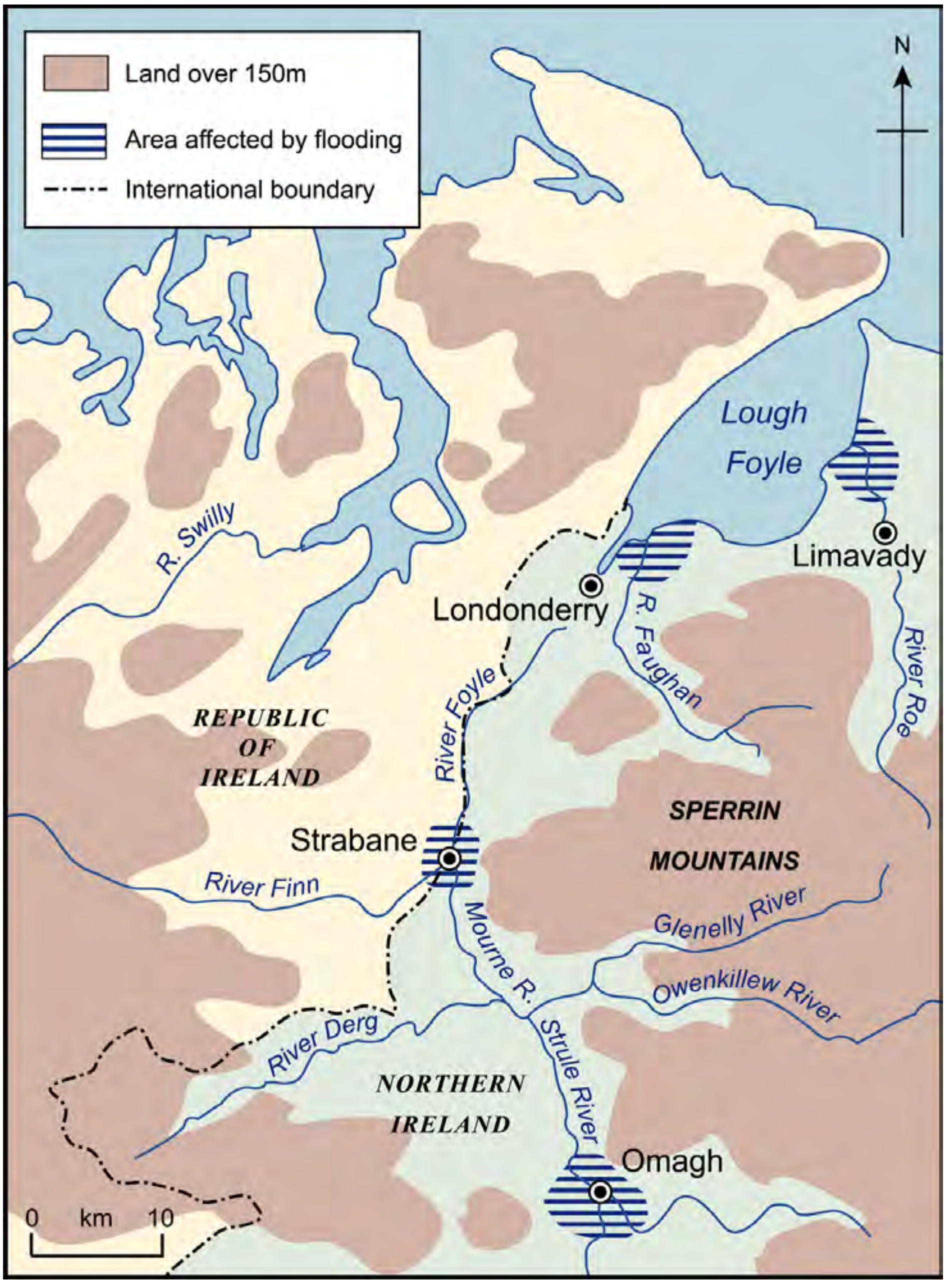


Low-lying areas of Strabane are particularly vulnerable to flooding and various flood defences have been constructed over the years to improve the degree of flood protection following previous flooding incidents. In the latter part of the 20th century the adequacy of the flood defences gave cause for concern. Following the September 1985 flood (1 in 10 year event), concern was expressed for the sufficiency of flood protection afforded to the town centre.

In June 1987, a report on the flood protection of Strabane (Department of Agriculture (NI) Drainage Division, 1987) concluded that under certain flood conditions, there was an unacceptable risk that existing defences might be overtopped or breached. Recommendations were made for improvements to flood defences that would give protection to the 1 in 100 year event.

Severe precipitation on 21st October 1987 produced unprecedented flooding in Strabane.

Meteorological situation
The frontal depression responsible for the flooding produced continuous, and at times, high intensity precipitation from early on the 21 October until about 0300 hours on the 22 October 1987. Over a 24-hour, precipitation totals of 50 mm were recorded at Strabane and falls up to 100 mm over surrounding upland (Betts, 1990a). In the Sperrin Mountains the magnitude of precipitation was classed as ‘remarkable’ (Natural Environment Research Council, 1975).

Impact of the storm
High precipitation totals earlier in the month reduced catchments’ infiltration capacity. At Strabane, the River Mourne breached a retaining wall, and together with floodwater from the confluent Finn, inundated 337 houses and 80 business premises to a depth of 1 m. Water levels began to subside by the 23 October, although rural areas remained flooded for several days.

Consequences of the flooding
What exacerbated the social and economic repercussions of this damaging flood, was the refusal of the national Government to designate the west of the Province a disaster area. However, limited state aid was granted to relieve immediate hardship, and to enable repairs to be undertaken. The European Commission also made available a grant of £57,000. The adequacy of this financial assistance can be judged from the fact that, damage to housing alone was estimated at more than £2,000,000. Dissatisfaction was further enhanced because in the town, only 34 per cent of affected households had insurance covering the cost of flood damage. Even several businesses discovered that their insurance policies failed to cover them for this same hazard.

In surrounding rural districts, the consequences for farmers were considerable. The inundation of pasture brought an abrupt end to the grazing season. Livestock were lost, but fortunately many animals had already been housed for the winter, and sheep were invariably safe on higher ground. Water-logged soils ruined any potato crops still to be harvested, delayed the germination of winter cereals already sown, and prevented unprepared fields being planted until the spring. In many areas the high velocity of the floodwater scoured topsoil and deposited fluvial gravel and other detritus over farmland. Farmers received little aid, and their fortunes depended on the extent of their insurance cover.

Transport networks were badly affected by the flooding. Protracted repairs to bridges caused considerable traffic flow disruption for several months after the event.

One major remedial measure undertaken was the construction of a flood protection wall in Strabane, Government funded, and designed to withstand the 1 in 100 year event.

Climate change and inland flooding

Under the UKCIP98 **Medium-high** scenario, a 20% increase is anticipated in both autumn and winter mean precipitation by the 2080s. The increases, however, could be as high as 35% and 27% respectively. These changes accompanied by increased precipitation intensities in autumn, winter, and also summer, may have significant implications in terms of future increased flood risk in Northern Ireland.

Anticipated changes in the precipitation climatology of Northern Ireland infer the possibility of an extension of the flood season, particularly if summer storms become a more prominent feature of the climate.

For those catchments potentially prone to flooding, a need will exist to undertake explicit modelling in order to assess how their properties might change in response to a future climate change. Climate change will have implications for existing flood defences, designed under present conditions to withstand the 1 in 100 year flood. In the future these may have to be degraded as affording protection to only the 1 in 50 year event.

Reinforcement of existing defences may be required to a higher standard of protection than is currently considered necessary based on historic data and hydrological modelling. Estimation of requirements will prove difficult, as potential increased precipitation variability must be considered in addition to magnitude of precipitation change.

A problem may similarly exist as to exactly what level of new defence protection should be planned for, and implemented. The current best practice method for river flood frequency estimation in the UK is the Flood Estimation Handbook (CEH Institute of Hydrology, 2000). The main method uses flood peak data pooled from a number of stations to estimate a flood flow at any particular site, rather than relying upon single-site data.

The possible increase in scale of future flood defences will further emphasise the need to have regard for their impact on nature conservation, landscape and built heritage values of rivers and river corridors.

Increased flood risk may necessitate the development of efficient public flood warning systems. Upgrading of rapid-response co-ordination with emergency services will also be required. In Northern Ireland some encroachment of residential and industrial development onto flood plains has occurred during the post-war period, although this is markedly less prevalent than elsewhere in the United Kingdom. Given the possible inadequacy of existing defences to cope with future climate change, however, inhabitants of flood plains may be at a considerably greater risk of flood hazard than at present.

Human-made modifications to urban rivers and their catchments damage the natural structure of rivers, resulting in unnaturally extreme flows, poor water quality and the loss of the natural habitats (Environment and Heritage Service, 2001c). In reaction to increased risk of flooding associated with future climate change, there will be a need to avoid many of these undesirable impacts where urban development is taking place. This can be achieved by applying good practice principles in the form of Sustainable Urban Drainage Systems.

Future strategies and climate change

The Rivers Agency is acutely aware of the need to make an assessment of how to deal with the impact of future climate change. In response to recent flood events in England and the high scientific profile of climate change, the Agency is considering formulation of future strategies from a large-scale viewpoint, rather than the traditional focus upon individual events.

Acknowledging that the UKCIP98 scenarios are only estimates of change, Rivers Agency will formulate future strategy in accordance with these scenarios until more precise data are available.

The need exists for the establishment of a Climate Change Unit for Northern Ireland. This unit will provide a focus for multi-disciplinary research to establish the nature of climate change and its impact within the Province.

Improved statistical downscaling methods for modelling of precipitation are required with incorporation of results within design methodologies and tools at the catchment scale.

To reduce increased risk of flood hazard in urban areas, Sustainable Urban Drainage Systems should be encouraged. The concept is being actively promoted by EHS to other Government Departments, Agencies and developers. Techniques available include the use of permeable surfaces to increase infiltration rates to groundwater, and use of wide grassed drains and retention ponds, rather than pipes, to slow down water release to watercourses.

A need to develop effective strategies to combat increased flood risk in relation to human occupancy of flood plains. This will require not only capital investment in terms of structural defences, but education and encouragement of the public to avoid flood plain development. Rivers Agency will undertake this, in liaison with the Planning Service.

In view of the considerable financial costs incurred by flood damage, threatened existing property located in flood plains should be flood-proofed. This might include a form of specialised protective covering for electricity supplies, and the non-plastering of walls.

Conclusions

It is accepted by stakeholders in the Water Industry that the scientific community will continue to develop and improve Global Circulation Model experiments, and that the Government, through UKCIP, will update the ‘best estimates’ of likely future climates. It is anticipated that, as the models improve and estimates of the spatial and temporal patterns of climate change over Northern Ireland become more certain, the results will be incorporated into strategies of the Water Industry. Particular attention must be directed to the repercussions of inter-annual variability and climate extremes.

4.1.3 Coastal and flood defence

Julian Orford and **Loraine McFadden**
School of Geography, Queen's University Belfast

Summary
There are three natural forcing factors of coastal change related to projected climate change over the next 50 years; change in sea level due to atmospheric warming; increased storminess that can create short-term (up to days) rises in Mean Sea Level (surges) and cause flooding of low-lying areas and property; and, changes in terrestrially derived sediment supply. Main impacts are: loss of intertidal areas of open coasts; diminished intertidal zones especially protected habitats in estuaries including a loss of marsh with its associated loss of bio-diversity; and dune coasts will suffer non-sustainable beach and front-of-dune erosion. East coast beaches with backshore sediment deposits are generally of late-Holocene age and are not being renewed at a constant rate to match current sea-level rise. This is reflected in recent media concern for diminishing Ulster beaches as a tourist attraction. Northern Ireland stakeholders, however, are generally unaware of changes in their coastline to come.

Introduction

Climate change implications for the coastal zone considered in this section relate to physical processes that directly determine the natural structure and human use of the coastal zone. Climate change impacts on coastal zone habitats and bio-diversity are considered in section 4.2.1.

There are three natural forcing factors of coastal change related to projected climate change over the next 50 years, each carrying a different message for coastal zone occupancy.

- Change in eustatic sea level due to atmospheric warming, i.e. a change in the total volume of water in the oceans causing a secular and persistent rise in the average mean sea level (MSL) position. This type of change is one that has been gradual in the historical past and scaled by a magnitude (<1m/century) that is often overlooked in its effects relative to human memory. Accelerated climate change inducing faster sea-level rise (SLR) rates is likely to be a different matter. Sea-level rise will prove to be persistent and insidious against a static infra-structural basis that society has created over the last two centuries along contemporary coastlines. We forget at our cost that the apparent overwhelming permanency of our coastal living is comparatively recent and sits uneasily on a dynamic coastal zone. The importance of sea-level position relative to the land is that it acts as the datum upon which the natural wave and tidal processes can operate. Thus we should recognise that rising sea-levels will both inundate low lying land as well as allow wave energy to erode land.
- Changes in storminess that can create short-term (up to days) rises in MSL (surges) and cause flooding of low-lying areas and property. The effect of a single storm can be brutal whether on the coast or over the land (i.e. the Boxing Day storm of 1998) and tend to leave a stronger mark on human memory of change in the coastal zone than does the effect of secular sea-level rise *per se*. Coastal storms also contribute to physical infrastructure damage due to excessive wind velocities, though this is not restricted solely to the coastal zone.
- Changes in terrestrially derived sediment supply to the coast are not usually considered in this type of future climate analysis, but climate change leading to increased precipitation

may cause disturbances in fluvial catchments, leading to an increase in sediment load transported to the coastal zone.

Relative sea-level change

Changes in eustatic SL are driven principally by two climate-induced factors: the expansion of sea water volume due to increased exchange of atmospheric heat to the upper oceans, and an increase in sea water volume due to a persistent negative budget in continental ice, i.e. melting of land ice. Expansion of ocean water due to atmospheric-ocean exchange of heat (the steric effect) is thought to account for approximately half of estimated future rise in MSL (Warrick and Farmer, 1990). Both recent modelling (employing a mid-range emissions scenario) and Houghton *et al.* (1996) suggest c. 49cm of sea-level rise over the next half century, with an expansion of up to 80cm of mean sea level by 2100AD. Such global eustatic estimates are constrained by the local effects of crustal change — both isostatic (i.e. a slow upward rebound of the Earth's crust following removal of glacial ice cover) and tectonic (i.e. driven by deeper forces) — that may accelerate or decelerate MSL changes. The combined eustatic and land movement rates at any one position at the coastline generate the relative sea-level (RSL) change rate. Whereas eustatic effects are global in scale, isostatic and neo-tectonic effects are regional at best, not amenable to generalist modelling and require local interpretation.

FIGURE 4-2: Relative sea-level changes at Belfast Harbour 1918-1963. Annual data are based on semi-diurnal levels of high and low water. Data from Carter 1982, supplied by Proudman Oceanographic Laboratory. Nodal detrending obtained using an unweighted 19-year smoothing term. *© 2001, School of Geography, Queen's University Belfast*

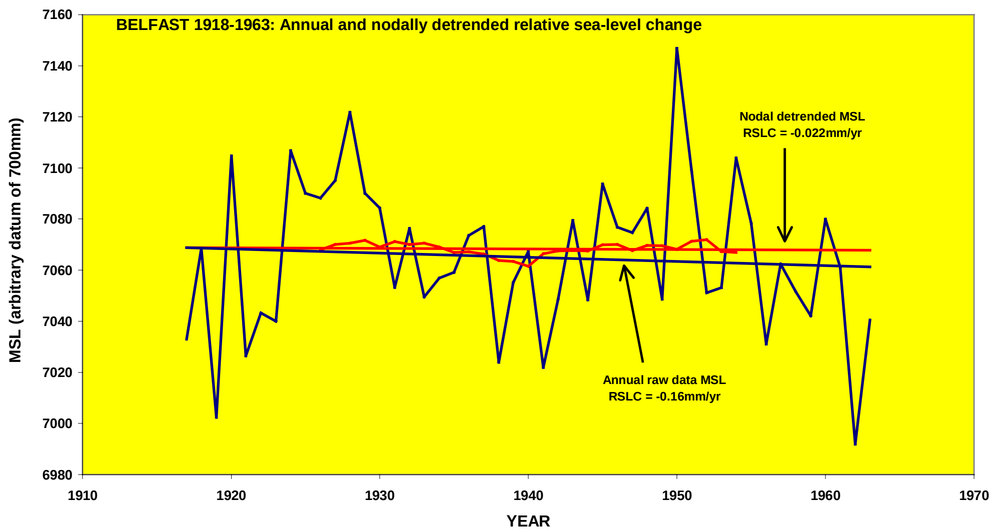
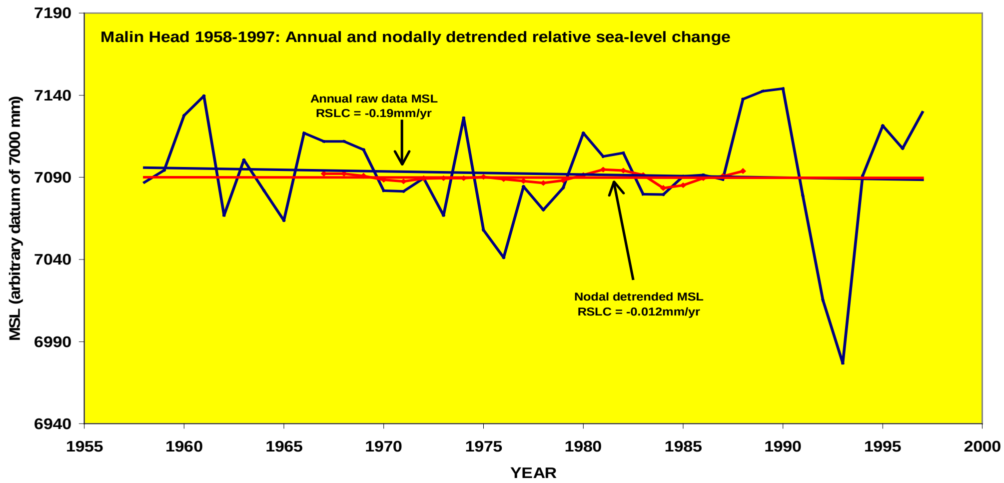


FIGURE 4-3: Relative sea-level changes at Malin Head 1958-1997: Annual data are based on semi-diurnal levels of high and low water. Data are from Proudman Oceanographic Laboratory. Nodal detrending obtained using an unweighted 19-year smoothing term.



Although contemporary annual RSL change rate varies from c. +1.5 to 2 mm/yr to +0.5 to 1 mm/yr on a south to north UK gradient (Woodworth *et al.*, 1999) there is no consistent estimate for Northern Ireland. Carter (1982) identified falling RSL trends of <2.5mm yr^{-1}, over the 20th century for Malin Head and Belfast Harbour, which he thought were due to a remnant isostatic signal from ice-unloading following the last glacial maximum. Carter further identified Belfast Harbour's physical expansion as possibly affecting the declining RSL signal that he obtained for that site. Orford (2000) specified the difficulties in estimating an overall Northern Ireland RSL change rate given the breaks in, and non-overlapping nature of tide-gauge data from the four data generating sites available. A key problem is the need to detrend the nodal tidal (18.6 years periodicity) signals from data series, which had not been undertaken by Carter. New analysis of detrended data from Belfast (1918-63) and Malin Head (1958-1995) indicated small RSL fall rates that could suggest remnant isostatic uplift. This declining signal has low-amplitude decade-scale oscillations (Figures 4-2 and 4-3) that have major implications for estimates of RSLC dependent on data window length, and are thought to have affected Carter's 1982 analysis. Analysis of recent (but not detrended) MSL data from Portrush and Bangor tide gauges (1996-200) identify positive trends in RSL of <2.5mm yr^{-1} at both sites (Orford, 2000). It is still uncertain whether these recent up-swings reflect eustatic acceleration of RSL, are part of the nodal tidal expansion, or relate to an upswing in the decade-scale oscillations running through NI data. Regardless of the origin of the upswing, there may be contemporary problems ensuing from this RSL rise in the present decade, regardless of any acceleration over the next 20-50 years. Such accelerations are likely to translate into an annual average RSLR of c.2 times the current extreme identified elsewhere in northern UK. The issue of variation around the decadal-century estimates of RSL is one still to be adequately specified, while clarification of RSL changes during the 20th-Century for the north of Ireland also remains a major research requirement.

Storminess change

Changes in storminess are likely to be characterised by changes in annual atmospheric depression number, depression intensity and depression approach vectors predominantly from across the Atlantic and impinging on to the north coast of NI. Easterly airflows are also important for NI. Storms and especially extreme storms (i.e. Boxing Day storm of 1998 with mean ground wind velocities of up to 50m s^{-1}) identify a wide ranging potential for change in short term rises in MSL due to surge and extreme wave generation. There are also the direct velocity and wave effects on coastal structures from such forces. It is important to recognise that there are two coastal NI provinces (north and east coasts) that may suffer differentially the effects of accelerated climate-induced change. Although storm modelling (ECHAMP2) using a doubling of CO_2 for the eastern Atlantic off Ireland indicates a slight reduction in depression number, there is a rise in intensity i.e. deeper depressions (Devoy and Lozano, 2000) moving over the Irish Atlantic coast. Lozano (personal communication, June 2001) further suggests that there is likely to be an increase of cyclonicity to the northwest of the UK, which may have an impact on the NI north coast.

Future increased equatorial warming may have a major effect on hurricane incidence in the North Atlantic and movement outside of their generating area. The influence of ex-hurricanes moving as deep depressions across Ireland from a southerly direction has been somewhat neglected, but should not be forgotten in the future storm scenario analysis (Cooper and Orford, 1998), albeit most of the extremes will be on the coast of Ireland outside of NI. The role of extreme storms on coastal configuration needs also to be reconsidered (Orford *et al.*, 1999), as do all storm tracks, given storm track modelling is still a relative unknown. Storm track direction is important as orientation changes have significant impact on the coast.

Changes in Atlantic offshore significant wave height over the latter part of the 20th-Century are thought to be within a natural variance (Von Storch *et al.*, 1993) despite earlier concerns that the North Atlantic was ‘roughening’ (Carter and Draper, 1988). We have little knowledge of future storm changes in the Irish Sea *per se*, as opposed to model results for the eastern Atlantic. Of some concern is any increased incidence in south-eastern Irish Sea storms as a consequence of an increase in high-pressure blocking conditions to the east and southeast of the UK. A few degrees change in south to south-easterly storm approach direction could have major impacts on the south Down coast, while any increase in coastal wave energy will be observed via a reduction in beach gradients and loss of beach sediment offshore. McFadden (2001) has modelled a south-eastern storm wave for present and a future +30cm SLR against the eastern NI shoreline. She identified the greater effect along the Down coast rather than the Antrim coast as a result. This is due to the changing offshore bathymetry and its effect on wave focusing. Recognition of wave changes along the coast as a result of storminess *per se* will be difficult to disentangle from the effects of RSLR.

Joint RSL rise and storminess change

It is important to appreciate the effect of increasing RSL on return periods of extreme water levels associated with storms. Unfortunately extreme water levels for Belfast are uncertain, but analysis of analogous situations in north-west UK (Barkham *et al.*, 1992) show that with a sea-level rise of c. 50cm by 2030AD (Houghton *et al.*, 1996), the return period of a current 100-yr flood level falls to 1 in 45 (Glasgow) and 1 in 25 (Silloth, Cumbria). UK ports in west Wales show alarming reductions in return period with 1 in 22 for Holyhead and 1 in 3.5 for Milford Haven. It is unlikely that east coast Ireland will experience the same return period reduction given the asymmetry of surge flow heights between eastern and western Irish Sea (Orford, 1989), but coastal infrastructures currently set to specific extreme tidal threshold levels will come under pressure.

Terrestrial sediment changes

Sediment supply to the coast comes from landward-derived sediment carried via rivers and cliff line material eroded by wave activity. The former does not seem not been a major influence in NI coastline over historical times, except for the Bann on the north coast. The issue of increased fluvial discharge and hence increased sediment load from catchments is not likely to be significantly changed, unless land-use practices materially alter so that more bare soil is exposed to increased precipitation. Urban catchments may experience greater runoff, and as a consequence deposition in tidal estuaries particularly Belfast (Orford *et al*., 1997) and Derry may be differentially affected. However there are no contemporary studies of this issue. Coastal erosion as a means of supplying sediment to the beach has been important for NI. Its importance has been gauged by estimates of source, transport and sink units making up longshore coastal cells for parts of the NI coastline (Bowden and Orford, 1984). Again, there have been no studies that estimate future rates of changes in these source, beach and sink volumes for NI. Increased precipitation could cause further coastal slope instability, in particular the coastal slopes of eastern Antrim are vulnerable to this process with both historically active mudflows and inactive Pleistocene debris flows being reactivated. A silver lining in this scenario is that such flows could provide some much needed replenishment of Antrim beaches that are currently sediment starved. Any influx of fluvial sediment to the coastal zone is likely to be observed primarily in the deposition of finer sediments to the estuaries. However the likely coastal squeeze due to the spatial persistence of engineered shorelines in our estuaries means that this sediment is likely to be lost in redistribution over existing intertidal areas and unlikely to be sufficient to help existing upper tidal zone marshes keep pace with rising sea levels.

Potential changes

A change in MSL is *per se* not an indicator of major coastal change, however MSL acts as the datum for wave and tide activity that are the causes of coastal change. The geomorphology of the coast is a physical expression of mitigation of forcing energy expenditure. Change the point of energy application and the configuration will change. Lifting the point of application through a MSL change means that the coastal configuration will change. Rates of coastal change are often out of step with sea-level change, such lags making predictions of coastal change very uncertain. These changes will be accelerated by any increase in wave energy or surge level that are associated with atmospheric changes. There is a widespread belief in the utility of the Bruun rule (Bruun 1962, 1988; SCOR, 1991) as a predictor of coastal response given any unit rise in sea level. Disregarding the finer points of this debate, the rule indicates through a simple budget of mass conservation, that an onshore and upwards shift in the beach profile under sea-level rise is associated with upper beach erosion as the source of sediment required to keep the lower shoreface rising in step with the sea-level rise. In brief, sea-level rise leads to erosion of the back beach area beyond the scale of mere inundation. The scale of erosion depends on the nature and height of the back beach and the height of the incident waves from the storm associated with a 10-year return period. The variations of these situations have been generalised by Carter (1991) into estimating annual retreat rates for the east, north-east and north coast of Ireland (Table 4-6) as a function of a 30cm increase in sea level by 2040AD, somewhat less than latest IPCC estimates identify.

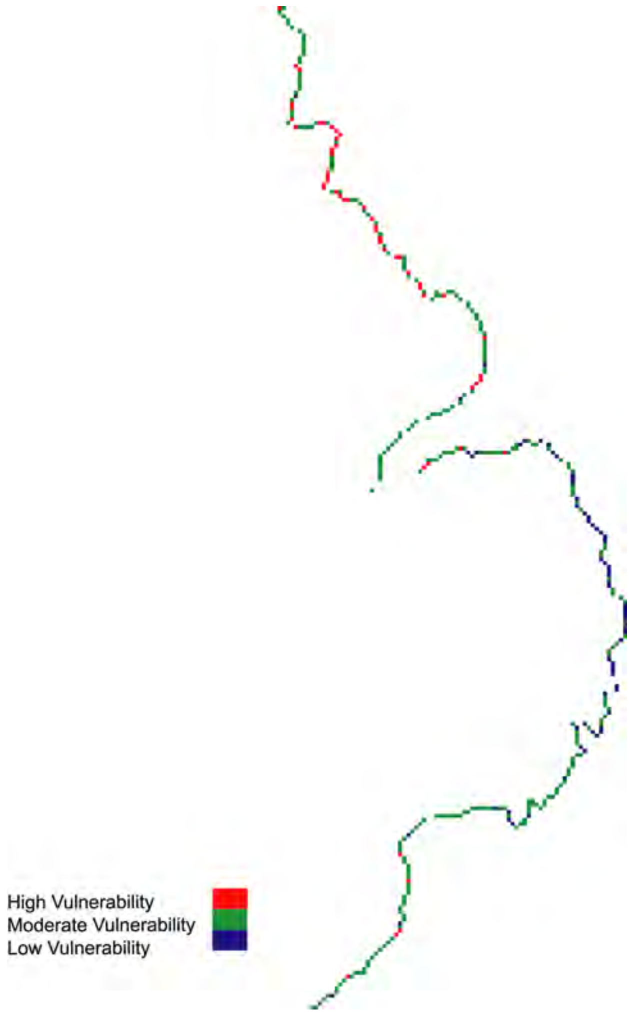
Table 4-6. Coastal recession rates (m yr^{-1}) for Northern Ireland using a Bruun-type analysis based on a projected rise in sea level of 30 cm by 2040AD (Carter, 1990). This equates to a RSLR of 6mm yr^{-1}.

Coastal element	*Shoreline*	*2m glacial cliff*	*10m glacial cliff*
North coast	2.14	2.00	1.58
North-East coast	3.21	2.81	1.87
East coast	12.03	8.59	4.01

A rise in RSL will lead to both increased inundation of low-lying coasts and erosion of soft coasts even before consideration of the effects of further increases in wave activity. The intertidal zone will be squeezed where the landward limit is constrained by a built-response. The loss of intertidal areas of open coasts, by coastal squeeze and increases in wave energy, will be seen in the stripping of sediment volume from beaches as well as a general coarsening of available sediment size. The loss of intertidal zones in estuaries will see a diminishment in protected habitats and a loss of marsh with its associated loss of bio-diversity. It is likely that dunes coasts will suffer non-sustainable beach and front-of-dune erosion. Soft and non-indurate cliff (glacial) coasts (Co. Down) are likely to retreat with rates increasing well in excess of the contemporary average <0.3m yr^{-1} recession rate. Hard rock coasts are unlikely to show any great change, though where hard rock has been a substantial foundation to soft glacigenic sediment perched above contemporary MSL (the Ards Peninsula), there may be major retreat of the glacigenic cover.

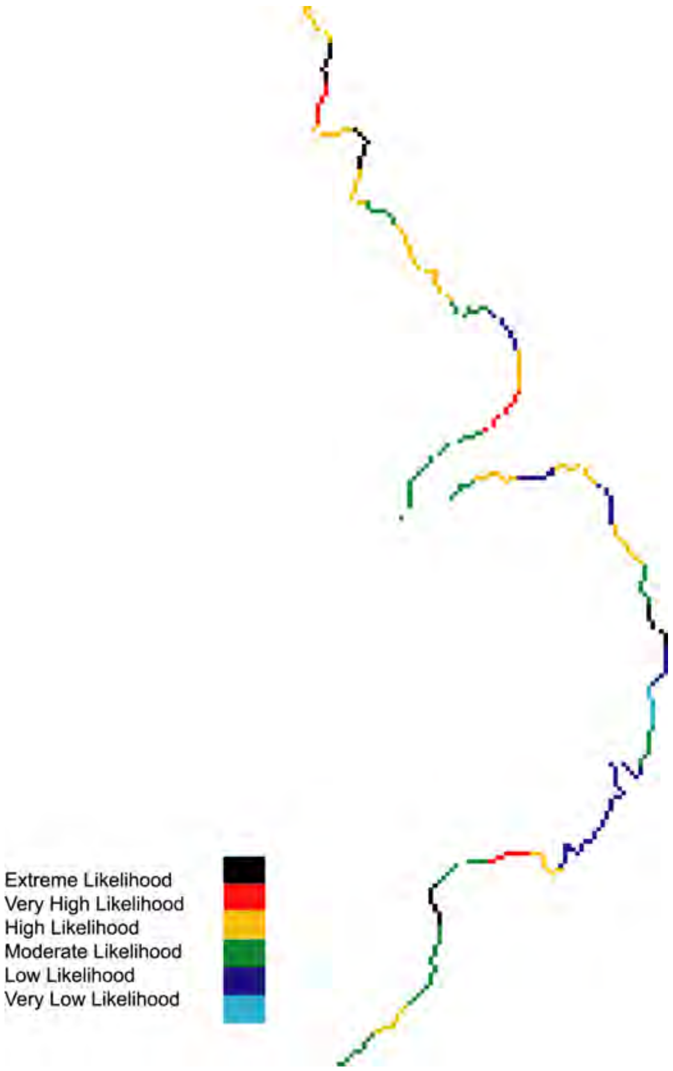
Existing beaches and dunes are likely to be under great pressure. East coast beaches with backshore sediment deposits are generally of late-Holocene age (c. 3,000 years: Murdy, 2001) and are not being renewed at a constant rate to match current sea-level rise. This is reflected in recent media concern for diminishing Ulster beaches as a tourist attraction. Increases in sea-level rise associated with any increase in storminess will result in diminishing beach volumes. The likelihood of increased erosion of adjacent glacigenic coasts (even if allowed by reducing coastal defences) is unlikely to be sufficient to replace this volume over the next century. The current practice of defending dunes (due to the presence of golf courses) is only adding to this depleted beach budget, though the likelihood of such courses retaining their coherency via engineering defence is also debatable (see below).

FIGURE 4-4: The vulnerability of the eastern seaboard of Northern Ireland (McFadden, 2001). Vulnerability is a measure of the physical and cultural functionality of the coastal zone, characterised on a 500m-cell basis. High vulnerability indicates cells that have high functionality and are prone to major disruption in terms of forcing activity.



The current state of the eastern Northern Ireland coastal zone has been characterised by McFadden (2001), in terms of functionality with respect to both the physical and socio-economic dimensions of coastal interactions. McFadden has specified the vulnerability of the coast in terms of coastal functionality based on a 500m-unit cell analysis of the coast (Figure 4-4). This vulnerability analysis attempts to establish the potential for change in the functioning of the coastal zone, given external pressure on the coastal system, e.g. south-east storms and RSLR scenarios (Figure 4-5).

FIGURE 4-5: The risk to coastal vulnerability of the eastern seaboard of Northern Ireland (McFadden, 2001). Risk is associated with the change in south-easterly storm waves due to a rise in mean sea level of 30cm by 2030AD. Colour gradations refer to the degree of forcing change expected as a consequence of RSL rise.



Stakeholder awareness

Awareness that has functional validity should be reflected in *response* rather than *intent* with respect to both physical changes and cultural challenges posed by climate change for the coastal zone (de Groot and Orford, 2000). Unfortunately on this basis, NI stakeholders (Appendix 1) are generally unaware of changes to come. The following points are reflective of general attitudes with respect to contemporary empowered stakeholders making and taking decisions concerning the coastal zone. The attempt to increase stakeholder involvement through a democratic process identified in policies defined as Integrated Coastal Zone Management is welcomed (cf. Ireland's attempt: Brady Shipman Martin, 1997). Such a move towards fostering broad-scale decision taking is however likely to uncover partisan debates that may hinder effective decision taking in the long-term. Understanding, via education, of the wider picture of changes consequent on climate change is a major issue for the immediate future rather than for the long-term. This issue would be facilitated if there were a coherent vision of what NI coastal stakeholders expect of their coast.

The following points attempt to calibrate the state of awareness of coastal pressures among various NI coastal stakeholders.

i. Government awareness should be evident through strategy. Northern Ireland has a lack of joined-up government with respect to strategic coastal policy. This is reflected in a piecemeal or sector-based *modus operandi* when faced with coastal problems. There is no explicit coherent coastal strategy that shows how horizontal or vertical sectors can work together for the NI coastal zone. There are too many independent organisations that operate in a fragmentary fashion, often in direct conflict with other agencies. The only overt attempt to produce a Coastal Zone Management policy was proffered by DoENI (1995). This was centralised around a coastal policy of habitat protection, but as it offered no strategic policy effective for the vast range of human activity, it was effectively sidelined by other agencies concerned with coastal use. Although this habitat approach has been reinforced with EU bio-diversity legislation and protection, it still does not cover the more immediate issues presented by human presence and pressure on coastal resources. NI is in a situation where coastal problems can only be approached through a bipolar legislative perspective, crudely termed as 'bird protection or built protection', leaving a major void between in which *ad hoc* and partisan decision taking is the norm.

ii. Contemporary CZM specifies four modes of management approach to the issues of RSLR and associated coastal stress: holding-the-line, do-nothing, accommodation, and managed retreat (now known under more neutral terminology as shoreline realignment). The movement to a shoreline realignment approach requires a major cultural shift away from the feasibility, utility and sustainability of engineered and interventionist solutions for coastal problems. At most decision-taking levels, NI still assumes a hold-the-line posture with engineered support as the desired outcome. The fiscal and functional abilities to maintain this posture are however, unlikely to be maintained in the face of increased coastal pressure. An acid test of future coastal awareness is when holding-the-line is abandoned for other than fiscal reasons. There is concern that holding-the-line may pass into a do-nothing phase as a result of the lack of government strategy.

iii. Sustainability of the coastal zone as opposed to the sustainability (= survival) of the landward infrastructure/investment is rarely contested in the NI analysis. Emphasis still tends to be placed on landward rather than seaward utility. Climate change effects are likely to stress the need to explore and use seaward utility as the premium, however future climate change on the CZ is likely to be seen as differentially pressurising the built-environment, forcing an engineering response for the quick-fix. There is an urgent need for NI to think out a strategy towards this issue rather than rely on a pragmatic *ad hoc* policy that tends to support the *status quo.*

iv. The strong NI agricultural lobby still holds to a priority of 'no-loss of land function' as the engendering basis for retention of engineered coastal flood defence. NI needs to explore how this tie can be loosened through the general re-assessment of subsidy support for agriculture in the coming decade. The use of set-aside land to allow shoreline realignment is something to be considered. Contemporary coastal flood defences particularly in the Foyle and adjacent coastline are going to be pressured in future decades, but there is no indication of other approaches being considered rather than continuing the existing engineering one. This position is disturbing, especially given UK change of heart in the early 1990s over the utility of coastal-engineered strategies defending agricultural land of marginal-quality.

v. NGOs are probably the most reflective of agencies in NI with respect to awareness about future coastal zone changes induced by climate change. However the extent of their understanding and ability to command a position in the decision-making process is often a function of the externalisation/globalisation of their interests and networking ties. There is also a risk that sector splits due to NGO's interests can produce a cross-partisan perspective that will be at odds with a general strategy of CZM. This could become apparent when discussing the future loss of freshwater upper margins to estuary coastal squeeze when saline elements expand under RSLR, as both areas having their habitat devotees. No net-loss policies have been suggested as a means of easing this balancing act, but this may prove to be contentious, given the limited spatial extent of NI's coastal zone. There is also NGO recognition that a major issue, as a consequence of coastal change for coastal land-owning NGOs, is that they are always at the mercy of up-drift landowners whose likely pursuit of non-sustainable policy approaches (to judge by what is currently happening), are likely to have detrimental impact on down-drift sites. This issue will happen regardless of the NGO status of landowner, but is more likely to be extreme in the situation when the NGO and the adjacent coastal owner pursue radically different strategies towards coastal change.

vi. The industrial and commercial sectors show no major concern with future coastal change, as they feel spatially removed from the problem. However freight transport links via ports are essential for NI economic development and as such port authorities need to think particularly about infra-structural data with respect to the rise in SWL and expected return periods of extreme water levels associated with climate change. There are clear implications for the new generation of fast-ferry operations if sea-states are expected to roughen with increases in storminess. Ferry companies are aware of these issues. All utilities that require discharge of fluids to the coast should be aware of the RSLR and its effect on changing data and reducing time frames within which contemporary discharges may be able to work efficiently.

vii. Tourism/leisure generally is not a sector that has an effective reactive arm to issues of climate change and does not appear to be able to respond readily to its probable long-term implications. The industry by the very nature of its diffuse structure is prone to react only to short-term initiatives that are often dependent on local economic imperatives, e.g. the mid-90s tourist boom on the back of the 'peace-dividend'. Although tourism is passively aware of climate change, there is a tendency to view this simplistically: any increase in temperature can only mean better times for holidays in NI. Associated downside climate impacts such as loss of beaches have not yet been recognised by this sector. However the ability to respond proactively to such negative issues is severely limited by the diffuse nature of the tourist sector as a stakeholder. Particular tourism sub-sectors with direct coastal links, such as golf courses and marinas have been more aware of coastal change (of a contemporary nature), though they tend to be somewhat reactive in their approach to climate change issues and believe they can only resort to engineering as a continuing protective basis. This is understandable given that they are often caught in a coastal squeeze, whereby they have no alternative site to which they can transfer activities. However radical rethinking of their operations might need to be made, if their futures are to be secured under climate change, as a coastal defences option are unlikely to be financially viable in the private sector.

viii. The accelerated incursion of new building for domestic, tourist and leisure purposes into the NI coastal zone is a major problem for the future. There appears to be a lack of understanding in the private sector, of the risks inherent in building close to the inter-tidal zone, particularly given that planning control cannot be used as a limiting procedure for *future* external safety purposes. The lack of a NI coastal zone strategy means that there is no effective planning control as a function of coastal proximity. This absence of policy allows the construction of property into what can be both hazardous positions *per se* and hazardous for surrounding habitats, within the life span of the property. To some extent the issue of positional risk to flooding/erosion has traditionally been seen as best controlled through private insurance. Both primary and secondary insurance companies are actively constructing (taking advantage of recent GIS and remote sensing methodologies) geo-referenced location, risk and knowledge databases about known flood areas. This means that future premiums could be differentially loaded to the point that owners of coastal property deemed to be at risk, may have to live without insurance cover, or be forced to sell below the comparable market value of such a property elsewhere. It is disconcerting that insurance may be the first *de facto* non-governmental instrument of control, on coastal living (Clarke, 1998). Insurance companies heightened awareness of climate change means that this instrument is already being conditioned for the effects of future climate change. There is the likelihood of a yawning gap between the public and insurer’s view of desirable coastal accommodation in future decades and issues of negative equity becoming common in the coastal zone. The issue of coastal setback controls on construction with/without short-term life spans or depreciation to zero value in the short-term have still not been discussed within the planning-finance-construction sectors. A sign of awareness maturity for NI will be when these concepts are openly discussed.

Conclusions

The Northern Ireland coastal zone will experience accelerated change over the next century. The kind and degree of change is still unknown and underlines why NI coastal stakeholders appear to be unaware, other than in very general terms, of what these changes will mean for the functioning of society in the coastal zone of the next century. There is an urgent need to develop a vision of ‘Future Coast’ for Northern Ireland with which the majority of coastal stakeholders can identify. Creating such a vision will need the implementation of a cogent and unified coastal zone strategy. Achieving non-partisan awareness over the widening base of coastal stakeholders is likely to be a major educational requirement in preparing for future NI coastal change.

4.1.4 Other natural processes

W. Brian Whalley and David Favis-Mortlock
School of Geography, Queen's University Belfast

Summary
Here climate change impacts on river basins and flood plains and in proximity to unstable escarpments are discussed. Flood abatement strategies, however, can be employed. These rely on land use activity e.g. afforestation upstream to minimise rapid runoff, is possible but must be used with careful planning controls. There is likely to be an increased incidence of floods, flowslides of mud, and rockfalls. Vulnerable areas require careful monitoring.

Geomorphological and hydrological changes

In general, the effects will be responses to the predicted increase in overall precipitation, particularly winter precipitation. Additionally, as there are predicted increases in variability and especially in the intensity of precipitation events, all of the processes listed below are likely to see increased activity.

River basins

Climate change is expected to produce a variety of effects within river basins with respect to hydrology and the land use in the basin. There may also be a secondary effect such that changes in land use (whether or not the result of climate change) will affect the hydrology. These secondary factors may have response times that vary from a few years to tens of years. Evapotranspiration changes will produce effects on the vegetation cover that need to be reviewed as part of the influence of secondary basin factors concerned with land use.

Stakeholders (Appendix 1) need to be aware of a number of, often interrelated, factors associated with climate change. Recent, highly publicised, events have probably helped to increased awareness of problems in floodplains.

Flooding

Rivers flood naturally. The flood plain is a consequence of this natural process over thousands of years. Where there has been human construction on the flatland of the floodplain there has usually been a response to control the river to stop it meandering and to keep the river within the confines of a canalised section to prevent the natural flooding. However, if a river does overtop (or break through) its lateral defences then the consequences may be severe. In the last few years there have been several instances of severe flooding to homes and commercial properties and these have often been attributed to 'global warming'. Most notably, the large river catchments in Kent, Sussex, Yorkshire and Devonshire in the October-November period of 2000 show the dangers of building on floodplains or close to canalised sections of river, even when the dwellings etc. have been there for many, perhaps hundreds of years. Unfortunately, even when there have been records of river levels/discharges over decades, it is not possible to predict what the frequency of 'anomalous' meteorological events will be. The future scenarios for rivers must ensure that current ('adjustment') methods for floodplain management are used. This entails the concept of the 'floodway' (one flooding event every five years) and a series of zoned areas on the floodplain. These zones have predicted flood events corresponding to different levels of economic activity and planning control. A second method, of minimisation of damage is ‘control’ but is probably not recommended as this is both expensive and unlikely to be of value in the Province. Flood abatement strategies, however, may be employed. These rely on land use activity, e.g. afforestation upstream to minimise rapid runoff, are possible but again must be used with careful planning controls.

Flooding of rivers in coastal areas present a particular problem which must be related to both sea level rise and coastal defence measures. The floods at Towyn (North Wales) well illustrate the problems of unconstrained holiday development in an area subject to spring tidal events and storms as well as river flooding.

Land use

Constraints may need to be applied to future development in basins associated with flooding. The hazard zonation schemes (supra) will need to be applied. New building styles (e.g. stilts) can minimise flood damage but health hazards from sewerage are additional and significant hazards. Any changes of vegetation in drainage basins, either human induced or natural will need to be evaluated with care. Not only may vegetation changes affect flooding but may also induce high runoff rates.

Slopes and slope failure

Certain slopes in the Province have a long history of failure after high intensity rainfall. These will undoubtedly be affected by the predicted changes in rainfall intensity and variability. In the main, the active failures are in the east of the Province, namely bog bursts, which are high magnitude but low frequency. These may be difficult to predict (Tomlinson, 1981). However bog bursts are localised events and thus only of importance in a limited number of vulnerable locations.

The east Antrim coast has long been known for small mud flowslides. These can occasionally block the road. Again, prediction long term is difficult. Long term monitoring suggests that the activity in the period 1985-2000 was rather lower than 1970-1985. As well as occasional high intensity storms that trigger events (which may or may not be sufficiently large as to endanger life or block the road) the antecedent moisture conditions in the slopes also have an effect. However, even monitoring slopes is not easy so that precautionary measures need to be undertaken.

Other areas that may occasionally produce enhanced slope failure are rock slopes. There are specific locations where these are potentially dangerous at tourist sites (Giant's Causeway Coastline, Garron Point) where heavy rainfall, especially preceded by prolonged rainfall, could increase the incidence of rockfalls of varying sizes of block.. As most slope failure events respond rapidly to high intensity precipitation events and the prediction of these is difficult, the next 80 years must be viewed with the assumption of additional hazards to certain areas in general and selected sites in particular.

4.2 The living environment

4.2.1 Biodiversity and habitats

W. Ian Montgomery
School of Biology and Biochemistry, Queen's University Belfast

Summary
There is concern that the direct and indirect impacts of climate change on the species-poor but unique ecological communities of Northern Ireland could be considerable even though these impacts go unnoticed by the general public. Direct effects, such as the invasion of more southerly, thermophilic (i.e. heat-loving) species replacing cold-adapted species at the southernmost edge of their ranges, may occur at different rates depending on habitats and taxa. However, these direct effects are likely to be severely compounded by other anthropogenic effects such as habitat fragmentation, agricultural change, invading species and eutrophication. Similarly, the impacts on migrant species that might occur in other parts of species ranges must be considered. For example, migratory birds are major components of the avifauna of Northern Ireland in both winter and summer. These are highly vulnerable to changing conditions in other parts of their ranges and during migratory movements. Although management of the effects of climate change may be possible for some species or habitats, a more holistic approach is suggested ranging from sympathetic interpretation and implementation of agricultural policies to improved management of freshwaters and creation of salt marshes in response to sea level rise.

Introduction

In considering the impact of climate change on biodiversity, it is critical to treat Northern Ireland as part of a discrete biogeographical unit from the rest of the United Kingdom. Ireland presents a different set of physical conditions and a biota with a distinct history from that of Britain. Contrasts with the rest of Europe are even more marked such that although species poor by comparison, Northern Ireland supports unique biological communities and genetically discrete populations of many species (Northern Ireland Biodiversity Group, 2000). Here we will examine how climate change might impact on Northern Irish ecosystems, habitats and species. While there may be substantial direct effects on communities, populations and individuals, indirect impacts on these levels of biological organisation will also occur through, for example, changing land use, agriculture and tourism. It is also critical that how regional change may be affected by climate change impacts elsewhere through effects on summer and winter migrant species. Perhaps the most dramatic and subtle effects will be the influence of interactions between climate change and other anthropogenic processes undermining biodiversity and, in particular, the unique species assemblages that are found in an island isolated on the north western edge of Europe. Interactions with habitat loss, pollution, invading aliens, agricultural change, for example, may be very significant.

Stakeholders (Appendix 1) felt that rather than high species turnover in the face of climate change, the relative abundance of species in communities would change with some common species becoming rare and some rare species becoming more common. In general, more thermophilic species and taxa will benefit while those favouring cooler conditions especially in summer will be affected adversely (see Box 4). For example, the two spot ladybird, *Adalia bipunctata*, well known in Britain, is a recent immigrant to Northern Ireland. For a time, we might discover increasing numbers of species represented by a few isolated individuals. Invading species, with or without the help of people, will blur the distinction of native and non-native species. Invasive species can have dramatic and unpredictable impacts on recipient communities but generally a 50 year timescale was envisaged to detect significant effects. Some stakeholders commented on the robust nature of a Northern Irish biota that already is isolated and has experienced a wide range of environmental degradation and change including climate change. We would stress the lack of reliable data[1] enabling confident prediction about changes in species ranges and abundance in the face of climate change and/or species adaptability. In particular, establishing a timescale for change is difficult. Stakeholders were not convinced that Government, industry and the voluntary sector has as yet devoted sufficient attention or resources to the impact of climate change. Government, for example, is regarded as reacting to rather than anticipating environmental degradation.

BOX 4

Case Study 3. Different groups of invertebrates respond differently to climate change

Cold-tolerant predatory Coleoptera displace more thermophilic groups e.g. the ants, cockroaches, mantids and grasshoppers, farther north. Climate change might slowly change this. Relict populations of boreal ground and rove beetles (Carabidae and Staphylinidae) are likely to be the first to go and there is evidence that this is already happening. Two species unique to the British Isles, *Bembidion argenteolum* (last record 1923) and *Stenus palposus* (last record 1983) have disappeared from the fauna feeding on the bacteria and algae of Lough Neagh sediments. The high northern ground beetle *Pelophila borealis* is still widespread in the north and west but is declining. Rising winter temperature minima are likely to be contributing factors to these changes.

The freshwater and wetland insects of Northern Ireland represent unique assemblages with northern cold-adapted species occurring at the southernmost limit of their range. These species tend to occur around the edge of large lakes and associated habitats of mesotrophic bogs and fens. Their presence is the direct result of post-glacial history and absence of competition from more southerly species. Global warming will be accompanied by the invasion of the latter, as is already apparent in more mobile species such as dragonflies (B. Nelson, personal communication). The effects on less mobile groups may be harder to detect. Rare upland species, such as the water beetle, *Dytiscus lapponicus*, the dragonfly *Somatochlora arctica* and the water bug *Callicorixia wollastoni* may be ousted by lowland species that with rising temperatures are able to move into higher and more western areas.

Millipedes, crustaceans such as isopods (woodlice and allies), and the molluscs are poorly represented in the impoverished fauna of Ireland compared to Britain and especially continental Europe. During the 20th century, however, these groups have been augmented by anthropochorous dispersal and this is likely to continue. For example, there are about 30 native millipede species and another 11 (41%) introduced. Fifteen percent of the non-marine Irish mollusc fauna (159 species) has been introduced and eight of these species are slugs with implications for pest control. More southerly species reaching Ireland undergoing

[1] The MONARCH study (Pam Berry, personal communication October 2001) was published as this report was being finalised.

amelioration of winter temperatures and enjoying more, warmer days in summer are more likely to be able to become established. The effects on endemic communities are unpredictable.

The most important climatic changes suggested likely to impact on animals and plants, and the functioning of ecosystems involving microbiological processes, are: increased mean temperature and, in particular, the rise in the number of degree days in excess of 25^{o}C and the fall in number of degree days below 0^{o}C; the rise in overall precipitation; the rise in evapotranspiration in winter and autumn; and the potential increase in the number of storms classed as major catastrophic events. Changing frequency and intensity of extremes of temperature and rainfall is also considered to be important for plants. Plant distribution and abundance is likely to be greatly affected by temperature, water availability and evapotranspiration all of which have a direct effect on photosynthesis, growth and productivity. Animal mortality is likely to be impacted by milder but damper winters while catastrophic events produce great change in whole communities, for example, due to loss of woodland or flushing of watercourses. Microbiological processes will be accelerated by higher temperatures. In general, community composition is likely to be affected most not by mean conditions but by extremes and chance events. A series of particularly hot summers or stormy winters, for example, would have more radical effects on woodland phytosociology, for example, than a gradual warming of mean temperature or increase in average storminess.

Several stakeholders were aware of possible disruption to the North Atlantic Oscillation, as the Arctic and Greenland ice retreat, leading to interference of the Gulf Stream and its ameliorating effect on the climate of the British Isles and much of northwest Europe. While current scientific opinion considers this unlikely within the timespan covered by the UKCIP scenarios (see Box 2), the rapidity whereby this might occur leading to a sudden cooling of the climatic conditions would have quite different implications for biodiversity than those discussed here. In the extreme, internationally important sites for overwintering water birds such as the shallow, rich feeding sites of Lough Neagh and Lough Beg could freeze and cease to be of any ecological value to the former communities.

Terrestrial environments

Rising temperatures, and increasing evapotranspiration and numbers of storms are likely to be the major influences of climate change in terrestrial ecosystems, communities and populations. The terrestrial habitats of Northern Ireland vary from fens to deciduous woodland and unimproved lowland wet grassland to sand dunes. The greater area in both upland and lowlands, however, is under pastoral agriculture. These factors cannot be ignored in considering climate change’s potential impacts upon biodiversity. Milder, damper summers could promote the growth of short-lived weeds and reduce indigenous grassland flora, and benefit some pests, particularly aphids and slugs, and fungal disease, such as rust in cereals, grasses and willows. Insectivorous birds and bats might benefit from longer periods of greater food availability. Agricultural diversification could be accompanied by newly introduced invertebrate species with unpredictable impacts. On the other hand, some pests are unable to withstand higher incidence of warmer days in summer e.g. the New Zealand flatworm that can reduce numbers of earthworms in gardens and pasture, has a lethal soil temperature of 20^{o}C.

Northern Ireland retains some excellent raised bogs and considerable areas of intact blanket bog (Tomlinson *et al.*, 2000). Under the climate change scenarios a number of effects may occur. Increased rainfall coupled with elevated water tables may lead to renewed bog growth. Depending on immediate conditions such as slope and exposure of peat surfaces increased rainfall might also lead to increased erosion and laying bare of the underlying bedrock or soils. Extreme rainfall events may lead to bog bursts but this would be on the local scale and not likely to greatly affect biodiversity.

Agriculture in Northern Ireland is likely to continue to be chiefly pastoral, although higher summer temperatures and increased degree days over 25^{o}C may promote a move to cereals and other arable crops. This land use change combining with climate change may have a positive influence on, for example, Yellowhammer and other cereal feeding birds that have declined in number in recent years, provided management favours spring-sown cereals and species-rich field margins. However, Government agricultural policies in the wake of epidemics affecting livestock in the UK might well encourage a move to less intensive forms of agriculture, organic products and diversification. Warmer summers combined with more extensive agriculture would go some way to reversing the decline in the making of hay as winter forage. This potentially would have a positive effect directly on grassland flora, ground nesting birds and the Irish hare, all of which have declined to an alarming extent since the 1960s. The major effect on terrestrial biotas, however, will be a longer growing season associated with higher spring and autumn soil temperatures. There are already data suggesting that breeding seasons start earlier. While this might permit additional recruitment in some species that can fit in extra broods, there are associated risks. Earlier breeding could be associated with greater likelihood of inclement weather after breeding has commenced with negative effects on plants, insects and birds affected by sudden frosts or high rainfall. The asynchrony of budburst and emergence of insects from overwintering eggs could have severe effects on nesting woodland birds in some years.

Severe storms have a positive effect in creating opportunities in woodland for young trees. Increased disturbance of a more frequent and radical nature could lead to a more homogeneous species and age structure of trees and ultimately reduced opportunity for associated plant and animal species. Old woodland is rare in Ireland and would be difficult to sustain and impossible to recreate. More southerly, introduced tree species, like the opportunistic Sycamore, are more likely to flourish in a milder, less extreme environment with more frequent disturbance brought about by storms, than natives such as Oak. Ash may also dwindle as winter mean temperature increases.

Migrant animal species to Northern Ireland may be categorised as coming to us from either low or high latitudes. The former include migrating birds and insects from southern Europe and Africa in the summer, and the latter species of waterbird breeding in the Arctic and arriving on our shores in autumn and remaining to the spring. These migrants are frequently significant components of the UK biodiversity and the effects of climate change on them in other parts of their range have been neglected. Migrant species may be more affected in other parts of their range because these are likely to be more extreme places with prolonged periods of high or low temperatures or drought to contend with. Further, greater storminess may reduce survival rates during migration particularly over seas and oceans. On the other hand, there may be increased recruitment in species breeding at higher latitudes if food availability is increased due to higher temperatures during the period for incubating eggs and rearing young or before passage as reserves of fat are laid down. In contrast, recruitment at lower latitudes could be depressed if hotter and drier conditions reduce food and water resources. Effects at lower latitudes may be severely compounded by anthropogenic effects brought on by abandonment of traditional land management and urbanisation.

Freshwaters

The freshwaters of Northern Ireland are particularly abundant. They will be affected by rising temperatures, rainfall and storminess, but already many of our freshwaters are largely degraded by eutrophication and introduction of alien species. Eutrophication will be promoted by higher temperature but greater rainfall will increase flow and dilute nitrate and phosphate concentrations, and increased wind speeds could reduce the chance of stratification of lakes during summer. Reduction in nutrient input is planned so the major effect of climate change may be a direct effect of temperature and increased run off. These may change distributions of plants locally and it is possible that losses of species from catchments will not be balanced by invasions due to low dispersal rates in water plants. Prolonged periods of higher summer temperatures could lead more easily to deoxygenation and, hence, it is important that planned reductions in nutrient inputs are realised. There are few pristine lakes remaining but these should be regarded as vulnerable to increasing temperature due to the higher incidence of degree days in excess of 25^{o}C. Very high or very low spring and summer rainfall could influence water level in shallow lakes notably Lough Neagh. Ground nesting birds such as gulls and terns are vulnerable to these extremes as they exploit low islands. Extremes of rainfall with rapid flushing or periods of stagnation may also have an adverse effect on the quality of inter-drumlin lakes characteristic of southern Co. Armagh and Co. Down. This could adversely affect relict populations of flightless water beetles supported by associated fens in the drumlin landscape.

The major effect on rivers is also likely to come from extreme events in the form of sudden rainstorms. These have the potential to erode riverbanks especially those lacking significant vegetation as in many NI rivers. Microbiological processes of lakes and diverse taxa such as aquatic bugs and beetles are temperature sensitive such that there should be a gradual change towards a warmer water biota incorporating species with high vagility. Higher rainfall could result in enhanced groundwater movement creating, for example, more freshwater flushes. These are associated with, for example, a specialist insect fauna. These rarities might become more common especially if they can produce more than one generation per annum.

The marine environment

The marine environment of NI is very diverse with extensive sheltered and exposed hard and soft sediment shores. Climate change impact on the latter is likely to be more dramatic than on the former. Rise in sea level will impact on the distribution of organisms in the intertidal. Rapid sediment movements may produce temporary discontinuities in some populations, such as eel grasses, *Zostera* spp., and algae, but in time there should be recolonisation although it is unlikely that there would be a return to former distributions or status. Northern Ireland has limited areas of saltmarsh having already lost much of this to land reclamation and sea defences. The small areas remaining in Lough Foyle, Strangford Lough and Carlingford Lough, would be under threat as sea level rises and incidence of storms rises if only marginally. Higher energy littoral environments associated with storms in addition to sea level rise might change vulnerable soft sediments substantially, potentially affecting their value to wintering wildfowl and waders.

Although biogeographical changes comparable to those affecting terrestrial and freshwater ecosystems with higher coastal sea temperatures leading to a gradual northward spread of southern species and loss of more northern species, the marine environmental presents little obstacle to dispersal of organisms with planktonic stages. Hence, species replacement in the marine environment may proceed more steadily and completely than in terrestrial or freshwater systems, and the coastal marine fauna of Northern Ireland may become increasingly like that of more south-westerly coasts in the British Isles. The combination of higher energy and temperature in the marine environment might remove a number of soft sediment types that are the product of a unique combination of sediment, aspect, tidal range and latitude. Highly valued sites such as The Dorn or even Strangford Lough in general, may be subject to change reducing their uniqueness. Stakeholders, however, acknowledge that predicting what would happen to the benthos of highly valued coastal sites is problematic given the vagaries of surface currents and spatfall. Occasional spatfall may sustain remote populations on the edge of ranges. The Horse mussel beds, *Modiolus modiolus,* of Strangford Lough, for example, are believed to be glacial relicts that have already experienced and survived considerable environmental change.

In the northern part of the Irish Sea frontal systems form in most years between south Down and the Isle of Man and between Donegal and the west of Scotland. These are barriers to planktonic dispersal and, hence, affect both primary production and distribution of consumers. The occurrence and location of these fronts is susceptible to climate change. Thus, we anticipate major change in the distribution and abundance of, for example, predominant, predaceous fish. This is already evident with the more southerly Haddock replacing the coldwater Cod in the Irish Sea fish catches. Relocation of fish in response to changed surface temperatures, particularly during the spring and summer, may also affect the energetics of seabirds nesting on coastal sites. Migratory habits of Atlantic salmon and eels that spend part of their life cycle in the sea and return to freshwater may be affected adversely by changes in river hydrology and maritime currents.

Hossell *et al*. (2000), have reviewed climate change impacts on species, habitats and current policy commitments in the UK although the emphasis is clearly Great Britain. They concluded that montane habitats, raised bogs, soft, supra-littoral sediments and chalk rivers, are the most sensitive to climate change, or consequent development, among Biodiversity Action Plan (BAP) habitats. Of these, raised bogs and soft, supra-littoral coastal sediments are of most relevance to NI, although it could be argued that these too are already limited in extent. At the time of writing, only a partial draft copy of the final report of Modelling Natural Resource Responses to Climate Change (MONARCH) is available (Pam Berry, personal communication, October 2001). This adopts a modelling focus on land use change and interactions with species’ distributions, dispersal in relation to habitat fragmentation and integrated management in conservation throughout the UK including NI, and aims at more quantitative prediction of the impact of climate change on major groups such as waterbirds living in estuaries and terrestrial birds in fragmented habitats such as woodland or reedbeds. For NI in particular, these predictions must be treated with caution since species distributions are frequently determined by a matrix of environmental factors, many of which are not adequately captured at the scale at which the MONARCH modelling methodology operates, and history. Similarly, Marine Biodiversity and Climate Change (MarClim) will assess and predict the influence of climate change on intertidal animals and plants. Hawkins *et al*. (2000) list over 120 species likely to be affected by either a northward or southward shift in their distributions. It is inevitable that some of these changes will affect the coastline of NI.

Adaptation

Stakeholders proposed a variety of adaptations to climate change impacts although these frequently addressed other anthropogenic effects on biodiversity e.g. increasing connectivity of wetlands and reducing nutrient inputs, better management of headwater wetlands and river flow, protection of saltmarshes and creation of new saltmarshes by ‘planned retreat’. There was also an emphasis on improved monitoring of key habitats, including fens, raised bogs, old growth woodland, and acid grassland, and fauna and flora sensitive to potential impacts. Biodiversity Action Plans are currently available on Irish hare, Chough and Curlew and should be considered in the light of climate change. The production of these species plans should be accelerated. There is also a need to monitor and limit the introduction of alien species particularly those associated with plant nurseries and garden centres, ports and shipping. This of course requires adequate funding and is regarded as a Government responsibility.

Why biodiversity is important

Biodiversity is fundamental to environmental quality as a whole and is of obvious importance to environmentalists. However, climate change impacts and the manner in which other anthropogenic factors interact with climate change are of direct importance to others. For example, pest control is a major concern in agriculture and horticulture both important parts of the Northern Ireland economy. Loss of biodiversity, for example, overwintering waterbirds on Lough Neagh and Strangford Lough, or loss of floral diversity in the wet meadows of Fermanagh, would have an effect on tourism reducing the attraction for many visitors. Responses to anthropogenic effects on biodiversity other than climate change, for example the rapid and effective introduction of Environmentally Sensitive Areas to address inappropriate agricultural intensification in parts of Fermanagh, Tyrone and Antrim, may mitigate the short- and medium-term effects of climate change in Northern Ireland. Maintenance of a heterogeneous landscape enhanced by a more mixed form of agriculture and more, warm days during summer, would be welcomed by many people. The more subtle direct and indirect effects of climate change, however, may be of little concern or interest to the wider public. Loss of biodiversity in freshwaters, however, would be an important signal of low water quality and, hence, a potential threat to human health, while quality of human life in general would deteriorate with the generally negative effects of climate change on the unique biota of Northern Ireland.

Concluding remarks

Regardless of the precise course of climate change, its impacts will not occur in isolation. Northern Ireland has a unique biodiversity in terms of ecological communities and sub-specific variation (Northern Ireland Biodiversity Group, 2000). While there are reserves and legislation in place addressing particular exemplar habitats and vulnerable species, these alone are inadequate to sustain many elements of our biodiversity in the face of multifarious threats. Climate change will compound, for example, the effects of habitat fragmentation, overgrazing and eutrophication. Therefore, in order to ensure that species can accommodate to changing climate, a more holistic approach to conservation of habitats and species should be implemented. While reserves are clearly of great importance, the management of the wider countryside for biodiversity will be required if the potential threat of climate change is to be overcome successfully i.e. both the ecological functioning and uniqueness of our biological communities and populations is maintained. This is the approach favoured by Harley (2001) in his paper to the Joint Nature Conservation Committee. If such a policy is to be implemented, education of both the public and Government is essential to win the debate.

4.2.2 Agriculture, horticulture and forestry

Jim McAdam and Roy Anderson
Department of Agriculture and Rural Development, and School of Agriculture, Queen's University Belfast

Summary
Agriculture in Northern Ireland is dominated by livestock farming, with most land under pasture or used for silage production. This will continue to be the case under future climate scenarios although farming in the west of the region is expected to become more marginal, with scope for greater diversification in the east. Climate changes may encourage a more mixed agriculture, with better conditions for arable farming allowing more, and a wider range, of crops to be grown, including non-food crops. There could be a return by some to a spring-sown cropping regime which, when managed appropriately, can benefit biodiversity.

The horticulture sector is not likely to change much although it may benefit from a limited market expansion. Conditions for apple production will improve slightly; mushroom producers may need to make capital investments to cope with warmer summers. Most of the impacts on forestry and woodlands are likely to be negative although there will be opportunities to plant a wider range of tree species, and to integrate trees into the landscape in more varied ways (eg agroforestry, silvopastural systems). Ancient, native and heritage woodlands will be under greater threat and will need more active conservation.

Overall, the impact of climate change will be relatively slow when set against the main policy drivers affecting this sector e.g. reform of the CAP, expansion of the EU. These will have a major effect and may serve to blanket changes in climate to some extent. Nonetheless, the implications of climate change for agriculture and forestry are significant, particularly with their importance to the future prosperity of rural areas in Northern Ireland.

Introduction

Agriculture in Northern Ireland is dominated by livestock production from grassland with approximately 2.7m sheep and 1.7m cattle grazing 78% of the land area (DARD 2000 & NICS 2000). Of this area 54% is improved grassland, 36% unimproved and semi-natural vegetation. Only 5.5% of the farmed land is in arable production.

The Forest Industry is a relatively small land user (6% in 2000) but there is the potential for significant expansion within current EU policy direction. About 20% of the forested area is privately owned, state afforestation (DARD) accounting for the bulk of the planting. Approximately 80% of tree cover is coniferous forest and 20% broadleaved woodland, mainly in small planted lots on private land.

There is also an intermediate land use category which will be termed *agri-forestry* which falls between the agriculture and forestry sectors and which embraces the integration of trees by more unconventional or intimate means into farmed landscapes. Such systems include short-rotation coppice, silvopastoral, silvoarable farm woodland, grazed woodland, shelterbelts and scrublands.

The impact of climate changes on these will be considered separately. Commercial and recreational fisheries (both marine and freshwater) are considered in section 4.2.3.

Climate change impacts

Background. The impact of climate change will be relatively slow when set against other main policy changes e.g. reform of the CAP, expansion of the EU. These will have a major effect and may blanket any changes in climate. Nonetheless the implications of climate change for agriculture and forestry are significant.

The agricultural supply and demand scenario affects prices and fortunes of farming more than any other primary industry. Hence changes (such as strength of sterling) which happen in another region, particularly part of the EU, can have a major impact. The impact of climate change on agriculture and forestry in Northern Ireland may to some extent depend on climate impacts in other parts of the world.. Climatic impacts in central Europe, for example, could have a major impact here. Water shortages elsewhere might affect cereal productivity and so influence the market in Northern Ireland.

Overall Changes. Climate change will impact on all aspects of agriculture and forestry in Northern Ireland. It will affect the main land use activities in different ways, the interactions between them, the relative importance of each in the future as well as the rural socio-economic infrastructure. It is predicted that, overall, climate change will not favour livestock farming, will widen the options available for cereal farming and will encourage the expansion of non-food crops. Moves in this general direction will lend to return to a more diverse farmed landscape with either greater specialism between farms in a more mixed farming scenario.

Arable sector

Climate change will provide the opportunity to grow a wider range of crops such as forage maize and hemp, and high protein crops such as lupin and alfalfa. This will impact on the livestock sector through a reduction in the land available for livestock production and a wider range of options for imported feed substitution and affect landscapes. There may be a move from winter to spring cereals. Cereal pests and diseases will likely increase and may become problematic if winters remain mild. Many arthropod pests will overwinter successfully and others will migrate from southern latitudes. More agrochemicals will need to be used and the efficacy of chemicals currently in use may decline, requiring new strategies. However, occasional cold winters or heavy frosts may be enough to keep disease and pests under control.

There will be greater opportunity for energy/industrial crops e.g. hemp, willow biomass. Changes in accumulated growing days and in atmospheric CO_2 levels will improve willow growth although a decrease in summer rainfall may offset potential advantages. There is always the element of serendipity and severe climatic events in individual years will have the potential to turn these advantages on their head and devastate crop production.

Livestock sector

While projected changes in climate may increase the potential for grass growth, it will make utilisation more difficult. Soils will be wetter later in spring and since wet soils take longer to warm up, soil poaching may present difficulties and with that reduce the opportunity to dispose of animal wastes (slurry) by conventional means. A potential problem for water quality is signalled here.

The choice of cropping and harvesting systems and their integration with livestock production may see change. It is expected that maize silage will increasingly replace grass silage, particularly in drier south-eastern areas less prone to attack by fungal disease. Current grass varieties may not be suitable for the altered climate. Modifying grass varieties to meet changed needs is a long-term process as it requires approximately 25 years to produce a new variety, so adequate long-term predictions of climate are essential for this sector. There are many other constraints within the sector and it is expected that concerns over water quality and nutrient management on farms will necessitate much more stringent nutrient management controls by regulatory agencies. This in turn will also impact the kind of varieties needed.

The amelioration of climate may benefit the upland sector by extending the grazing season but weather extremes could also have a serious negative impact. If an improvement in upland conditions were perceived by government, financial pressure within the EU (accommodation of new entrants from eastern Europe etc.) could ensure contraction of the currently designated ‘disadvantaged’ or agri-environment areas in Northern Ireland although this would largely be a policy-driven decision. Direct support to agri-environment schemes might potentially be affected and with that the ‘buffering’ effect which this funding provides in reducing impacts of intensification as well as climate change.

It appears at present that livestock farming will become less competitive in the west and easier (combined with a diversified arable impact) in the east of Northern Ireland. Traditional low-intensity livestock farming will be more difficult under the projected scenarios but there will be opportunities to diversify for the larger and more entrepreneurial producers.

Horticulture Sector

The Horticulture Sector is not likely to change much within Northern Ireland as a result of climate change but will be strongly influenced by the world market and by growing conditions elsewhere.

With the apple crop, checks and balances on disease could be altered by climate change. Cool wet summers favour apple scab, hot dry summers favour apple mildew. Arthropod pests may become more damaging if climate becomes warmer e.g. incidence of the codling moth may increase. Currently the most serious constraint upon cropping is weather. The difference in the total Northern Ireland apple crop between a good year (40 kilotonnes) and a bad year (9 kilotonnes) is substantial. These differences are due almost entirely to the incidence or otherwise of late frosts. If climate change produced a change in the frequency of cold snaps in late spring, the effect on apple production could be substantial. Overall, there may be room to expand the apple industry slightly with favourable (predictable) weather but the overall area for crop production is unlikely to change much.

Mushroom production has been affected by recent warm summers and there is a problem if this should become a regular feature of climate here. Capital investment in better air circulation or conditioning facilities will certainly be required in the longer term and any drop in summer precipitation will incur the additional risk of more dust in the production units, which in turn increases the prevalence of competitive (weed) or disease fungi in the beds.

The vegetable industry is very small and is in the hands of a few large producers and there is unlikely to be much change.

Forestry and woodland

The key functions of the forestry sector are to produce marketable timber and to provide forest recreational facilities.

Most of the impacts on forestry and woodlands are likely to be negative. Catastrophic events such as severe storms and late frosts will have major impacts on forest infrastructure, especially current Sitka Spruce stands on deep peat. This will impact on both timber marketing and recreation.

There is likely to be an increase in arthropod pests and in some fungal diseases in addition to frost damage. This will be offset to a degree by a longer growing season and higher overall productivity. The range of tree species suitable for planting in Northern Ireland is also likely to increase. Some native species with a long cold season requirement (e.g. ash) will decline.

Ancient, native and heritage woodlands will be under greater threat and will need more active conservation. The genetic base of native tree species may be diluted by wind damage and the selective removal of ancient timber. The diversity of saproxylic arthropods associated with old growth forest (*urwaldtiere*) will certainly be seriously impacted.

There may be more scope for land use systems which can adapt to a wider range of climatic variables and which will enhance the landscape and possibly biodiversity e.g. agroforestry, silvoarable, silvopastoral and farm woodland systems.

Socio-economic impact

Livestock farming in less-favoured areas will come under greater pressure as a result of climate change. Farmers see climate change as something which is already adversely affecting them — they notice problems with silage cutting, turf cutting, hay making etc as wetter winters are reaching further into the summer, and in particular the spring harvesting period. This is a comparatively small sector, however, and a major impact of climate change on farming as a whole is not predicted. Changing patterns of climate elsewhere in the world may well have a much bigger, and probably positive, influence upon market conditions here.

Climate change will be more beneficial to consumers than producers in the short term. As mentioned above, world market conditions are likely to change, perhaps catastrophically, in the longer term and may advantage producers at the expense of consumers i.e. food prices will almost certainly rise in the longer term as many producers elsewhere in the world are producing cheaply but unsustainably and will be much more severely impacted by climate change than producers in western Europe. The major difficulty for producers here will be to ride out the current period of world over-production until climate change and other factors tilt the balance back in their direction. In the meantime considerable investment by government into sustaining rural communities is essential.

While it is important to move away from a culture dependent on subsidies, agriculture supplies more than just agricultural products to the community and the above observations reinforce a need to sustain agriculture communities in the short term to retain a viable landscape, with recreation and other facilities, in the longer term. Climate changes should make farming a more viable business, eventually. In the meantime there is a clear need for continuing agri-environment subsidy as well as for farmers to diversify their activities.

Measures to encourage diversification have met with little success in the past, and greater levels of support and guidance are needed if diversification is to be a realistic adaptation option.

Service provision in rural areas is unlikely to improve with time and climate change. The viability of rural life will also be impacted by energy costs as oil reserves decline.

The implications for tourism are quite good. Drier summers could help attract visitors. Heritage could be exploited and protected within this scenario.

Biodiversity and farming (see also section 4.2.1)

The impact of a changed agricultural scenario on biodiversity is very hard to predict. Some species will be lost, others will gain more prominence. Introduced species may be a key problem. The opportunity to increase the area of mixed farming and broad leaved woodland into the wider Northern Ireland countryside should improve the impact of agriculture on biodiversity, but wetlands and coastal habitats present particularly difficult problems.

Climate change adaptation

Northern Ireland will remain very vulnerable to factors beyond its control and this may be even more so in a climate change scenario. Models to predict the likely impact of changes in competitiveness of certain sectors should be utilised as they can greatly help adaptation.

Arable sector

New crops and varieties of crops can be grown to adapt to the change in climate. A switch from winter to spring crops and from food to industrial crops will aid adaptation. A mixed farm scenario may emerge where locally grown fodder can be fed to livestock as substitute for grass silage. Breeding programmes will need to adapt to this type of scenario. Pesticide usage and nutrient loading (e.g. in soil and water) will need to be more tightly controlled and an acceptance of lowering crop yields is likely. There is also a need to develop pesticides to meet more stringent environmental standards.

Livestock sector

Grass breeding programmes may concentrate on more hardy and persistent varieties with genetic material from similar ecoclimatic zones being collected and used. Utilisation may become more important than productivity. This process must start soon as grass breeding is a long-term process. The potential of genetic modification of existing cultivars to adapt more rapidly to climate changes should not be overlooked and should be included in the overall GM crops debate. Numbers of livestock should continue to decline to adapt to changing climate (though the more obvious drivers will be socio-political). Issues such as soil poaching, methane emissions and the ability to grow higher quality forage than normal grass silage will all contribute to reduce the intensity of livestock production. There will be continued emphasis on farming for quality of product rather than quantity.

Water quality will become a major environmental and economic constraint in future, so nutrient management planning may become a key element in farming practice and regulation. The knowledge base and technology to implement improved nutrient cycling on-farm is largely available but the will to implement is still lacking.

The area of energy cropping should expand significantly with more individual farm support schemes.

Horticulture

There is some limited room for expansion here, particularly in the quantity of apples grown - the development of a cider apple growing industry is one suggestion which might be investigated. More pesticide use will become inevitable and there is a need to better target specific pests than the broad spectrum pesticides currently available.

Some specialist vegetable growing as a result of climate change may allow limited niche market expansion.

Forestry and woodland

The shift from upland conifer planting to broad-leaved planting on land displaced from agriculture and the introduction of trees into farmed landscapes by more novel means will allow greater impact of trees in a land use options. Further planting should be centred on native species on soils better suited to those trees. The incorporation of relict and ancient woodlands into larger areas of planted woodlands could act as a buffer to the adverse impacts of climate change. Connectivity of habitats is considered to be important for maintaining biodiversity in the face of a changing climate. Hedgerow systems are particularly important for the ‘connectivity’ of disparate woods and should be maintained as a mitigating factor in climate change.

The introduction of a Carbon Tax will have a slow but significant impact and planting for the purpose of carbon sequestration will become an important land use. The response of the forests and woodlands to severe and catastrophic events will need to underpin planting and management plans. Contingency plans for catastrophic events will need to be in place. Most of the development in this sector will occur in the private sector which will be channelled by Forest Service grant provision and policy direction. As it takes 80-100 years for many tree crops to mature consideration of the range of species planted should begin now and species planted, even on a trial basis, which are at present on the extreme limit of their climatic range in Northern Ireland.

Woodland and farm management systems which enhance biodiversity, such as farmland trees, multifunctional woodlands and agroforestry systems offer options to meet significant shifts in climate.

Socio-economic impacts

The main problem with sustainability in agriculture is encouraging younger people to become involved and in improving the skills and training base to cope with changing conditions. Older farmers tend not to be adaptable, are not ready to improve their business acumen and to look forward, so there is an education issue here. The change from producer to entrepreneur is a particularly difficult one.

The east/west split in farming and rural land use in Northern Ireland will likely be exacerbated by the climate change scenarios. Farmers need to be fuel-efficient members of society and there may be an increase in co-operatives. Two types of farmers will clearly emerge - productive/intensive/full time and small scale, agri-environment farmers who will not survive without subsidy. How they fare will have a knock-on effect on the whole community.

Training is still a major problem - and training farmers to adapt to and to diversify in the face of changing climate etc will be a big issue. Training and skills acquisition needs to allow more for part-time farmers etc. Most farmers have poor business acumen. Farmers are not well versed in dealing with insurance issues, more extreme events will exacerbate this problem. The move away from stability will be difficult to adapt to.

The key issue is to maintain and manage the shift in the delicate balance between agriculture, the environment and the rural community (only a minority of whom are farmers).

Recommendations and Further Issues

Many of these have been discussed already. Generally, shifts in farming practice are slow to happen and will likely follow in the wake of climate change and will therefore be a sort of post-event adaptation. Reductions in livestock farming and increases in cereal and industrial crop growing will generally help ameliorate the impact of climate change and will create a more diverse landscape which should foster biodiversity.

The whole carbon balance situation relative to land use types in Northern Ireland soils is poorly understood. The loss of N_2O from soil is favoured by poor drainage. Adaptation might involve improving drainage combined with reseeding to reduce the risk of P loss. This could be offset by potential increases in C mineralisation.

There is a need to devote resources to appropriate, long term monitoring. Phenology and ECN monitoring are key examples of these. We also urgently need to be able to predict the impact of changes in water balance in soils and the seasonal provision of water upon nutrient export from farming systems as this may seriously impact upon water quality.

Flood defence measures on some farmland may need to be strengthened. It is important that the interdependence between economic drivers and technical issues is developed e.g. in relation to watershed studies. The scientist and the economist should interact to produce whole system models which could then cope with implications of climate change before they happen.

It must be borne in mind that major shifts in policy and the incorporation of key issues such as climate change into policy can take up to 10 years. Pressure will eventually come from EU directives but these will take a long time to embed into farming practice.

The whole area of training farmers and other rural land users to diversify and adapt to changing climate scenarios and their implications on rural businesses must be a key policy objective. Business sense and planning are practically non-existent on many farms and this will affect the ability to adapt to change.

The environment and rural development are the key sectors to the future of rural prosperity in Northern Ireland so the ability to adapt to the impact of climatic shifts and extreme climatic events within these sectors will be crucial to the survival of agriculture and the development of a well balanced land use policy.

4.2.3 Fisheries

Dai Roberts
School of Biology and Biochemistry, Queen's University Belfast

Summary
Fisheries is vulnerable to the predicted effects of climate change because in most aquatic species seasonal cycles are temperature dependent and sensitive to small changes in temperature which may take place over relatively short time scales. Indeed, it has been speculated that recent increases in water temperature may already be contributing to changes in the spawning patterns in freshwater or anadromous species such as salmon. Further, some cultured species of shellfish that currently do not spawn may do so in the future creating a species introduction with unpredictable effects on local biodiversity. It is unlikely that climate change will offer any opportunities or benefits to fisheries or aquaculture. Increases or decreases in primary production will lead to increases or decreases in catch quantities whereas changes in boundaries of species distribution are only likely to lead to changes in the composition of fish catches. The greatest impact will be felt by rural communities, particularly those involved in fishing and aquaculture in coastal areas and those dependent on angling and tourism. Opportunities to realise their economic potential in the region may therefore be restricted.

Climate impacts

Socio-economic drivers and pressures

The Fisheries and Aquaculture sector encompasses the marine and freshwater environments and includes large- and small-scale nearshore fishing and aquaculture enterprises and angling. The management of fisheries and aquaculture resources and activities is complex and is regulated through international, European and national legislation and through regional legislation and bye-laws. These controls aim to maintain sustainable exploitation to meet local and international demand for both cheap and luxury fisheries products and from the recreational and tourist angling sectors. Pressures on all these activities are currently very high and will increase rather than decrease in future as a consequence of rapidly diminishing stocks of exploited species, the search for new stocks to exploit and deteriorating water quality. As a result, many rural communities, particularly in coastal areas have been particularly hard hit economically; the shift from traditional fishing to aquaculture will only partly alleviate these problems.

Attributes that may be affected by climate change

The main predicted effects of climate change include changes in sea-level, ocean circulation and seasonal patterns of temperature and rainfall and elevated temperatures and associated with these an increased frequency of extreme weather events. All of these effects would have consequences for aquatic species, including those of commercial importance.

Rising sea-level would lead to changes in aquatic/terrestrial boundaries which may increase turbidity, reduce productivity and reduce the suitability of sites for aquaculture in coastal waters. In recent years there have been declines in commercial fish stocks throughout the world, which have been attributed to over-fishing and pollution. These declines in stocks have resulted in significant reductions in Total Allowable Catches (TACs) and quotas of important commercial species such as cod under the Common Fisheries Policy. More recently, it has been suggested that changes in ocean circulation, a possible consequence of climate change, would also contribute to stock decline by affecting food availability and the dispersal of both larval and adult fish.

Changes in seasonal rainfall patterns would lead to greater fluctuations in river runoff (flooding/drought); predicted changes in rainfall patterns for Northern Ireland are for drier summers and wetter winters. Fluctuating river runoff, especially flooding, is likely to affect temperature, oxygen levels, pH, levels of suspended solids, nutrients and pollutants, densities of benthic invertebrates, river and bank vegetation and riffle and pool sequences. Such changes would have severe impacts on fish fauna, particularly on game species such as salmon and trout due to deterioration of spawning and nursery habitat and feeding. In addition, although pollutant runoff from the land may be reduced during dry summers, reduced water levels could caused elevated concentrations of pollutants during the summer months.

Temperature fluctuations would increase and have both direct and indirect effects on exploited animals in both marine and freshwater environments. Direct effects would include possible changes in gametogenic and spawning cycles and periods of larval development, increased growth rates of cultivated species (a possible benefit) and the increased likelihood of spawning and settlement of cultivated non-native species such as the Pacific oyster (*Crassostrea gigas*), and the northward shift of north-south biogeographical (species) boundaries. Species cultivated intertidally would be subject to greater thermal stress in both summer and winter as a result of increased temperature fluctuations. Indirect effects could include changes in primary production patterns which would, in turn, impact on the productivity of commercial species. While not indicated in the UKCIP98 scenarios (see Box 2), decreases in mean sea temperature which may result from changes in oceanic water circulation, would have the opposite effects.

Elevated temperatures will have direct impacts on the survival of aquatic species. Oxygen demand increases with temperature; this effect is exacerbated for aquatic species because dissolved oxygen concentrations decline with increasing temperature. Therefore, aquatic species, particularly fish species which have high metabolic demands, are likely to experience respiratory stress as a consequence of climate change. These impacts are likely to be significant in lakes, deeper rivers and in aquaculture ponds.

Rate of change and sensitivity to climate change

Fluctuations in the abundance of some fish stocks are directly attributable to short (< 10yr) and medium (>10yr) cyclical changes in oceanic climate and sea temperatures. Classical examples include: the collapse of Californian sardine stocks that resulted in the loss of the regional canning industry described in John Steinbeck's *Cannery Row*; the Russell Cycle which describes changes in the relative abundance of herring, pilchards and mackerel in the English channel between the 1930s and the 1970s; the collapse of the Peruvian anchovetta fishery in the 1970s as a result of El Niño-Southern Oscillation (ENSO) events and its recent recovery. A similar climatic oscillation (NAO: the North Atlantic Oscillation) is known from the Atlantic.

This sector is consequently vulnerable to the predicted effects of climate change because in most aquatic species seasonal cycles are temperature dependent and sensitive to small changes in temperature which may take place over relatively short time scales. Indeed, it has been speculated that recent increases in water temperature may already be contributing to changes in the spawning patterns in freshwater of anadromous species such as salmon.

Opportunities and benefits

It is unlikely that climate change will offer any opportunities or benefits to the Fisheries and Aquaculture sector. Increases or decreases in primary production will lead to increases or decreases in catch quantities whereas changes in species boundaries are only likely to lead to changes in the composition of fish catches.

Consequences of potential impact

Marine and freshwater species are exploited for food and sport (angling). Both means of exploitation are of significant economic importance to Northern Ireland and there are opportunities to expand their economic potential in the region. Species of economic importance in Northern Ireland include the marine fisheries of the Irish Sea and north-east Atlantic; salmonids such as the Atlantic salmon, brown and sea trout including important regional stocks; molluscan and crustacean shellfish such as prawns (*Nephrops norvegicus*) and scallops (*Pecten maximus*) and oysters, mussels and clams which are important in aquaculture. Consequently the greatest impact will be felt by rural communities, particularly those involved in fishing and aquaculture in coastal areas and those dependent on angling and tourism. Opportunities to realise their economic potential in the region may therefore be restricted.

Possible alternatives

Fishing and aquaculture products are sold in a global commodity market that is highly competitive. Changes in response to climate change (e.g. changes in catch composition for wild fisheries and changes in species exploited for aquaculture and angling) will be driven by the ecological changes outlined above. To suggest that currently exploited species may be replaced by others either in fishing, aquaculture or for angling is too simplistic. In this context it is particularly important to acquire biological data on new target species, where this is not available, to prevent overfishing. Consequently, further desk-top research is required to predict possible changes in available species and to identify how the industry might respond to either changes in the production or demands for different species.

Uncertainties

Although it is difficult to predict precise consequences of the effects of climate change on regional fisheries and aquaculture, the case studies outlined above should facilitate the development of predictive models for this purpose. Development of these models should first target species that are currently of major economic importance in Northern Ireland (e.g. *Nephrops*).

Adaptation to climate change

Adaptation strategies and likely costs

Future responses to the ecological consequences of climate change that will affect the sector are difficult to predict but may necessitate replacement or modification of fishing gear and aquaculture equipment to exploit different suites of species. Such changes are likely to take place gradually so that investment costs can be spread over time. However, the increased likelihood of extreme weather (storm) conditions are likely to lead to an increase in damage to fishing and aquaculture equipment, entailing costs in design improvements, and a decrease in available fishing days.

The best strategy may be to increase diversification (the range of exploited species) so that the industry becomes less dependent on a narrow range of single species stocks without relinquishing the ability to exploit such stocks. Such changes are already being adopted in response to declines in commercial fish stocks.

Adaptation in response to sea-level rise and changes in river flooding have important implications for all sectors including fisheries and aquaculture. The costs of coastal defences, maintenance and development of fishing port facilities and river management programmes will have to be weighed carefully against likely benefits.

Environmental and social impacts

Environment impacts of strategies adopted in response to climate change are likely to be similar to current environmental issues facing fishing, aquaculture and angling. These include: high pressure on wild stocks and the possible expansion of intensive aquaculture leading to overfishing and pollution. Research to address these issues is already underway.

The fishing and aquaculture industries have in the past demonstrated a high degree of adaptability to changing fish stocks and market demand. However, the industry has undergone a period of rapid change in recent years. This is likely to continue indefinitely into the future in response to changing fish stocks.

Management implications and resistance to change

In Northern Ireland the fisheries, aquaculture and angling sectors are of economic importance and have the potential for significant expansion. In addition these sectors will become increasingly important as changes occur elsewhere in the rural economy. It is therefore important that, in their longer term planning, the responsible government departments (Department of Agriculture and Rural Development and Department of Culture, Arts and Leisure) take into account the potential impacts of climate change outlined above. Because the fishing, aquaculture and angling sectors are currently undergoing significant upheaval, resistance to change across social, political and institutional boundaries is declining.

Climate change mitigation

Fishing activities are unlikely to be major contributors to climate change. However, large scale aquaculture enterprises may produce methane under unfavourable circumstances. This problem is continually being addressed by the industry in the interests of increasing production efficiency and product quality and is not seen to pose a major problem.

4.2.4 Landscape and cultural heritage

Jude Stephens
Gibson Institute, Queen's University Belfast

Summary
There is a general level of knowledge concerning climate change but most stakeholders could not predict specific outcomes or pinpoint particular endangered sites due to uncertainties about precise changes in weather patterns and, hence, their likely effects. Recent cataclysms, such as BSE and Foot and Mouth Disease, are currently fuelling the debate on, for example, agricultural intensification and are promoting the exploration of possible alternative strategies. Discussion of climate change seems less immediate but cannot be ignored in these debates. Climate change is anticipated to degrade Northern Ireland's designated sites, while global impacts of climate change will produce an array of disaster scenarios. Resource wars and an influx of refugees and economic migrants will inevitably put pressure on both rural and urban landscapes and their communities. Local communities could provide a good deal of the data required for forward planning in landscape conservation in relation to Climate Change. Corporate commitment to the reduction of emissions is patchy with only a few organisations engaging in positive environmental practices. Stakeholders focus on the potential offered by the NI Assembly and suggest that government should be encouraged to take a more flexible approach with regard to legislation. Climate change will produce a challenge in recreation and leisure management.

Introduction

Northern Ireland has a rich natural heritage, comprising mountains, lakes, rugged coastline, peatlands, and a range of diverse habitats, some unique within Europe. The Giant's Causeway, which lies on the Antrim Coast, is Northern Ireland's only World Heritage site. Awareness amongst stakeholders (Appendix 1) of the likely impacts of climate change varied. There was evidence of a general level of knowledge but the majority of stakeholders were not inclined to predict specific outcomes or pinpoint particular endangered sites. This was largely due to uncertainties about precise changes in weather patterns and hence to the likely effects of these changes. Stakeholders gave more general opinions on the kinds of action, which would raise awareness, provide data on weather and assist any adaptation strategies.

The deleterious effects of Climate Change in Northern Ireland cannot easily be compartmentalised and separated from damage which occurs as a result of more 'natural' causes. A good deal of the harm caused by changes in weather patterns is inseparable from any erosion that was considered likely to have occurred regardless of human activity. For some, reparation gains urgency with human culpability. It is significant that other recent cataclysms, such as BSE and Foot and Mouth Disease, are currently fuelling the debate on, for example, agricultural intensification and are promoting the exploration of possible alternative strategies.

Findings of specific relevance to Northern Ireland

Landscape effects

In general, there would be changes in the landscape due to habitat loss or degradation. Degrading of Northern Ireland's designations was anticipated by many stakeholders. Some believed there would be a loss of salt marshes in tidal areas due to rising sea levels. This could also lead to loss of agricultural farmland. More locally there might be increased soil creep on the Antrim Coast, leading to the destabilisation of dwellings, or increased erosion on peatlands and on the Mourne Mountains, and coastal erosion around the Giant's Causeway.

Cultural Heritage

The National Trust has a number of built structures situated on the coast around Strangford Lough and Murlough Bay. Of particular concern is the erosion of 'The Moles' at Portstewart Strand that protect the mouth of the river. Loss of the Moles will also lead to changes in the configuration of the beach. Mussenden Temple situated at Downhill is at risk of falling into the sea. Some 10 metres have already been lost in recent years, although this is not due solely to climate change.

Greater extremes in temperature will result in rapid and more frequent rates of structural expansion and contraction, causing objects such as garden statues and external sculptures to react violently, splintering and cracking. Changes in rainfall patterns and the increase in heavy downpours and flash floods will have a direct impact on buildings where old rainwater systems cannot cope. High water levels in buildings prone to flooding will impact on their contents at ground or basement level or in upper storeys near blocked waterspouts. Maintaining an equal environment for the contents of buildings, such as those located at Castle Ward and Mount Stewart, in order to reduce fading and organic decomposition will call for increased Ultra Violet protection on windows and appropriate means of controlling relative humidity. It is likely that all historic properties will be at some risk here.

Parks and gardens

Warmer summers are likely to produce an unprecedented increase in the numbers of native insects, resulting in damage to a variety of organic materials. There is also the possibility of plant damage due to the arrival of foreign insects such as the death watch beetle. Water logging and severe frosts are damaging to gardens and parklands and the loss of trees will affect vistas to, from and around buildings, estates and the rural landscape in general. Changing water levels will influence areas such as the Mosses at the Argory and the sump and mound system on which the oaks at the Argory are planted. There is also likely to be a significant change to the substructure. Existing estate roads of the more traditional type which allow lying water to seep away gradually, will be unable to tolerate wetter conditions and may be replaced by non-natural materials such as tarmac, which will lead to high run off of water in wet weather.

In addition to the environmental changes that will be brought about, the global impacts of climate change will produce an array of disaster scenarios. Resource wars and an influx of refugees and economic migrants will inevitably put pressure on both rural and urban landscapes. This presents a challenge to the Province if we are to avoid developing a 'fortress Northern Ireland'

Adaptation opportunities and management strategies

Local level

Local communities could provide a good deal of the data required for forward planning in landscape conservation in relation to Climate Change. Natural history groups are well equipped to collect the kind of information that will provide detailed pieces of the Northern Ireland jigsaw through the establishment of local nature reserves and educational resources, instilling a sense of local pride and ownership. This kind of local level involvement could assist in refining the detail required for the monitoring of species and distribution although some form of scientific validation would be required. Local efforts should go hand in hand with long-term monitoring of areas such as the Strangford Lough mudflats.

Corporate level

Corporate commitment to the reduction of emissions is patchy with only a few organisations engaging in positive environmental practices. National Trust, for example, no longer burns fossil fuels in open fires, promotes the use of green transport on its sites as part of visitor facilities and has made efforts to use non peat based composts in gardens and parkland. The Trust has also taken steps to increase energy efficiency in some of its larger houses, thereby reducing both fuel use and emissions.

Government level

Stakeholders (Appendix 1) focus on the potential offered by the NI Assembly and suggest that government should be encouraged to take a more flexible approach with regard to legislation. Currently government documents, such as the Habitats Directive, tend to presuppose a stable environment without challenging the climatic status quo. It may be necessary to consider the re-registration of certain areas and accept the inevitable loss of others. This policy dimension is vital since public money cannot legitimately be spent to retain the integrity of a bog that is destined to flood.

Stakeholders suggest that the government should:

- lead by example in terms of its own energy consumption, recycling and waste disposal, a philosophy ingrained in other European countries.
- be proactive in its planning policy in river valleys, flood plains and coastal areas where new build may be inappropriate and short term. Where new buildings are to be constructed in both rural *and* urban landscapes, consideration should be given to siting these in such as way as to reduce energy consumption through sensitive landscaping.
- be prepared to provide guidance and alter its current system of funding for land management strategies. Grazed landscapes, for example, have been preserved through the use of traditional farming and management techniques. These techniques may no longer be appropriate if Climate Change is significantly altering such landscapes.
- introduce additional weather testing and meteorological stations to provide further data for the comparison of extremes and frequency of bad weather days.
- promote lifestyle changes that will reduce emissions locally thereby prompting spin offs for local services and businesses.
- ensure that public information on Climate Change is not couched in terms which imply uncertainty but presents an evocative message which encourages specific action and clearly communicates the results of those actions.

Likely barriers

Looking beyond the local to the global may present a difficulty for the Northern Irish public who are sometimes charged with adopting a *laissez faire* attitude to the problems of Climate Change. The corollary of this has been an emphasis on ameliorative action rather than tough mitigating strategies and a corresponding preference for piecemeal reform rather than radical legislation. Behavioural change is therefore an important area and there is a need to prepare for adjustment by developing a new culture of adaptation. All proposed action should lead into a long-term, integrated, holistic strategy. The monitoring and identification of change must go hand in hand with mitigating strategies and a recognition of the importance of a healthy environment.

Increasingly there was evidence amongst stakeholders of a philosophy of 'letting nature take its course'. To what extent is human intervention advisable and should buildings or sites at risk due to coastal erosion or habitats under threat be reprieved or allowed to deteriorate as part of a natural process? Already, for example, a pathway at the Giant's Causeway, an important geological site, has been (and will remain) closed due to slippage of the slope. This philosophy of 'managed retreat' raises interesting questions about the role of human beings in preventing or reversing damage caused by global climate change. There is no guarantee that intervention will not be adverse or counter productive.

Benefits

It is likely that climate change will produce a challenge in recreation and leisure management. Warmer summers in the Province, combined with weather changes in continental Europe and increased airfare emission taxes, may reduce the public's current inclination to visit traditional Mediterranean haunts in preference for the Northern Irish countryside, thereby boosting the local tourist economy.

Other specific beneficial outcomes suggested by stakeholders include:

- The potential for new crops such as reeds or willow, reviving a traditional industry or creating a new one in, for example, renewable energy technology.
- Land no longer suitable for traditional crops may instead be used for native trees, producing hardwood for local industries.
- Government grants should focus on funding to support land management rather than subsistence strategies. A starting point would be pilot schemes and studies to explore the viability of such schemes.

BOX 5

Case study 4. Mourne Heritage Trust

Mourne Heritage Trust is the management body for the Mourne Area of Outstanding Natural Beauty. The Trust consists of a board of 25 trustees composed of local farmers, fishermen, tourism operators and Local Authority members. Currently the area for which the Trust is responsible is a designated ASSI and is a candidate for ASC status to become the first Celtic National Park, opening the way for local products to be branded and marketed. The region embraces a range of discrete and sensitive eco-systems. The majority of farms in the area are small, 20 hectares or less. Granite extraction and fishing account for a small part of the economy but increasingly people are commuting to work in Belfast or other towns close to the city. The traditional pattern of building in the Mourne landscape is thus a dispersed construction pattern, which places a heavy reliance on fuel. There has, to date, been little eco-consideration in building design and no landscaping to reduce energy costs.

The stated aim of the Trust is to manage the landscape for the sustained benefit of the local community. In terms of land management, the Trust represents a unique model whose transparency avoids the common criticisms of favouritism within the tourism sector. The Trustees have adopted a holistic approach in their promotion of the area thereby galvanising legitimate local support from all sectors.

The threat of global climate change is likely to stimulate radical and speedier solutions when a catalyst such as foot and mouth disease places immediate pressures on, for example, the agricultural industry. Traditional hill farming in the Mournes could benefit from a warmer climate which would facilitate a diverse crop production where, with an increase of 2 degrees in temperature, oil based crops such as evening primrose oil, could be grown on the mainly small farms for the cosmetic industry. This would change the visual aspect from a grazed landscape to a purely agricultural landscape and would require the introduction of new, tailored management techniques. It would also result in the loss of the Wilderness Experience so avidly sought after by tourists to the area and thus create a tension between traditional land use and the requirements of the recreation industry.

The cultural impact of traditional farming practices on the landscape
The notion of a ‘tourism crop’ does not sit comfortably with the farming purist who places a high value on good husbandry and agricultural skills and takes pride in restoring and maintaining traditional farming culture. Woodland grant schemes have been of limited use to Mourne farmers and there is a growing recognition that the current state of farming in the Mournes is simply not sustainable. Weekend and ‘hobby’ farming has become the norm for many. A warmer, wetter climate might provide a viable alternative more allied to the practices and conventions of the farming community.

Mourne Heritage Trust aims, where possible, to implement win/win solutions to problems. Sustainable pitch paths have enabled new access points to be secured and provide new opportunities for recreation whilst recompensing landowners. Redundant farm buildings have been transformed into landscaped car parks using the same topographic footprint.

Increased rainfall will undoubtedly boost the Spelga Dam’s water levels, which have dropped over recent years. The risk of Cryptosporidium, however, which has always existed on the mountains, is a major factor in water quality. It is not unreasonable to surmise that an increase in the rates of infection may be linked with warmer summers and that, as levels of Cryptosporidium rise on the mountains, they will increasingly find their way into the water supply.

4.2.5 Health

Vivienne Crawford
School of Medicine, Queen’s University Belfast

Summary
Poverty, social inequality, deprivation and social and health policy, including employment and industrial policy are key factors in driving the health sector. Climate change may impact any of these and, hence, will impact upon health. We also lack understanding of the interrelationships between climate, health and other sectors. There are potential opportunities and benefits offered by climate change but these will depend upon the nature of such change and the balance of harmful/beneficial effects e.g. a reduction in metabolic bone disease with increased sunlight may be offset by an increase in skin malignancy. New diseases may enter Northern Ireland from warmer countries but more likely would be an increase in rodent-borne diseases. Rain and relative humidity are particularly important for infectious disease transmission and survival promoting prevalence of respiratory tract infections. Trauma resulting from road accidents may increase in stormy/wet weather. In financial terms, further plans to improve energy efficiency by Health Trusts may afford substantial savings that could be redirected at patient care. There is significant room for improvement with respect to public transport to hospitals especially in Belfast.

Impact

The health sector is a publicly funded, demand led service and as such its socio-economic drivers and pressures are intimately linked to the general economy. The sector is also politically driven, technologically driven and affected by public expectation. Poverty, social inequality, deprivation and social and health policy, including employment and industrial policy are key factors in driving the health sector. If climate change impacts upon any of these it will impact upon health.

More directly, disease patterns and demands upon the health service both temporally and spatially will be affected by climate change. Effects on water and food supply will clearly affect health. Temperature change is particularly relevant with morbidity and mortality from a number of health conditions being directly affected. The possibility of new diseases entering NI from warmer countries should be monitored but more likely would be an increase in rodent borne diseases. Rain and relative humidity are particularly important for infectious disease transmission and survival. Respiratory and gastrointestinal infections are renowned seasonal events and survival and transmission of droplets is greater in high relative humidity. Water transmission of infections may be affected by changes in rainfall and evapotranspiration. Any effect on waste disposal would also be pertinent to public health. In addition, an increase in the severity/frequency of storms is particularly relevant with an increase in trauma expected. Trauma resulting from road accidents may increase in stormy/wet weather. Adverse effects of climate change on buildings will also impact upon health.

The time scale for the effects of climate change to be felt are difficult to assess but may be immediate particularly with respect to temperature and changes in the food market, were effects to be monitored within the same year. Globalisation is important to note here. Goods and services will be impacted upon by climate change outside NI. There may be transport disruption due to adverse weather that would affect deliveries to the island. Some stakeholders (Appendix 1) however, held the view that it would take decades before climate change had any significant impact upon health. Spatially, health throughout NI would be affected by climate change but local effects may emerge.

The potential opportunities and benefits offered by climate change are difficult to ascertain and will depend upon the nature of such change and the balance of harmful/beneficial effects. For example there is the balance between the possible beneficial effects of a small compared with a large temperature rise and the associated effects of air pollution. We may see an initial decline in winter cardiovascular and other morbidity and mortality but this benefit may eventually be offset by a summer increase. We may see a reduction in metabolic bone disease with an increase in the amount of sunlight while we may record an increase in skin malignancy. Increased UV may reduce certain pathogens e.g. Foot and Mouth transmission declines dramatically as sunlight increases. With regard to public health issues benefits are difficult to perceive, however indirect benefits could be substantial. For example with an increased growing season an improved food supply could result in improved public health. One of the key features of the health sector is that to a great extent, other sectors will determine the impact of climate change upon it and thus cross-sector issues must be fully explored.

Climate change will affect everyone, particularly the frail and vulnerable. The changing demography of our population means an increase in the number of older people and thus a more susceptible population.

Adaptation

One of the recommendations (no. 22) of the Foresight Panel on Health (2000) was that a "Health and natural environment forum be established to develop a strategy in which health considerations are placed at the forefront of environmental policy". As far as we know, there is currently no recognised portfolio in NI government for addressing climate change. We must increase awareness in order that it becomes factored into future policy decisions. An important driver is likely to be the economic consequences of adaptation. The costs are entirely unpredictable and depend on the balance of beneficial/harmful effects. They may be high or there may be modest savings but until cost is associated with response, it is unlikely that action will be taken. Irrespective of climate change, the future funding of the NHS is unknown and we can expect substantial change some time in the future regarding medical infrastructure in NI. Other barriers to adaptation include political and institutional mindset. Government should be to the fore in driving adaptation and therefore NI may have particular problems with respect to government issues. A business case within a regional framework is urgently required. We also lack understanding of the interrelationships between climate, health and other sectors and increased research activity is required. Such research would by nature involve long-term prospective studies. The question of who might fund such research needs to be asked.

A global increase in monitoring impacts of climate change upon health is essential. This presents difficulties since regions offering the greatest opportunity for observing the effects will have different infrastructures to our own and may keep poorer health records. Attention to local housing stock, particularly for high-risk groups is important with respect to public health. The monitoring of changes to the microbiological environment will be a key area for data collection at a local level and surveillance systems for communicable diseases may need to be reassessed. Environmental protection should become a major focus particularly with respect to our water sources. When environmental incidents occur, for example the recent local *Cryptosporidium* outbreaks and the flooding events in England, people can react angrily. The negativity of single-issue protest groups could seriously harm attempts to adapt to future events, that is, the public may not necessarily react in a positive way if adaptation strategies are implemented.

The subject of climate change is usually presented negatively and is therefore perceived negatively. The only positive anecdotes mentioned in consultations were a ‘Mediterranean Climate’ and the possibility of wine production! The current situation is in the main reactive due to the prevailing uncertainties surrounding the issue and surrounding the NHS itself.

Mitigation

For the last 12 years the NI Department of Health and Social Services has been recording the energy use of all hospital Trusts. Four Trusts in the Eastern Health and Social Services Board (BCH, RGH, LVH, MPH) have full time energy efficiency officers and all other Trusts have part-time officers. There is a regional committee to oversee energy use in hospitals. The aim was to reduce energy usage by 20% in the NI health service over 8/9 years. This aim has been achieved and indeed NI hospitals are top of the league in the UK with respect to energy efficiency! The BCH Trust commissioned an outside company to appraise energy use on site and in recent years has converted from oil to gas. There are further plans to improve efficiency and this Trust no longer incinerates on site. Transport to the BCH comprises a railway station on site, but there is significant room for improvement with respect to public transport (approximately 4000 people using cars). Government incentives are required.

With respect to future climate change, air conditioned buildings would suffer increased energy costs with a rise in temperature unless energy saving incentives are provided. The government in NI has been supportive in this area in the past. The possibility for installing combined heat and power systems is currently being explored. These systems would allow adaptation to climate change however they are very costly to implement and business cases show that it is a long-term investment.

4.3 Infrastructure and socio-economic development

4.3.1 Construction, infrastructure and transportation

David Hughes[1] and Austin Smyth[2]
[1]Department of Civil Engineering, Queen's University Belfast
[2]Transport Research Institute, Napier University

Summary
Northern Ireland enjoys a comprehensive internal transport network complemented by external gateways reflecting both the physical separation of the area from the remainder of the United Kingdom (UK) and the associated patterns of trade, commerce and social and cultural ties with Great Britain. In its dependence on air and sea transport the area, as an entity is unique in the UK. It is also unique as part of the UK in having a land boundary with another EU Member state, the Republic of Ireland. Modes of transport interact with effects in one having consequences for others. Air services and seaports, crucial travel links for Northern Ireland, may become less reliable due to increased disruption by severe weather. In addition to the direct impacts that may be felt, for example by the service providers or operators of airports or ports reacting to fog, gales or other severe weather event, each transport mode or operator impacts on other transport elements. Consequences of airport closure include diversion to other airports and bussing of passengers. The awareness of the impact of climate change on the transportation sub-sectors in Northern Ireland is variable. In some cases notably ports, airports and on the railways remedial measures are being taken or being formulated to address the unusual conditions experienced in recent years. However, there is no comprehensive awareness of the longer-term implications among strategic planners in the overall sector. The publication of the United Kingdom White Paper on Transport in the summer of 1998 heralded an attempt to forge an integrated and sustainable transport policy across the UK. This represented the first comprehensive attempt to address — amongst other challenges — those that are posed by transport for Greenhouse Gas emissions. However, the extent to which its writ runs throughout the UK was already brought into question by the somewhat different tones of the transport policy documents issued by the various devolved administrations as their response to and interpretation of the UK White Paper. De facto Scotland and Northern Ireland and to a lesser extent Wales have adopted their own transport policies, which while paying some regard to the UK document reflect the perceived priorities within their own jurisdictions.

The value of construction in 1999 was almost £2 billion. 9% of the Northern Ireland workforce is employed in this sector. Climate change will have a major effect on the spend in construction through increased commissioning of construction projects such as flood prevention schemes, improvements to water treatment plants to improve quality of water discharge, drainage schemes, coastal defences and ports and harbour works. The awareness of the impact of climate change on the construction sector in Northern Ireland is low. The industry has adopted in general a reactive approach to climate variability, such as flooding or drought, rather than planning a long-term strategy.

Introduction

Northern Ireland enjoys a comprehensive internal transport network complemented by significant number of generally high quality external gateways reflecting both the physical separation of the area from the remainder of the United Kingdom (UK) and the associated patterns of trade, commerce and social and cultural ties with Great Britain. In its dependence on air and sea transport the area, as an entity is unique in the UK. It is also unique as part of the UK in having a land boundary with another EU Member state, the Republic of Ireland. Thus the pattern of travel and freight movement is very different from the UK as a whole. The propensity for air and sea travel is more in line with that experienced elsewhere in relation to long distance rail coach and car travel, although inevitably at a somewhat lower level. Moreover catastrophic demographic change stemming from the Famine period in the mid 19th Century has resulted in the area being endowed with a uniquely generous level of road provision for the population served today. Transport policy has at least until the last few years either promoted or facilitated car use allied to a planning regime, which embraced dispersal of population from the main population centre in Belfast. Combined with flight to the suburbs, a phenomenon generated by the Troubles, the effect has been to create a society with a level of car dependency unprecedented in the UK or most of the EU.

It is important to acknowledge the contribution transport emissions make to Greenhouse Gas emissions. In this respect given its dependency on the private car for internal movement and air for external trips as well as road freight, Northern Ireland on the basis of its population quite probably contributes a disproportionately high share of UK transport-related Greenhouse Gas production. This can be measured, in the case of road traffic, in terms of exhaust emissions. In other instances, such as the operation of rail and electric vehicles, the impacts are more dispersed. Electricity generation and its transmission add to Greenhouse Gas emission, while diesel rail services contribute directly without the regulatory controls imposed on private cars. All new multi modal studies of transportation schemes take into account environmental impacts and a particular objective is to reduce 'Greenhouse Gases' (Guidance on the methodology for multi-modal studies, DETR, 2000)

The construction sector has for much of the post-war period been used as an instrument of regional development policy in part to offset the long-term decline in the traditional manufacturing base and the effect of 30 years of communal strife and instability. Thus for instance the rate of new house building per capita has typically exceeded the UK as a whole and tended to be double that experienced in the South East of England.

Given the diverse nature of this sector we have chosen to consider impacts on each mode separately preceded by an overview of impacts as viewed by the construction, consultancy industries and interest groups. After considering each transport mode we return to consideration of mitigation across the transport sector as whole reflecting the current policy agenda nationally.

Impacts across the construction industry

Contracting and Consulting Engineers in Northern Ireland have little knowledge of Climate Change studies or data on scenarios for climate change. Impact on this industry will be driven by changes in public spending and by client demands. Construction practice, innovation and strategies are usually driven by research and development and through education in this sector. Currently there has been little dissemination of knowledge through the Construction industry and little research into the many aspects of Climate change that will affect this sector.

The value of construction output in 1999 was almost £2 billion and 9% of the Northern Ireland workforce is employed in this sector (DFP, 2000). Climate change will have a major effect on this spending by directing money into related projects such as flood prevention schemes, improving the quality of discharge from water treatment plants, affecting drainage schemes and coastal defence works and ports and harbour works. Areas of expertise within the Construction industry will need to be developed and skills and human resource implications considered.

The awareness of the impact of climate change on the construction, infrastructure and transportation sectors in Northern Ireland is low. The industries have adopted in general a reactive approach to climate variability, such as flooding or drought, rather than planning a long-term strategy.

Transport 2000 commented on the likely impacts of reducing emissions. Vehicular emissions form the second largest contributor to greenhouse gasses in the city of Belfast. Enforcing stricter emissions controls on private vehicles (via the MOT test) has had an effect on reducing some of the harmful emissions, but is likely to have a small impact on global climate change. More substantial benefits may be achieved through management of transport or as the result of more stringent emission regulations on the lines of US models. Experiences in the US state of California, where zero emissions regulations have been in place since the mid 1990’s may provide some indication of the potential impacts arising from such measures. However, such regulation would a matter reserved to the UK Parliament.

Californian experience can also be used to highlight the link between city structure, vehicle use and harmful emissions. Achieving meaningful reduction in car use and diversion to public transport is much more problematic in low-density areas so much a feature of the United States, and increasingly prevalent in Northern Ireland over the last 30 years. Transport 2000 also sees an urgent requirement for public education of the impacts of travel in addition to increased regulation of vehicular emissions.

Impacts and Adaptation Related to Transport

Transport infrastructure and services exhibit a very wide range of attributes that can be vulnerable to impact across a range of climatic conditions. Physical infrastructure, including highway and airport runway, can be damaged by extremes of temperature and surface water, while coastal railway routes are impacted by erosion and ageing coastal defences (Table 4-7).

Table 4-7. Potential impacts of climate change on NI transport infrastructure

Impact/ infrastructure	***Reduction in extreme cold***	***Extreme heat***	***Surface water***	***Coastal flood***	***Fog and low cloud***
Railway track	Fewer snow cover problems	Rail expansion	Flooding and failure of track circuits	Track bed erosion	-
Railway trains	Decreased freezing of engines	Vehicle overheating	Access to infrastructure	Access to infrastructure	-

Trunk highway	Less surface degradation	Surface degradation	Driving hazard	-	Driving hazard
Airport operations	Less runway surface cracking	Runway surface cracking	Landing hazard	Airport flooding possible at Belfast City Airport	Landing hazard
Port operations	Decreased freezing of localised channels	Quayside degradation		Access to harbour/ quay	Sailing/ navigation hazard

The provision for, or management of movement during periods of adverse weather have provided the focus of activity for operators thus far, and are understandably of key concern to the travelling public. These are typified by an airline's planned alternative destination airport, and the corresponding bad weather plans of the airports themselves. In addition to the direct impacts that may be felt, for example by the operator of an airport having to respond to fog, each transport mode or operator impacts on other elements of the transport system. Weather related airport closure could result in diversion to other airports and bussing of passengers. Analogous impacts exist for rail – bus substitution with consequences for modal split. In the case of private vehicle use route changes may become necessary over short periods.

Impacts on the Rail System

State of the Industry

Northern Ireland Railways Co. Ltd (NIR) operates 342 kms of track on the 1.6m Irish Gauge and shares a cross border service to Dublin with Iarnrod Eireann (Irish Rail). The trackbed and formation along the Belfast to Larne route, between Downshire and Whitehead, and from Ballycarry to Larne Town forms a primary sea defence against the Belfast and Larne Loughs, while services from Downhill to Magilligan face the Atlantic Ocean.

Vulnerability to climate change

The operator has identified a specific concern over the stability of embankments, particularly in the presence of Easterly gales. NIR's Infrastructure Executive envisages a need for a formalised policy on climate impacts to be in place within a 3 year time period, while emphasising that serious impacts from coastal erosion have already occurred where defences have been, or are in the process of being strengthened. The cost of mitigation is estimated at £1m for the current 15-mile stretch of sea defence. On the basis of changes in sea levels, the strength and resistance of newly replaced sea defence is felt to be sufficient for their design life.

Railway services have proven to be vulnerable to the extremes of temperature. These can affect both track and vehicles. Extremes of heat cause rail to expand and crack, while extremes of cold impact on the availability of train sets to operate and on clearing access to the track infrastructure. Such extremes have been rare in Northern Ireland hitherto: the UKCIP98 climate predictions indicate warming in summer periods but a reduction in the increases of winter cold.

The geotechnical infrastructure is currently being assessed with respect to stability. Increased periods of heavy rainfall will cause embankments and cuttings to be less stable. NIR have noted a significant increase in embankment and cuttings instability and failures and this will continue to be an increasing liability in the future should winter rainfall levels increase.

A further seasonal and climate related problem observed on railways in Great Britain is the impact of 'leaf mulch' from deciduous trees. This is the compacted and crushed debris of fallen leaves, which forms a particularly slippery surface on rail tracks, limiting the efficiencies of braking systems, particularly on newer trains.

Adaptation to climate change on the Rail System

Strengthening of coastal defences has now been completed, including the redesign of some stretches of the Larne line. Train sets in operation on commuter services differ in design of braking systems to those in operation in Great Britain most susceptible to leaf mulch, although this has remained a minimal problem. Assessment of geotechnical structures is being undertaken.

Impacts on Airports and Air Services

State of the Industry

Air services are of particular importance to travel in Northern Ireland. Any significant impacts of climate change on reliability will therefore have a more significant impact than elsewhere in the UK. There are three commercial airports in Northern Ireland, Belfast City, Belfast International and City of Derry, with an additional commercial charter service operating from Enniskillen, and a private airfield at Newtownards.

Vulnerability to Climate Change

Airport operations rely on availability and serviceability of landing and take-off runways. These share some characteristics with highways, the difficulty in remaining open in inclement weather, i.e. clear from snow and ice cover. In addition to concern about wind direction and speed, wind and thermal fluctuations can additionally affect landing and take off. Belfast City Airport also expressed concern about electrical storms, and felt any increase in their frequency would impact adversely on airline operations. Belfast City Airport is particularly susceptible to tidal flooding. Landing and taking off aircraft are particularly affected by thermal fluctuations resulting in turbulence. The airports' climate policies are largely based on current need rather than a further-reaching climate change policy.

Adaptation to climate change in the Air Transport Industry

Most airport policies are aimed to accommodate adverse weather conditions in the current climatic situation. As weather conditions alter, so the airports' policies will also alter. There are few policies directly and solely addressing the needs of the operator in response to climate change. Belfast City Airport states that it has no single approach to climate change, as climate-related impacts result from emissions and transports interfaces and are felt to benefit from a variety of cross-airport impacts. The airport has identified a number of areas where positive adaptations may be identified (Table 4-8). These have been observed across the industry.

Table 4-8. Potential adaptation to climate change at NI's airports

Operations	• Taxiways can be designed to reduce waste from aircraft with running engines • Aircraft environmental requirements, currently 'chapter 3' are increasingly strict across a variety of environmental impacts
Technologies	• Instrument landing reduce the impacts of poor visibility impacts

Impacts on Ports and Short Sea Shipping

Ports: State of the Industry

Northern Ireland is well provided for ports and harbours. Three commercial and one private freight harbour are complemented by a series of private landing stages particularly commercial and industrial related stages such as Blue Circle Cement, and power station landing stages for coal and oil.

Vulnerability to climate change

As with most sea infrastructure, ports are affected by coastal erosion, changes in sea level, and changes in the state of the tides. However the operational requirements of modern ports dictates most quayside infrastructure being secure against existing forces of wind and tide. New design, and the development of ports has to take into account the vulnerability of the harbour to any anticipated changes in prevailing wind direction, changes in wind force, and changes in the mean sea levels. Port infrastructure is unlikely to be sufficiently flexible to accommodate longer term increases in the mean sea levels.

Adaptation to climate change in the Port Industry

One example highlights awareness in this sub sector of the potential implications of climate change. The operator at Larne Harbour has already commissioned work on raising the level of quay walls to accommodate any increase in heights of tides.

Ferry operators: State of the Industry

There are three large passenger ferry operators linking Northern Ireland with Great Britain. The Ferry companies use a range of vessels some of which are more susceptible to wave height and sea condition than others. The recent trend in the Roll-on Roll-off passenger and freight sector has been to use vessels that travel at high speed and have a quick turnaround time. Some of these vessels cannot operate in conditions as severe as those that can be accommodated by more traditional heavy displacement ferries.

Vulnerability to climate change in the Ferry Sector

More severe winter weather conditions will have an impact on ferry timetables. Ferries most susceptible to heavy sea conditions will be more severely affected. New designs must also take into account the vulnerability of the port to changes in prevailing wind direction, changes in wind force, and changes in the mean sea levels.

Significantly, Northern Ireland relies on ferries to import most freight and most basic food items both for human and animal consumption. The cancellation of ferry services across the Irish Sea, even for a few days, can result in shortages of items in the food supply chain. Should the frequency of disruption to ferries increase, the logistics of food supply and freight transport would need to be reviewed.

Adaptation to climate change in the Ferry Sector

Ferry operators may have to reconsider the design of vessel best suited to Irish Sea routes. Substantial research has already been undertaken in relation to vessel design and, wave height and on the interaction between high speed ferries, the wakes they create and shorelines. Already the largest operator employs conventional slower ferries not only as back up to fast ferries but also a replacement for the latter in adverse conditions The financial implications of this insurance strategy are clearly very substantial.

Impacts on Roads and Public Rights of Way

Roads and Public Rights of Way: State of the Network

Trunk routes in Northern Ireland are provided and maintained by the Roads Service of the Department for Regional Development (DRD). The complete public road network is just under 24,6000km long, with some 1,200km of trunk roads linking major towns. Road traffic is seen as a major contributor to climate change, particularly the contribution to greenhouse gases made by private cars, and this has been the focus of management and engineering based studies in the past. As noted Northern Ireland has a strongly car dependent population with some 90-95% of all journeys being made by private car; while the national fleet in Northern Ireland is newer than that elsewhere in the United Kingdom. Although Roads Service are aware of issues such as air quality and monitor this continually there is no long-term strategic plan to deal with the impact of climate change.

Vulnerability to climate change

Road infrastructure is sensitive to changes in climate, particularly freezing, while driving conditions deteriorate with excess surface water, and localised flooding. In specific areas, Northern Ireland road infrastructure forms a first barrier to coastal estuaries and Loughs. In such instances, the routes, such as the M5 at Fortwilliam are increasingly vulnerable to changes in sea levels and coastal erosion.

Other forms of public rights of way, including walkways and cycle tracks are also vulnerable in the same way as highways. Segregated cycle tracks running from Belfast to Jordanstown are affected by freezing and have no treatment during winter months.

In general the impacts on the road infrastructure could be severe. Changes in annual average temperature will have a significant impact on the winter maintenance programme. Several million pounds are spent each year on winter maintenance; changes in mean winter temperatures will have an impact on this. Road surfacing and pavement deterioration models could be severely affected by temperature and rainfall changes. The life of bituminous surfacing is likely to be reduced if annual average temperatures increase. Subgrade moisture contents will be increased should rainfall levels increase; this will also have a detrimental effect on pavement life. Increased intensity of rainfall will have an impact on surface water drainage and generation of spray, which could have an impact on driver behaviour and safety.

The geotechnical infrastructure will also be adversely affected should winter rainfalls increase. The correlation between rainfall intensity and instability and failure of cuttings and embankments is well established. Recently the frequency of occurrence of landslides has been increasing most likely due to several wetter than average winters causing softening of the soil. A research project is currently underway within the School of Civil Engineering at Queen’s

University of Belfast (sponsored by Roads Service, Department for Regional Development), on a major landslide triggered by several days of intense rainfall. The cost of the repair of this landslide will be significant. The research study recommends that other similar slopes be examined to assess risk of a landslide occurring and, if the risk of failure is high, preventative cost effective treatment of the slope should be carried out to improve stability. This is a typical example of how an effective strategy can be developed to assess the impact of climate change on a sector and take measures to mitigate these effects.

Changes in soil moisture content will also have an impact on foundation design and the shrinking and swelling of clays. This will have an impact on foundation design and could lead to increased incidence of settlement and movement of shallow foundations.

Adaptation to climate change by the Highway Network

Although few policies exist at present within the Roads Service current studies on geotechnical issues are being carried out and may result in forward planning to accommodate climate change. Other maintenance and design impacts are yet to considered although constant monitoring of the road condition will allow theses impacts to be considered and taken into account over a period.

Mitigation of Climate Change in the Transport Sector

Mitigation of the climate change impacts attributable to transport encompasses a variety of potential initiatives ranging from fiscal devices to infrastructure investment to softer measures including education and awareness campaigns. Many of the infrastructure measures and soft measures have traditionally been drawn up at a local or regional level while fiscal measures have been reserved to Westminster. However, 1998 was claimed by government to be a watershed when for the first time a UK-wide policy framework was announced by central government at Westminster. The publication of the United Kingdom White Paper on Transport in the summer of 1998 heralded an attempt to forge an integrated and sustainable transport policy across the UK. This represented the first comprehensive attempt to address amongst other challenges that posed by transport for Greenhouse Gas emissions.

The Government promised that the White Paper would set a radical new agenda for transport in the UK based on rights and responsibilities. The UK Government committed itself to promoting a strong economy, a sustainable environment and an inclusive society. For the UK as a whole the central tenet of the White Paper was a move away from a philosophy of ‘predict and provide’ to one where the transport system was to be managed to ensure that mobility requirements — insofar as these are necessary to underpin society’s economic and social goals — are realised without stimulating demand for movement unnecessarily and impacting negatively on the opportunities for future generations.

Traditionally no part of the United Kingdom had implemented an overarching policy for the transport sector. Typically policies have addressed individual modes or sectors of the industry or specific geographical locations such as large urban areas. Most attention has been focused on those industries either within the state sector and/or experiencing financial difficulties, e.g. railways and roads.

Central to realising the UK Government’s goals of an integrated transport policy are provisions for the effective delivery of initiatives. The period since 1998 has also coincided with progressive moves towards devolution of government in Scotland, Wales and Northern

Ireland. In each of these areas of the UK however the powers and role of the devolved administrations in relation to transport differ markedly.

The devolved bodies have assumed considerable consultative and/or executive influence in the development of policy for Scotland, Wales and Northern Ireland as a whole. The consensus is that the execution of the UK's integrated transport policy has been poor. While similar arrangements for devolution of powers to those for Scotland apply to Northern Ireland the Northern Ireland Executive and Assembly have rather more extensive powers in the transport sector than those enjoyed by their Scottish counterparts. The Department for Regional Development is also responsible for control of public transport including provision of revenue support. Unlike most of the remainder of the UK public transport, both bus and train services, remains both fully regulated and in public ownership.

It will be apparent from consideration of how individuals make decisions about travel and the current nature of the marketplace for travel (i.e. its failure to incorporate environmental, congestion and social costs) that the potential for achieving significant modal switching in different areas varies very considerably. Public transport can only compete where it offers comfort and either a substantial in-vehicle journey time or access/egress time advantage over the car. Such a situation will occur where there is serious congestion and/or nearby parking is not readily available, or is expensive, and public transport is able to avoid the effect of congestion, i.e. it is segregated from the private car. This is particularly true for central London. In contrast, in most provincial cities public transport faces a bigger challenge in winning market share as well as retaining it. The same is even truer of smaller centres and particularly in rural areas. In both cases it is hard to envisage circumstances where, given a choice between the bus and car, the former can compete successfully.

Thus it is not unexpected to find limited progress in much of the UK but in particular in Northern Ireland in advancing the principles set out in the White Paper and those complementary statements issued by the devolved administrations. In the last four or five years moreover, car registration levels in Northern Ireland have risen significantly with the effect of closing the gap in average car ownership levels between the Province and the UK overall. Against this backdrop it is not unexpected to find a continued decline in the overall markets held by public transport in Northern Ireland even with cessation of much of the violence and tensions, which have engulfed Northern Ireland for so long. Even in Belfast's city region where the potential for achieving behavioural change is greatest, the portents for reducing car dependency and closing the mobility gap are not particularly optimistic even in the medium term.

Continuation of differences in society's values within constituent parts of the UK will ultimately determine whether a coherent Integrated Transport Policy founded on the principles of sustainability, will be recognisable throughout the country in the new Millennium. Significantly, residents of Northern Ireland do not perceive transport related environment problems as being as serious as their counterparts in England. Moreover, survey evidence in Northern Ireland indicates less support for improving public transport than the rest of the UK, much greater dependency on the car, but perhaps somewhat surprisingly, little difference in acceptability of traffic restraint measures.

The extent to which the objectives and actions contained in the UK White Paper are mutually consistent raises issues of the relative priorities which society considers being attributable, for instance, to economic development and environmental sustainability. Viewed from the periphery of the UK, it is evident that the priorities of government officials and many in industry in Northern Ireland, Scotland and Wales differ from the typical resident or policy maker in London and the South East. The devolved administration in Northern Ireland recognises the need to promote more sustainable transportation because of the significant contribution it can make to achieve important social, economic and environmental objectives. However, there is a strong body of opinion that investment in transport infrastructure will result in a reduction in overall transport costs faced by industry and as such considerations are claimed to be important considerations in determining business location, transport projects and policies can have an important impact on the economic growth of a region, particularly one on the periphery of the EU.

The island of Ireland's geography and location inevitably increases the costs of travel and freight transport compared to countries with adjacent land boundaries. Dependence on shipping or air services inevitably reduces both flexibility and also increases substantially transit times for short distance movements for which air is not a realistic alternative.

The emphasis in the UK White Paper undoubtedly reflects a London perspective. The extent to which its writ runs throughout the UK was already brought into question by the somewhat different tones of the transport policy documents issued by the various devolved administrations. De facto Scotland and Northern Ireland and to a lesser extent Wales have adopted their own transport policies, which while paying some regard to the UK document reflect the perceived priorities within their own jurisdictions.

4.3.2 Buildings

Christopher Tweed
School of Architecture, Queen's University Belfast

Summary
The construction, maintenance and use of buildings, account for much of the energy consumed and CO_2 emissions produced in the UK. Greater efficiency thus will contribute disproportionately to mitigation of climate change. With increased rainfall and heavier downpours, flooding will become more frequent with damage resulting to buildings and their contents especially in the West. Increased rainfall may also reduce the number of days available for outdoor construction work and so cause more interruptions. Higher rainfall may render some land unsuitable for development because of a greater risk of subsidence in the soil, higher rainfall and flooding could adversely affect the operation of some septic tanks. Changes in the water table may lead to localised soil subsidence and shrinkage, especially in soils with significant clay content. An increase in humidity will promote condensation, particularly in housing, that are more attractive to fungal and insect attack. Increased wind loadings on buildings and driving rain could lead to more structural damage. There is an urgent need to review regulations and best practice in the light of predicted climate change, because many of designs now on the drawing board could be around for the next 60 years.

Introduction

Relations between climate, buildings and people are widespread and complex. The built environment is not only affected by changes in climate but is responsible for many of the emissions that are implicated in climate change. Buildings — their construction, maintenance and use — together with the activities they house, account for a large percentage of the energy consumed and CO_2 emissions produced in the UK. It is understandable that most of the research on buildings and climate to date has focused on the possible impact that our use of the built environment has on climate and resources, on what is referred to here as mitigation. Few studies examine how changes in climate could affect buildings and our use of them. The general aim of this study, as part of the larger investigation, has been to explore the possible impact of changes in the climate of Northern Ireland as predicted by UKCIP and local experts in the School of Geography at Queen's University.

Scene-setting

Northern Ireland is distinct from the rest of the UK climatically, economically, and politically. Unlike England, Scotland or Wales it has no significant energy resources and relies on imported fuel to heat and power its buildings. It is therefore highly vulnerable to interruptions of supply as well as to changes in fuel prices. In recent years, there has been a marked switch from coal and other solid fuels to oil, and, to a lesser extent with the completion of the natural gas pipeline, to gas in home heating (NIHE, 1999). Across the UK, the issue of fuel poverty has emerged as a major concern. Here, a fuel poor household is defined as one that spends more than 10% of its income on maintaining comfortable conditions (21°C in the living room, 18°C elsewhere in the home). There are variations in the definition used in the UK with a threshold of 6% total expenditure on heating or 10% on all energy sources applied in certain cases. Even with a fairly simple definition, it is very difficult to measure accurately the number of ‘fuel poor’. Recent estimates suggest that 170,000 households (28%) in Northern Ireland are at risk of fuel poverty (DETR, 2001). To some extent, fuel poverty has overtaken the earlier focus on improving energy efficiency in dwellings, as the links between poor housing and ill health have become clearer. Despite continuing improvements, most notably in the housing sector (NIHE, 1999), Northern Ireland enters this period of climate change in a rather precarious position in terms of its continued reliance on external sources of energy to make its buildings habitable.

The principal method of this study has been to identify possible impacts of climate change on the built environment and, through interviews, to discuss these with key stakeholders (Appendix 1) in the building industry in NI. In the time available, it was not possible to survey all potential stakeholders, however, those who have been consulted provide a good coverage of interests within the industry. One of the major obstacles is that many of the organisations engaged in the construction industry in NI are represented through regional offices that rely on policies and research carried out in head offices based in mainland Britain or in the Republic of Ireland. It is rare to find technical staff based in NI.

The report begins with a general discussion about relations between buildings and climate before considering changes in climate which are predicted for NI and their possible impact on the built environment. The final section discusses the main points of the analyses and interviews with stakeholders.

Building/climate relations

We do not need to return to the basic needs of shelter to explain the relations between humankind, climate and buildings. Suffice to say that all of us rely heavily on the built environment on a daily basis.

Internal/external relations

There are several approaches to building-climate relations, depending on the severity of specific climates and the needs of the activities to be accommodated. One approach is to try to limit the impact of external climate on the internal environment as much as possible. This implies the creation of hermetically sealed enclosures in which the building envelope is required to serve as a barrier to external conditions. In practice, this is so difficult to achieve that it is rarely adopted, unless demanded by internal activities that can only be carried within a very narrow range of environmental parameters, e.g. some industrial processes such as spinning of man-made fibre. To create and maintain conditions, often in opposition to the external climatic forces, requires significant input of energy for space conditioning.

More commonly, the building is seen as a filter between the external and internal environments. The intention is that the building envelope should be able to admit what is desirable and reject what is unwelcome or harmful in the external environment. The intention is laudable, but in practice it often proves difficult to achieve. There are many reasons for this. The fabric of a building provides myriad paths for exchanges between internal and external environments. The opaque fabric admits (on both sides) heat, air movement and sound. Whilst translucent elements allow light and electromagnetic radiation to enter and leave the interior, the various openings which allow movement into and out of the building pose further problems in filtering external conditions.

Structure and fabric relations

Relations between climate and buildings are not restricted to the exchange of light, moisture, precipitation and heat between external and internal spaces. Climate also impinges directly on the structure and fabric of the building. Whilst most attention is given to providing internal conditions that meet the thermal, visual and auditory needs of occupants, it should be remembered that this is only made possible by a robust and durable fabric and structure.

Climate change predictions and possible impacts

Analysis of the supplied predictions for climate change in Northern Ireland suggests a range of possible impacts on buildings, both positive and negative. Buildings, of course, also directly change the microclimate of their environs and through the use of geographically distant resources and production of greenhouse gases. At a local level, it is highly likely that interactions between existing buildings and changes in climate may have unpredictable consequences. In this short study it is not possible to consider such second-order effects as these require detailed knowledge of particular conditions and buildings. This section considers only the first level of change.

Increased rainfall

The figures undermine the local intuition that NI is one of the wettest regions of the UK. Whilst subjectively it may seem that we suffer from very high rainfall at present, the records suggest otherwise. Serious flooding is a rare occurrence. If, however, rainfall is to increase, and especially if this occurs in heavier downpours, then flooding may become more frequent with damage resulting to buildings and their contents. This is likely to be most critical in the Western part of the province (Fermanagh and Tyrone). Increased rainfall may also reduce the number of days available for external construction and so cause more interruptions. It may also be necessary to provide additional protection from the rain for work in progress.

A more likely consequence of higher rainfall is that some land may become unsuitable for development because of a greater risk of subsidence in the soil. Problems of earth slippage are already evident on sloping sites and this is likely to worsen with more rain. Earth slippage can result in serious structural damage or failure, in extreme cases rendering entire buildings unusable. The number of sloping sites in NI, however, is small.

Whereas previously much of NI's rural housing stock relied on septic tanks for sewage disposal, most collections of rural houses are now served by small sewage treatment installations. Higher rainfall and flooding could adversely affect those septic tanks still in use, but modern designs allow for the flotation effect by incorporating a concrete ring around the tank to keep it anchored to the ground. Inspection chambers ('manholes') are not weighted to the same degree and may begin to float in if the water table rises significantly. This could damage entire sewerage systems.

Higher potential evapotranspiration (PET) values

Increased rainfall may be partly offset by increased PET, particularly in the summer. The average water content of the soil should remain similar to present during winter and fall in the summer. Higher PET and rainfall suggest greater extremes of wetting and drying of the soil, which may result in wider fluctuations of the water table on some sites. Changes in the water table may lead to localised soil subsidence and shrinkage, especially in soils with significant clay content. This could have a major impact on buildings, though there is relatively less clay in NI than elsewhere in the UK. Nonetheless, soil movement could have a significant impact on the structure.

Higher humidity

The predicted increase in humidity is a genuine concern for NI. Its greatest impact is likely to be greater incidence of condensation, particularly in housing. Condensation in housing is already a recognised problem in NI, exacerbated by lifestyles of occupants. Ironically, condensation has become a bigger problem as more energy efficiency has been introduced because of reduced ventilation rates. For new housing, one possible solution is to incorporate whole-house ventilation with heat recovery. Opponents cite the added cost of systems. High levels of condensation are implicated in a range of respiratory diseases, including asthma and bronchitis.

High levels of humidity can also damage building materials and may lead to eventual failure of components. In organic materials, such as timber and fibre boards, greater moisture content can lead to rot and greater vulnerability to fungal or insect attack. Changes in moisture content of these materials can also produce changes in their dimensions. Timber is a ‘living’ material which ‘moves’ depending on environmental conditions. Timber floors are likely to pose problems, since with greater expansion and contraction, previously adequate movement joints may not accommodate the greater range of movement. In concrete, interstitial condensation can corrode steel reinforcement.

Increased severity of gales

There are two main conditions to consider. First, increased wind loadings on buildings could lead to direct damage to structure and envelope. Second, increased wind speeds, combined with increased rainfall, will result in more ‘driving’ rain. NI already has one of the highest driving rain indices in Europe. Rain penetration of the envelope is likely to increase, with concomitant rises in entrained moisture (in envelope materials) and in the moisture content of internal air.

In recent years, severe storms have caused major damage to a few buildings in NI. Schools and blocks of flats have lost their roofs but devastating as they are, catastrophic failure is rare. Buildings are at greatest risk from wind during construction. The potential for increasing severity of gales will leave them more vulnerable and may require expensive temporary structure to prevent damage or injury. There may also be disruptions to construction either directly or indirectly because of electric power outages. Loss of electricity will also disrupt activities in occupied buildings and homes.

Depending on the frequency and duration of gales, there may be interruptions to the supply of building materials, since most of the materials and elements found in our buildings are imported by sea.

Higher mean annual temperature

Predicted higher mean annual temperatures, at first sight, appear to be a benefit of climate change. Anything that reduces the heating requirement in buildings is a plus. However, there may be some disadvantages arising from this change. Higher temperatures coupled with higher humidity create conditions that are more attractive to fungal and insect attack on organic building materials (timber, fibre, etc.). Much of the increase in average temperature will come from increases in summertime temperatures. Currently, few buildings in NI need air-conditioning, but even a small rise in temperature could make larger buildings uncomfortable. It is difficult to predict how many buildings such a rise would affect without carrying out a detailed study, but it should be noted that retrofitting air-conditioning in existing buildings is seldom a viable proposition because of the practical difficulties. In the context of reducing energy demand, air-conditioning is to be avoided if possible through better building design, though obviously this only applies to new buildings.

As noted above, higher temperatures may also create ideal conditions for fungal and insect attack on building fabric. Dry rot, in particular, can remain dormant for up to 12 years waiting for the right conditions for it to thrive. High summer temperatures and increased humidity could provide these conditions, if not one year then another.

Increased cloud cover

Despite the generally high cloud cover in NI, there is significant potential for solar heating in the province. It is only in recent years, however, that the potential of passive solar heating has been recognised and consequently few buildings have been designed to take advantage of this resource. Active solar heating systems have been used, but mainly in demonstration houses. An increase in cloud cover will reduce direct solar radiation, but does not destroy the viability of solar heating. The major obstacles to active solar heating installations at present are the high capital cost of photovoltaics (PVs). Economies of scale are beginning to emerge as the demand for PVs increases, and advances in hydrogen storage and fuel cells will further improve the economic viability of active systems. The second means of active solar heating, solar thermal by which sunlight is used to heat hot water in panels or vacuum tubes may become more attractive with increased incidence of fine summer weather. A local firm, Thermomax produces good quality vacuum tubes in Bangor. The potential for passive solar heating will remain roughly the same. However, designers need to become more aware of the potential and the techniques required to tap into it.

Greater cloud cover is likely to reduce daylighting in buildings during winter months. Occupants will probably rely more heavily on artificial lighting.

Adaptation

The general trend would appear to be a widening of the range of climatic conditions in which buildings will be designed, constructed and operated — more extreme wetting and drying of the earth, greater diurnal and seasonal temperature swings, and more severe gales. Many potential impacts will depend heavily on where buildings are located, on other factors that may work in combination with climate change. Increased rainfall may only be an issue where certain ground conditions prevail, such as heavy clay, will impede natural drainage, or where the ground is prone to shift, such as on sloping sites. The impact of climate change is likely to be small overall but will vary considerably depending on conditions on individual sites. Two of the biggest problems that currently affect buildings in Northern Ireland are wind driven rain and dampness. Both seem certain to get worse.

Since many of our existing regulations and best practice advice are based on 'design conditions', which in turn are derived from weighing up the probability of certain conditions occurring, and the consequences of exceeding their extremes, these may be inadequate in changed circumstances. There is an urgent need, therefore, to review regulations and best practice in the light of predicted climate change, because many of designs now on the drawing board could be around for the next 60 years. A corollary of the enduring legacy of built forms is that solutions to new problems thrown up by changes in climate must always accommodate the existing stock. Whilst it is nearly always possible to arrive at workable solutions for new buildings — by increasing levels of insulation, for example — it is much harder to successfully retrofit these to the often obdurate buildings that are in place.

The construction industry is notoriously slow to respond to new challenges and often will do so only as and when required by legislation. However, to treat the construction sector in isolation is dangerous. The adoption of energy conserving and environmentally beneficial design and construction practices depends on the social, economic and political context in which buildings are procured and used. So, for example, unless deliberate and environmentally sensitive design is rewarded it is unlikely to find favour with occupants, developers, contractors or designers. As suggested by one of the interviewees, one of the main obstacles to increased use of renewable energy sources is the reluctance of the larger utility companies to allow smaller companies to feed energy into the national grid. Establishing incentives and structures that will promote integration must become a key priority.

Cross-sectoral issues

The central role which buildings play in our everyday activities ensures that impacts of climate change on the built environment will spill over into other sectors, and possibly interact with them in complex ways. Statistical correlations between inadequate dwellings and poor health have already been established, though little is known yet about the exact role of the built environment in specific illnesses. This is clearly an area which needs detailed further research. Buildings are also a significant part of our cultural heritage and their preservation and maintenance is crucial to our sense of identity and of belonging to a continuing community.

Mitigation

The built environment plays the dual role of being affected by and contributing to changes in climate. Minimising the impacts of construction and subsequent use of buildings has been a major focus of research since the 1970s. Thus, there is already concerted action towards reducing CO_2 emissions resulting from the use of fossil fuels to power and heat buildings in NI. Mostly, this is driven by legislation and government targets — for example, those set by the Home Energy Conservation Act of 1995. Parallel concerns surrounding fuel poverty have provided additional motivation to reduce energy consumption in dwellings. Climate change predictions suggest that we will require less energy for heating than now. However, as has been noted previously, impacts are likely to vary depending on local conditions.

As Lo *et al.* (2001) suggest, when the resources available for reducing the impact of buildings on the environment are scarce, it is essential to direct available resources to the improvements that will have the greatest effect. The difficulty facing key decision makers is the lack of adequate tools to assist in complex cross-sector analyses. This is exacerbated by the absence of a key individual (or agency) with responsibility for environmental sustainability across all sectors (buildings, transport). Tools to support ‘joined-up’ decision making are now under development (Tweed and Jones, 2000), but without someone to look at the ‘bigger picture’ the necessary integration will not be achieved.

As this is the first study of its kind in NI, and because predicted changes are only just beginning to emerge, it is not surprising that few organisations have considered long-term implications. None of the stakeholders were able to suggest the likely cost of changes in climate over the timescales considered here with any confidence. This study suggests that further research is needed urgently.

4.3.3 Energy

William Beattie[1], Brenda Boardman[2] and Austin Smyth[3]
[1]Electrical and Electronic Engineering, Queen's University Belfast
[2]Environmental Change Institute, University of Oxford
[3]Transport Research Institute Napier University Edinburgh

Summary
Northern Ireland has some severe energy problems due to its need to import fossil fuels and to high levels of fuel poverty. The impact of climate change, in the near future, is not likely to have a major additional effect. Other, cleaner energy sources that produce lower carbon emissions should be supported e.g. extension of the gas network, and combined heat and power (CHP) given suitable sites and embedded diesel generator sets. The latter would provide a potential opportunity to use waste or coal in an efficient manner. The need to support mitigation and reduce the threat of climate change supports the search for solutions to the existing problems, in particular, improved energy efficiency and greater development of renewables. Research into the opportunities for renewable energy supplies would reduce the need for costly imported fossil fuels, enhance security of supply, provide further employment opportunities (similar to the Thermomax experience), as well as contributing to lower carbon emissions. Northern Ireland has, for instance, substantial potential for wind-generated electricity. The use of peat could be replaced with wood-burning stoves that burn the products of local coppicing. All renewables are relatively more cost-effective in Northern Ireland given the existing high fuel prices. However the potentially erratic nature of supply for some renewables may pose risks.

State of the sector

One of the largest sources of emissions in Northern Ireland is the stationary energy industry. Energy for transport is considered under that section of the report. All fossil fuels have to be imported. There is no nuclear power. Cross-border electricity interconnectors provide additional supply security. The lack of natural piped gas has been, until recently, a major factor in the Northern Ireland energy profile. This has changed significantly in the last few years.

The non-availability of natural gas has created over-reliance on other energy sources and been the main factor leading to energy being responsible for higher emission rates and a higher proportion of greenhouse gases in Northern Ireland compared with other UK regions. For instance, in 1995 electricity generation represented 36% of total Northern Ireland emissions compared with 30% for the UK as a whole. A contributory factor is the complete absence of nuclear power stations serving Northern Ireland. The conversion of Northern Ireland's largest power station to gas in 1996 and the arrival of the natural gas pipeline for both the industrial and domestic market are expected to make a dramatic impression on the next set of emission statistics.

The domestic use of solid fuel causes sulphur dioxide and PM_{10} pollution in Belfast. The former is high in UK terms and occurs under 'stable' or 'inverted' atmospheric conditions (BRE 1998, pp. 17-9). The switch from coal to oil will have had beneficial effects on carbon dioxide emissions, because of improved appliance efficiency. However, greater reductions are available from switching to natural gas, if this option is available to consumers.

The electricity industry

Electricity is generated in four power stations. Ballylumford has been converted to natural gas whilst the other three are still powered by oil or coal (Robertson and Butt, 2001).

Natural gas is the least polluting (in carbon dioxide terms) of the domestic fuels. The direct use of coal and oil in the home provide intermediate levels of carbon dioxide; in all cases actual emissions depend upon the efficiency of the equipment used (boiler, refrigerator, light bulbs, etc). Construction of new Combined Cycle Gas Turbines at Ballylumford (near Larne) and Coolkeeragh (Co. Londonderry) will lead to further significant reductions in emissions.

There are six distinct business activities associated with Northern Ireland's electricity. These are:

- generation (G)
- transmission (T)
- distribution (D)
- supply (S)
- transmission system operator (TSO)
- power procurement (PPB)

While all electricity industries have the first five of these activities the PPB activity is not ubiquitous. In Northern Ireland privatisation included provision for the power stations to be sold with long term contracts that guaranteed the generators that they would have a market for their power. Thus a PPB was a key element in the arrangements for privatisation leading to a monopoly of the wholesale electricity market. With market opening, the PPB monopoly has been broken and its guaranteed share of the market will decline to 65% by April 2001.

Competition in the generation and supply markets is in its infancy. The other four monopoly business activities were entrusted to Northern Ireland Electricity (NIE) at the time of privatisation. NIE has organised the four monopoly activities into two separate businesses. The PPB and the TSO are currently grouped in a single business known as the Power Procurement Business. Under the European Union's Internal Market in Electricity (IME) Directive however, the TSO must become a separate independent entity. However, the local system is very small relative to those existing elsewhere in the UK. In Northern Ireland and in the Irish Republic transmission has been linked to distribution. In England and Wales, electricity is transmitted over hundreds of miles by a company known as the National Grid Company (NGC), which is also the TSO in England and Wales. In Scotland transmission and distribution have also been linked but have separate price controls.

In Northern Ireland separate price controls for Transmission and Distribution will be required in the future as a consequence of the opening of the competitive market. The interconnection of Northern Ireland with the Irish Republic and Scotland and the development of cross-border trading increase the importance of the transmission business and make separate, transparent and cost reflective pricing for the use of the transmission network a necessity.

Transmission and distribution costs

A unit of electricity in 1992/93 cost 0.291p more to transmit and distribute in Northern Ireland than in England and Wales. By 2001/02 it will cost 0.743p more using outturn prices.

The T&D element in the bill is largest with domestic customers where this year it is about 40% and smallest with the largest industrial users where it is less than 15%. Overall, T&D represents 30% of the Northern Ireland electricity bill and of this T accounts for 5% and D 25%. T&D are therefore very significant elements in the economic life of Northern Ireland, costing £155m last year. As they are monopolies they are subject to price control by regulation. A new price control will come into effect in 2002.

The price of electricity and price controls

The price of electricity in Northern Ireland has typically been higher than in GB, the difference being primarily a function of the cost of oil fired generation. Northern Ireland was until the eighties 90% dependent on oil. At privatisation T&D charges in Northern Ireland were about the GB average for the average domestic customer. Since then they have diverged increasingly and this year will be about 57% higher. The divergence trend is equally discernible whether the GB average is taken, or only the more rural companies (increased trading may however blur this distinction). Moreover, at privatisation the cost of transmitting and distributing the average unit of electricity was lower than in Northern Ireland.

Government at the time of privatisation set the first price control. It allowed NIE to raise revenue by 3.5% per annum above the rate of inflation and T&D prices by 1% per annum above inflation until 1997. However, Northern Ireland Electricity remains unique in that it has never had a T&D price control set by a Regulator. The Monopolies and Mergers Commission (MMC) — now the Competition Commission — split the difference between the Ofreg proposals and the NIE offer. The second price control therefore did not reverse the pattern of divergence in T&D prices — indeed it exacerbated the problem.

Demand for stationary energy

Electricity production per capita in Northern Ireland is about 20% below the UK per capita figure. This is largely because Northern Ireland has few energy intensive industries. However, this may also reflect suppression of demand linked to high end user charges.

Consumers pay more for energy in NI than in the rest of the UK; as we have noted this is particularly true of electricity. The liberalisation of the market may have a limited effect on prices, because NI is a small, isolated market. Households have low average incomes and are of above-average size in comparison with GB. As a result, fuel poverty (the inability to afford adequate heating and other energy services) is relatively high and recognised to be a major social problem. Many households underheat their homes at present.

Solid fuel, oil and bottled gas are the main fossil fuels used in the home. There has been a shift from solid fuel to oil, certainly since 1991 (BRE 1998, p6; Robertson and Butt 2001). Natural gas is now available to many people in the eastern parts of Northern Ireland as a result of the interconnector with Scotland, but household acquisition is proceeding more slowly than expected (Robertson and Butt 2001). The proposed network is limited, at present, to the Belfast area. The availability of gas is likely to encourage inward investment by industry (BRE 1998, p11).

Considerable extra energy demand, as elsewhere, is expected from new household formation — we are living in smaller units — and this interacts with the ageing population. This creates the need for more housing construction and, therefore, the opportunity to add very efficient homes to the stock if the Building Regulations are tightened (see buildings section of this report). Further demand can be anticipated from the growth in domestic consumption, particularly of electricity for consumer electronics and home office equipment.

More efficient appliances (refrigerators, washing machines, light bulbs, etc) are becoming available as a result of European Commission initiatives. The reductions achieved through these initiatives are insufficient to offset growing demand for consumer electronics and other new equipment in the home (ECI 2001).

Electricity environmental issues

At present 1500 consumers in Northern Ireland have elected to buy renewable electricity though they pay a premium for standing up for their principles. This is a higher proportion than in the rest of the UK suggesting that there is less differential as local electricity prices are already high. It would be feasible to provide incentives for NIE to encourage renewables to take a larger share of the market by allowing greater revenue for renewable units of electricity.

Impacts of and adaptation to climate change in the energy sector

Introduction

The impact of climate change on energy is often not appreciated. Most are aware of the possibility of a small average rise in temperature, but the real impacts could be due to the greater extremes in climate conditions. Increased violence of storms, and hotter periods, could be a consequence of a gradual increase in average global temperature. An example might be the serious impact on wind-power caused by a change in the tracking of depressions across the Atlantic or the need for increased pumping to deal with extremes of rainfall, or indeed the effect on power station efficiency due to increased sea temperatures. These issues will all have an impact on Northern Ireland.

Power stations

Power stations require large amounts of both fuel for the boilers and cooling water for the condensers and therefore these act as constraints on the possible sites for a station. In NI all power stations are situated in coastal regions. Here the fuel may be delivered by ship and the proximity to dock facilities is a key issue. In this situation sea water is used for cooling and again the range of temperatures will be important. However in this situation an increase in sea water temperature may cause increased marine growth in the cooling system with consequent reductions in cooling efficiency but since at present the seawater is treated chemically to inhibit marine growth in the cooling tubes, the increase in sea level may prove to be the more serious issue.

Power stations operate in a regime that requires them to generate the exact power required at each instant. In some circumstances it is possible to have storage of energy, usually by pumping water into a high reservoir so that it can be released to produce power from a turbine when required. There is no such energy storage in NI and therefore the system must operate at all times so that it can supply the demanded energy in the event of a sudden change in demand or a sudden loss in generating capacity. Operating all sets at below their rated power output covers this. The result is that the machinery is likely only to be operating at full load for short periods under emergency conditions. This is particularly the case in NI where the number of generating sets is small. The fact that the equipment is rarely operating under full load should allow for continued operation under increased ambient temperature conditions of the levels being considered. Again it is important to remember that electrical equipment can stand significant overloads for short periods, say 30 minutes. Moderate overheating is not likely to result in an immediate disastrous breakdown but will have a small influence on the life of the equipment. Since increased ambient temperatures are likely to occur during summer periods when electrical demand is low, the impact is not likely to be significant for machinery.

Electrical transmission systems

Electrical transmission systems are a key feature in the distribution of electrical energy. However they are subject to interruption due to lightning storms, which can cause flashover on the insulators. This may or may not cause a disruption in the supply but will cause transient voltages on the system, which may damage electrical equipment. An increase in lightning activity is likely to result in a reduced quality of supply. Again NI does not experience the severity of lightning storms found on the continent but nevertheless, with a relatively large percentage of 33 and 11 kV lines which have little lightning protection, the reliability of supply can suffer severely from lightning. The basic reason will lie in the fact that high-voltage lines of 275 kV and above will have a special grounded conductor on the top of the pylons, which acts as a screen against lightning strikes. Such a conductor would not be economic on lower voltage lines.

High winds are an important aspect. Their effect is very dependent on the wind direction. Thus winds can induce oscillations in the overhead cables, which can cause them to snap. Various design features are incorporated in an attempt to ameliorate such conditions but will not provide 100% protection. The oscillations can be stimulated either by gusts or by high steady winds. Storms can result in other objects such as trees falling onto a line and causing serious disruption of supply for an extended period. This is likely to be relevant for lines of 33 kV and below which form the core of the rural network. Due to the nature of the network this will influence restricted areas.

On a coastal line salt spray is a serious issue. This is very dependent on wave and wind action. If it is accompanied by steady rain then the salt tends to wash off the insulators. However, if the spray occurs with little or no rain the warmth in the insulators causes the salt to form a crust on the surface which causes a short circuit when the rain arrives. Designs in situ have taken into account the problems of salt spray and the prevailing wind directions. If the wind directions were to change then the problems may move to other areas. Changes in direction of the prevailing wind could change the pattern of problems caused by salt spray.

Mitigation: Alternative energy sources and implications of climate change on measures

Wind is potentially a significant alternative energy source in NI and thus any change in average velocity or wind direction can produce a significant effect. Thus, in order to obtain the best wind flow conditions, wind turbines are usually erected on rising slopes facing the prevailing wind direction. In this situation the wind turbulence is reduced and a steadier flow is obtained. However if the wind were to blow from the opposite direction, then the power produced by the turbine would be significantly reduced over the year. It would be possible to generate up to 30% of our electrical energy from wind but this will almost certainly never be realised as many of the best sites are in reserved areas.

At present most of the possible land based sites in NI have been utilised and the increasing battle in public hearings is likely to result in few other sites being economic. The potential for wind power to have a major impact is in installing wind turbines offshore. This would typically be about 10 to 20 km from land, although at Blythe, Northumberland, the installation is 0.5 km offshore, and preferably in relatively shallow water. The potential in the Republic of Ireland (RoI) for off-shore wind power is good but NI has relatively few suitable sites, the most likely location being at the mouth of the Foyle. Even this site is likely to meet serious opposition from the local airport, tourism and ornithologists.

With wind turbines the desirable scenario is a consistent wind speed with few extreme wind velocities and few periods of calm. It would appear that the forecast scenario for climate change is likely to provide more erratic conditions, which will be detrimental to the extraction of wind energy.

Although there is a factory in NI, which makes and sells solar panels it is virtually all an export market and very few systems are installed here. Increased infra-red radiation could make the use of solar panels more attractive. Infrequent but very extreme winds could result in increased damage and therefore increased maintenance and insurance charges covering solar panels.

There are a few hydro plants in NI but these suffer from the extremes of flow in the rivers. This has not been helped by the DoENI drainage policy and in addition the environmental issues will make the installation of hydro plant at any further potential sites almost impossible. The types of tariffs set by the electricity supply company are such that there is no value added term for electricity generated during the winter days when it would prove most valuable. An example of the problem is that a potential site on the Lagan could generate 200 kW during the winter months but effectively nothing during the summer. Only if the price offered per unit were related to the winter value would such a site offer a commercial proposition.

Energy from sea waves is not at present a viable option in NI because of the prevailing wind direction. However if the prevailing wind were to come from the Northeast then the situation would be entirely different, with the north coast offering considerable potential for wave power.

Embedded generation

A growing feature of modern power systems is an increase in embedded generation i.e. generators connected at low voltage within local distribution systems that are in turn connected to the high voltage network. This may be equipment such as wind turbines but a much more common form is the use of diesel or gas turbine generators in the industrial plant. This may be combined with the use of waste heat from the exhaust in the industrial process, so called combined heat and power (CHP). There are number of issues which arise from the use of oil or gas power embedded generation.

The use of CHP can provide greatly improved efficiencies. Thus in general the local generation of electrical power will be more efficient than that supplied by the power authority although it will require higher quality oil. In the case of gas powered engines the overall efficiency will again be higher than that offered by the supply authority but the engine sizing will be greater than that of an oil powered diesel. If the waste energy from the exhaust heat of the engine is used, efficiencies of up to 80% could be achieved which could be compared with an on site efficiency in the electrical supply of perhaps 25%. Change in climatic conditions is only likely to have a marginal impact on CHP systems but they do offer the opportunity for savings in carbon dioxide production. However they will only be efficient when the heat and electrical demand are suitably matched to each other.

While much emphasis is placed on CHP, a standard diesel generating set in a factory, is much more efficient than the supply obtained from a power station even without the use of CHP. These sets are frequently used during peak periods over the winter months when the energy cost may be 20% of the supply authority. A change of tariffs that could more easily reflect the instantaneous electricity cost could allow these machines to be used more widely.

Gas supplies

Gas supplies are by undersea pipeline and the use of gas is at present in the development stage. Gas, oil and electricity are now in direct competition and it would appear that, where gas is available, it would provide a more convenient heat source. It also has the advantage of reduced pollution in that the sulphur content will be negligible compared with oil and coal. The use of gas in heating systems avoids the production of sulphuric acid and therefore allows the manufacture of condensing boilers without the expensive stainless components that would normally be required to resist acid degradation. This allows more energy efficient heating to be provided more cheaply.

Machinery

Electrical machinery in factories will provide the most important issue as other types of equipment do not have the sensitivity to temperature which electrical equipment exhibits. A more serious consequence stemming from climate change would lie in the fact that if the reliability of the supply were influenced, then the factory equipment would experience increased stresses due to transient voltages and repeated starting of machinery. This also has an impact in the quality of product produced since a shut-down of plant will result in loss of product produced but can also produce serious problems before the plant can be restarted. An example might be a plant producing powdered milk where the partly dried milk will have to be dug out of the equipment and the plant cleaned and sterilised before it can be restarted again.

Refrigeration plant is a key item in almost any food plant and this will be seriously affected by any change in temperature. This influence will be due to three effects. Firstly the heat leakage into the cold stores will increase with increased ambient temperatures, secondly, the product being placed in the store will be warmer and therefore require more cooling to reduce it to acceptable temperature storage levels, and thirdly, the refrigeration equipment will not operate as efficiently over larger temperature differences. Refrigeration is a major load in meat and poultry plants and increased ambient temperatures will result in increased costs and possibly in the need for an increased refrigeration capacity.

Lighting

In recent years there have been dramatic changes in the efficiency of lighting equipment. Although lighting equipment is not influenced by small temperature changes, the increased efficiency will offer significant savings in energy consumption and hence a reduction in carbon dioxide production.

Buildings

Building design criteria are covered elsewhere in this report (section 4.3.2) but it is clear that insulation of buildings is a key issue in dealing with either the warming or cooling of the living or working environment. The prime influence here is due to government regulations, which specify the level of insulation required in the construction of new buildings. These regulations tend to be based on financial criteria as to what is an economic level of insulation. Due to the low price of energy this is a relatively low level of insulation. In addition these regulations have tended to lag behind the gradually increasing costs of fuel. It would be desirable that building regulations should be more forward looking and, since the cost of insulation is relatively small, to look more to the future when energy costs will certainly be more expensive.

Climate change and energy demand : Impacts and adaptation

The main factors affecting the use of energy — additional household formation, ageing population, higher levels of appliance ownership — are held constant in all UKCIP scenarios. Most of the discussion has tended to be about the developments until 2020: predicting the effects on human behaviour beyond this date is problematic.

Electrical energy demand

Domestic electrical energy consumption accounts for about one third of the total in NI. Any change in the behaviour of the domestic consumer, therefore, is likely to have a significant impact on the total demand. This domestic demand is largely made up of water and space heating, lighting and cooking. Of these loads, heating and lighting are likely to be influenced by a change in climatic conditions. At present it is possible to track a heavy rainstorm as it crosses the province due to the increase in the lighting load. Thus if the climate scenario were to result in more heavily overcast days then there is likely to be an increase in demand for artificial lighting. In general, climate change will influence use of all fuels not just electricity.

Demand for electrical space heating increases whenever the temperature falls from 18 to 12 °C as more consumers use electric heating. Below 12 °C the main central heating system is likely to be employed which will generally either use oil or gas. There is still a significant electrical off-peak heating load but it has been falling in recent years due to increased competition from oil and gas. A reduction in the future frequency of cold periods will have an impact here.

Electricity is likely to be used for space heating if the temperatures fluctuate rapidly from one day to the next. Indeed in the past coal importers reckoned that a cold day with rain on the windows encouraged people to light fires and it was likely that they would then continue to light fires for the remainder of autumn and winter. There would appear to be a trigger, which is set by a combination of circumstances, which encourages people to resort to central heating.

Warmer winters should reduce the need for energy for heating. The extent of reduced demand, and the speed with which it is realised, depends upon the success of policy on eradicating fuel poverty. At the moment, a minimum of a third of households is under heating the home, mainly because of financial constraints. Warmer winters will allow them to be warmer for the same expenditure, so there will be no net reduction in energy demand, though there ought to be improved health and lower National Health Service expenditure. Real energy savings and reduced emissions of carbon dioxide can be created by improved energy efficiency in homes. These may be brought about by changes in building regulations and would be taken advantage of by middle classes ahead of lower socio-economic groups.

Warmer summers may produce a demand for air conditioning. This is most likely in offices, shops and other commercial premises, where air-conditioning is already marketed as a status symbol, often linked to higher rents (Hulme *et al*., 1992). Electrical air conditioning can be avoided by careful building design and attention to natural ventilation (see housing section). Warmer summers may produce lifestyle changes, for instance more outdoor activities and BBQs, more salads and cold meals, more cold drinks, less indoor cooking and hot drinks. These could have an effect, gradually, on energy consumption for cooking in the home, but is likely to be minimal. There may be an offsetting increase in demand for cold storage.

Higher ambient temperatures in the home should not affect electricity consumption by refrigerators significantly, as these are becoming more efficient, better insulated and less responsive to ambient temperatures. Increased cloudiness could result in greater demand for lighting, but, again, this should be offset by higher ownership of compact fluorescent lamps (CFLs), which use only 20-30% of the electricity.

The most significant effect could be the impact on public awareness and preparedness to reduce consumption, perhaps through higher levels of comfort associated with energy efficiency, in order to limit the effect of climate change. With the present low levels of knowledge about the links between energy use and climate change, the awareness will have to be informed by public education campaigns.

Climate change and energy demand: Mitigation measures

Mitigation measures encompass a variety of policy levers and market pressures, including public policy initiatives within the public sector estate, fiscal and regulatory measures and aid to address fuel poverty in part through energy efficiency grants.

Public sector fuel policy

Work to reduce emissions is being taken forward on a number of fronts. Under the Gas (Northern Ireland) Order 1996, there is a duty on the Department of Enterprise, Trade and Investment and the Office of the Regulator of Electricity and Gas to promote the development and maintenance of an efficient and coordinated gas industry in Northern Ireland.

The Northern Ireland Housing Executive (NIHE) has hitherto pursued a fuel neutral policy towards home heating. However, as it also functions as Northern Ireland’s Home Energy Conservation Authority it has announced that, where natural gas is available, it will be the preferred option for home heating. Where gas is not available, oil will be installed and solid fuel room heaters will be phased out.

Renewable energy policy and the Non-fossil Fuel Obligation

Northern Ireland has resources for the further development of renewable electricity from wind (on- and off-shore) and, possibly, tidal, wave or current-generated electricity, if these become economic. These will all be subject to high costs arising from opposition on environmental grounds. The opportunities for and the use of biomass are somewhat problematic. The UK has a national target of renewable energy providing 10% of UK electricity supplies by 2010. Northern Ireland’s energy objectives include diversification of supply and encouragement of cleaner production and more efficient use of energy. Northern Ireland’s Department of

Enterprise, Trade and Investment has used its powers under the Electricity (NI) Order 1992 to place a Non-Fossil Fuel Obligation (NFFO) on the recently privatised Northern Ireland Electricity plc, requiring it to contract for specified amounts of electricity from non-fossil sources. There should be further consideration of changes in the system of planning covering renewable energy sources.

The Government's current target is 45 MW of renewable plant in Northern Ireland by 2005. Developers bid for contracts under the NFFO Order and are assessed on technical and economic grounds, the most competitive being successful. Direct price comparison is difficult as wind power, for example, will not be available at all times, but in general will receive a premium price for electricity generated. This is financed through the general electricity tariffs not, as in Great Britain through the Fossil Fuel Levy (FFL does not apply in Northern Ireland). By August 2000, 18 projects (17.5 MW) had been commissioned under the NFFO arrangements — eight hydro power schemes, eight wind farms and two biomass schemes. Currently less than 2% of Northern Ireland's electricity demand is met from renewable sources. A major problem is that after contracts are awarded the developer may not take up the offer and the potential supply of renewable energy is therefore lost.

The latest findings published in July 1999, indicates a potential of approximately 8% of electricity consumption in Northern Ireland being met from renewables. The Department of Enterprise, Trade and Investment plans to publish a consultation paper seeking views on the development of Northern Ireland's renewable resources. The paper will table the following:

- setting a target for Northern Ireland as a proportionate contribution towards the overall UK target by 2010;
- the continuation of the NFFO arrangements or their replacement by an obligation on electricity suppliers, in line with the provisions of the Utilities Act:
- the development of a regional planning infrastructure and targets for renewables under the Regional Strategic Framework for Northern Ireland; and
- observations on the implications for renewables of the opening up of electricity markets in the UK and the Republic of Ireland, and the increasing interconnection between grids.

Renewable energy policy and the public sector

It is not possible to say what proportion of Government's energy requirements is met from renewable sources. Public expenditure constraints have effectively precluded Government departments from adopting a pro-active policy of procuring electricity generated from renewable sources. Following the establishment of the Northern Ireland Executive the structure and role of the Inter-Departmental Committee on Energy Efficiency in Northern Ireland have been reviewed. Plans are now in hand to develop a more focused system of monitoring the use of energy and emissions to the atmosphere by the public sector.

Climate change levy

The climate change levy is a reserved matter for Parliament at Westminster. However, the Government has recognised that Northern Ireland's energy market is different from that in Great Britain. The 2000 UK Budget made provision for a temporary exemption of up to five years for natural gas subject to EU permission. This is intended to promote development of the emerging gas market in the area. A substantial market share for natural gas could enable Northern Ireland to make a significant proportionate contribution to the UK's climate change targets.

Climate change levy and Combined heat and power

When the Integrated Pollution Prevention and Control Directive and the climate change levy are implemented in Northern Ireland, regulated sites will have to use energy efficiently. This will provide a drive for the uptake of combined heat and power (CHP). The availability of natural gas will also provide the opportunity for an increase in the installation of CHP, of which there is currently only 22 megawatts in Northern Ireland. Only high quality CHP schemes will be supported and with present fuel prices it is difficult to make a good economic case in many situations where it might be thought attractive.

Energy and business

In addition to the UK Energy Efficiency Best Practice Programme a locally focused service is available to Northern Ireland companies through the Industrial Research and Technology Unit (IRTU). Loans for energy efficiency improvements and advice/support for environmental audits are also available.

Fuel poverty and energy efficiency for social housing

The domestic sector, at 21% of emissions of carbon dioxide, is the fourth largest source of emissions in Northern Ireland. This represents about 5% of UK domestic sector emissions which is significantly higher than would be consistent with the population This reflects the heavy reliance on the consumption of coal, burning oil and gas oil in the domestic sector. Improvements in energy efficiency resulting from the new fuel poverty programme will help contribute to the climate change programme.

Government initiatives, such as the Domestic Energy Efficiency Scheme (DEES), are aiming to reduce fuel poverty and to eradicate it for the vulnerable by 2010 (DETR 2001) and for other households by 2015. The Department for Social Development plans to introduce a new Domestic Energy Efficiency Scheme to provide warmer, healthier homes in Northern Ireland. The new scheme, which will be called DEES II, will build on the success of the existing scheme and target those people most at risk from ill health caused by fuel poverty, particularly the elderly and families on low incomes, the disabled and the chronically sick. DEES II will provide a wider range of insulation measures including improvements in heating standards. It is estimated that the new scheme package will reduce the amount of fuel required by households by £300 to £600 per annum, depending on the energy efficiency of the property before improvement. However, energy savings may be less spectacular if people choose to be warmer.

The NIHE is tasked with achieving a 34% improvement in the energy efficiency of the housing stock by 2006. It is also engaged in a number of other initiatives. These include, as part of the Building Research Establishment Housing Working Group, the completion of the first INTEGER (Intelligent and Green) House in the UK. Research will examine the scope for applying these principles to housing in Northern Ireland. The NIHE through its membership of the European Sustainable Housing Group, has recently produced a draft design guide that sets down standards of accessibility, energy efficiency, sustainability and design for social housing in Northern Ireland.

Other technological developments

Thermomax produce vacuum tubes for heating hot water with sunlight when placed on the roof (solar thermal), but the majority of the output is exported, with a small domestic market in NI. Other opportunities for solar power are discussed under housing, for instance the design and orientation of buildings to make the most use of sunshine for lighting and heating (passive solar) and the installation of photovoltaic (pv) panels on the roof to convert sunlight to electricity. Passive solar applies to new buildings, whereas the installation of solar thermal or pv panels is appropriate to existing buildings

Conclusions

Northern Ireland has some severe energy problems due to its need to import fossil fuels and high levels of fuel poverty. The impact of climate change, in the near future, is not likely to have a major, additional effect. The need to support mitigation and reduce the threat of climate change supports the search for solutions to the existing problems, in particular, improved energy efficiency and greater development of renewables. Two particularly important policies are the strengthening of the building standards, for both new and existing buildings, and research into the potential for renewable energy in the province. These both have short and long term effects: the building stock is very long-lived, as many of today's houses will still be occupied in 2080, and new renewable resources will require years of development before they are a real technical and economic potential.

Research into the opportunities for renewable energy supplies would reduce the need for costly imported fossil fuels, enhance security of supply, provide further employment opportunities, as well as contributing to lower carbon emissions. The development of on-shore wind may need to be supported by new planning guidance and off-shore wind is an important new initiative. In addition, the use of solar and biomass could probably be enhanced. The historical use of peat could be replaced with wood-burning stoves that burn the products of local coppicing. Other, cleaner energy sources that produce lower carbon emissions should be supported. The extension of the gas network is a primary example, but so is the use of combined heat and power (CHP). The latter would provide the opportunity to use waste or coal in an efficient manner.

4.3.4 Waste

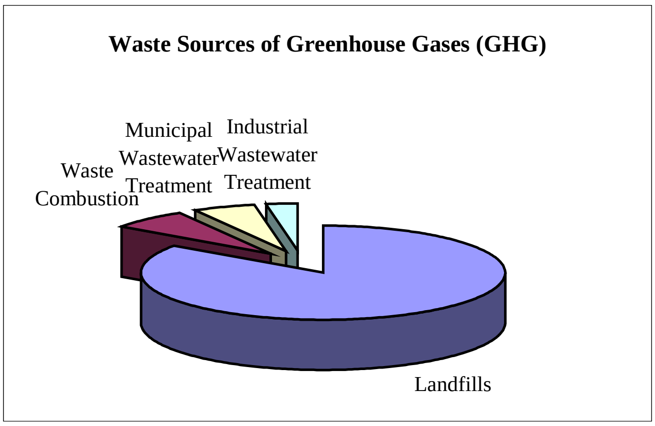
Bob Kalin
School of Civil Engineering, Queen's University Belfast

Summary
The direct impacts of climate change on the waste industry include: Municipal Solid Waste Disposal (refuse), Municipal Solid Waste Combustion (incineration), Municipal Wastewater Treatment (sewage treatment), and Industrial Wastewater Treatment. The main impacts of climate change on the waste industry are secondary in nature and are focused on the emission of greenhouse gases (GHG) during waste handling / treatment activities, and by the potential of the waste industry to reduce energy use though efficient recycling of materials. The Landfill Directive introduces progressively diminishing limits on the landfill of biodegradable municipal waste, thereby helping to fulfil the objective of reducing methane emissions from landfill. The waste industry is affected by Climate change, but the attitudes and practices in society must change if the objectives of the Landfill Directive are to be met The implementation of legislation combined with a change in societal attitudes will result in the largest impact of climate change on the waste industry.

Introduction

This section focuses on the impact of climate change on the waste sector and the resulting impacts on society. The direct impacts of climate change on the waste industry — which includes Municipal Solid Waste Disposal (refuse), Municipal Solid Waste Combustion (incineration), Municipal Wastewater Treatment (sewage treatment)[2], and Industrial Wastewater Treatment — are not intuitively obvious. Changes in weather patterns may influence discharge consents to rivers and seas, and changes in temperatures may have a limited effect on the rate of biodegradation of wastewater or refuse. More importantly, the major impact of climate change on the waste industry are secondary in nature and are focused on the emission of greenhouse gases (GHG) during waste handling / treatment activities, and by the large potential of the waste industry to provide an overall global reduction in energy use though efficient recycling of materials.

FIGURE 4-6: Waste sources for emission of greenhouse gases (data source: US EPA Report 236-R-00-001 ***Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 –1998*****).**

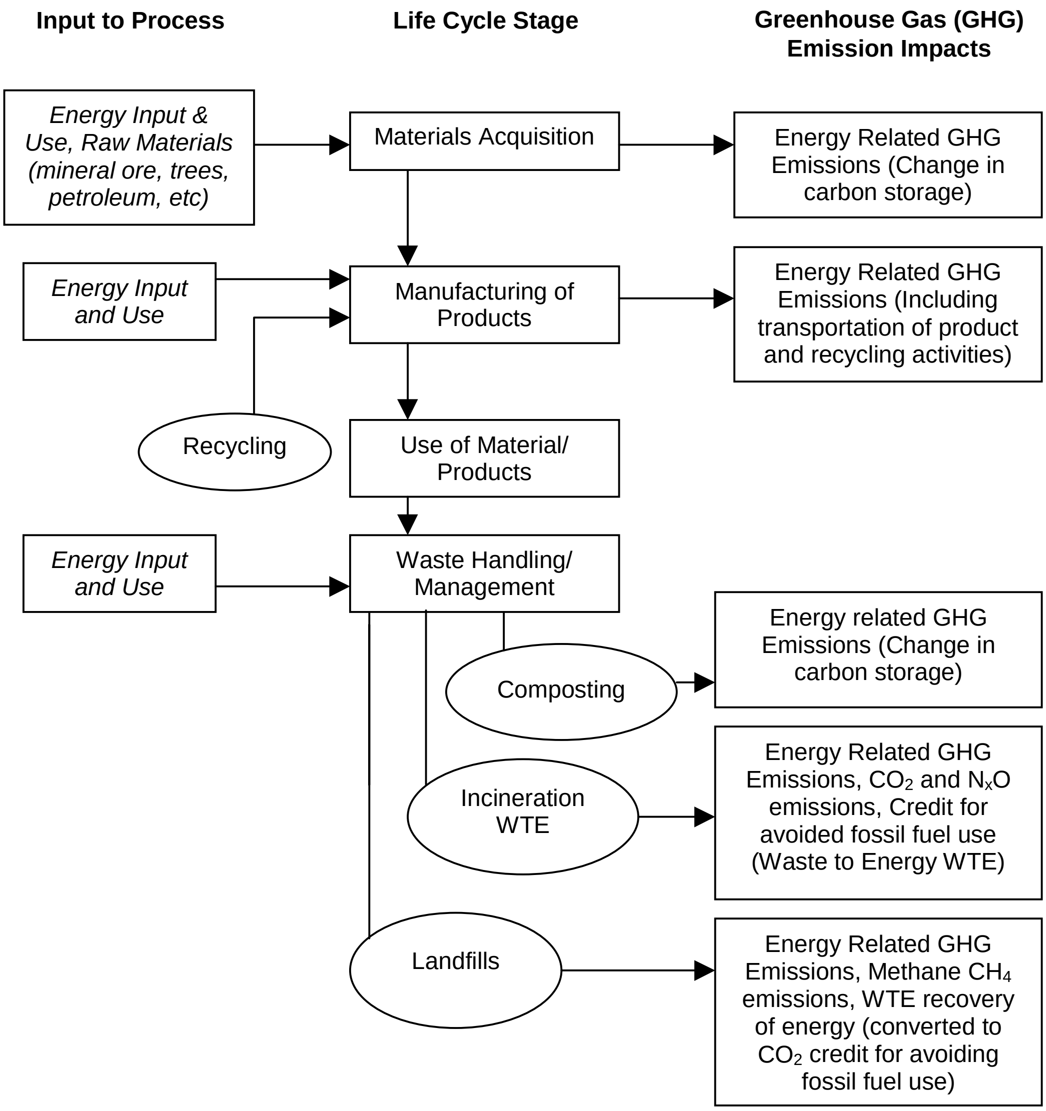


[2] See also section 4.1.2 regarding the Urban Waste Water Treatment Directive.

The waste industry is an overall source for GHG emissions (Figure 4.6) that globally may account for 200-500 million metric tonnes carbon equivalent (MMTCE) of emissions. In the USA and Europe, landfills are the largest single source of methane (CH_4) emissions, accounting for 33 percent of the US total. Waste to Energy plants (WTE) that use waste as a fuel source produce both CO_2 and nitrous oxide (N_2O) emissions. Wastewater treatment plants produce both CO_2 and CH_4 depending on the type of plant, however as little study of the emissions of these activities have been undertaken, the full impact of wastewater treatment on GHG emissions is not yet understood. All waste activities also emit non-methane volatile organic compounds (NMVOCs) in minor amounts, many of which have effects on the global climate system. Therefore, the impact of climate change on the waste industry is focused on regulation of GHG emissions and reuse of materials / energy.

The impact of climate change on the waste industry is not only one of regulation (e.g. the Landfill Directive 1999/31/EC), but also it is one of perception within society that will ultimately produce a significant impact on the industry. It is the general public and the society in which we live that demand products that result in waste, and it is the same society that determines values placed on waste and energy recovery activities. Therefore, evaluation of the Life Cycle of products and the generation of waste must include impact of waste activities on society and the global climate if impacts to/from the waste industry are to change (see Figure 4-7). The total volume of waste produced in the EU is uncertain, however the European Environment Agency (EEA) estimates that a total of 1,300 million tonnes of waste is generated each year in the EU. Given the relative lack of concerted recycling effort throughout all Northern Ireland (in contrast the Netherlands recycles approximately 38% of municipal waste), the per-capita waste production / landfilling in Northern Ireland is above the EU average. Not only is volume of waste of concern (given the pending crisis of available landfill volume in Northern Ireland), but also it is important to note the results of French studies that suggest that up to 15% of all freight transport involves the movement of waste and 5% of the transportation sector's energy is associated with waste transportation (EEA statistics). The full implementation of the landfill tax in Northern Ireland aims to improve the position of recycling and energy recovery activities.

FIGURE 4-7: Greenhouse gas life cycle associated with municipal solid waste stream (after US EPA Report 530-5-98-013 ***Greenhouse Gas Emissions From Management of Selected Materials in Municipal Solid Waste,*** pg. ES-8).



The EU Packaging Directive and its implementation in Northern Ireland aims to decrease waste generation through decrease in packaging or recovery and recycling of packing waste. EEA statistics show that in 1997 136kg/capita of packaging waste was generated (almost 1/3 of total waste from household and commercial activities). The Packaging Directive Target 1 requires member states to reach a recovery level of between 50% and 65% by weight of all packing materials, Target 2 requires a recycling level of between 25% and 45% by weight of all packaging materials, and Target 3 requires a recycling level of 15% on specific materials (one example might be reuse of construction materials to reduce emissions of CO_2 during manufacturing of lime). This indirect impact of Climate change on the waste industry is significant.

The aim of the Landfill Directive (1999/31/EC), and its implementation in Northern Ireland, is to prevent or reduce the effect of landfilling waste on the environment. One of the main objectives of the Directive is to reduce the emission of methane from landfill sites. Where methane is to be produced by landfilling activities, the Directive aims to ensure that it is used productively. The impact of Climate change has therefore had a direct effect on the Landfill Directive and thus the waste industry, and the implementation of energy recovery activities such as use of methane from landfills to produce energy will displace CO_2 emissions from the burning of fossil fuels to produce energy. The Landfill Directive introduces progressively diminishing limits on the landfill of biodegradable municipal waste, thereby helping to fulfil the objective of reducing methane emissions from landfill. There will be a continuing impact on the waste industry and Society as these limits are enforced and met. Thus, not only is the waste industry to be affected by Climate change, but also the attitudes and practices in society must change if the objectives of the Landfill Directive are to be met.

Conclusion

The impact of Climate change on the waste sector in Northern Ireland is one of changing one or more of the following:

- *Energy Consumption* associated with the manufacturing, transportation, use, and disposal of products or materials that become a waste,
- *Non-energy related GHG Emissions* such as CO_2 emissions during the formation of lime for cement/concrete,
- *Methane (and other GHG) Emissions* from landfills where biodegradable waste is disposed and use of methane for energy recovery,
- *Carbon Sequestration* where carbon is stored for long periods of time away from the atmosphere by either natural or man-made processes or by the reduction in the use of fossil or renewable carbon sources (e.g. forest and peat lands are carbon sinks).

The implementation of legislation combined with a change in societal attitudes will result in the largest impact of climate change on the waste industry.

4.3.5. Sport and recreation

Simon Allen
Centre for the Study of Environmental Change and Sustainability, University of Edinburgh

Summary
Sport in general generates in excess of £250 million per year in Northern Ireland. Stakeholders in this sector were generally unfamiliar with the potential impacts of climate change. None of the impacts considered were thought serious, beyond the possible increase in transport costs. Some 'winter' sports have instituted or are contemplating a possible winter break. Air-sports such as hang-gliding are sensitive to a higher incidence of extreme wind speeds.

State of the sector

Sport, popular culture and arts events are common forms of recreation in Northern Ireland. Almost 6 out of 10 of the adult population (59%) participate in one or more sports. The three most popular activities are walking (43%), swimming (11%) and keep fit (9%). Many of the popular sports in Northern Ireland, such as golf, soccer, rugby, squash and tennis are also played throughout the United Kingdom, but distinctive gaelic games such as hurling, gaelic football, camogie and handball also have a wide following. The sporting industry supports 12,500 jobs in Northern Ireland and generates £254 million in revenue annually (SCNI, 2001).

Development of the sport sector in Northern Ireland aims to increase levels of participation in sport, with a focus on increased participation by youth and disadvantaged communities. As well as providing clear health benefits, increasing the level of sporting activity is seen as a means to support peace and reconciliation, and there are many cross-community initiatives.

Impacts

It is unlikely that the change in climate suggested by the scenarios could have any significant impact on popular culture or arts events, or on the most common forms of physical exercise: walking, swimming and keep fit, so these were not considered in the study.

All interviewees were unfamiliar with thinking about the impacts of climate change, which appears to be an issue that is not considered in the strategic planning of the sport sector. They suggested, however, several types of possible impact, though none were considered serious.

Many outdoor team sports are weather-sensitive, to the extent that matches are cancelled if inclement weather makes the sport unsafe, for instance when heavy rainfall affects pitch conditions. Bad weather also causes lower attendance of spectators, as it reduces their level of comfort and can also reduce the quality of game play, making the sport less interesting to watch. One interviewee reported that recently the Gaelic Athletic Association had decided to delay the playing season, moving it from September-January to February-July. This was their response to recent wetter winters, which have caused matches to be cancelled and have reduced the quality of play through poor pitch conditions.

Outdoor adventure sports and leisure activities such as hill-walking, mountaineering, rock-climbing, kayaking, boating, yachting, golf and fishing are clearly sensitive to weather conditions. As with team sports, weather affects both safety considerations and the comfort of participants, though in some cases a degree of discomfort is an accepted aspect of the activity. In many cases the likely climate changes will probably have a small beneficial impact. Drier and warmer summers would provide better conditions for many outdoor sport and leisure activities. Increased winter rainfall could be of benefit to white water kayaking through increased river flows. Air-sports, such as light aviation, hang-gliding and paragliding are most sensitive to changes in storminess and wind-regimes, particularly wind-direction, which determines the degree of lift that can be obtained from particular topographic features. The impact of climate-induced changes in the flow regime of rivers on fishing is considered in section 4.1.2.

The interviewees were not aware of any research previously undertaken to consider the impact of climate change on the sector. Neither were they aware of any sports facilities vulnerable to direct impacts from climate change, such as stadiums or leisure centres located in areas of high flood risk.

Adaptation

Interviewees considered that sport is inherently adaptable to changes in the weather, as it is mostly a voluntary activity: events can be rescheduled; outdoor activity sports can be relocated, for instance hill walks can be re-routed to less exposed terrain in windy conditions. Changing the timing of the Gaelic football season has been a successful response to a perceived change in the climate, resulting in less match cancellations and higher numbers of spectators. This shows the ease with which some effective adaptation measures can be taken. The general increased interest in indoor sports and investment in all-weather facilities, such as the Odyssey arena in Belfast, will also tend to reduce the need for specific adaptation measures.

Mitigation

The interviewees did not know of any initiatives specifically focused on reducing the emissions of greenhouse gases produced by sports facilities and activities. In the general effort to drive down operating costs, there has been some use of simple low-cost energy efficiency measures in leisure centres, for example installation of low energy light bulbs and motion sensors that automatically switch off lights in unoccupied rooms. Swimming pools were identified as having a high energy requirement for water heating, and there is beginning to be some interest in energy efficiency technology to reduce their running costs.

The interviewees were concerned about policy measures that might increase the cost of fuel and transport in general. For a few specialist sports, fuel is a significant cost element, for instance light aviation. In team sports, minibuses are the most often used form of transport to take teams to matches. Most outdoor activity sports take place in rural areas that are not accessible by public transport, so there is a heavy reliance on cars and minibuses. Higher transport costs would probably also increase the cost of participation in sports that require expensive imported equipment, for instance hang-gliding.

4.3.6. Tourism

Simon Allen
Centre for the Study of Environmental Change and Sustainability, University of Edinburgh

Summary
The political situation is the most important factor affecting tourism to Northern Ireland. Indirect effects of climate change, such as perceptions of the attractiveness of the region, were considered more important than direct effects. There was concern about how increased transport costs might affect visitor numbers.

State of the sector

During 1999, 1.66 million staying visitors made trips to Northern Ireland to visit friends and relatives, for business, on holiday or for other reasons. The majority of visitors were residents of Great Britain (60%) or the Republic of Ireland (23%). The revenue generated by visitor tourism during the year amounted to £265 million. Although visitors from North America, Europe and elsewhere overseas made up 16% of those staying in the region, their spending accounted for 27% of the total revenue. Residents of Northern Ireland also take holidays in the region and in 1999, 510,000 domestic holidays generated £57 million in revenue (NITB, 2000).

Interviewees were unanimous in their view that the political situation in Northern Ireland is the most important factor affecting the tourism sector. Visitor numbers are strongly affected by the perceived level of terrorist activity. Between 1994 and 1995 holiday-makers, who make up almost one in three of all visitors, increased by more than two-thirds to 461,000, reflecting the paramilitary ceasefires in the Autumn of 1994 (NISRA, 1997). The current difficulties in implementing the Good Friday Agreement and the media focus on them are considered bad for tourism. Political stability is necessary to ‘normalise’ Northern Ireland as a tourist destination, and to provide the conditions necessary for continued business investment in tourist facilities.

The tourist sector also faces a range of challenges that exist in many other destinations. The vast majority of businesses in the sector are small or medium-sized enterprises, often operating close to the margin of profitability. There is a need for training and financial support to raise standards to meet the increasing expectations of clients. Better marketing is needed to enable Northern Ireland to compete with other destinations, attract higher-spending visitors and increase the length of the season.

Impacts

The interviewees reported potential impacts falling into both direct and indirect categories. Indirect impacts, such as the effect of the weather on visitor’s perceptions of the attractiveness of Northern Ireland as a destination and the ‘visitor experience’ itself, were considered most important. There was much less concern about direct physical impacts on tourist accommodation or attractions.

Northern Ireland is not marketed as a ‘sun’ destination, but rather for its lush green landscape. Its primary attractions are places with literary and artistic associations, culture, history and outdoor activities such as walking, playing golf or fishing. Visitors do not expect perfect weather, so interviewees considered its appeal to visitors to be much less sensitive to climate change than other destinations, especially those in Mediterranean countries. The prospect of warmer and somewhat drier summers is seen as positive, allowing the visitor to pursue outdoor activities more easily and increasing their ‘feelgood factor’. This is likely to encourage repeat visits by first time visitors who form a good impression of NI as a destination and to increase the likelihood of recommendations to friends. It is most likely to benefit domestic short-break tourism, as local residents are more sensitive to good weather than visitors from outside the country and would be more likely to choose to stay in Northern Ireland rather than holiday outside it. Climate change could also benefit Northern Ireland by reducing the appeal of some competing destinations: for instance destinations such as southern Spain may become too hot, and experience problems of supplying adequate water to tourist centres in a drier climate.

The majority of interviewees thought that the direct impacts of climate change on the tourism sector would not be significant. No major hotels or tourist attractions are situated in areas of high flood risk. Some important tourist attractions on the north coast, such as the Giant’s Causeway and the Carrick-a-rede Rope Bridge already have to be closed occasionally for safety reasons in stormy weather, and such closures might become more frequent. The coast road (A2) from Larne to Portrush passes through the highly scenic Glens of Antrim and along the Causeway Coast and is perhaps the most important tourist route in the country. In some places it passes through areas of unstable soil (particularly the Lias Clay between Glenarm and Carnlough) and is vulnerable to landslides: these may become more frequent as a result of increased winter rainfall. The Marble Arch Caves in Co. Fermanagh are also sensitive to the weather. After heavy rain they have to be closed to the public for safety reasons, and the frequency of closures may increase under climate change.

Adaptation

As the potential impacts of climate change on tourism in Northern Ireland seem to be mainly beneficial, interviewees did not consider adaptation measures to be a significant issue. The perceived lack of direct physical impacts on tourist facilities means that there is no obvious need for new investment in response to climate change. The increase in summer temperatures envisaged in the scenarios is not great enough to require hotels to be fitted with air-conditioning. Any responses to climate change are likely to be reactive, in response to actual occurrences of extreme weather events, rather than as a result of strategic planning in response to predictions of climate change.

Mitigation

Interviewees reported that levels of awareness of environmental and sustainability issues in the sector are generally low, though this is beginning to change. Early in 2000 the Causeway Initiative was launched to promote sustainable practices in the tourism industry in the North East. This initiative aims to develop a visitor management strategy for the eight local authorities from Co. Londonderry to Co. Antrim. The visitor management strategy is designed to help the region ameliorate the impact of the large number of people (about 500,000 per year) who visit the Giant’s Causeway, and will include consideration of transport links. The initiative is also managing a Pilot Sustainable Tourism Support Scheme providing grants to tourism businesses in the North East area to encourage them to adopt best environmental practice. The initiative is also developing sustainability indicators to monitor progress.

The Climate Change Levy, which was introduced by Government in April 2001, has begun to make hospitality operators more aware of their energy usage, but is seen as counterproductive by some in the hotel industry. This is because it represents an additional cost to hard-pressed businesses, because little compensation is provided through reductions in National Insurance contributions, as many workers are employed on a part-time or casual basis. The need to pay the levy reduces the likelihood of money being available to make investments in energy efficiency measures. In March 2001 the Hospitable Climates initiative was launched in Northern Ireland. This is a Government backed energy conservation programme for the hospitality industry, which aims to facilitate effective energy management by providing the necessary tools, information and advice.

Interviewees were concerned about any mitigation policies that might result in increased transport costs. Already it is generally more expensive for overseas visitors to travel to Northern Ireland than to competing destinations such as England, Scotland or the Republic of Ireland. Within the region, public transport is not well developed, so that private transport is in many cases the only viable means available to visitors wishing to access attractions in rural areas. There is a general appreciation of the need to improve public transport, to the benefit of both residents and visitors, and the Department of the Environment is about to commission a study of transport in the North East, to assist in developing a transport strategy. Development of improved public transport would be beneficial for mitigation of climate change, as well as producing wider benefits for business and the community.

4.3.7. Insurance

Simon Allen
Centre for the Study of Environmental Change and Sustainability, University of Edinburgh

Summary
Changes in rainfall, temperature, wind regime and sea level increase risk of losses in almost every category of insurance: hence higher premiums might be expected. River flooding and coastal inundation are the greatest perceived threats, with parts of Belfast and Londonderry especially vulnerable. A campaign to increase public awareness of increasing risk would be of value, as would the mapping of properties which are at risk of flooding.

State of the Sector

In the last five years the insurance sector has gone through rapid restructuring, mainly by mergers and acquisitions, reducing the number of major insurance companies operating in Northern Ireland to a handful. This has mainly been driven by the need to maintain profitability through efficiency cost savings in the face of low premiums arising from over-capacity in the market and aggressive competition. There has been an accompanying trend of increased centralisation, with some of the major companies handling their business in Northern Ireland though offices in Dublin or Glasgow. Recently insurance premiums have started to increase as a result of reinsurers raising the rates they charge insurance companies. This has been stimulated by the increased losses experienced globally by reinsurers, as a result of an apparent increase in the frequency of catastrophic events across the world.

Over the same period, the industry in the UK has suffered increasing claims from extreme weather events, and there is a perception that climate change has begun to increase the risk of weather related losses, particularly those caused by flooding. The serious floods that occurred in England during 2000 have focused the industry's attention on the need to re-evaluate risks and premiums charged when underwriting new business. Two research reports into the implications of climate change for the insurance sector and the management of weather related risks have been published recently (CII, 2001; Crichton, 2001). Although Northern Ireland escaped the serious flooding experienced in England, localised flooding occurred in Belfast last July, an unprecedented event, reinforcing the perception of a changing climate.

The insurance sector in Northern Ireland is also affected by the particular socio-economic and political situation of the region. There has been a long-term decline in traditional heavy industries, with reduced wage rolls and therefore less requirement for insurance. Although recent investments in new high technology industries are beginning to reverse this trend, these are dependent on continuation of the Peace Process to a successful conclusion. In general wages are still lower than in the rest of UK, reducing the disposable income available to be spent on insurance services. There is also a lack of skills and local knowledge within the insurance industry, as a result of the losses of experienced staff made redundant during the restructuring process. The current outbreak of foot-and-mouth in the UK is likely to increase claims in Northern Ireland, mainly through its impact on tourism.

The respondents in this study also reported that within the industry a decline in its public image is perceived. This has arisen from recent premium increases in home and motor insurance and high profile business failures, such as that of The Independent company. The industry needs to plan its response to climate change carefully, as it could either provide an opportunity for it to improve its image, or if mishandled, could tarnish it further.

Impacts

The respondents agreed that the changes in rainfall, temperature, wind regime and sea level suggested by the UKCIP scenarios appear to increase the risk of losses in almost every category of insurance business. Increased losses caused by more frequent and severe flooding of rivers and coastal inundation are the main concern. Particular concern was expressed over the vulnerability of parts of Belfast and Londonderry to increased flooding, which combined with the high values of properties there, could result in serious losses for the industry. Respondents reported a wide range of possible impacts, including: increased losses of properties caused by flood, storm, subsidence, coastal erosion and forest fires; more losses of stored grain and animal feed to fire; changes in the travel and motor insurance businesses; increases in liability claims for products unable to cope with increased heat and windspeeds, food-poisoning and interruption of business by failures in water and power supplies.

Adaptation

The experience of larger losses by the insurance sector will inevitably result in higher premiums for customers. It is likely that the risks insured will be assessed more carefully when underwriting new business. However, the trend to centralisation will make it harder to assess risks appropriately, because of a lack of experienced staff with strong local knowledge. Customers could be rewarded with lower rates if they have invested in measures to reduce risks of damage, by for example, improving drainage or the resistance of buildings to wind damage. Alternatively, insurance companies may impose ‘warranties’: these are mandatory actions required of a policy holder to reduce risk before insurance cover will be renewed. One extreme possibility is that property in some areas, especially those highly vulnerable to flooding, could become uninsurable. This could ultimately lead to reductions in property values in such areas and shifts of population.

Respondents suggested that measures designed to increase public awareness of climate change and weather-related risks would be helpful to the industry. Moreover, changes in planning guidance, building regulations and improvements in the accuracy and timeliness of flood alerts would help to reduce losses.

The industry is likely to become much more proactive in managing and reducing risks. This will be achieved by more partnerships with Government, Local Authorities and other agencies, and the insurance industry having an input into the design of flood defences and other major civil engineering projects.

The insurance sector's capacity to adapt to climate change appears to be constrained by a lack of the fundamental data needed to assess risks accurately. Respondents identified the need for more accurate predictions of future climate, particularly extreme events, and an answer to the question of whether recent climate trends are ‘just a blip’ or indicative of a long-term change. A particular need was identified for large scale maps, showing the vulnerability of properties to flooding, to be produced for Northern Ireland.

Mitigation

Government policies designed to mitigate climate change by reducing greenhouse gas emissions will affect the insurance industry in a complex way. Effects will be both direct, by forcing changes in the industry's operations, and indirect, by affecting the risks it insures and the willingness of organisations and individuals to pay for cover.

Respondents considered that any additional cost burden on private industry resulting from energy taxes or compliance with other mitigation policies would be likely to reduce insurance revenue. In particular, reductions in the size of company car fleets will have a negative effect on income from motor insurance. Measures aimed at conserving energy through efficiency measures could have the benefit of reducing insured losses caused by pollution. Alternative energy generation is perceived to carry a lower risk of fire than fossil fuel based technologies, and could therefore provide a positive benefit by reducing insured losses of property.

Chapter 5. Cross-sectoral considerations

W. Ian Montgomery
School of Biology and Biochemistry, Queen's University Belfast

Summary
The impacts of climate change in one sector are likely to have an effect in another. However, cross-sectoral effects are difficult to discriminate from direct effects. Similarly, the impacts of climate change will not occur in isolation from impacts of other environmental, socio-economic and political considerations. These interactions — more often than not — compound the negative effects of climate change.

Three interconnecting themes are identified here that interconnect a number of sectors: water, rural environment and energy. These reflect the unique combination of factors within Northern Ireland where freshwaters are highly significant aspects of the environment, there is continued reliance on pastoral agriculture, and stationary energy costs are higher than the rest of the UK while mobile energy use is profligate.

Introduction

During the course of discussions with stakeholders (Appendix 2) and among the task managers, it became increasingly obvious that the impact of change in Northern Ireland's climate on the sectors under review could not be viewed in isolation i.e. effects of climate change in one sector are likely to have an effect on another. We define these interaction effects as *cross-sector*, for example, the link between energy and transport, energy and buildings, and energy and health. Such cross-sector impacts, however, may be difficult to discriminate from direct effects of climate change on a sector.

Similarly, stakeholders and task managers observed frequently that climate change impacts interacted with other environmental, socio-economic and political changes. For example, under the theme of agriculture, changes in the Common Agricultural Policy leading to lower stocking levels and incomes in areas of marginal agriculture activity could lead to greater aggregation in spatial demography that in turn require significant changes in the provision of services such as waste disposal.

Under the theme of water, projected effects of climate change on surface and ground water, water extraction and sewage disposal will have to be considered in the light of changing demography and agricultural intensification. We have termed such interactions involving climate change impacts and at least one other factor as *multi-factor* impacts.

Emergent cross sector and multifactor themes

Table 5-1 summarises cross-sector and multi-factor interactions regarded as beneficial (positive) or detrimental (negative) to human interest. There are three multidimensional themes appearing in the consideration of interactions among the sectors and other pressures from changing environment, socio-economic and political conditions.

Table 5.1. Summary of cross-sector and multifactor interactions of climate change in NI by sector. Asterisks below the shaded boxes indicate detrimental interactions. Dollar signs above the shaded boxes indicate interactions that might prove beneficial

	Mitigating interactions															
	Minerals	Water	Coastal	Other processes	Bio-diversity	Agri-culture	Fisheries	Land-scape	Health	Infra-structure	Build-ings	Energy	Waste	Sport	Tourism	Insur-ance
Minerals and other natural resources																
Water resources	**															
Coastal and flood defence		*			$					$						
Other natural processes		*														
Biodiversity/habitats		***	**			$						$$$				
Agriculture, horticulture, forestry		***	*		***			$	$						$	
Fisheries		***	*		***	*										
Landscape and cultural heritage		***	***		**	**	*			$		$$				
Health		***			*	**										
Infrastructure and utilities		*	***			*		*								
Buildings	*	**						**	**			**				
Energy		*				**			**	*	*					
Waste		**			***	*			*							
Sport and recreation		**							*							
Tourism		**	*		*	*	*	**			*		*	*		
Insurance		***	**			**	*			***	**					

Detrimental interactions
$ limited or local mitigating interactions
$$ more general and widespread mitigating interactions
$$$ general and widespread mitigating interactions
* limited or local detrimental interactions
** more general and widespread detrimental interactions
*** general and widespread detrimental interactions

Firstly, the future well-being of *water*, both in terms of quantity and quality impacts throughout all sectors. This was the most notable outcome of our deliberations during the Task manager follow-up seminar to the workshop. There are important links between water and every other sector. For instance, increasing incidence of heavy rainfall will lead to a higher incidence of flash flooding. This could be exacerbated in areas lying downstream of agricultural land where soil compaction has arisen from the increased stocking levels of recent decades and loss of earthworms due to the introduced planarians. Soils rather than absorbing rainfall will channel it rapidly to low-lying areas and main watercourses. Areas consistently vulnerable to flooding may face rising insurance premiums and falling house valuations potentially leading to the abandonment of properties in areas prone to flooding e.g. in parts of Belfast, Holywood, Newtownards, Strabane and parts of the north west around the Foyle and Limavady.

Secondly, the *rural environment* in contributing to the wealth, health and cultural identity of people and constituting the major source of biodiversity in Northern Ireland, presents a complex of interacting factors that extend to include energy. The theme also encompasses agriculture, biodiversity, landscape and cultural heritage, coastal, and tourism sectors. For example, the Government is committed to greater use of renewable sources of energy as part of an international effort to reduce CO_2 emissions. Northern Ireland has an appropriate environment to support substantial biomass based power generation. There has also been considerable research conducted. Willow biomass production would provide an alternative source of income in rural areas and would have advantages in terms of promoting biodiversity and soil stability. Forest management akin to that found widely in continental Europe could also provide raw materials for construction and pulp production and reduce dependency on timber imports.

Tourism in Northern Ireland is tied closely to scenic and cultural attractions. Similarly, there are strong community and cultural ties or a sense of place throughout much of the region. Changing climatic conditions whereby the incidence of hotter summer days increases should enhance tourism. A longer growing season, perhaps aided by changing agricultural policies and incentives, also should promote the interests of tourism as agriculture becomes more mixed and cereals become more viable in, for example, the east of the region particularly Co. Down. The resultant mosaic of arable and pastoral fields would increase landscape heterogeneity generally regarded as a positive landscape feature. Abandonment of marginal areas because farmers become unable to sustain a viable lifestyle in the face of higher incidence of extreme conditions, however, may lead to a less attractive landscape where dereliction and a sense of economic distress is common. Hence, climate change interacting with socio-economic factors might render some areas of Northern Ireland less and other areas more attractive to a struggling tourist industry.

The third unifying theme has been termed *energy*. The challenges posed by energy encompass both stationary energy and that linked to the energy demands of transport. Northern Ireland has severe energy problems linked to its need to import fossil fuels, resulting in high fuel costs and 'fuel poverty'. While it is widely recognised that temperature increases will affect the demand for energy, more significant shifts in demand are likely to occur with a greater incidence of extreme conditions (note that one third of Northern Ireland's energy demand relates to the domestic sector). Moreover, stationary energy generating and supply systems are vulnerable to extreme weather events and effects linked to sea temperature change and storm activity. Energy considerations impact upon health through the fuel poverty problem, and via lifestyle changes. Finally, adaptation and mitigation challenges are likely to be significant in addressing Northern Ireland’s contribution to UK greenhouse gas emissions: there are potentials for use of novel power sources from agriculture, wind and offshore.

These three themes should be regarded as unique to Northern Ireland where the combination of greater importance of freshwaters coupled with high rainfall of the northwest of the British Isles, the continued reliance on pastoral agriculture and the high dependency on non-renewable, expensive energy, sets the region apart from other parts of the UK.

Many of the possible interactions are weak or might only be of local influence. For example, those involving sea fisheries would only pertain to the four fishing ports of Co. Down. There is a consensus that the cross-sector and multi-factor effects of climate change in Northern Ireland generally will be negative from the human interest perspective whereby the effect of climate change in one sector will exacerbate the influence of climate change in another, or climate change will add to the problems arising from other detrimental processes. Further, negative cross-sector and multi-factor effects are often stronger than any possible advantage with the exception of those involving energy and agriculture and energy and buildings. Some interactions, however, have both negative and positive elements emphasising the complex relationships among sectors and the various changes to which these are subject.

Conclusion

While there may be little that can be done at regional level to prevent global climate change, and the time required to redress increases in greenhouse gases is considerable, many of the factors that might exacerbate the effects of climate change are more tractable. For example, freshwater eutrophication, habitat fragmentation, soil compaction, energy conservation and health considerations in the built environment, and waste management, have local and relatively short term solutions.

Chapter 6. The Irish Border Dimension

Austin Smyth
Transport Research Institute, Napier University

Summary
Northern Ireland shares a lengthy land boundary with The Republic of Ireland, being the only part of the United Kingdom with a land boundary to any other member of the European Union. Northern Ireland also shares many features of both physical and human environment with its southern neighbour: this commonality makes it highly desirable to give explicit consideration here to the Irish Border Dimension. UK-based national publications and regional studies — with a few recent exceptions — do not explicitly cover the Republic of Ireland in the context of climate change. Moreover, the Republic's own National Climate Change Strategy also fails to refer to either Northern Ireland or the wider UK in its provisions and documentation; standardised scenarios (such as those from UKCIP) are not used, rendering comparison difficult.

The Republic of Ireland is intending to undertake its own detailed assessment of the impacts of climate change on the natural and human environments. A preliminary overview summarised in the National Strategy indicates an appreciation of many of the same impacts identified for Northern Ireland. Thus there appears to be both a clear benefit from, and imperative for, promoting awareness of the impacts of climate change in both jurisdictions; as well as benefits arising from an interacting research strategy, mutual development of adaptation strategies and mitigation measures, and sharing of lessons learned on either side of the Irish border.

International context

Global consensus has recognised that cuts of up to 70% in global emissions are needed over the next century in order to stabilise concentrations CO_2/GHG concentrations in the atmosphere at twice the pre-industrial level and therefore avoid the worst impacts of climate change. The impacts of climate change on Ireland will be significant, but will be more damaging on many countries, which are least able to afford to take action or adapt. As a first step the United Nations Framework Convention on Climate Change (UNFCCC) required developed countries to put in place policies and measures with the objective of returning emissions of greenhouse gases to 1990 levels by the end of the decade. However, in recognition of the need to take more substantial action, developed countries agreed legally binding targets in Kyoto in 1997, to reduce global emissions of six greenhouse gases by 5.2% in the period from 1990 to 2012. The EU will reduce emissions by 8% overall.

The target for the Republic of Ireland

As part of the EU target, Ireland has agreed to limit the growth in greenhouse gas emissions by 13% above 1990 levels. Without the action set out in the National Strategy it is projected that net annual emissions would increase by 37.3%. Reductions of emissions of 13.1 million tonnes (Mt) CO_2 equivalent on this projected figure will be required to meet the national target.

Sources of Irish emissions

The main greenhouse gas in Ireland is carbon dioxide (CO_2) mainly arising from the burning of fossil fuel in transport, heating and electricity generation. Irish emissions of other greenhouse gases including methane (CH_4) and nitrous oxide (N_2O) are proportionately higher than other countries, and emissions from the agriculture sector were 35% of all greenhouse gas emissions in 1990, the highest of all sectors. Emissions from the transport sector are forecast to have the largest increase (by180%) by 2010.

Impacts of climate change

The Republic of Ireland is intending to undertake its own detailed assessment of the impacts on the natural and human environments arsing from projected changes in the climate experienced. Already an overview summarised in the National Climate Change Strategy indicates an appreciation of many of the same impacts identified for Northern Ireland.

Guiding Principles for the National Climate Change Strategy

The strategy recognises that the burden for the Kyoto commitment period and beyond must be borne equitably within the economy. The criteria to achieve this include:

- the requirement to promote sustainable development;
- maximisation of economic efficiency, including a preference for the use of 'no regret' and least-cost measures;
- achievement of sectoral equity (relative costs and effort achievement of reductions across the economy);
- protection of economic development and competitiveness (market-based instruments, exploitation of new markets and opportunities); and,
- generating an impetus for early action.

Reduction of emissions will be achieved through an integrated approach, using the full range of instruments and policy options. These include:

- the use of economic instruments (including taxation and emissions trading) with broad sectoral and/or cross-sectoral application;
- a broad range of policies and measures tailored specifically to relevant sectors;
- a vigorous and appropriate pursuit of common and coordinated policies and measures implemented at EU and wider international levels; and,
- participation in international emissions trading.

Sectoral initiatives

Cross-sectoral market based instruments will include:

- taxation variations; and,
- EU and wider international emissions trading.

Local authorities are seen to have a key cross sectoral role at local level and with local energy agencies.

The energy sector in 1990 contributed 21.6% of all greenhouse gases. A do-nothing scenario is projected to reduce emissions by 25% by 2010 with proposed measures including cessation of coal burning in power stations, an expansion of renewable energy, exploitation of combined heat and power, demand side management and local authority schemes to upgrade older property.

In the transport sector, responsible for 9.5% of emissions in 1990 and projected to increase to 18.9% by 2010 in the absence of action, initiatives include:

- fuel efficiency measures, through taxation, eco labelling and state sector policy initiatives;
- very substantial investment in public transport to encourage modal shift; demand management; and
- development of biomass and anaerobic digestion of animal waste for energy generation

In industry and commerce 13.5% of emissions in 1990 and 14.6% by 2010 measures include a combination of:

- market instruments;
- negotiated agreements with industry;
- taxation incentives links between grant aid and emissions and efficiency attributable to investment; and,
- expansion of Irish Energy centre programmes.

In the built environment, accountable for 17.6% of greenhouse gases in 1990 and 14.4% in 2010, measures include:

- improved energy use guidelines and spatial planning;
- more efficient new buildings; and,
- promotion of sustainable buildings through financial grant incentives promotion of awareness via education.

In agriculture, attributable for 34.6% of greenhouse gases in 1990 and 25.6% in 2010 a reduction in CH_4 from the animal herd will involve intensification and research into feeding and slaughter policy as well as strengthening links between forestry and agriculture and reduced use of nitrogenous fertiliser. In forestry measures will seek to enhance the potential of the sector for use as carbon sinks.

Measures in waste are in line with national strategy, based on the principles of the waste generator pays for the costs incurred.

Chapter 7. Communicating climate change and its impacts

W. Brian Whalley
School of Geography, Queen's University Belfast

Summary
Communicating the issues, impacts, adaptation and mitigation measures to individuals and organisations requires a combination of raising the awareness of issues among the population in general; instilling concern and the need for action; provision of targeted information about particular sectors; and dissemination of regulatory, financial and design guidelines by responsible authorities and other bodies. Northern Ireland society has not exhibited a strong interest or concern surrounding environmental issues.

Introduction

Communicating the issues, impacts, adaptation and mitigation measures to individuals and organisations in Northern Ireland requires a combination of:

- raising awareness about the issues generally among the population;
- instilling concern and the need for action;
- provision of targeted information about particular sectors; and,
- dissemination of regulatory, financial and design guidelines by responsible authorities and other bodies

Northern Ireland's society has not tended to exhibit strong interest in or apparent concern for environmental issues in the round even if displaying strong reaction to individual isolated or local events. The fact that Northern Ireland escaped major flooding endured by many parts of England last year also limited a raising of consciousness locally about the potential long term impacts of climate change.

The research team has identified an urgent requirement for initiating a robust survey of awareness and concern about climate change and are in discussion with the Department of the Environment (NI) with regard to taking this further. This would provide a starting point for development of a well focused education and awareness drive both for the population generally and targeted at key sectors identified in the course of this study or from other related work elsewhere. In the current study provision was made for engaging with a range of stakeholders (Appendix 1) representative of the sectors identified in the study's terms of reference. A survey was mounted among stakeholder representatives contained on a specially prepared database to gauge reaction across a range of matters relating to climate change.

Just under half those contacted responded and many of these subsequently took part in a workshop attended by all task managers and intended to generate discussion between stakeholders and between researchers and stakeholders with particular reference to cross sectoral issues. While the response to the survey was anonymous attendance at the workshop tended to point to much greater interest in the issues of climate change from NGOs working in the environmental sector and governmental professional staff engaged in areas directly affected by environmental matters while conversely little apparent concern was exhibited by industry and commerce. The remainder of this chapter provides an overview of the findings arising from the survey while the discussions arising from the multi sector workshop have been incorporated in relevant sections of this report.

The questionnaire

The questionnaire sent to stakeholders is in Table 7.1.

Table 7.1 Questionnaire sent to stakeholders.

The purpose of this questionnaire is to gain some basic information about your organisations' awareness of future climate change and its implications for Northern Ireland. It relates specifically to your organisation and its consideration of these climatic effects, rather than what specifically might need to be done with regard to climate change. Such aspects will be considered in any future discussions you may have with the NI SNIFFER Team.

The questionnaire is anonymous and the data produced will only be used in aggregated form. However, we hope that it will provide the basis for a better understanding of how various organisations are considering the implications of climate and environmental change. We encourage you to fill out the form but if there are questions you cannot or would rather not answer then please feel free to leave them.

1	Is your organisation: (please cross out which do not apply)	Government	NGO	Charity
2	Are you responding to this questionnaire:			
	a In a personal capacity?		Y	N
	b As a representative of your organisation?		Y	N
3	Is someone in your organisation responsible for 'long term', strategic, planning?		Y	N
4	Over what time period would 'long-term' represent?	10 yrs	40 yrs	80 yrs
5	Has your organisation produced any sort of collective perspective about climate/environmental change in the last 5 years?		Y	N
6	Have recent weather-related events (e.g. floods in England last winter) prompted formal discussion about climate/environmental changes in your organisation?		Y	N
7	Has your organisation set up any sort of 'task force' or committee to consider the implications of climate/ environmental change?		Y	N
8	In the light of what you currently know about climate/environmental change, do you consider that there will need to be any review of your operations?		Y	N
	If 'Yes', how radical might this be?	Very Little	None	Major
9	Is the issue of 'environment-friendly' policies apposite in your organisation?		Y	N
10	If yes, do you anticipate any increase of these policies with respect to climate/environmental change?		Y	N

Results of questionnaire

The purpose of the questionnaire was to derive some information about levels of perception of the effects of climate and environmental change from managers in the region. The questionnaire was anonymous and responses may have been weighted by a variety of factors, e.g. that there might have been more than one person in an organisation responding. Personal views (52%) were given in many cases and these might not coincide with the 'official' view (44% were returned as 'a representative of the organisation'). The nature of employment, lack of large firms and the role of various forms of local/province government meant that there was a lack of large industrial/commercial firms responding. Nevertheless, we believe that the questionnaire did provide some useful information about views concerning environmental change. It was kept simple to elicit a wide response and, again, to give some general feeling about the issues involved.

The results of the responses to questions are given in Table 7-2.

Table 7.2. Summary of responses of stakeholders to questionnaire

		%	Yes (%)	No (%)
1	Is your organisation:			
	Government	59		
	NGO	7		
	Charity	3		
	University	23		
	Commercial	3		
2	Are you responding to this questionnaire			
	In a personal capacity?	52		
	As a representative of your organisation?	44		
3	Is someone in your organisation responsible for 'long term', strategic, planning?		49	46
4	Over what time period would 'long-term' represent	10 yrs 59%	40 yrs 15%	80 yrs 10%
5	Has your organisation produced any sort of collective perspective about climate/ environmental change in the last 5 years?		36	60
6	Have recent weather-related events (e.g. floods in England last winter) prompted formal discussion about climate/ environmental changes in your organisation?		51	47
7	Has your organisation set up any sort of 'task force' or committee to consider the implications of climate/ environmental change?		39	55
8	In the light of what you currently know about climate/environmental change, do you consider that there will need to be any review of your operations?		51	46
	If 'Yes', how radical might this be?	Very Little 46%	None 30%	Major 5%
9	Is the issue of 'environment-friendly' policies apposite in your organisation?		64	34
10	If yes, do you anticipate any increase of these policies with respect to climate/ environmental change?		52	38

Analysis

We have not provided a more precise breakdown of the data than the above table, e.g. NGOs following a specific policy etc. However, there does seem to be a general interpretation that although some organisations seem to view climate change possibilities seriously and over a long term, there are many that look only at the short term (given the climatic scenarios extending to 80 years on). Further, that even recent 'climatic' events (Q 6) do not yet seem to have made much impression.

It would be unfair to conclude that there is, overall, a lassitude about viewing the potential of climate/environmental change by organisations questioned in the Province. However, there certainly does not appear to be a significant move towards adequate planning.

Chapter 8. Concluding remarks

8.1 Introduction

This study, the first of its kind in Northern Ireland, has produced insights which are both interesting and potentially of considerable value. It must be borne in mind, however, that it is a scoping study only: its role is to be a starting-point for future work. This is work which is urgently required. The present study has thus made a start in galvanising locally-based expertise to focus upon the challenges imposed by 21st-century climate change: but there is generally a low state of awareness and concern about climate change and its impacts across all sectors in Northern Ireland[3]. The Province thus lags behind the rest of the UK in terms of development of adaptation strategies.

No stakeholder identified or anticipates a single severe impact of climate change in the region. While this of course may be a result of the newness of the issues involved, a priority of the experts who contributed to this report was to distinguish between stakeholders being unable to identify impacts, and lack of any impacts. We are confident that this distinction has been made. Generally, the negative impacts identified in this study are both less acute, and less mutually-reinforcing across sectors, than might have been originally anticipated. They are, however, still mostly negative; though there are some opportunities present in e.g. energy generation and agriculture. Impacts will generally compound existing environmental stresses that have arisen from poor environmental management, inappropriate agricultural policies and poorly planned economic development. Threats are chronic rather than acute but nevertheless constitute significant change.

8.2 Summary of potential impacts

Transport to and from Northern Ireland will be affected more adversely than transport to and from other regions of the UK. This has implications for Northern Ireland’s economy with respect exploiting ‘just in time’ opportunities in retailing and manufacturing supply. Energy supply in Northern Ireland faces greater problems than the rest of the UK. Energy costs are high relative to the rest of the UK and the Republic of Ireland although introduction of natural gas offers some short term benefit. There seems little chance of amelioration long term in the present state of knowledge. Attempts to reduce energy consumption by increasing prices are likely to meet with antipathy while energy savings due to increased temperatures may be difficult to detect due to heterogeneity in day to day weather conditions.

We might expect some water shortages in summer but equally there will be localised flooding due to flash floods. The interaction between eutrophication of freshwaters and the effects of climate change should be addressed urgently. Any consideration of the future of agriculture should be reviewed taking into account climate change; the mix of agriculture will change, perhaps for the better, but further diversification of the rural economy is required. This may present opportunities in agrotourism, use of biofuels and promotion of biodiversity. In general, climate change will gradually reduce the uniqueness of Northern Ireland’s

[3] Although some stakeholders consulted during the study were able to identify detailed impacts on their sector.

biodiversity and exacerbate existing pressures due to habitat fragmentation, overgrazing, eutrophication, introduction of alien species and so on. Forestry and fisheries are both under pressure due to the effects of climate change. Both activities concern species that are adapted to cool damp conditions or coldwaters e.g. there is a threat to tree productivity of traditional forestry species such as Sitka spruce and there is a chance of losing the remnants of populations of salmonids. The distributions of sea fish have been or will be affected with coldwater species gradually replaced by more thermophilic species.

Health effects might be restricted to increased infection risk due to foreign travel but continued fuel poverty leads to unhealthy living conditions. Energy generation should be diversified to include more renewable sources and away from coal burning simultaneously reducing greenhouse gas emissions and promoting clean air health. There is a strong opinion that fuel price should not be used to conserve energy which could be better addressed by investment in fuel efficiency and conservation without exacerbating fuel poverty and incurring the extra cost of increased health care provision. Similarly, mitigation of climate change through housing planning, design and quality of build is highly desirable. Spatial aspects of housing should be considered with, for example, use of brown field sites. This would have implications for transport and rural environment but would afford an opportunity to adopt best practice elsewhere in UK and further afield. Again addressing the problems of transport with respect to emissions would reduce risk to health and fuel consumption.

8.3 The political context

Development of adaptation and/or mitigation measures against the impacts of climate change are constrained by the structure and interrupted history of government in Northern Ireland. Devolution offers some opportunities but unless enabled by national Government these might dissipate rapidly. There is an obvious north-south dimension in Northern Ireland that does not apply elsewhere in the UK. The presence of a land border with another EU state is unique in the UK. Sharp contrasts in national policies can lead to confusion throughout both jurisdictions where transnational interactions are frequent and routine. This problem must be considered with the peculiar politics of the region, both north and south of the border. Collaboration on both sides does not come easily. The Republic of Ireland has prepared its own strategy to address greenhouse gas emissions. It has an agreed objective to increase emissions by 13% on 1990 by 2010 at a time when the UK is trying to reduce by 12.5% over the same period with a 20% reduction in CO_2 as a UK domestic target. The EU agreed to a 13% increase in the Republic’s emissions because of the high rate of its economic growth during 1990s. While the UK appears overall to be making progress towards its target, the Republic is projecting a 30% increase. This great disparity in ambition and achievement is likely to create difficulties in persuading the Northern Irish population of the need for change.

There is a strong argument that Northern Ireland should be treated differently from the rest of the UK. British and Irish documentation on climate change does not refer to each other explicitly and neither take much account of Northern Ireland. There is a lack of awareness of cross border concerns in both jurisdictions and the Republic does not use UK projections or scenarios but their own methodologies informed by international practice and based on IPCC data. Regardless of how issues are taken forward within each jurisdiction, stakeholders require urgency of action, education, implementation of recommendations and research where there are significant gaps and uncertainties.

8.4 Priorities in future research

Research without clear objectives becomes a drain on both our financial and intellectual estate. We have tried to resist preparing a wish list of pet research areas of the participants in this report. Rather we have identified sectoral and cross-sectoral interests peculiar to Northern Ireland as a region of the UK that have the potential to yield clear benefits through facilitating amelioration of or adaptation to climate change. These either address information gaps or hopefully break new ground that has not been covered in other regional or national studies. In addition, we have included attitudinal surveys regarding awareness of climate change issues.

The present project has demonstrated many of the difficulties of bringing together researchers from different backgrounds and gathering the views of stakeholders in a consistent and rapid manner. Northern Ireland's unique position within the UK is seldom taken into account in national reports. Similarly, engaging the attention of researchers and others with wide interests can be difficult. Hence, as a means of facilitating climate change research relevant to Northern Ireland we recommend the rapid development of a locally based, multidisciplinary Climate Change Research Centre directed to work closely with colleagues in the rest of the UK and, importantly, jointly with leading researchers in the Republic of Ireland. This would facilitate and promote an understanding of the impacts of climate change, no respecter of political boundaries, and development of adaptation and mitigation strategies that meet the needs of the whole island of Ireland in addition to wider UK interests. The current study has already been a catalyst for initiating more intensive North-South dialogue on the topic of climate change suggesting that significant added value would be generated by a new initiative and that such an initiative would be welcome.

A first step could be a cross-border workshop to put this objective into effect within a year of publication of this report. SNIFFER may be an appropriate organisation to co-host such an event. There is an immediate need to determine the consequences of methodological differences in UK/Northern Ireland and the Republic of Ireland studies for the development of best practice in adaptation and mitigation throughout Ireland.

Specific project recommendations

Study 1. Education and awareness of climate change and its impact in the general Northern Ireland population and among key groups e.g. younger age classes. It is an urgent requirement for the extent of awareness in the general population to be established, and for the way in which this is distributed across sectors and among key stakeholders to be identified. Measures must be taken quickly in order to prepare the general population and interested groups for anticipated effects of climate change and the necessary change in lifestyles that ensue.

Studies 2-4. Three major themes have been identified among climate change impacts embracing major sectoral and cross-sectoral concerns; water, rural environment, and energy. Each requires a more in depth, quantitative study in order to identify priorities for investment or the impacts of climate change as policies at national and European levels develop. These studies should reflect the multidisciplinary nature of the themes and focus on constructing robust 'models' that predict both the magnitude and distribution of climate change impacts, and the countering effects of adaptation and mitigation procedures. Development of a range of measurable indicators of impacts is a precursor to these studies. These studies should commence with an audit of available data on which to measure future change against a baseline. Where appropriate data are not available resources need to be deployed to establish the necessary foundation for future monitoring and study. These investigations should encompass consideration of adaptation strategies and mitigation measures for which the devolved administration and/or local authorities have responsibility and authority, as opposed to those powers reserved by Westminster. This will facilitate the fine tuning and targeting of strategies intended to address conditions unique to the region.

A number of further more in depth, sector-specific studies are required as set out below. We regard all three exemplar studies as priorities for the future well being of the region.

Study 5. Socio-economic models of impacts of climate change with particular reference to inequalities in adaptation and mitigation opportunities. This will require extensive primary data collection and analysis in conjunction with collation and interpretation of existing indicators held by regional Government departments. This study should address resistance to adaptation and mitigation measures for the human environment.

Study 6. This study should examine the interaction of climate change impacts and the effects of other environmental factors. For example, priority should be given to the complex interactions between predicted changes in climate and water quality as influenced by eutrophication of freshwaters and agricultural activity.

Study 7. The unique conditions applying to both the internal and external transport sub-sectors serving Northern Ireland warrant comprehensive assessment of the implications of, adaptation to, mitigation measures for climate change affecting this sector. The high dependency and profligate use of fossil fuels makes the region particularly vulnerable to climate change and strategies intended to address this challenge as developed by Westminster.

A number of methodological programmes of research are also called for. Examples are set out below.

Study 8. Northern Ireland requires a robust inventory of greenhouse gas emissions at an appropriate spatial resolution and confidence in accuracy of current projections of climate change based on national models at the regional and sub-regional levels.

Study 9. Application of down-scaling methods and/or regional climate models appropriate to geographical size, heterogeneity and scale of Northern Ireland landscape domains and coastal zone, is an essential step in achieving the goals of study 5.

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Appendix 1. List of expert respondents/stakeholders

Name	Job Title	Company
	Chief Executive	Belfast International Airport
Tom Adamson		Water Service
Geoff Allister	Director of Engineering	Roads Service, DRD
John Barnett	Infrastructure and Property Manager	Translink
Alan Bill	Director	John Graham Dromore Ltd
Brian Bloomfield		Freight Transport Association
P Boaden		School of Biology and Biochemistry, Queen's University Belfast
Linda Brown		Institute of Directors
Louise Brown	Corporate Policy Manager	Northern Ireland Tourist Board
R Brown		Royal Society for the Protection of Birds, Northern Ireland
Jim Carmichael		NIAPA
Sue Christie		Northern Ireland Environment Link
John Clarke		Hydrometric Section, Rivers Agency
Louise Cook		Plant Pathology, APSD Newforge
Stanley Conn	Property Underwriter	Alliance Cornhill (Northern Ireland)
Chris Cornelius		Evergreen Resources Inc., Denver, CO, USA
Peter Coyle	Regional Virologist	Royal Victoria Hospital, Belfast
Philip Davidson		World Wildlife Fund
John Davis		Agri-Economics, DARDNI
P Davison		National Trust, Northern Ireland
Malcolm Dawson		DARDNI Loughgall
John Doran	Chief Executive	Belfast City Airport
L Eason		ARINI
D Erwin		Ulster Wildlife Trust
Alun Evans	Professor of Epidemiology and Public Health	Queen's University Belfast
Lisa Fagan		Friends of the Earth
Lyn Fawcett	Lecturer	University of Ulster
A Ferguson		School of Biology and Biochemistry, Queen's University Belfast
Trevor Fisher	Centre Manager	Tollymore Mountain Centre
Ian Fleming	Reinsurance Purchaser	Hibernian Insurance
Ken Fullerton	Director of Medical Services	Belfast City Hospital
Gabriel Gallagher	DRD Geotechnical Panel	Ferguson and McIlveen
Dennis Galway	Chief Executive	Larne Harbour Ltd
Colin Gibney		Water Quality Unit, Environment and Heritage Service, DoENI
C Gibson		DARDNI

Alastair Giffen	Senior Partner	WRD & RT Taggart Consulting Engineers
Raymond Gilfillan	Senior Lecturer	School of Architecture, Queen's University Belfast
John Gilvray	Managing Director	FARRANS
Sydney Glenn		WJ McCormick, The Quarries, Ballynahinch, Co. Down
Alastair Good		Northern Ireland Hotels Federation
V Hall		Institute of Irish Studies, Queen’s University Belfast
Gareth Harper		Rural Community Network
Peter Harper	Project Manager	The Causeway Initiative
Glenn Henry		Whitemountain Quarries, Hannahstown, Belfast
Ted Hesketh	Managing Director	Translink
John Hill	Chairman of the Institution of Structural Engineers/Senior Partner	Doran Consulting
P Hunter-Blair		Forest Service, DARDNI
D Johnston		NIHPBS Loughgall
Frank Kee	Professor of Epidemiology and Public Health	Queen’s University Belfast
Bertie Kennedy	Convenor of Air Group	NI Sports Forum
Robert Legg	Energy Efficiency Officer	Belfast City Hospital
Chris Lundy		Belfast City Airport
Dick Mackenzie	Deputy Secretary	Planning and Local Government, DoENI
C Maggs		School of Biology and Biochemistry, Queen’s University Belfast
Peter Marlow		National Trust
Gary McCandless	Head of Geotechnical Division	Construction Service, department of Finance and Personnel
Mark McCaughan	Chief Fisheries Officer	Department of Agriculture and Rural Development
Conall McCaughey	Consultant, Regional Virology Service	Royal Victoria Hospital, Belfast
Alastair McCracken		APSD Newforge
Ian McKee		Environmental Policy Division, DARDNI
Gareth McKibbin	Transportation Engineer	Roads Service Transport Unit, DRD
Malcolm McKibbin	Director	Regional Transportation Strategy Division, DRD
Moria McMaster		Ulster Farmers Union
C McMurray	CSO	DARDNI
Mike Meharg		Environment and Heritage Service, DoENI
B Nelson		Ulster Museum

Brian Norton	Dean, Faculty of Engineering	University of Ulster
Shaun Ogle	Head of Sports Development Unit	The Sports Council for Northern Ireland
Dennis O'Hagan	Head of Transportation	Roads Service Transport Unit, DRD
Roger O'Sullivan		Rural Community Network
Stephen Patterson	Regional Director	McAvoy House
Howard Platt		Environment and Heritage Service, DoENI
Diane Poole		Seacat
William Poole		CBI (NI)
Danny Quinlan		Irish Salt Mining and Exploration, Carrickfergus, Co. Antrim
Cormac Reilly		Northern Ireland Housing Executive
Bob Rodwell	Past Chairman	Ulster Gliding Club
Karen Simpson	Chief Executive	Fisheries Conservancy Board for Northern Ireland
Nigel Smith		CBI (NI)
RJ Stevens		School of Agriculture, Queen's University Belfast
Bob Stout	Dean	Faculty of Medicine and Health Science, Queen's University Belfast
Paul McDowell Veitch		Mourne Heritage Trust
Bill Weir		RJ Maxwell, Carmean Limeworks, Moneymore, Co. Londonderry
Eugene Young	Lecturer	University of Ulster
B Wood		Formerly University of Ulster
John Wood		Friends of the Earth
Tom Woolley	Chairman/Professor of Architecture	Northern Ireland Building Regulations Advisory Committee (NIBRAC)/Queen's University Belfast
Dawson Wray		Hydrometric Section, Rivers Agency

Appendix 2. Project management and staffing

Management. We intended putting together a team structure which encompasses both specialist expertise in depth within the consortium institutions allied to a small number of task managers who take ownership/assessment of related groups of issues(Figure 1). These task mangers in turn report to the Project Director, Professor Austin Smyth. A Management Group with senior representatives of each partner organisation oversees the study. The Project Director has the prime responsibility for delivery of the various work packages. He is to be assisted in this by the Project Advisor.

Staffing. A provisional list of task managers was provided in the original proposal submitted to the client. Some changes have been introduced in relation to the project Management Group and Task Manager allocation. The principal changes relate to Professor B Smith, whose position on the Management Group is now assumed by Professor Brian Whalley, Head of the School of Geography and Professor Ian Montgomery, Head of School of Biology and Biochemistry, both within Queen’s University. In addition, Professor Whittaker has been forced to revise his own role to act as co-ordinator of input from Queen’s University’s Faculty of Engineering. Thus more substantive roles under the relevant tasks are now assumed by Dr. Tweed, Dr. Elliot, Dr. Beattie and Professor Kalin. A revised list of Tasks and Task Managers is presented at the start of this report.

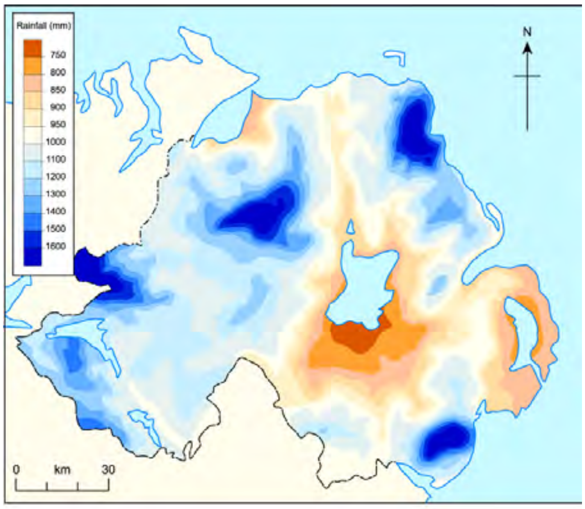
Contractual arrangements. These were agreed between SNIFFER and the consortium early in the New Year. In addition, certain detailed changes were agreed between the consortium and the client in relation to timescale of the project. These are detailed below. However, the key modification was to change delivery date of the draft final report to allow for the anticipated and now perennial problem in Northern Ireland of heightened community tension arising from ‘the Marching Season’, which for the last five or more years has seriously disrupted society in Northern Ireland during July. Project management Arrangements were initiated in January. However, since preparation of the original bid a number of staffing changes have had to be introduced due to resource constraints and recruitment procedures.

Project Assistant. Emma Muise was been appointed as Project Assistant on the DoE/SNIFFER Climate Change Impacts Study for Northern Ireland. Her background is in life sciences with a Masters in Applied Environmental Sciences at Queen's. Since graduating she has been involved in a number of projects involving bibliographic, field and laboratory work on diverse environmental issues.

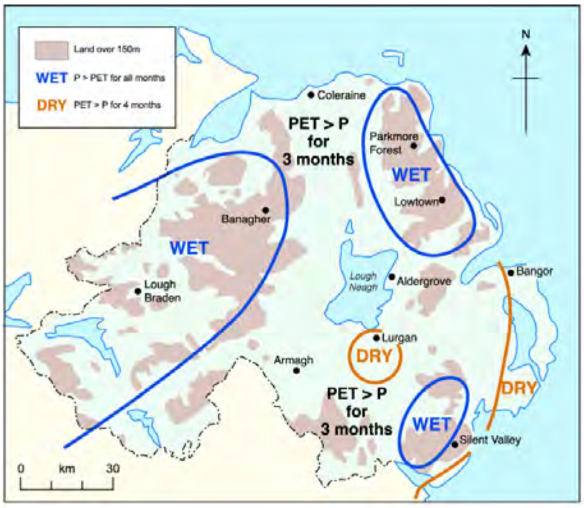
Appendix 3. Information supplied to respondents/stakeholders

FIGURE APPENDIX 3_1: The information sheet which was supplied to stakeholders. Note that more detailed information was available both upon request, and on the project's website (http://boris.qub.ac.uk/sniffer/). *© 2001, School of Geography, Queen's University Belfast*

Northern Ireland's present-day climate, and possible future climate

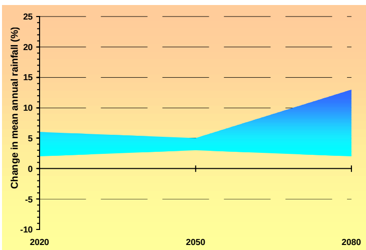


Present-day rainfall distribution

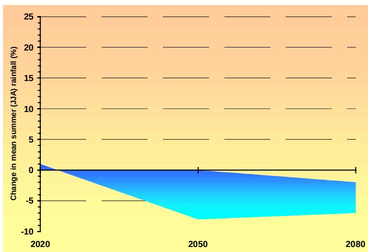


Present-day water balance: potential evapotranspiration (PET)

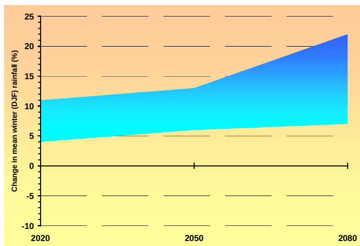
Future climate scenarios for Northern Ireland



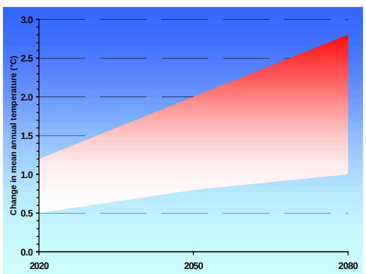
Change in mean annual rainfall (%)



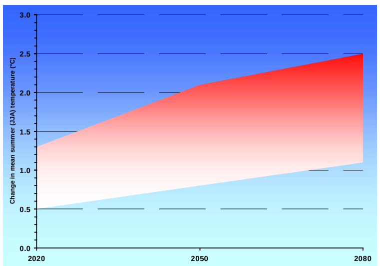
Change in mean summer rainfall (%)



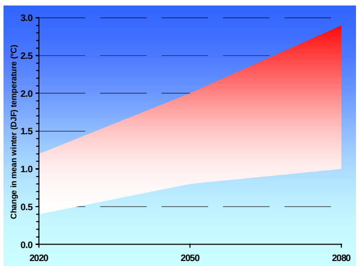
Change in mean winter rainfall (%)



Change in mean annual temperature (°C)



Change in mean summer temperature (°C)



Change in mean winter temperature (°C)

Conclusions from the scenarios include:

- Annual mean temperatures show warming of +0.5 to 1.2°C by the 2020s, +0.8 to 2.0 by the 2050s and +1.0 to 2.8°C by the 2080s. Winter warming +1.0 to 2.9°C and summer warming +1.1 to 2.5°C above 1961-90 means by the 2080s.

- Annual rainfall increases up to 5 per cent by the 2050s, and 13 per cent by the 2080s. Winter rainfall increases between 6 and 13 per cent by the 2050s; summer rainfall decreases by up to 8 per cent. Rainfall intensities are expected to increase in both winter and summer.

- Potential evapotranspiration may increase by up to 12 per cent in winter and 18 per cent in autumn.

- The mean annual number of accumulated degree-days for a maximum temperature above 25°C more than trebles by the 2080s.

- The mean annual number of accumulated degree-days for a minimum temperature below 0°C decreases more than 70% by the 2080s.

- Accumulated degree-day temperatures above 5.5°C increases by more than 5% per decade over the 21st century.

- While the number of winter gales is expected to decrease, extreme storms may occur more often.

More detailed information on the present and possible future climate of Northern Ireland is available at the web pages of the DoE/SNIFFER Climate Change Impacts Scoping Study for Northern Ireland: http://boris.qub.ac.uk/sniffer/.

Appendix 4. Guidance document for task managers

A. Research Design

The research design includes the following activities:

- Provide an overview of the existing information on the impacts of the climate change based on existing reviews, research and monitoring studies
- Provide an overview of the best current information on the likely climate scenarios for Northern Ireland
- Develop, on the basis of previous work, a protocol of critical issues for use during small workshops and interviews with stakeholders and experts
- Identify key stakeholders who will be most affected by climate change and assess the views of stakeholders on the likely impacts on their interests. Report on how they expect to respond, including any plans for adaptation and mitigation
- Assess stakeholder views on the local impact of Government emission targets and mitigation measures
- Provide a cross-sectoral analysis of the impacts of climate change
- Identify vulnerabilities and adaptation opportunities for different sectors, activities and sub-regions in Northern Ireland
- Present adaptation options for the region for the 2020s, 2050s and 2080s
- Identify key information gaps and uncertainties in assessing the impacts and identifying adaptation options and recommend ways to respond
- Consider current and desirable levels of public awareness of climate change issues
- Assess the implications of climate change for the strategic planning and decision-making process in Northern Ireland
- Identify priorities for research.

To fulfil these, the Project's methodology has the following stages.

Stage	*Name*
1	Review of Literature, Expertise and Policy
2	Analysis of Regional Climate Change Scenarios
3	Development of Critical Issues Protocol
4	Expert Assessment and Elicitation
5	Stakeholders' Assessments
6	Synthesis, Analysis and Writing of the Final Report

The methodology is described in more detail in the edited version of the proposal which is on the Project's website (http://boris.qub.ac.uk/sniffer/).

B. Role of Task Managers

Each Task Manager's role therefore encompasses:

- Steering and leading Stages 1, 4 and 5
- Jointly with colleagues, developing the critical issues protocol which is intended to guide the workshops and interviews with experts and stakeholders (Stage 3). (The development

of the protocol follows from previous work by members of the project team, including its use as a successful tool in the Scottish Climate Change study)
- Co-authorship with colleagues of the main deliverables (Stage 6).

Stage 1 is a literature review of past and on-going research on climate change impacts, adaptation and mitigation strategies in Northern Ireland (and in the wider UK where appropriate). The key sources of expertise within Northern Ireland will be identified within universities, research institutes, and private and public sector organisations, through institutional and personal links in addition to searches of databases such as BIDS. Expertise from the Republic of Ireland will also be consulted. A review of policy initiatives in Northern Ireland will be instigated, and supplemented by information derived later from stakeholders at workshops and interviews and by expert elicitation.

In **Stage 4** the critical issues protocol will be used, in conjunction with the analysis of climate change scenarios, to examine each sector and landscape domain. evaluate the necessary research required to produce an adequate knowledge of the impacts of climate change for each landscape element and sector. Information from the expert advisors will be incorporated into information distributed as briefing packs to be distributed to stakeholders in advance of their participation in workshops during stage 5.

In **Stage 5** Stakeholder groups will be identified and approached to elicit their expertise and opinion on the quality and coverage of predicted impacts and the mitigation of climate change in their sector. It is envisaged that Stakeholders opinions will be obtained via a combination of survey following distribution of briefing packs, interviews and workshops to be hosted by Queens University.

In each of these stages, Task Managers will have access to the Project Assistant who will be based in QUB's School of Geography (Elmwood Avenue). The Project Assistant will be responsible for variety of activities in support of the project including:
- contributing to the design/production and sending out questionnaires and invitations as requested by Task Managers and the Project Director
- arranging meetings and for corresponding with team members
- collating relevant documentation/other material in support of the project
- arranging workshops and organising reports for the Project Director and Task Managers.

The School of Geography has provided an office for the project equipped with a telephone (calls charged to the project) and a networked computer. The School will also supply cartographic and DTP assistance for the production of the final report. This facility (two experienced cartographers with equipment providing full digital capability) will be available in close proximity to the project office. A small amount of funding is also available to each institution for use in support of the project as deemed appropriate by that institution.

C. Briefing Pack

This may well be different for each Task. All briefing packs will include the same summary information on current climate and future climate scenarios (these based on the UKCIP98 scenarios, and informed by Nick Betts, QUB Geography), plus a list of possible impacts for the particular Task. It is envisaged that this list, covering maybe one A4 side, will be drawn up the Task Manager.

Each Task Manager will also be asked to draw up an initial list of stakeholders to receive the briefing pack (the number will vary from Task to Task; it could be as few as just three or four key individuals or organisations for some Tasks, more in others.) The Project Assistant will put together the briefing packs for each Task and send them out under the direction of the Task Manager.

D. Consultation with Stakeholders

Each Task may make use of telephone interviews, or questionnaires (or a combination?) to do the follow-up with each stakeholder. The choice is approach to be decided by each Task Manager.

If telephone interviews are used, then the stakeholder is phoned by the Task Manger at a pre-arranged time. Arrangements can be made by the Project Assistant on behalf of the Task Manager. The interview should cover the points mentioned in the UKCIP guidelines.

If questionnaires are used, these are designed by the Task Manager (with the Project Assistant helping with layout etc. if desired) and distributed to the stakeholders by the Project Assistant. The questionnaire should cover the points mentioned in the UKCIP guidelines. The Project Assistant will process responses but the Task Manager will need to interpret them.

E. Cross-sectoral Workshops

These will be arranged for some (not all) Tasks, and will bring together combinations of Tasks that have some synergy, such as Agriculture/Biodiversity and Infrastructure/Energy, with the aim of focusing on cross-sectoral issues. The relevant Task Managers will identify invitees, and the Project Assistant will organise the meetings. Task Mangers will chair the meetings.

F. Final Report

Each Task Manager is invited to prepare c. 2000 words to synthesise the results from stakeholder consultation. For some Tasks, these early drafts will be sent to External Experts for comment. Members of the Steering Group will then edit these Task summaries and produce the Final Report. Some Task write-ups will probably be combined for this. Selected stakeholders may be written up as case studies.

Appendix 5. Outline questionnaire supplied to task managers

Climate impacts:

- What are the key socio-economic drivers and pressures on your sector?
- What are the attributes of your particular sector that may be affected by climate change?
- On what time and space scales is climate likely to have an effect?
- What is the sensitivity of your sector to specific elements of climate change?
- What are opportunities and benefits presented by climate change for the sector?
- Why does the potential impact matter and to whom does it matter?
- Can the attributes in your sector that are sensitive to the climate be substituted with other attributes?
- What are the key uncertainties in your assessment of climate change impacts on the sector and what data would be required for greater certainty?

Climate change adaptation:

- What adaptation strategies can you envisage that would moderate the impact of climate change on your sector in the short, medium and long term?
- What are the likely costs of such responses?
- What are the environmental and social impacts of such responses?
- What are the barriers to the uptake of such responses: technical, economic, social, cultural, political and institutional? How might such barriers be overcome?
- What are the key uncertainties?
- What are the resulting management implications for the sector?
- What will be the public perception of changes to the sector?

Climate change mitigation:

- What approaches could be used to reduce the emissions of greenhouse gases from your sector?
- What is the likely cost?
- How will Government mitigation strategies affect the sector: e.g. taxes, regulatory framework?
- What opportunities are available to maximise the benefits of proposed strategies e.g. carbon trading?

We are currently reviewing comments on this design as well as taking account on advice provided by Dr Richenda Connell of UKCIP. The latter provided guidance on stakeholder interviews identified a range of considerations including the following:

- Summary information about the UKCIP98 scenarios should be provided to the stakeholder interviewees prior to the interview/ with the covering letter. In practice, only a highly simplified discussion of the scenarios will be possible at the interviews; it is useful to present information about extreme values of these parameters, as well as average changes.
- Use of climate change analogues can help people envisage the future. e.g. saying that the average temperature / average precipitation in N Ireland in 2050s will be the same as the

average temperature/average precipitation in another location. However, there are important limitations with this approach

- Understanding how the recent wet weather affected stakeholders' businesses/operations will be a very useful way to stimulate discussion about future climate change impacts and how to adapt.
- The interviewer will need to assess quickly whether he is talking to an expert or a novice and may need to alter the depth of questions accordingly.
- Before the interview, the interviewer should think about the adaptation options for the stakeholder's sector, in case they need to prompt.
- Distinguish future change arising from climate impacts from future change arising from other social and economic pressures by asking stakeholders to identify all the factors that drive change in their sector.
- As well as finding out about how the stakeholders perceive their organisations could be affected, the interviewer should also probe for information on research and options/potential for adoption by the relevant body as well as future activity by government and others.
- It will be useful if the N Ireland scoping study report can present some information from the stakeholder interviews as case studies.
- Awareness of the main limitations of stakeholder interviews in relation to the time available complexity of the issues and difficulties in identifying the most appropriate interviewee.

Appendix 6. Acronyms and abbreviations used

BCH	Belfast City Hospital
CAP	Common Agricultural Policy
CFL	compact fluorescent lamp
CHP	combined heat and power
CZM	coastal zone management
DARDNI	Department of Agriculture and Rural Development, Northern Ireland
DEES	Domestic Energy Efficiency Scheme
DETR	Department of Environment, Transport and the Regions
DoENI	Department of the Environment, Northern Ireland
DRD	Department for Regional Development
EC	European Community
EHS	Environment and Heritage Service
EU	European Union
GB	Great Britain
GCM	general circulation model, or global climate model
GDP	gross domestic product
GHG	greenhouse gases
HOST	Hydrology of Soil Types
ILO	International Labour Office
IME	internal market in electricity
IPCC	Intergovernmental Panel on Climate Change
LVH	Lagan Valley Hospital
MMC	Monopolies and Mergers Commission
MMTCE	million metric tonnes carbon equivalent
MPH	Musgrave Park Hospital
MSL	mean sea level
NGC	National Grid Company
NHBC	National House Building Council
NI	Northern Ireland
NIE	Northern Ireland Electricity
NIHE	Northern Ireland Housing Executive
NIR	Northern Ireland Railways
NMVOC	non-methane volatile organic compound
PET	potential evapotranspiration
ppmv	parts per million by volume
PPB	power procurement
RCM	regional climate model
RoI	Republic of Ireland
RSL	relative sea level
RSLR	relative sea-level rise
RVH	Royal Victoria Hospital
SLR	sea-level rise
SMD	soil moisture deficit
T&D	transmission and distribution
TIFF	total income from farming

TSO	transmission system operator
UKCIP	United Kingdom Climate Impacts Programme
UV	ultraviolet
WMO	World Meteorological Organisation
WS	Water Service agency
WTE	waste to energy
ybp	years before present