Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

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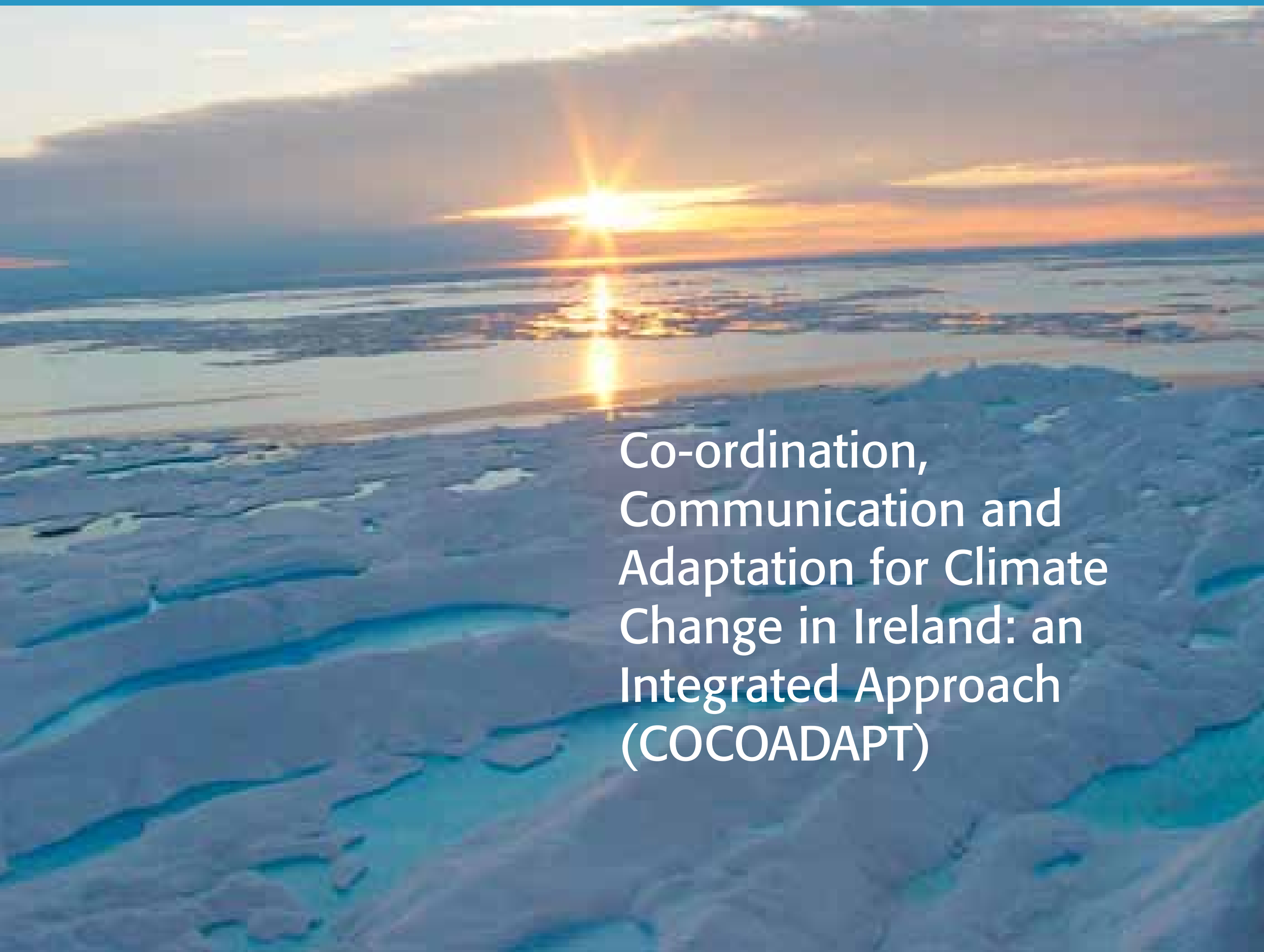

Co-ordination, Communication and Adaptation for Climate Change in Ireland: an Integrated Approach (COCOADAPT)

SSTI
Strategy for Science, Technology and Innovation

Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

Environmental Protection Agency

The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

The EPA is an independent public body established in July 1993 under the Environmental Protection Agency Act, 1992. Its sponsor in Government is the Department of the Environment, Community and Local Government.

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- Office of Environmental Enforcement
- Office of Environmental Assessment
- Office of Communications and Corporate Services

The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

EPA STRIVE Programme 2007-2013

Co-ordination, Communication and Adaptation for Climate Change in Ireland: an Integrated Approach (COCOADAPT)

(2007-CCRP-2.2.6a)

End of Project Report

Prepared for the Environmental Protection Agency

by

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DISCLAIMER

The EPA Climate Change Research Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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Executive Summary

A blueprint for climate change adaptation was published by the European Commission in 2009 in recognition of the profound effects climate change is likely to have throughout the continent. This was followed in 2012 by the European Climate Adaptation Platform or Climate-ADAPT, an initiative designed to help member states consider the current and future vulnerability of regions and sectors, and develop adaptation tools, strategies, and options, to cope with expected climate change. At the end of 2012 Ireland published its own National Climate Change Adaptation Framework.

The following report seeks to contribute to this process. What follows is an abbreviated version of the work. A fuller account of the research is available online at EPA.ie and in three standalone reports on Water, Biodiversity and Governance.

Surface Water Resources

An adaptation framework to assist planning and decision-making under uncertainty was developed. Contrasting case studies from the River Moy and the River Boyne were used to examine the vulnerability of the water supply as an initial step, and subsequently the degree of success of robust adaptation options.

Key findings include:

- Projecting future supply and demand conditions suggests that water stress will increasingly occur as both climate and water demand changes. Uncertainties related to climatic and non-climatic factors are relatively high and therefore future adaptation planning in the water sector will need to account for this uncertainty.
- In the short term many elements of adaptation planning can be identified that are robust to uncertainty, particularly non-climatic factors such as demand and leakage control. It is recommended that such robust, flexible strategies should form an important aspect of adaptation planning in the near term.
- An approach based on process-oriented “vulnerability thinking” instead of an “impacts thinking” in adaptation planning is advocated. Such an approach combines flexibility with planning over long time horizons, as well as adaptive management, recognising the uncertainty in projected hydrological changes.
- The available options will not always entirely reduce the occurrence of water stress. In such situations, consideration should be given to what are acceptable levels of risk.
- Where investment in new infrastructure is required, it is recommended that such infrastructure be subjected to a sensitivity analysis of performance under the full range of uncertainty associated with climate change.

Biodiversity

Relevant datasets for 274 species and 20 habitats were used in conjunction with climate model output to project potential changes to climate space for the species and habitats concerned. Clear evidence emerged that many species, and many protected habitats and their plant communities, will experience negative consequences. Many species will also experience potential range expansions although it remains uncertain whether these will have the capacity to disperse fast enough to keep up with shifting areas of suitable climate.

Key findings include:

- Potential climate change impacts need much greater priority in the assessment and management of Natura 2000 sites if appropriate actions to protect vulnerable species and habitats are to be implemented in time. Successful adaptation requires that future assessments should ensure that the latest data and state-of-the-art modelling techniques are used feed directly into these assessments and recommendations.

- Climate change will have implications for invasive species and their management requires further knowledge regarding the timescales over which particular species are projected to cause problems.
- The maintenance and promotion of connectivity in the wider landscape and between Natura 2000 sites is vital to ensure species adapting to the new climate conditions can reach new areas of suitable climate space. The creation of green infrastructure will help maintain a heterogeneous landscape facilitating dispersal to these new areas of suitable climate and habitat.
- Restoration of degraded habitats will improve the extent, integrity and resilience of vulnerable habitats such as blanket and raised bogs with knock-on benefits for species dependent on such habitats. This would include the reduction of grazing and trampling pressures especially in (upland) peatland habitats.
- Given the significant distances between some of Ireland's designated sites, the role of well-designed agri-environment measures in non-protected areas (mainly agricultural areas) will be critical in maintaining heterogeneity and connectivity in the wider landscape.
- To aid adaptation, future biodiversity conservation planning and management will require a more dynamic approach to site designation and protection. The identification of current sites where species will be able to persist in the future, sites where species will migrate to in the future, and areas that connect these sites should underpin long-term planning. More flexibility will be required to achieve effective planning and management to adapt to and mitigate against the worst effects of climate change.
- Some species will not be capable of adapting to new conditions. If future conservation objectives deem these to be a priority, then assisted migration to areas with suitable climate and habitat may be necessary to avoid extinction.
- Long-term monitoring and research is central to the detection and quantification of climate change impacts on Ireland's vulnerable species and habitats. This should be integrated as a core part of management planning at site level. This monitoring will aid long-term survival of species through the identification and rapid implementation of appropriate conservation management actions and will also ensure that current designated sites are effectively protecting the species and habitats intended.

Construction

Frequency and magnitude of construction-critical parameters such as frost days, wet days, wind speeds, humidity and maximum and minimum temperature are likely to occur as climate changes. Three key aspects with particular implications for construction are analysed: wind-driven rain, domestic wastewater management in one-off housing, and the subsequent need for revision of the Building Regulations 1997-2011.

Key findings include:

- Wind-driven rain is likely to become a growing issue, especially in western and north-western zones, due to expected increases in precipitation and wind. Exterior materials appropriate for prevailing conditions may no longer provide the resistance needed should the severity of rain penetration increase. Maintenance requirements may also need revising as rendered surfaces, sealants and pointing will require more frequent attention.
- Domestic wastewater management, specifically septic tank operation, may be adversely affected by changed precipitation regimes. Increases in winter rainfall will lead to rising winter water tables and an increased risk of faecal coliforms being introduced into groundwater. This has implications for

existing and planned housing in sensitive areas.

- Septic tank densities are greatest around towns and cities. The primary potential problem areas are therefore the peri-urban areas, where significant septic tank densities, projected increased precipitation, a general lack of mains sewerage and the likelihood of further development exist.
- Building Regulations revisions should be informed by the most recent modelled climate data to incorporate climate mitigation and adaptation measures at the design and build phase.

Tourism

Tourism is seen as both a vector and a victim of climate change. As a vector, tourism contributes to climate change through its greenhouse gas emissions, while, as a victim, tourism resources, infrastructures and markets may be negatively impacted by changes in local climate. With projected increases in Irish temperatures and reductions in summer rainfall, the potential exists to develop tourism in off-peak times such as spring and late autumn. Less desirable consequences in terms of precipitation and extreme weather events may also occur. A Tourism Climatic Index is used to further examine how adaptation to future climate change may occur.

Key findings include:

- Climate change will see a warmer, more reliable summer tourist season for Ireland. The frequency of two very good summer months being experienced will gradually increase. There is a possibility the Irish tourist season can be successfully extended into the shoulder periods of April/May and potentially October. Unlike popular Mediterranean regions, heat will not be overly oppressive. This poses an opportunity to attract visitors who are migrating away from hotter destinations and also to diversify the tourism product further.
- It is important Irish tourism will have the sustainable product offerings available to reap maximum benefit. The look and feel of Ireland's landscapes, and unique ecosystems and habitats is expected to change. Since these are among Ireland's primary assets and core tourism drivers, it is imperative for successful adaptation that they are protected and their integrity maintained. The tourism industry should therefore continue to be proactive in its role and responsibilities concerning the natural environment.
- Integration of tourist-related adaptation issues with other sectors is essential. High volumes of visitors to water-stressed locations will create additional pressures on availability, particularly during peak high-season periods and such considerations require to be factored into both supply and waste-water treatment infrastructure planning.

Economic Analysis

The Stern Review, concluded that the overall costs of unabated climate change would equate to losing at least 5% of global GDP annually, with a risk that this figure could rise considerably. The main conclusion was to emphasise that the benefits of strong, early action on mitigation and adaptation would greatly outweigh the costs of inaction. For Ireland, an impact of even 2.5% of GDP would equate to approximately €4B per year. A similar calculation for adaptation costs provides estimates in the range €80-800M per year, corroborating the logic of undertaking early adaptation. Analysis of three sectors vulnerable to adverse climate change impacts has confirmed that vulnerability has potentially high economic costs involved.

Key findings include:

- Coastal zones, especially in eastern Ireland, are economically vulnerable to relatively small sea level rise and associated increases in storm surge activity. Approximately 350km2 is exposed under a 1m rise, with potential property insurance losses of over €1B.

- Modelling a 2m rise in river levels across 4 Irish catchments indicated 1,800 exposed properties with potential flood insurance claims of close to €46M.
- While losses of wetland habitat with a 1m sea level rise are difficult to quantify economically, estimates based on internationally established valuations approximate to €24M per year.

Economic cost estimates are highly dependent on the assumptions and models employed. However, it is clear that a compelling economic case for adaptation exists.

Governance

Local authorities, in conjunction with national government, are required to safeguard their people and protect the local environment. This requires that relative exposures and impacts be assessed for how they vary in local areas and throughout the country. A relative ranking assessment of exposures and impacts was prepared using existing national datasets regarding climate-relevant exposures, and newly created datasets regarding actions being taken at local, regional and national levels. This initial assessment places the local experience in a national context and highlights areas that will require further assessment for individual sectors and for climate change overall.

Key findings include:

- While all counties are exposed to climate change, this varies when considering areas within local authorities' current legislative responsibilities of flooding, landslides, water supply, coastal erosion, sea level rise, and biodiversity.
- Most local authorities have made limited progress on climate change adaptation as evidenced by limited inclusion of climate concerns into local policies.
- National government has not yet integrated climate change into other policy areas as evidenced by limited statutory backing for climate mitigation, and the absence of regulations or incentives for climate adaptation.
- Ireland needs to act on climate change now by acknowledging climate change explicitly into national and subnational policies, and by moving towards concrete adaptation actions.

Overall Recommendations

- Planning for adaptation will always be conducted in a situation of uncertainty. Robust, flexible strategies will be required based on what is considered at the time to be an acceptable level of risk. Major investments in infrastructure should be subjected to a sensitivity analysis of performance under the full range of climatic uncertainty likely during their effective lifetime.
- Successful implementation of the Habitats Directive will require greater understanding, and incorporation, of the impacts of climate change on species and habitats, especially invasive species and species close to their current climatic boundaries. To ensure Ireland's biodiversity resources are not any more adversely affected than necessary, the creation of green infrastructure and actions to maintain a heterogeneous landscape require to be formally integrated into landscape management approaches. For protected sites, future designations will require to achieve effective planning for this, while in the wider landscape, appropriate agri-environmental measures are required.
- Given limited resources, a conservation focus on those species and habitats identified in this work as most vulnerable is recommended. Future research efforts are required to incorporate dispersal, biotic interactions, and land use change scenarios to ensure that the conservation sector is equipped with the best available projections on which to base adaption decisions. Long term monitoring and the maintenance of research capacity in climate-biodiversity must be supported to achieve this.
- For construction purposes, design standards should be based on climate conditions which can be reasonably

expected to occur during the expected lifetime of the structure. This means planning permissions should take account of materials proposed for building fabric as well as location exposure more overtly. Double leaf housing construction should be considered as a requirement for those areas most exposed to higher winter rainfall conditions with hollow-block single leaf construction only permissible in sheltered locations.

- Higher winter water tables pose increased pollution potential for poorly located or defective septic tanks. Stricter planning guidelines in vulnerable areas are therefore recommended with connections to mains wastewater systems the preferred strategy where possible. The extension of the groundwater monitoring network is recommended.
- The most recent model climate scenarios should be utilised when reviewing building regulations, and issuing new Technical Guidance Documents, particularly in terms of projected increases in wind-driven rain and consequent increases in moisture ingress. A strengthening of the functions of local authorities in monitoring and enforcing the building control system is necessary to achieve the required adaptive response.
- The potential for tourism expansion be investigated further using survey and focus group techniques in conjunction with climate change scenarios incorporated into the Tourism Climatic Index. Specific adaptation options require to be examined using detailed cost-benefit analysis. In particular, water and waste water treatment projections require to be incorporated into tourism infrastructure calculations.
- Economic costing of potential climate change impacts require to be considered when protective infrastructure is being contemplated. Under almost all scenarios, potential impact costs far outweigh adaptation costs. An extension of the Catchment Flood Risk Assessment and Management Studies (CFRAMs) and of Integrated Coastal Zone Management to incorporate the most up to date climate change scenarios is recommended. Difficult to quantify losses in ecosystem goods and services require also to be incorporated in economic quantification of adaptation strategies.
- It is recommended that local authorities build adaptive capacity by establishing structures such as a high level climate change team responsible for developing and overseeing the implementation of a climate change strategy. This should be integrated into their current Development Plan. Regional authorities should oversee the integration of these local climate change strategies at a regional level.

1. It is recommended that national government must create the conditions for mainstreaming of climate change considerations into general policy development and legislation. Cross-sectoral teams working on target-led objectives are essential to achieve this. Most importantly, management ‘buy in’ at the highest level of government must be evident in the reporting structures to provide the essential leadership necessary for the climate adaptation process to succeed

1. Introduction to Climate Change Adaptation

1.1 The Need to Adapt to Climate Change

Model projections of future climate continue to possess elements of uncertainty that inhibit their ability to provide clear guidance for policymakers. Despite substantial growth in sophistication arising from greater computing power and the consequent ability to run multiple ensembles of earth system models, unresolved issues such as sub grid scale processes and feedbacks continue to be problematic. Even in the absence of these, however inherent uncertainty will remain in terms of how global emissions of greenhouse gases will change as finite fossil fuel sources become depleted and the climate change drivers of global population and economic development evolve.

Modellers have traditionally handled these uncertainties by developing a series of 'storylines' which ultimately result in a number of possible future global emission scenarios. The Special Report on Emission Scenarios (SRES) commissioned by the Intergovernmental Panel on Climate Change produced 40 plausible future storylines which could be used to drive global climate models and provide a range of possible future outcomes (Nakicenovic et al, 2000). These are now being superseded for the 5th Assessment Report by a new set of scenarios based not on emissions but on Representative Concentration Pathways (RCPs).

Figure 1.1 shows the average global warming from multiple model runs under the different SRES scenarios. This forms the basis for the 4th Assessment's best estimate that within 80 years or so global temperatures will have increased by 1.8-4.0^{o}C relative to the two last decades of the 20th century. Divergence of the various temperature trend lines is, however, only marked from about mid century onwards. For the next 4 decades or so, irrespective of what emission scenario is selected, a relatively similar temperature increase is likely (Meehl *et al*, 2007). This reinforces the necessity for adaptation to accompany mitigation and explains why adaptation has become such an important agent of climate change management in recent years. It is now accepted that a twin track approach provides complementary risk management strategies which can lessen both the causes and effects of climate change.

Because of the initial emphasis on mitigation, the challenge of adaptation is less well understood and adaptation strategies have been slow to appear to complement a primary policy focus on mitigation through top down national and international initiatives. In recent times, however, awareness has grown concerning the vulnerability of social and environmental systems to climate change (Adger et al, 2007) and the attribution of changes in extreme events to human induced climate change has become more definitive (IPCC, 2012). The realisation that a significant measure of climate change is inevitable over the next few decades has also stimulated the emergence of adaptation strategies. These are also seen as 'no-regrets' strategies since most impacts of climate change are not new, but rather the intensification of known hazards such as floods or heatwaves or loss of biodiversity. It is also increasingly recognised that adaptation is ultimately related to the prevailing level of social, economic, technological and institutional development of a country, and that this, together with a country's exposure to climate hazards determines its vulnerability. But, even if the 'preconditions' are present, successful adaptation also requires strong political will and leadership. Ultimately, it must be stressed that adaptation offers opportunities for nations, such as Ireland, and various economic sectors of prime national strategic importance, to remain competitive and productive in the changed milieu of the future.

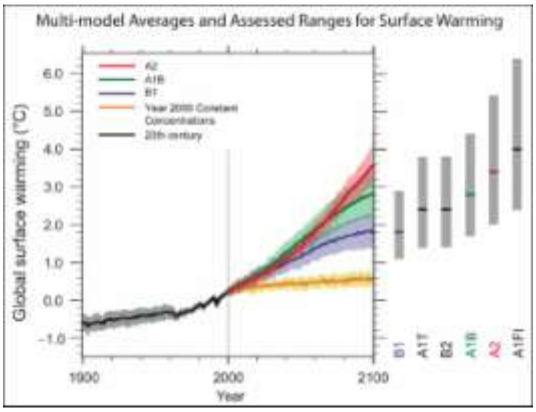


Figure 1.1 Projected temperature trends under different emission scenarios (Source: IPCC, 2007)

1.2 International and National Progress on Climate Change Adaptation

At an international level, a number of finance instruments have been developed to foster climate change adaptation as part of the administrative infrastructure of the United Nations Framework Convention on Climate Change (UNFCCC). National Adaptation Programmes of Action (NAPA) have been submitted by several developing countries to prioritise adaptation needs and to avail of these funding opportunities. Developed countries also have begun planning for adaptation and many have national frameworks in place. Following an EU White Paper on the options available (European Commission, 2009a) a number of countries have adopted a National Adaptation Strategy, and by September 2013 some 14 Member States plus Switzerland had achieved this (European Environment Agency, 2013). An element of rebranding of existing policies is often evident in such exercises and mainstreaming of climate adaptation into national legislation is often quite limited. Indeed mainstreaming is often more apparent at the level of city or region where some innovative initiatives are apparent (Coffee *et al*, 2010). All Member States have also submitted information on the status of their adaptation plans to the UNFCCC as part of their 5th National Communication.

A comprehensive national adaptation plan has yet to be developed by Ireland, although a National Climate Change Adaptation Framework was published in late 2012. It is intended that research such as was carried out for this report will assist in providing some of the tools necessary to progress this.

1.3 Climate Scenarios for Adaptation: a Cautionary Note

Whilst there is considerable agreement among global climate models regarding the general direction and broad spatial characteristics of climate change, particularly for temperature, some parameters, such as rainfall, remain difficult to model with a high degree of confidence. When downscaled to regional levels for areas such as Ireland, these uncertainties persist (Foley, 2010). Caution must therefore be exercised when using single model derived climate scenarios as a basis for decision making. For the various sectors examined in this work a range of different future climate scenarios was employed based largely on previous work (McGrath et al, 2008; Sweeney *et al*, 2008). The main model output employed was that of the Community Climate Change Consortium for Ireland (C4I). This involved the Hadley Centre (UK) Global Circulation model (HadCM3L) driving a Regional Climate Model (RCA3) using the A1B Emission Scenario. Output from this was at a horizontal resolution of 14km. To conform with other datasets used in the study this was processed in house to yield new outputs at 10km resolution. This output approximated closely to the broader ensemble output produced by the

C4I team for the period until mid century. For some parts of the study point location data was required and this was derived from statistically downscaled ensemble outputs created in previous work at ICARUS (Sweeney *et al*, 2008).

In some cases, the adaptation tools developed were independent of specific future simulations. In others, the best available climate scenarios were utilised as described above, employing a mix of statistically downscaled global circulation models and regional climate models as appropriate to the sector concerned. Pending the production of high temporal and spatial resolution future climate scenarios for Ireland, produced from multi model ensembles, this approach offered the best available solution. Thinking on adaptation has, however, also evolved considerably in recent years away from a predict-and-provide, top-down approach, based on rigid use of current climate scenarios, towards a bottom-up approach that uses climate scenarios to explore the robustness of adaptation options to the uncertainties involved. Adaptation is increasingly seen as not a process with an end point, but rather an iterative feedback process to be constantly renewing itself as better knowledge concerning climate change scenarios and impacts become available. The report should therefore be seen as an exploration of climate change adaptation options for various sectors in Ireland which will be further refined as new model outputs and methodological approaches become available.

2. Vulnerability Assessment and Adaptation Appraisal for Surface Water Resources

2.1 Introduction

Climate change has the potential to impact significantly on Irish water resources. The Intergovernmental Panel on Climate Change (IPCC) states in its Technical Report "Climate Change and Water" (Bates *et al*., 2008) that changing climate over the past several decades can be associated with changes in a number of key components of the hydrological cycle. For instance, changes in annual and seasonal precipitation, intensity, and extremes, have been observed around the world (Bates *et al*., 2008). These alterations can result in changes in annual and seasonal flow regimes and groundwater-surface water interactions. They, therefore, can affect raw water availability, which can in turn also affect water quality and biodiversity.

Precipitation changes will also not occur uniformly around the globe. Some locations will receive more rainfall, whereas other regions may suffer from extended drought periods. The impact of climate change on water resources and supply systems will not only depend on the geography and magnitude of changes in the hydrological system but also on the water supply system itself. Depending on the characteristics of water supply systems, the same change in climate may have different effects. For example, a resilient water supply system can be thought of as one with large excess capacity (Dessai and Hulme, 2007). Such a system has a high resistance and even a large change in inputs will have little effect on the system. In contrast, in a system operating towards the limits of its capacity, even a small change in climate or a relatively infrequent extreme event can push it past a critical threshold.

Climate change assessments for Ireland to date suggest that climate change will alter catchment hydrology over medium and long time scales. In response to these anticipated changes it is important that adaptation focuses on identifying options that are equitable both locally and on a catchment scale. However, it is also important to recognise that climate change is but one pressure on water resources and management. Other factors include: population changes, changes in water demand, legislative changes (e.g. the Water Framework Directive or introduction of water charges) as well as infrastructural changes driven by policy (e.g. leakage reduction).

2.2 A Robust Approach to Adaptation

In responding to the challenge of adaptation, robust strategies have been identified as those that:

- are *low-regret,* in that they provide societal benefit under a wide range of climate futures,
- are r*eversible*, in that they keep at a minimum the cost of being wrong,
- provide *safety margins* that allow for climate change in the design of current infrastructure or easy retrofitting,
- use *soft strategies* that avoid the need for expensive engineering and institutionalize a long term perspective in planning,
- reduce the decision time horizons of investments, and
- are *flexible* and mindful of actions being taken by others to either mitigate or adapt to climate change (Hallegatte, 2009 and Wilby & Dessai, 2010).

However, the movement to such an approach for adaptation necessitates a shift in how climate change information is used from a predict-and-provide, top-down approach, towards a bottom-up approach that allows climate scenarios to be used in exploratory modelling exercises that test the functionality of adaptation options to the uncertainties involved. Frameworks for robust adaptation and example applications in the water sector are beginning to emerge internationally and in Ireland (Dessai & Hume, 2007; Lopez *et al*., 2009 and Hall & Murphy, 2012a). Key among these emerging examples is the usefulness of moving away from considering climate change impacts explicitly, but rather identifying where and when vulnerability to climate change may emerge and the application of frameworks for the identification and selection of robust adaptation options.

Adaptation measures need to be context specific and planned and implemented on international, national and regional levels. National planning and water management at the river basin scale can help to identify and understand current and future vulnerabilities. Individual river basins are the level at which detailed adaptation plans have to be implemented. In line with Matthews & Le Quesne (2009) we promote the application of a process-oriented "vulnerability thinking" instead of an "impacts thinking" approach in adaptation planning. A vulnerability thinking approach combines flexibility with planning over long time horizons, is adaptive, and recognises the uncertainty in projected changes in water availability.

2.3 A Framework and Decision Tool for Adaptation

The adaptation framework used in this study is a stepwise process to framework consists of three circular processes (Figure 2.1) This recognises that adaptation is an iterative feedback. The key components to the process that support decisions are vulnerability assessment and robust adaptation option appraisal (blue circle on the right). Within this circle the step of robust adaptation encompasses a circular framework (yellow cycle) for scenario-neutral adaptation planning adapted from Wilby & Dessai (2010). All these iterative adaptation processes as a whole are influenced by observational evidence, socio-economic and ecological pressures, as well as by uncertain future climate projections.

In operationalising this framework, the decision support tool depicted in Figure 2.2 couples a hydrological rainfall-runoff model (HYSIM) with a water-accounting model that accounts for the water supply system architecture and operating rules (WEAP). Uncertainty in future climate change impacts derived from future emissions of greenhouse gases, uncertainty in Global Climate Models (GCMs), downscaling techniques, and rainfall-runoff model uncertainties can be readily incorporated. The Water Evaluation And Planning (WEAP) model allows current water supply architecture and operating rules to be incorporated, along with current and emerging pressures on the water supply system. The flexibility of the tool means that as updated climate scenarios emerge from the next generation of global climate models and emissions scenarios, they can be incorporated. Most importantly, when used effectively, the tool can provide important information and appraisal of robust adaptation pathways to support crucial decisions.

2. 4 Application of Approach

In an illustrative application of the framework and tool, two contrasting case studies are summarised: in the wetter west the River Glore, a subcatchment of the River Moy, and in the drier

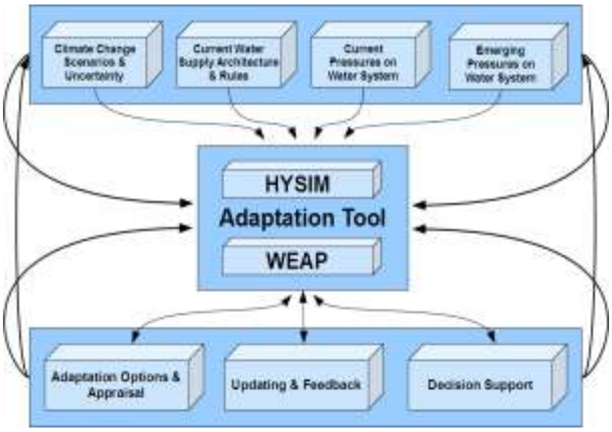


Figure 2.1 Adaptation Framework for Planned Anticipatory Adaptation

east the river Boyne. In both cases the framework is applied to examine the vulnerability of the water supply, and subsequently the degree of success of robust adaptation options in reducing future water stress is explored.

Specification of future climate employed the scenarios detailed in Sweeney et al. (2008) which represent six individual climate change scenarios derived from three Global Climate Models forced with two greenhouse gas emissions scenarios. The climate change scenarios were used to force a hydrological model in order to derive future changes in river flows and thus water availability. Where the investigated surface water abstraction points have no locally measured stream flow records the hydrological model was used to model the river flows for each abstraction point individually. In such cases the model parameters were obtained according to the catchment's physical characteristics- parameters that required calibration against observations were conditioned using a split-sample, proxy-basin procedure.The Water Evaluation and Planning model Version 21 (WEAP21) was used to integrate simulated changes in catchment hydrology with water supply modelling in order to assess vulnerability and evaluate adaptation options. The water mass balances were calculated on node structures, which are linked to water supply and demand sites. The location of the individual water abstraction points was obtained from the '*National Abstractions Further Characterisation Project*' for the Water Framework Directive conducted by CDM (2009). The amount of water abstracted is based on the individual water scheme's population and abstraction volume obtained from *'The provision and quality of drinking water in Ireland'* report (EPA, 2009).

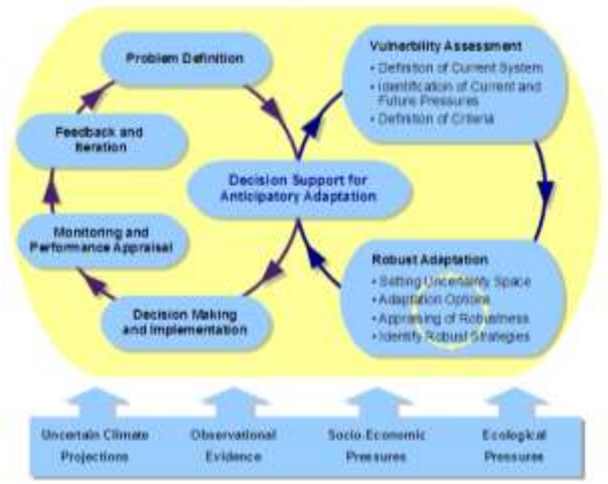


Figure 2.2 Schematic of the adaptation tool design showing the inputs and possible feedback mechanisms

Water use scenarios were developed in order to appraise the vulnerability of current systems to climate change in tandem with changes in population and water demand. The scenarios were based on the individual water scheme's population and abstraction volume obtained from '*The provision and quality of drinking water in Ireland - A report for the years 2007-2008'* (EPA, 2009) and from the 'National Abstractions Further Characterisation Project' for the Water Framework Directive conducted by CDM, 2009). Future scenarios for the abstraction points were based on population projections (CSO, 2008) while estimates of leakages were based on published values (Forfás, 2008; CDM, 2004).

Four future 'what-if-scenarios' were modelled;

- Scenario A—'Business as Usual'. The population of 2008 is extrapolated into the future using the CSO projections. Per capita water abstractions and supply infrastructure remain constant. The level of unaccounted for water is the national average of 43%.
- Scenario B—'Reduced Water Demand'. Increasing awareness in water conservation results in a stepwise annual per capita water demand reduction up to 5% by 2020. The level of unaccounted for water remains unchanged at 43%.
- Scenario C—'Reduced Leakages'. Improved water supply infrastructure results in an annual stepwise-reduced leakage level from 43% to 25% by the 2015. Daily per capita water demand remains unchanged on its 2008 level.
- Scenario D—'Reduced Demand and Reduced Leakages' Combination of Scenario B and Scenario C. Reduction of the per capita water demand and leakage reduction, as above.

Characterising water stress is difficult given that there are many equally important facets to water use, supply and scarcity (Brown and Matlock, 2011). Common indices are built around human water requirements (e.g. the Falkenmark Indicator), water resource vulnerability, indices incorporating environmental water requirements and others built on Life Cycle assessments and Water Footprinting. Here the Water Use-to-Resource Ratio (URR) was employed. This physical index of vulnerability is the water used (withdrawals) divided by the available water supply, on average and provides a local index of water stress. The index is divided into four categories as shown in Table 2.1.

Table 2.1 Water Use-to-Resource Ratio (URR)

Withdrawal / Q	<10%	10%–20%	20%–40%	>40%
Classification	No Stress	Low Stress	Stress	High Stress

2. 5 Case Study Application 1: River Boyne

The River Boyne catchment is located in the Eastern River RBD and extends over an area of ~2,692 km^2. The catchment has an average elevation of 89m and ranges from zero to about 338m. On average the slopes are gentle with a mean slope of 1.6%. Flat and undulating lowlands are the prevailing physiographic feature with Grey Brown Podzolics being the principal soil class (30.6%), followed by Gleys (24.5%.) and Minimal Grey Brown Podzolics (20.5%). The parent material of the dominating soils is Limestone Glacial Till (24%), Limestone Shale Glacial Till (21.6%) and Alluvium (12%); resulting in locally important aquifers underling about 68.6% of the catchment. The main land use types within the catchment are pastures (~79.4%) and arable land (~8%), as well as peat bogs (~4.2%), mainly located in the southern parts of the catchment. Table 2.2 shows the abstraction points analysed. Liscarthan and Kells show a high level of vulnerability to future water stress. Both are analysed in detail in Hall et al. (2012b). Summary results are provided here for the Kells abstraction.

Table 2.2 Boyne Abstractions studied, Information Supply (CDM, 2009; EPA, 2009)

Scheme Name	Scheme Code	Population Served	Volume (m^3/day)
Athboy Water Supply	2300PU B1001	3000	2200
Drogheda	2100PU B1019	23077	27692
Kilcarn: Navan/ Midmeath	2300PU B1016	5600	2800
Liscarthan: Navan/ Midmeath	2300PU B1016	22400	11200
Oldcastle / Kells	2300PU B1011	2024	1447
Trim Water Supply	2300PU B1009	8000	3200

For both water abstraction points, all future scenarios in winter and spring remain below the low water stress threshold. In summer and autumn, all ranges of water stress are can be found within the different scenarios modelled. Generally, throughout the simulated time period, the number of simulations falling into the water stress categories increases over time for all water scenarios as the simulation length increases, as does the spread of the simulation outcomes. This increasing spread of data represents the increasing uncertainty ranges. Business as usual has the highest uncertainty ranges and the highest occurrence of simulations in the water stress categories. The number of simulations falling into water stress categories is subsequently reduced in water scenarios B and C resulting in a significant reduction in Scenario D.

Figure 2.3 presents the increase in the percentage of all summer simulations located in the High Water Stress Category for the Kells and Liscarthan abstractions. It is clear that the frequency of High Water stress increases with time. While each adaptation measure is successful in reducing the frequency of high water stress it is evident from the results that such soft strategies alone may not be sufficient to avoid the occurrence of high water stress. More water demand and leakage reduction or additional measures may be necessary to increase the robustness of water supply to climate change.

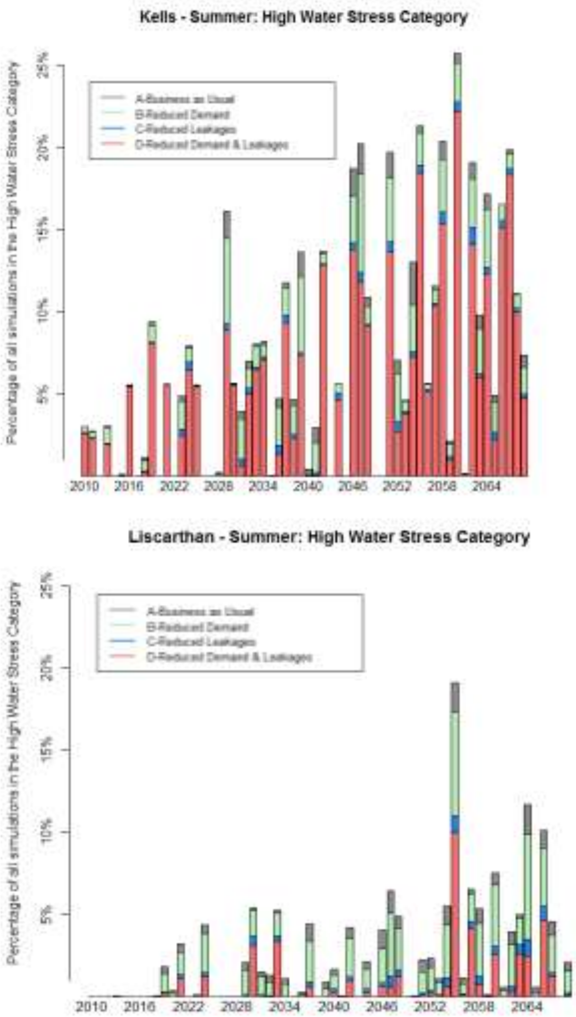


Figure 2.3 Percentage of all simulations in the High Water Stress Category for Kells and Liscarthan

2.6 Case Study Application 2: Glore catchment

The modelling approach described above was applied to the River Glore sub-catchment located in the River Moy catchment, in the west of Ireland. The Glore catchment has an area of 64.72 km^2 and the elevation varies from 52 to 156 m. The main land cover of the catchment is pasture (44%) with 22% peat bogs. The dominant soils present in the catchment are well-drained degraded grey brown podzolics (47.7%), shallow brown earths (19.3%) and podzols (10.3%) as well as poorly drained basin peat (19.1%). The catchment is underlain by “regionally and locally important aquifers” but groundwater recharge rates are generally low with most of the catchment receiving 100-200mm of replenishment per year (Working Group on Groundwater, 2008). The surface water abstraction site investigated in this study withdraws on average 814m^3 per day and serves a population of 3,989 people, resulting in an average daily water supply of 204 litres per capita (including losses through leakages).

For the 2020s, low-water-stress was detected for 11 out of 360 months in scenario A. The demand decreases in scenario B result in a reduction in the frequency of simulations falling within this category and were further reduced following implementation of scenarios C and D.

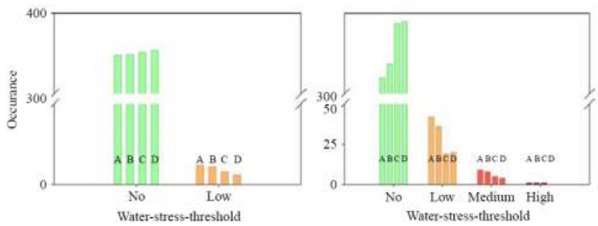


Figure 2.4 Water-stress-threshold exceedance (number of months) of the 0.95-Quantile for the 2020s (right) and 2050s (left) for each scenario analysed.

The frequency of months indicating water stress increases for the 2050s where ~14% of months indicate low water stress or higher. This is in line with progressive decreases in flow simulated for summer months under the climate change scenarios used. The adaptation options examined are successful in reducing the occurrence of water stress, where for example, the leakage reduction in scenario C reduces the frequency of months indicating low levels of water stress to 6.94%. All adaptation scenarios show a robust performance under the uncertainties incorporated in this modelling framework.

2.7 Conclusion and Recommendations

The modelling framework and tool developed in this research allows the identification of vulnerability within water supply systems and the assessment of robust adaptation options. The tool derived is flexible and can be used with different threshold criteria and can be updated as new information and projections become available. For these case studies, climate change is likely to result in a reduction in the reliability and resilience, and an increase in the vulnerability, of the water supply. In many cases the reduction of leakage and demand is successful in reducing the occurrence of water stress. However, for some abstractions such soft strategies alone will not be sufficient to avoid high water stress and alterative supply sources may be required. Thus, consideration will need to be given to what is an acceptable level of residual risk once demand management options have been exhausted.

- From the case studies conducted, uncertainties for the future are high. These are related to climatic and non-climatic factors. Future adaptation planning in the water sector will need to account for this uncertainty.
- In the near term many elements of adaptation planning can be identified that are robust to uncertainty, particularly non-climatic factors such as demand and leakage control. It is recommended that such strategies should form an important aspect of adaptation planning in the near term.
- We promote the application of a process-oriented “vulnerability thinking” instead of an “impacts thinking” approach in adaptation planning. A vulnerability thinking approach combines flexibility with planning over long time horizons, as well as adaptive management, recognising the uncertainty in projected hydrological changes.
- Where investment in new infrastructure is required it is recommended that such infrastructure be subjected to a sensitivity analysis of performance under the full range of uncertainty associated with climate change.

3. Climate Change Impacts on Biodiversity in Ireland: Projecting Changes and Informing Adaptation Measures

3.1 Introduction

Globally, there is evidence that species are shifting their ranges in response to changes in regional climates (Fischlin *et al*., 2007); that species are altering their phenology (Jones *et al*., 2006; Donnelly *et al*., 2008), and that some species are facing extinction, or have become extinct (Fischlin *et al*., 2007). Further evidence of climate change impacts includes; changes in species altitudinal and geographical ranges and changes to population density, community structure, species genetics and evolution (Fischlin *et al*., 2007). Therefore, developing effective adaptation strategies to offset the climate change threats to species persistence will be critical in maintaining species and genetic diversity (Thuiller *et al.*, 2008).

The ecological impacts associated with climate change will not occur in isolation; rather climate-driven changes will combine with, and exacerbate, existing stresses on Ireland's natural systems. As a result, conservation will require that not only are the environmental problems of the past addressed, but that those of an increasingly uncertain future are also a prepared for. Rapid climate change is widely considered to be the defining conservation issue for this generation and the inherent uncertainties associated with climate change projections underpin any impact assessment.

3.2 Aims

- To apply state-of-the-art future climate scenarios to project possible impacts of climate change on Ireland's biodiversity to inform adaptation strategies.
- To project changes in the distribution of climate space associated with a range of species and habitats of conservation interest in Ireland under projected future climate change, and to assess the potential implications for plant communities associated with habitats protected under the Habitats Directive.
- To discuss the results of these model projections in the context of the future conservation management of Ireland's protected habitats and the implications for climate change adaptation strategies.

3.3 Methodology

Relevant datasets of species and habitat distributions, together with other environmental data were obtained from available data sources as well as a number of key providers and merged to a common modelling grid. Observed climate and climate change data were then referenced to the biological and environmental data.

274 species and 20 habitats were modelled using established SDM techniques. The outputs from these models were improved by incorporating additional environmental and ecological data. Models were rigorously evaluated prior to fitting using the baseline climate data and other environmental information. Performance was evaluated using a range of commonly applied test measures. Figure 3.1. illustrates the conceptual framework outlining the key components of species distribution modelling. Biogeographical and ecological theory underpin the approach and identify the characteristics of species and environmental data required for calibration which can then be applied to produce a map of

predicted and projected species distribution using climate data

To complement the machine-based model specification, a parallel approach was undertaken for selected wetland habitats using a manually-based approach to model construction and testing. A combination of SDM techniques was applied to the habitat data and the effects of different variable selection explored. To distinguish models constructed via this approach, these are referred to throughout as bioclimatic envelope models (BEMs) although the same principles are applied as for SDMs.

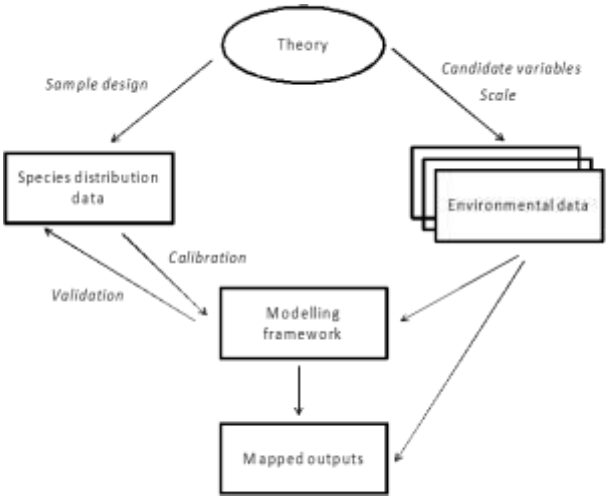


Figure 3.1 Conceptual framework outlining the key components of species distribution modelling. (Source: adapted from Franklin, 2009)

The SDMs and BEMs were re-fitted using climate change data (2031-2060) from a regional climate model (RCA3) dynamically downscaled from a global climate model (HadCM3) (McGrath *et al*., 2008). The re-fitted models were used to project potential changes to climate space for the species and habitats following an evaluation of model spatial performance for the baseline period for selected case study species and habitats. Two dispersal scenarios, unlimited (where species can colonise all potential new areas) and fully limited (cannot colonise potential new areas), were used to assess the ability of species to colonise new areas of suitable climate.

3.4 Key Findings

The results yield clear evidence that many species, currently with or without direct protection, and many of our protected habitats and their plant communities will experience negative consequences of climate change. The outputs of the models also project that many species will experience potential range expansions although it remains uncertain that these species will have the capacity to disperse fast enough to keep up with shifting areas of suitable climate.

The predictive accuracies of SDM based on the Area Under the Curve (AUC) and Kappa performance statistics identified species that could be modelled successfully using a range of climate and topographical variables, but also highlighted those species with a poorer predictive performance (due to the absence of variables crucial to defining their distribution, inadequate distribution data, etc). The addition of topographical and other ecological variables to basic climate variables resulted both in a significant improvement in the predictive capacity of the models and in more realistic spatially mapped model outputs (Figure 3.2.)

The performance of models was shown to vary with the modelling technique used (Figure 3.3). Performance also varied for species in relation to the distribution patterns of these in Ireland as well as with species associated with major biogeographic groups across Europe (Figure 3.4).

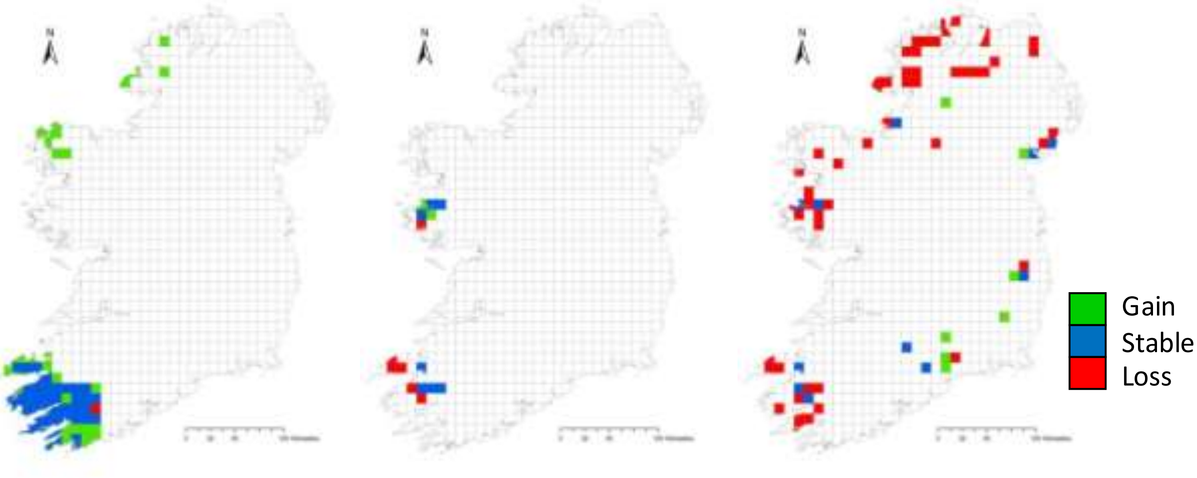


Figure 3.2 Spatially mapped species distribution model outputs for three case study species Kerry Slug, Wood's Whipwort and Dwarf Willow. The Kerry Slug is seen to experience range expansions, while the Wood Whiport and Dwarf Willow are shown to experience contractions, to higher latitudes and higher altitudes, respectively.

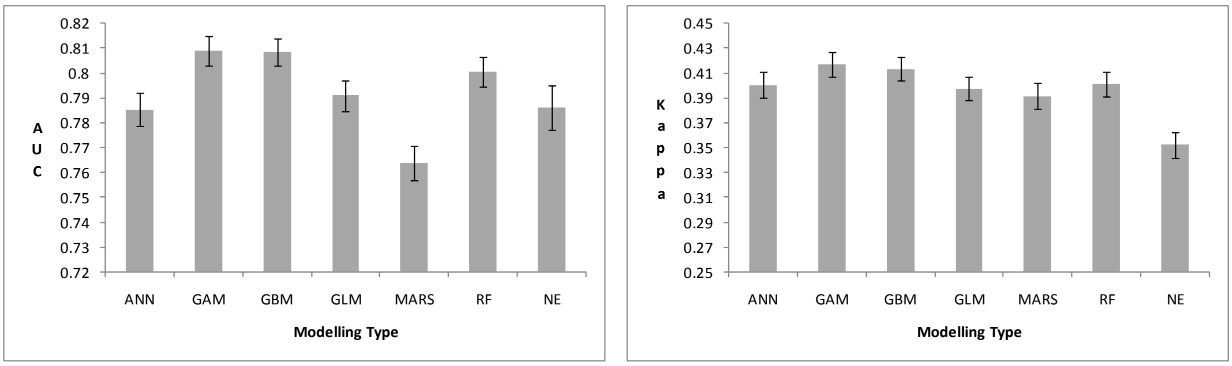
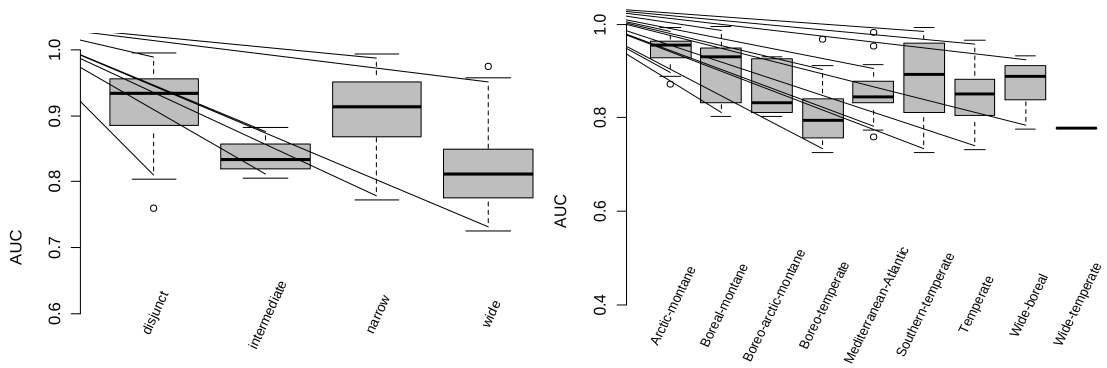


Figure 3.3 Comparison of the mean performance of each modelling type in terms of AUC (a) and Kappa (b) of each modelling type. Standard errors of the mean are shown by vertical bars. ANN = Artificial Neural Networks, GAM = Generalised Additive Models, GBM = Generalised Boosted Models, GLM = Generalised Linear Models, MARS = Multivariate Adaptive Regression Splines, RF = Random Forests, all of which were implemented in BIOMOD; and NE = Artificial Neural Networks implemented in Neural Ensembles



(a) Irish distribution (b) European distribution

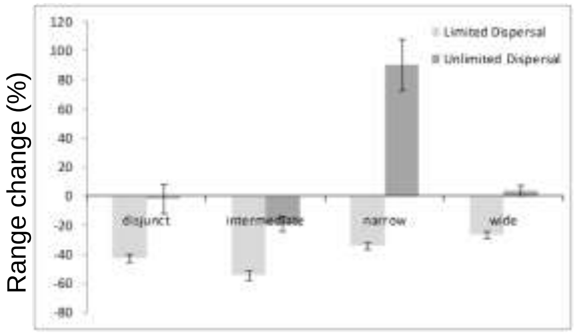
Figure 3.4 Predictive performance (AUC statistic) of the species distribution model (Neural Ensembles) for species in relation to (a) distribution in Ireland, and (b) major biome European distribution of the species

.

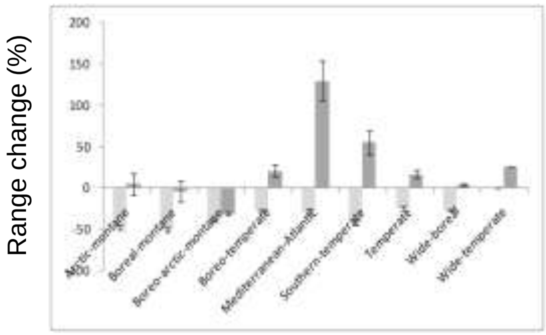
Species with disjunct and narrow distributions are projected to experience the largest range changes (Figure 3.5a). In general, moss, liverwort, and fern species are projected to experience range contractions. Some angiosperms may potentially expand their distribution, while the climate space associated with other species may contract. species at higher latitudes and altitudes tend to suffer the largest range contractions (Virkalla *et al*., 2008; Engler *et al*., 2011).

Species representative of Arctic-montane, boreal-montane and boreo-arctic montane biomes will be most vulnerable (Figure 3.5b). In Ireland these species will not have higher altitudes and latitudes to move to. While it might be expected that oceanic mountains would be buffered against climatic change by their more limited annual temperature range, by comparison with higher mountains such as the Alps, the lack of a permanent snow line zone limits the potential upward migration of species (Crawford, 2000), at least for marginal arctic-alpine species already near their southern range limit.

This potential upward migration is also likely for species with distributions more typical of lower latitudes and altitudes which were projected to experience significant expansions in ranges. These include species categorised in the Mediterranean-Atlantic and Southern-Atlantic major biomes. Thus, changes in climate leading to a reduction in the severity of the abiotic environment may lead to increased inter-specific competition associated with the invasion of species currently limited to lower elevations (Ellis and McGowan, 2006; Hodd and Sheehy Skeffington 2011). Shifts in the isotherm values associated with present maritime upland vegetation zones under selected scenarios of climate change could be substantial (Coll *et al*., 2010).



a) Irish distribution



b) European distribution

Figure 3.5 Projected range changes under limited and unlimited dispersal scenarios in relation to (a) species distribution pattern in Ireland, and (b) major biome (biogeographic element/European distribution). Standard errors of the mean are shown by vertical bars

Plant communities in many protected habitats are likely to see significant changes in their composition. The following habitats may be the most vulnerable to climate change impacts: upland habitats (siliceous and calcareous scree, siliceous and calcareous rocky slopes, alpine and subalpine heath), peatlands (raised bog, blanket bog), and coastal habitats (fixed dunes combined with the additional threat of sea level rise to coastal habitats).

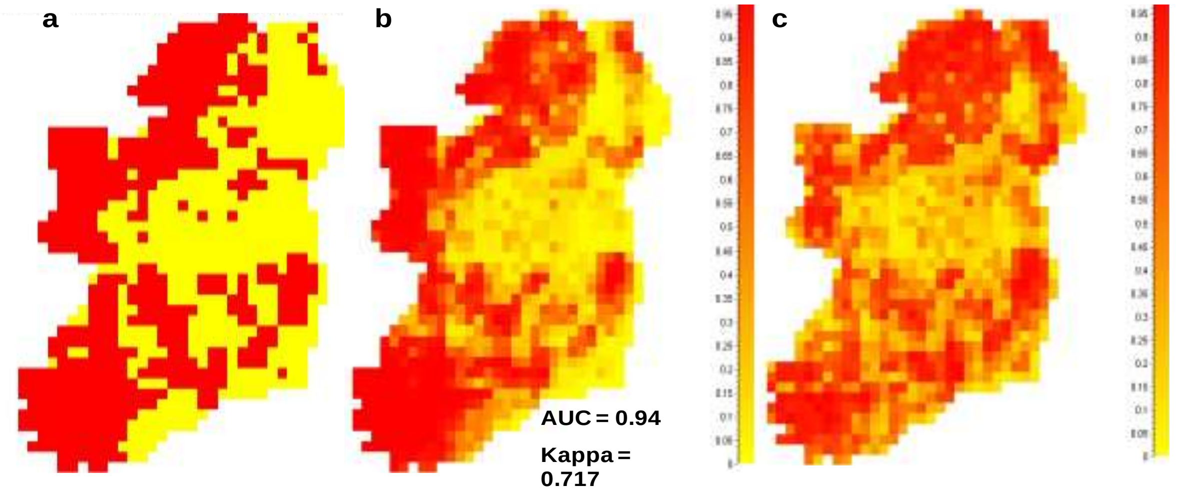


Figure 3.6 Wet heath habitat distribution on 10 x 10 km grid: a) NPWS and JNCC observed, b) Modelled baseline probability surface, c) 2050s climate space projected probability surface. Red squares denote habitat presences, yellow squares absences; scale bars denote the modelled probability of occurrence. The shading variation in the model-projected maps reflects the range of predicted probabilities for each of the grid cells

.

Of the key wetland habitats modelled, some were also found to be more vulnerable than others. For example, the climate space associated with the degraded raised bog and active blanket bog habitats contracted substantially more than the climate space associated with wet heath. However, the regional pattern of change varied for each of the habitats as an altitudinal pattern of projected changes was superimposed on a latitudinal gradient of change. This is illustrated with reference to the changes projected for the wet heath habitat; although there is little net loss of available climate space overall, the regional *distribution* alters (Figure 3.6).

3.5 Recommendations

1. Potential climate change impacts need much greater priority in the assessment and management of Natura 2000 sites if appropriate actions to protect vulnerable species and habitats are to be implemented in time. Future assessments should ensure that the latest data and climate modelling techniques should be used to inform these assessments.
2. The composition of plant communities in Natura 2000 sites in the future is likely to be different from today. A more dynamic approach to habitat classification and what is deemed to be a high quality habitat is required to account for these changes. The likelihood of new species assemblages in the future is high and the conservation sector will need to be prepared to amend its conservation objectives accordingly.
3. More research is necessary to understand the impacts of climate change on invasive species on ecosystems and ecosystem services. This should include greater understanding of the timescales over which particular species are projected to cause problems.
4. The maintenance and promotion of connectivity in the wider landscape and between Natura 2000 sites is vital to ensure species can reach new areas of

suitable climate space. The creation of green infrastructure will help facilitate dispersal of species to these new areas.

5. Restoration of degraded habitats will improve the extent, integrity and resilience of vulnerable habitats such as blanket and raised bogs. This would include the reduction of grazing and trampling pressures.
6. Given the significant distances between some designated sites, the role of well-designed agri-environment measures in non-protected areas (mainly agricultural areas) will be critical in maintaining heterogeneity and connectivity.
7. Future biodiversity conservation planning and management will require a more dynamic approach to site designation and protection. The identification of current sites where species will be able to persist in the future, sites where species will migrate to in the future, and areas that connect these sites will underpin long-term planning.
8. Ireland's species and habitats currently face a multitude of threats including land-use change, habitat fragmentation and the introduction of non-native species. The conservation sector will increasingly need to consider the cumulative effects of these current pressures alongside the future impacts of climate change. A greater understanding through more research is required to understand the complex relationships between biodiversity, ecosystem functioning, ecosystem service provision and the consequences of environmental change.
9. Some species will not be capable of migrating to new areas of suitable climate and habitat or of adapting to new conditions. If future conservation objectives deem these species to be a priority, then assisted migration to areas with suitable climate and habitat may be necessary to avoid extinction.
10. It is recommended to focus limited conservation resources on those species and habitats in Ireland that are most vulnerable. The current research has identified many of these and they are referred to in this study.
11. Long-term monitoring and research is central to the detection and quantification of climate change impacts on Ireland's vulnerable species and habitats and should be integrated as a core part of management planning at the site level. This will aid long-term survival of species through identification and rapid implementation of appropriate conservation management actions, and ensure that currently designated sites are protecting the species and habitats intended.
12. More research and a retention and extension of the capacity developed here is needed to ensure that the tools required to provide the conservation sector with the best projections are available.

Most of the actions that can be taken to protect species and habitats from these impacts are similar to those currently being implemented to counter other pressures on natural systems. Nevertheless, vulnerability assessments facilitate adaptation planning by identifying those species or systems that are likely to be most affected and contribute to understanding why these resources are vulnerable by elucidating the interaction between climate shifts and existing stressors (Glick *et al*., 2011).

4. Adaptation Issues for the Construction Industry

4.1 Introduction

The construction sector's importance to Ireland is substantial. At its peak in 2006 it contributed to 25% of GNP equating to a value of output of €39 billion (SCSI, 2012). Such figures underline the importance of understanding the impacts of climate on construction, and there must therefore be applied an Irish climate change perspective in order to prepare mitigation and adaptation strategies that will increase resilience of the construction sector in vulnerable areas. Three key areas for investigation were identified: wind-driven rain in the context of the built environment; domestic wastewater management in one-off housing in the context of planning; and the Building Regulations 1997-2012 in the context of structural resilience.

4.2 Overview of sub-sectors to be addressed

Wind-driven rain (WDR) is rain that is given a horizontal component by wind. It increases vertical surface wetting, which affects U-values and increases wear on components such as building façades, roofs, windows and doors. Current WDR receipt and modelled increases are calculated herein by employing the latest International Standards Organisation (ISO) standard to calculate a Driving Rain Index (DRI) for Ireland.

Domestic wastewater treatment may be affected by rising winter water tables as a result of climate change. The resulting vulnerability of groundwater to contamination is investigated. The impact of this on construction will be assessed in the context of more restrictive planning regimes and the installation, maintenance and/or replacement of over 435,000 domestic wastewater treatment systems currently in use in Ireland.

Building regulations are traditionally assessed in the context of climate through analysis of historical data. With current advances in climate modelling it is now feasible to also analyse building regulations in the light of future climate scenarios. Existing provisions for weather-proofing buildings in the Building Regulations 1997-2012 and associated Technical Guidance Documents will be assessed and modifications proposed.

4.3 Wind-driven rain: Introduction

Wind-driven rain, also known as driving rain, is a phenomenon that primarily affects the northern, western and southern parts of Ireland. It is one of the most important climatological factors to affect the hygrothermal performance and durability of building envelopes (Blocken, 2010), and can increase the amount of moisture present in a structure by more than 100 times due to vapour diffusion (Karagiozis *et al*, 1997). Indeed, driving rain is considered the most critical exterior environmental load factor in over 90% of building envelopes (Karagiozis, 2003). In terms of its impact on the built environment, rain penetration over the life of a building can cause significant damage to components such as bricks, insulation, interior and building finishes.

To calculate an omni-directional driving rain index (DRI) for Ireland, the Irish Standard IS EN ISO 15927-3:2009 'Hygrothermal performance of buildings – calculation and presentation of climatic data – part 3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data' (NSAI, 2009) was employed. New driving rain indices were calculated for Ireland for the periods 1961-1990, 2021-2040 and 2041-2060 using hourly observed and modelled wind and rainfall data. Observed data for the period 1961-1990 was supplied by Met Éireann from 13 synoptic stations: Malin Head; Belmullet; Clones; Claremorris; Mullingar; Dublin Airport; Casement; Birr; Shannon Airport; Kilkenny; Rosslare; Cork Airport; and Valentia. Modelled data was derived from the C4I project and processed to provide $10km^2$ resolution dynamically downscaled scenario outputs.

4.3.1 Results: Driving Rain Airfield Index (I_A)

Table 4.1 shows all calculated DRI values, with values in the order of 887 litres per year indicated at Malin Head, while Valentia and Belmullet register 794 and 784 respectively. Steadily reducing values characterise the inland zones. Figure 4.1 illustrates 1961-1990 values of driving rain receipt, while Figure 4.2 illustrates modelled index values for 2021-2040 applied to 1961-1990 levels. Increases of 9-16% in inland areas and 7-12% in more exposed areas are indicated. Such increases in the levels of driving rain will make adaptation to future climate conditions necessary for construction, and the built environment in particular.

Table 4.1 Driving Rain Airfield Index (IA).

STATION NAME	1961-1990 OBS I_A	2021-2040 MODEL I_A	2041-2060 MODEL I_A
Valentia	794	864	873
Shannon Airport	485	524	525
Dublin Airport	400	446	440
Malin Head	887	952	922
Belmullet	784	892	894
Clones	420	464	446
Rosslare	543	577	597
Claremorris	543	596	583
Mullingar	423	467	457
Kilkenny	292	347	349
Casement Aerodrome	426	466	454
Cork Airport	697	727	717
Birr	309	347	344

Spatially, the areas suffering the more extreme effects lie along the western coastal zones. However, increases are noted throughout inland Ireland. Overall, the prognosis is that walls will be wetter for longer, with consequent impacts on thermal performance and implications for mould growth and deterioration of surfaces. More rain will penetrate the building envelope during severe spells, with consequences for occupant health and the structural integrity of buildings over their lifespan.

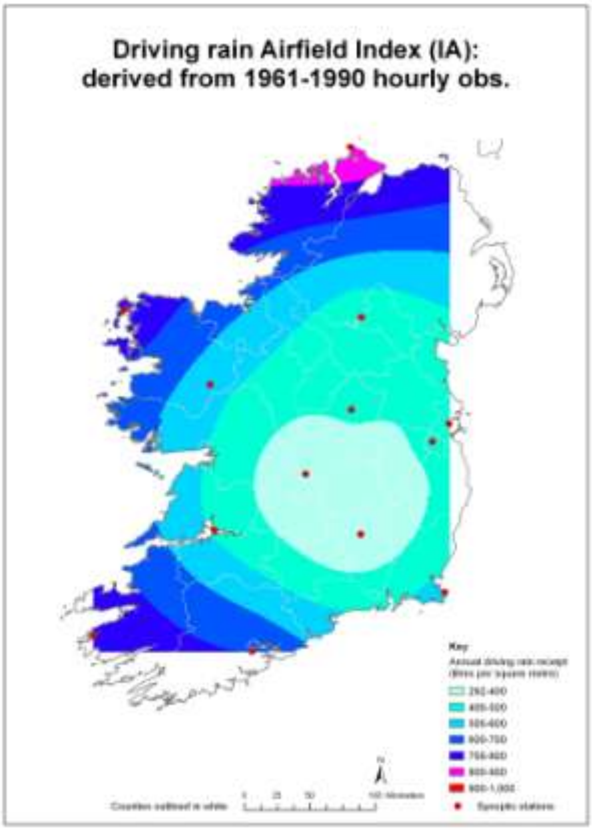


Figure 4.1 Airfield Index (I_A): observed synoptic data 1961-1990

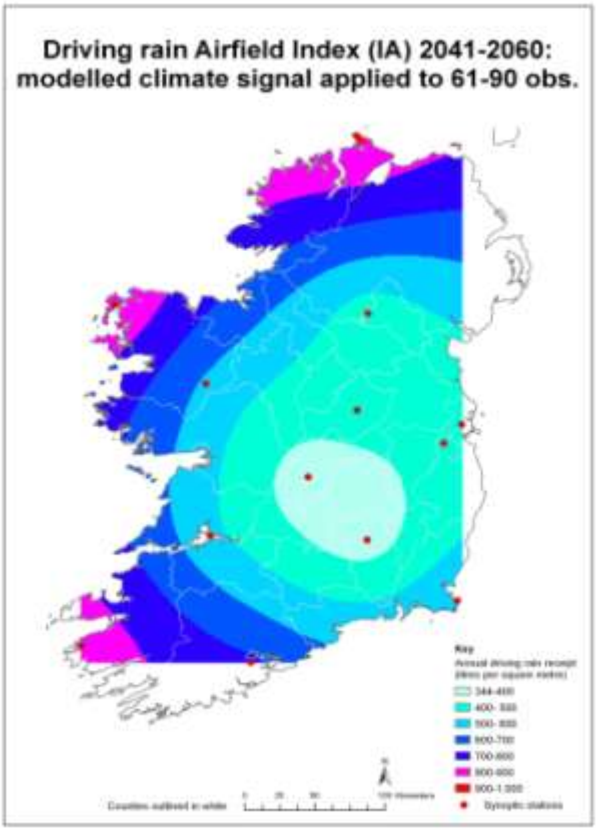


Figure 4.2 Airfield Index (I_A): 2041-2060 Climate signal applied to observed data.

It is important to note that the Airfield Index maps are not intended for meteorological use. For example, corrections for values such as surface roughness and station proximity to the coast are not calculated. The maps are designed purely as reference aids for planning departments in Local Authorities considering exposure to driving rain in a construction context. It is essential that individual construction projects use full IS EN ISO 15927-3:2009 specification for site-specific evaluations, utilising the extensive network of Met Éireann rainfall measurement stations in conjunction with local wind knowledge. Nevertheless, the modelled data projected onto the 1961-1990 baseline provides a first-pass quantification of likely climate regime shifts, where an eastwards progression of zones of increased driving rain can be seen.

4.3.2 Conclusions

Exterior materials initially selected as appropriate for prevailing conditions may no longer provide the resistance needed should the severity of rain penetration increase. Maintenance requirements may also need revising as rendered surfaces, sealants and pointing will require more frequent attention.

Wind-driven rain is a complex problem because it is dependent on factors such as building location, building geometry and local variations in wind speed and direction. For this reason any national driving rain index can only ever give approximate guidance as to conditions in a particular area. Local calculations using the full ISO 15927:2009 specification should be used. Even so, it can be said that while spring and summer precipitation and wind speeds are projected to decrease in Ireland, the upward autumn and winter trend is likely to have significant implications for construction, which should plan to adapt accordingly.

Recommendations

- ISO 15927-3:2009 must be used for site-specific WDR evaluation.
- Materials for building fabric must be designed and selected for projected exposure conditions rather than current conditions.
- In exposed zones, restrict planning permissions to sheltered areas.
- Double-leaf housing construction should be considered for more inland areas.
- Hollow-block single-leaf construction should only be used in areas determined as low exposure.

4.4 Domestic wastewater treatment: Introduction

Domestic wastewater management is an issue that warrants particular attention in Ireland. Approximately 40% of the population live in rural areas while almost a third live in one-off housing without access to mains sewerage. The most widespread system used to treat domestic wastewater is the septic tank. When sited in suitable conditions septic tank systems are an efficient method of wastewater treatment. However, conditions for the siting of septic tanks in Ireland vary from 'slightly to seriously inadequate' over an estimated 40% of the country (Daly *et al*., 1993). This is due to a combination of factors; for example, granite lies very close to the surface in many areas of western Galway, making septic tank construction largely inappropriate, and over 50% of Ireland is underlain by carboniferous limestone that tends to have fissure permeability so that contaminants experience little attenuation once percolation through subsoil has occurred (Lee *et al*., 2008).

In 2011 there were 437,652 septic tank systems in operation (CSO, 2012). If located and constructed within procedures laid down by the Sustainable Rural Housing Guidelines for Planning Authorities (DEHLG, 2005) and the EPA's 2009 Code of Practice for Wastewater Treatment and Disposal Systems Serving Single Houses, there should be minimal threat to groundwater quality. The principal cause for concern is legacy septic tanks, constructed under SR6:1991 legislation before the EPA's Manual on Treatment Systems for Single Houses (2000) and Code of Practice (2009) came into force. In 1991 there were 339,365 septic tanks in use (CSO, 1991). It is reasonable to assume that a significant proportion of these are still in use today.

Septic tank density (STD) has been recognised as one of the most important factor influencing groundwater contamination (Yates, 1985). Although a properly functioning septic tank system can filter most pathogens, high-density installations can cause nitrogen contamination and negative impacts on groundwater due to cumulative loading. Moreover, for effective effluent treatment to take place there should be a minimum 300mm of gravel beneath the septic system's percolation pipes to the subsoil and a further 1.2m of suitable subsoil to the water table or bedrock (Keegan & Clinton, 2009). If there is insufficient depth or unsuitable sub-soil, and groundwater encroaches into this purification zone, partially treated effluent could enter groundwater pathways.

4.4.1 Results

Septic tank density was calculated by Electoral Division (Figure 4.3). The nominal STD threshold to indicate potential vulnerability was set at 17 septic tanks per square kilometre. This was based on the US EPA designation that any density greater than 16 constitutes a 'region of potential contamination' (US EPA, 1977; cited in Yates, 1985). The density threshold can be considered nominal because although density is a key factor in assessing potential contamination, other factors such as subsoil, bedrock geology and groundwater level are also significant in assessing true vulnerability.

Results identify the primary potential problem area as being the suburban peripheries, where significant septic tank densities, increased precipitation, a general lack of mains sewerage and the likelihood of further development exist. Zones of particular interest lie in the peri-urban areas of Galway, Cork and Limerick. For example, Beara (on the periphery of Galway City) contains 30 septic tanks per km^2; Cahelag (Cork City) 22/km^2; and Clarina (Limerick) 21/km^2. It is interesting to observe the contrast with suburban Dublin. For instance, Lucan (County Dublin) is densely populated but has a septic tank density of 12/km^2. This can be attributed to the existence of a mains sewerage network. Other pockets of note include Roscommon, where the STD is high at 21/km^2 and where *c*.75% of the population depends on groundwater for drinking.

4.4.2 Vulnerability Index

To further refine areas of vulnerability, modelled DJF precipitation between the baseline period 1961-1990 and 2041-2060 was mapped (Figure 4.4), and Water Framework Directive (WFD) groundwater vulnerability scores also mapped (Figure 4.5). By comparing and contrasting STD, modelled precipitation and WFD score, a Vulnerability Index and a Vulnerability to Contamination map were created.

To create the Vulnerability Index, vulnerability thresholds were allocated to STD, modelled precipitation and WFD score. A Vulnerability Rating of 1 was allocated to STD >16/km^2, precipitation increase > 20% and WFD score of 1a. If these parameters were not met, 0 was allocated. Subsequently, a Vulnerability Index was calculated by summing the Vulnerability Ratings for each Local Authority area. Vulnerability to contamination was mapped from the resulting totals (Figure 4.6).

Using the WFD's 'one out, all out' framework, the highest vulnerability rating calculated for a Local Authority area was taken to be the overall score for the Local Authority, even if that Local Authority also contained areas of lower risk. Thus, any mitigation and adaptation strategies formulated would be aimed at developing policy for a worst-case scenario and a no-regrets outcome. However, it is important to note that the Index is only indicative of vulnerability at the national scale; many local factors will need to be incorporated to develop appropriate strategies at finer scales. However, the index represents a first-pass at analysing the risks posed by septic tank systems in the context of climate change.

As can be seen in Figure 4.6, the greatest vulnerability under the criteria outlined above lies in a band stretching from Cork in the south west to Wicklow in the east. Under this band of vulnerability are several productive aquifers, including the important Curragh aquifer in County Kildare which is classified as high 4.4.3

Conclusions

The maps illustrating Septic Tank Density and Vulnerability to Contamination highlight the risks to groundwater quality from septic tank systems in the context of climate change. Although resolution of the maps ranges from ED up to a relatively coarse county level, identification of particularly vulnerable zones can be made for the purposes of further investigation and potential adaptive planning.

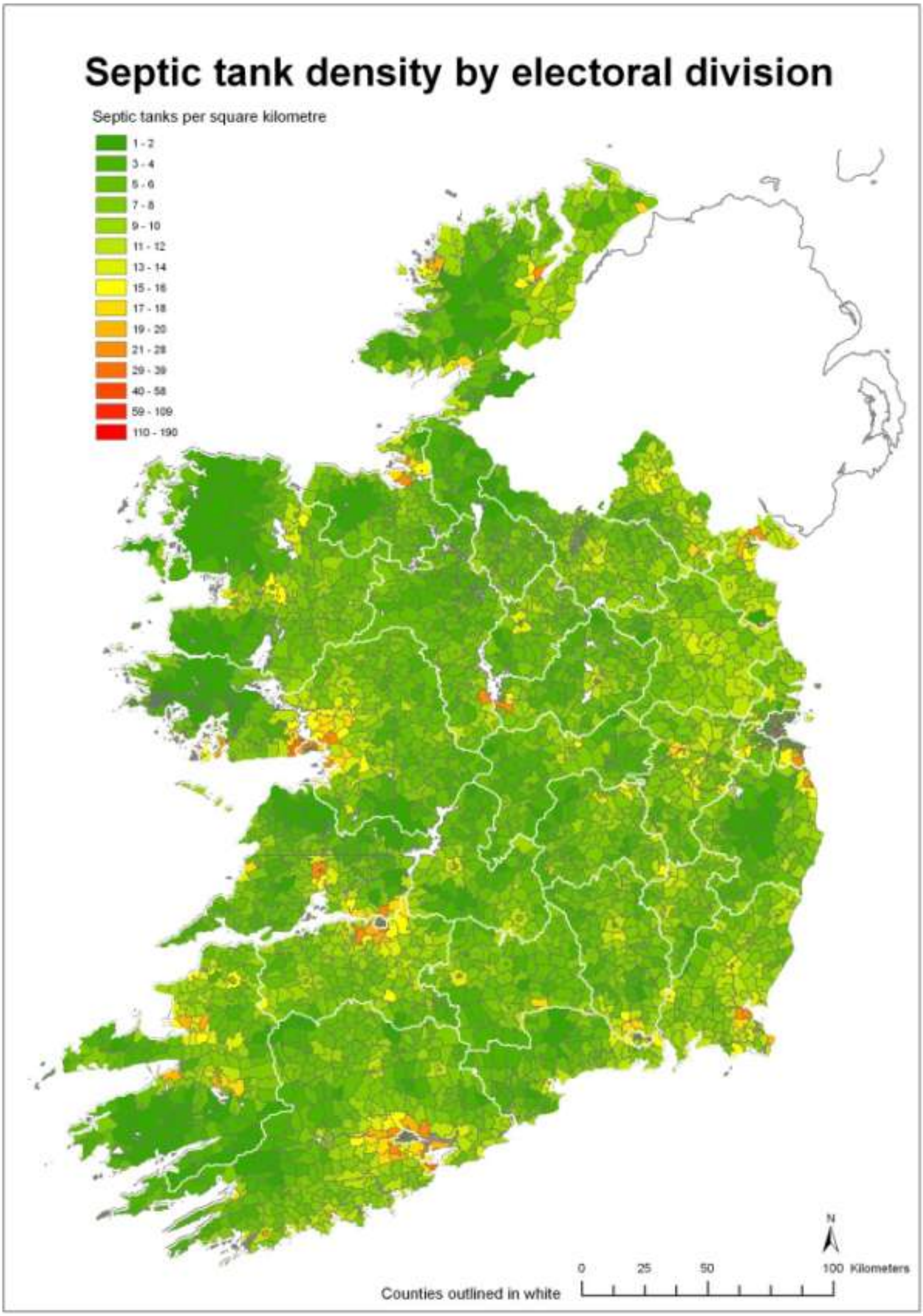


Figure 4.3 Septic tank densities at Electoral Division resolution

The construction industry could be affected in two ways. Firstly, the upgrade or replacement of septic tanks could mean a substantial amount of work for construction companies. While it could be argued that the WFD is the primary driver, it can be seen that rising winter water tables as a result of climate change may act as a catalyst for the implementation of such adaptation strategies. Secondly, geographies of construction may be altered. Concerns over the impact on groundwater of septic tank effluent means that planning guidelines are likely to apply much stricter conditions to one-off housing. Indeed, it is already recommended that a 'precautionary approach' be adopted by planning authorities (DEHLG, 2010). permeability, high vulnerability (Misstear & Brown, 2007).

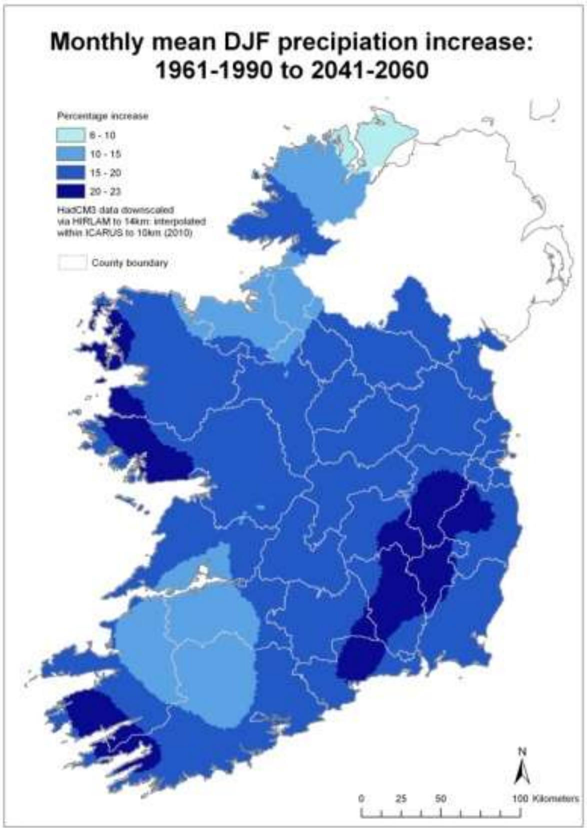


Figure 4.4 DJF precipitation increase for 2041-2060 over the 1961-1990 base-line

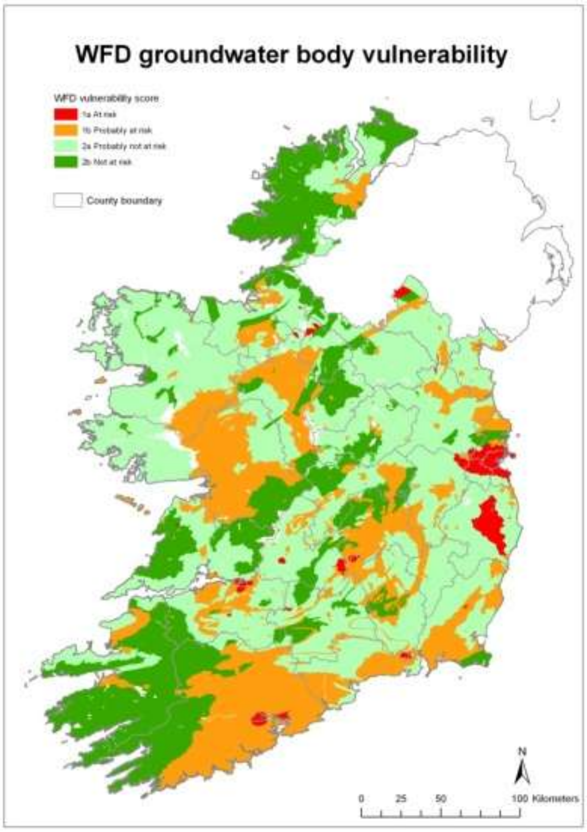


Figure 4.6 Water Framework Directive groundwater vulnerability assessment

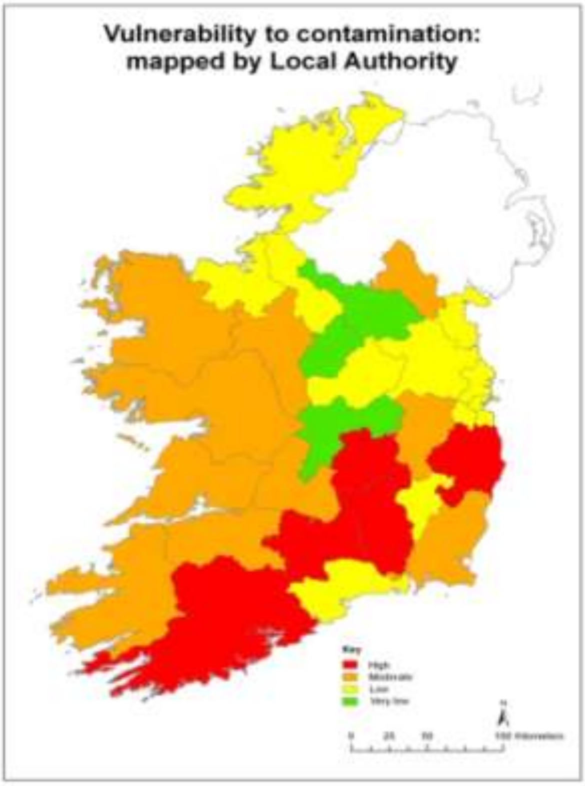


Figure 4.5 Vulnerability to contamination based on STD, precipitation increase and WFD score.

Recommendations

- Dwellings should be connected to mains sewerage where practicable.
- Increase investment in wastewater treatment facilities to cater for increased load.
- Open dialogue between construction actors and local authorities must be maintained when assessing site suitability.
- Onsite wastewater treatment system density must be taken into account when assessing sites for suitability.
- The groundwater monitoring network for quality and levels should be extended to cover aquifers anticipated to become vulnerable as a result of climate change.

4.5 Building regulations: Introduction

Buildings constructed under the current Building Regulations may not have the required resilience for future climate regimes. As Smith points out, 'Creating volume housing that is genuinely future-proof will require a radical shift in design standards compared with current building regulations' (Smith, 2010: 37). In a climate change context, regulations are essential to effect change in a sector where autonomous adaptation is not a viable option due to the probability of sub-optimal measures (EU, 2009). Indeed, Morton (2010) noted that 'clients associated environmental considerations with increased cost and […] were unwilling to bear this cost except in so far as it was necessary to meet government requirements'. Moreover, financial constraints and investor profit-maximisation remain the main barriers to climate change adaptation (Stern, 2006; Sisson *et al.,* 2007), with the result that the Building Regulations require modification for change to take place.

The Building Regulations are expressed in general statements of intent or broad functional requirements rather than specific methods of construction. Further parts of the Regulations indicate how they may be satisfied, but the practical guidance on how the statutory requirements in the Building Regulations may be met is contained in a series of Technical Guidance Documents (TGDs). TGDs cover the core practicalities relevant to the Parts A to M of the Regulations listed in Table 4.2 (there is no Part I), and also refer to other documents for more detailed information on parts of the guidance.

Table 4.2 Parts of the Building Regulations.

Part	Area
A	Structure
B	Fire Safety
C	Site Preparation and Resistance to Moisture
D	Materials and Workmanship
E	Sound
F	Ventilation
G	Hygiene
H	Drainage and Waste Water Disposal
J	Heat Producing Appliances
K	Stairways, Ladders, Ramps and Guards
L	Conservation of Fuel and Energy
M	Access and Use

The Building Regulations and TGDs are maintained by the DECLG and are revised as required to take into account the latest research and information. The Building Regulations Advisory Body (BRAB) advises the Minister on matters relating to the Building Regulations, and recommends endorsement of revisions to Building Regulations and TGDs or further review.

Examination of the Building Regulations *per se* will not serve the aim of this report; the language contained therein is that of intent. Rather, it is the practicalities of construction concerning weather-proofing contained in the TGDs that warrant examination. Furthermore, within the context of this report it is not feasible to analyse and make recommendations for each of the relevant Irish and European codes, standards and publications. The numbers that comprise full guidance run into hundreds. Also, to propose quantifiable amendments that reflect climatic influences, significant engineering expertise is required that lies outside the remit of this report. As such, the following will not recommend specific amended values and parameters, but will be a discursive investigation highlighting areas where climate change is likely to have an impact.

The TGDs that are relevant to the weather-proofing of buildings and require further attention from a climate change perspective are:

- TGD A: Structure
- TGD C: Site Preparation and Resistance to Moisture
- TGD F: Ventilation
- TGD L: Conservation of Fuel and Energy – Dwellings

TGD A and C are relevant to wind speeds and precipitation and will be assessed with reference to one-another. TGD F and L are relevant in the context of building envelope permeability and thermal bridging and will also be assessed simultaneously.

4.5.1 Results

TGD A (2012): Structure

TGD C (2004): Site Preparation and Resistance to Moisture

Despite the lack of reference to climate change in the Part A Regulation, TGD A (2012) may provide a *de facto* response to climate change issues. In this context, the following sentence is significant:

'*The selection of relevant critical situations for design should be made reflecting the conditions that can reasonably be foreseen during future use*.' (DECLG, 2012: 6)

The key phrase is 'conditions that can reasonably be foreseen'. Given the substantial evidence for climate change, it can be argued that climate change can 'reasonably be foreseen', with the consequence that building design should reflect this. An example of a potential practical application of this phrase would be the use of double-leaf construction in more inland parts of Ireland due to projected increases in wind-driven rain. Historically, double-leaf was used only in the more exposed outer regions as it was always assumed that the outer leaf would not remain watertight, necessitating an inner leaf to maintain the integrity of the building. That said, TGD A does not specify particular structural systems or designs for individual examples; the appropriate competency involved needs to be assessed on a case by case basis.

Climate change also has implications for calculation of parameters such as wind loading, which currently utilise the Structural Eurocode IS EN 1991-1-4:2005. This is important when considering building height. While climate analysis reveals with high confidence that the frequency of high winds is set to increase, it is less certain whether peak wind speeds will increase. However, it would seem prudent to argue for a nominal increase of 10% in calculations to allow for higher wind loading, which would result in only minor increases in construction costs (Saunders, 2006).

In terms of precipitation, increases will impact site works particularly in relation to site drainage (DECLG, TGD C, 2004). In addition, modelled increases in winter precipitation mean that up-slope subsoil drainage for houses built on inclines may have to manage increased run-off. Similarly, calculations pertaining to size values for openings and recesses (DECLG, TGD A, 2012) should be cognisant of projected increases in wind-driven rain and take into account potential increases in moisture ingress.

TGD F (2009): Ventilation
TGD L (2011): Conservation of Fuel and Energy - Dwellings

The aim of ventilation is to provide adequate air movement while limiting energy use and avoiding occupant discomfort. For this reason TGDs F and L are inextricably linked. Air tightness is common to both documents. TGD F provides guidance on ventilation for buildings with an air permeability of at least $5m^3/(h.m^2)$ (5 cubic metres per hour per square metre) at 50 Pa pressure or greater, while TGD L specifies that air tightness of building envelopes should have an upper level of performance of $7m^3/(h.m^2)$.

The probable impact of climate change on ventilation is that during more extreme events air permeability will change due to pressure differentials caused by turbulence around buildings. This will result in a potential greater loss of energy but can be considered unavoidable. One alternative would be to recommend installation of energy efficient Mechanical Ventilation Systems. Capital cost issues aside, good mechanical ventilation with a heat recovery system should be able to recover more heat energy from the air extracted than the equivalent electrical energy used by the fans. This would fulfil the aim of limiting 'the use of fossil fuel energy and related carbon dioxide emissions arising from the operation of buildings' (DECLG, TGD L, 2011).

Buildings using the traditional method of openings in the eaves 10mm wide to limit condensation in roof spaces (DECLG, TGD F, 2009) are vulnerable to precipitation being driven into the roof space due to increases in winter wind-driven rain. However, the relative humidity of outside air is a more significant factor in the ability of eaves ventilation to manage attic condensation and moisture ingress. Climate modelling currently detects no significant trend in relative humidity so eaves ventilation can be considered sufficient at this juncture, although as buildings become more airtight it is important that adequate ventilation is maintained to minimise risks such as mould growth and condensation.

In terms of TGD L and fuel and energy, the area of a building that the weather has most impact on is the fabric. Insulation and thermal bridging (heat transfer *via* a conductive or non-insulating material) can be amplified by moisture on walls and in wall cavities. This leads to a reduction in thermal performance of the building envelope and an increase in the energy needed to heat it. Again, little more can be advised regarding recommendations for weather-proofing measures that are not previously referred to within the Regulations.

4.6 Conclusions

Amending the Building Regulations to mitigate for and adapt to a changing climate regime is a rational strategy. It would increase resilience incrementally against some of the extreme events that characterise various aspects of climate change. Although the risk of over-adaptation is a concern, the extra cost associated with designing to higher standards would be relatively modest compared with the cost of retrofitting adaptation measures and/or refurbishment (Camilleri *et al*., 2001; Gething, 2010). Moreover, in terms of competitiveness, legislation would ensure that no party is disadvantaged; all would have the same opportunities because they would be bearing the same climate change related costs. However, unless best practice is adhered to and enforced through Building Control Regulations, the finished product may still not offer the resilience required.

The current Building Regulations and TGDs are comprehensive and are maintained and revised as required, but it is difficult to incorporate specific climate change parameters. It takes 2 to 3 years to review and publish a new TGD, which places even more emphasis on using modelled climate data to inform the standards employed in such revisions. That said, the TGDs incorporate phrases that encourage the use of all available climate information. The key challenge is to encourage reviewers of regulations, TGDs and building standards to utilise future climate projections as well as contemporary and historical data in their revisions. Already, Scotland's Building Standards Division are advocating considering climate change in all Building Regulations reviews.

Recommendations

- Utilise the most recent climate projections to inform regulatory policy with regard to the Building Regulations and Building Control Regulations.
- Incorporate the following phrase into all TGDs:

'*The selection of relevant critical situations for design should be made reflecting the conditions that can reasonably be foreseen during future use.'*

- Revise Building Control policy to meet the standards of other EU members.

4.7 Summary and General Remarks

For robust mitigation and adaptation in the context of construction and climate change, a no-regrets approach is advocated. In a sector in which the final product is designed to last 60 years or more, it will be many years before it becomes apparent whether mal-adaptation has taken place. In a construction context, the cost of over-adaptation is minimal compared to the cost of under-adaptation. Nevertheless, the over-riding contemporary concern within the industry is survival, not climate change. This inertia will have to be overcome before mitigation and adaptation strategies can be effective. This lends weight to the recommendations in this research being enshrined in legislation and incorporated into policy.

On a practical level, increases in zones of wind-driven rain and areas increasingly vulnerable to groundwater contamination will place a premium on land suitable for development, creating a higher demand for space that is likely to exacerbate impacts created by climatic changes. Tighter planning and Building Regulations will also place more pressure on the industry. However, opportunities also exist. The retrofitting of buildings in the context of wind-driven rain, and remedial actions with respect to septic tank systems, offer significant revenue streams. The inclusion of no-regrets adaptation measures at the planning and design stage too can be considered an opportunity to make a step-change in construction practice. If planners and policymakers are cognisant of the issues surrounding projections of more severe wind-driven rain and a greater threat to groundwater from septic tanks, and make the necessary Building Regulations modifications, the result should be a built environment in Ireland that is as climate-proof as is reasonably practicable.

5. Tourism and Climate Change in Ireland – Impacts and Adaptation

5.1 The Tourism and Climate Relationship

Climate is a major pull factor in deciding upon a holiday destination (Bigano *et al.,* 2006; Lise and Tol, 2003; Smith, 1990). Ireland's climate however, does not symbolise the traditional sun, sea, sand package to attract tourists. Ireland's primary tourism drivers are its scenic landscapes (91%), perceived high quality environment (84%) and people (92%). Figures in parentheses indicate percentage of overseas visitors citing the particular factor as 'very important' when selecting Ireland as a place to visit (Fáilte Ireland, 2010). Values have altered slightly over time but these attributes have consistently been the principal ones attracting visitors to the island. Analyses of the annual Visitor Attitudes Survey (VAS) show visitors have reported Irish weather as a negative aspect of their trip. Over the 2002-2010 periods, this ranged from 14-25% of respondents citing the factor. Indeed, 13% of respondents in the 2010 VAS said they would recommend Ireland as a destination but with reservations specifically because of its weather. Largely, this is due to the unreliability of Irish weather and abundance of rainfall (750-1250mm annually) which may interfere with the planned activities of visitors and literally 'dampen' the visitor experience. Because tourism is such an integral component of Ireland's economic and social success, it is essential climate and climate change is considered when discussing the future of Irish tourism at all scales (local, regional, national) so that the industry can optimise adaptation strategies.

5.2 A Changing Climate, a Changing Destination?

Crucially for the peak tourism season in Ireland, July temperatures will increase by 2.5ºC by 2050 and a further increase of 1.0ºC by 2075 can be expected resulting in average maximum July temperatures of 22.5ºC. With projected increases in mean temperatures across all seasons (Sweeney *et al*., 2008), potential exists to develop tourism in off-peak times such as spring and late autumn. While tourism may become more desirable in summer months due to increased mean temperatures there may be less desirable consequences in terms of precipitation and extreme weather events.

It is projected the south and east will be most severely affected by reduced summer precipitation rates. Reductions may reach 25% with decreases up to 40% in some parts of the south and east (Sweeney *et al*., 2008). Such reductions are particularly noteworthy since these regions are the most frequented by visitors. Winter increases in precipitation may result in negative reactions from those who visit Ireland in the off-peak season, particularly November-January. Visitor satisfaction may be negatively affected as Ireland's poor weather is frequently cited as one of the main disadvantages of choosing Ireland as a destination to visit. It must be acknowledged that greater uncertainty exists with precipitation projections than with temperature projections. Since the chance of having 'good weather' is a key motive in choice of holiday destination, it is likely tourists will adapt their travel behaviour according to changes in climate and this may lead to seasonal and regional shifts in tourist flows (Deutsche Bank Research, 2008). Hamilton and Tol (2006) project that countries at higher latitudes and higher altitudes will see increases in tourist flows as a consequence of the shift away from the equatorial regions. Similarly, Perry (2006) suggests the Mediterranean region may become uncomfortably hot for tourists as this century progresses. Ireland is likely to benefit from rising temperatures at the equator, as it will make Ireland and Northern Europe in general, a more desirable destination for tourists, both overseas and domestic.

5.3 Establishing a Tourism Climatic Index (TCI) for Ireland

Climate assumptions help form established tourism flows particularly in the case of regions with favourable conditions for tourism (Holden, 2008). Given that there is a demand for a unitary indicator of climate to quantify significance of climate for tourism, various climate indices have been developed over time for use in tourism climatology research (de Freitas in Hall and Higham, 2005). The most prevalent of these indices is the Tourism Climatic Index (TCI) developed by Mieczkowski in 1985.

The TCI is a quantitative approach used to evaluate an area's climate for the purpose of general tourism activity (light outdoor activities, particularly sight-seeing, the most common tourist activity) and is centred on the notion of tourist's thermal comfort. This human comfort concept was derived by Mieczkowski following an extensive review of scientific biometeorological literature on how temperature, humidity, wind etc. impacted on a person's thermal comfort (Hatch, 1984: Heurtier, 1968; Crowe, 1976). The climate thresholds used in the initial paper by Mieczkowski continue to be used in present day research (e.g. Amelung and Moreno/PESETA Project, 2009; Amelung *et al.*, 2007; Amelung and Viner, 2006; Scott *et al.*, 2004; Whittlesea and Amelung, 2010). Research has indicated the TCI of countries such as the UK will increase, and outdoor activities in northern Europe may become more attractive (Viner, 2006; Amelung *et al.*, 2007). Overall, the development of a TCI in this paper provides an assessment of Ireland's future climate suitability for tourism with the expectation that improved climatic conditions over time can help stimulate and strengthen tourism flows into Ireland.

Mieczkowski's TCI uses seven climate variables, categorised into five sub-indices (Table 5.1). Each variable is assigned a rating between -3 to 5 (see full report for details). The sub-indices are then weighted according to their influence on a person's thermal comfort at a destination (Table 5.1).

Table 5.1 Climatic Components of TCI

Sub-Index	Monthly Climate Variable (Absolute Values)	Weight (%)	Influence on TCI
Daytime Comfort (CID)	Max. Daily Temperature (˚C) Min. Daily Relative Humidity (%)	40	Thermal comfort during peak tourist activity period.
Daily Comfort (CIA)	Mean Daily Temperature (˚C) Mean Daily Relative Humidity (%)	10	Thermal comfort over 24 hours.
Precipitation (P)	Total Precipitation (mm)	20	Negative impact.
Sunshine (S)	Total Sunshine (Hours)	20	Varies depending on amount.
Wind (W)	Average Wind Speed (km/hr)	10	Can be + or – influence.

Table 5.1 Climatic Components of TCI

The rating scores are input into the TCI formula (below) to produce final monthly index scores which can highlight the spatial and temporal distribution of climate resources for general tourism activity.

TCI = 2 [(4 x CID) + CIA + (2 x P) + (2 x S) + W]

Once the final TCI score is calculated, it is possible to label the region's climate according to its suitability for general tourist activity as set out in Mieczkowski's ten qualitative, descriptive categories (Table 5.2).

Table 5.2 TCI Score Descriptive Categorisation

TCI SCORE	CATEGORY
90-100	Ideal
80-89	Excellent
70-79	Very good
60-69	Good
50-59	Acceptable
40-49	Marginal
30-39	Unfavourable
20-29	Very unfavourable
10-19	Extremely unfavourable
9 to -30	Impossible

Historical observed data (1961-1990) was first used to create a baseline TCI for each of the 14 synoptic stations and also aggregated to produce a national TCI. Secondly, TCI was calculated for the 14 synoptic stations using simulated climate projections for the future (2021-2050 and 2051-2080). This permits an examination of the climate change impact on distribution of climatic resources for the country's tourism sector. It is envisaged the mid-century projections can serve as a guide for regional scale action and adaptation while the late-century projections serve as an eye to the long term future where long term adaptation strategies can be developed and implemented.

This research is the first application of the statistically downscaled data from the HadCM3 global climate model dataset generated by Fealy and Sweeney in Sweeney *et al.* (2008) to a tourism climatology model for Ireland. Tourism Climatic Index scores were calculated for the future time-slices of 2021-2050 (mid-century) and 2051-2080 (late-century) under the A2 SRES projection. This study is limited to the A2 (medium-high) scenario given this is now assumed to be closer to the reality of our future emissions pathway than the B2 scenario, which was also part of the Fealy and Sweeney (2008) work. Using these projections, future TCI scores were calculated for the 14 synoptic stations under two future time-periods and also aggregated for a national TCI score for Ireland for the 2021-2050 period and 2051-2080 periods. Sunshine and Wind variables are not included in the modelling of future climate scenarios. Therefore, the observed baseline data for Sunshine and Wind was also used for the future modelling. This approach has been employed in similar studies on future TCI calculations where certain variables are lacking (e.g. PESETA Report, 2009).

5.4 Discussion of TCI Results

Using Scott and McBoyle's (2001) conceptual typology of annual tourism climates, Ireland's Tourism Climatic Index over the three time periods analysed illustrates a 'Summer Peak' distribution (Figure 5.1) becoming more pronounced later into the century. The TCI scores from the shoulder seasons (late-spring and autumn), are projected to broadly increase thereby offering the potential to extend the current summer high-peak season. When disaggregated, each of the fourteen synoptic stations examined also display a summer peak distribution in their TCI curve with significant improvements in TCI scores as the century advances. Changes in reliability of the climate and expansion of the tourist season will not be immediate, but will become more evident within 25-35 years. The earliest beneficiaries will be tourism facilities along the southern and eastern areas of Ireland which are projected to have significantly drier climate conditions.

Seasonal breakdown of TCI scores highlights the seasonal pattern to Ireland's tourism industry with most suitable conditions for general tourist activity occurring during the summer season (Table 5.3) for the Baseline 1961-1990 period. This season falls into the Acceptable-Good category (Table 5.2).

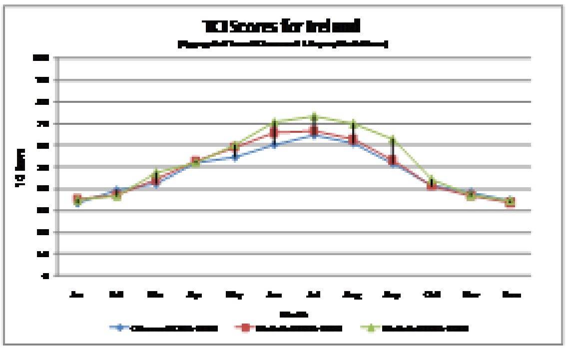


Figure 5.1 Monthly TCI scores for Ireland over three time periods under A2 SRES

Table 5.3 TCI Scores for Summer 1961-1990

Month	May	Jun	Jul	Aug	Sep
TCI Score	54	60	65	61	53

TCI scores improve as the century progresses, increasing to 'Good' in some summers. A slight extension of suitability into May occurs during 2021-2050 (Table 5.4).

Table 5.4 TCI Scores for Summer 2021-2051

Month	May	Jun	Jul	Aug	Sep
TCI Score	59	66	67	63	53

Again, in the third time period studied 2051-2080, TCI scores improve with three summer months classified as being 'Very Good' (Table 5.5) which is the desirable level according to TCI literature. Importantly, May sees a significant improvement in TCI score from the Baseline period.

Table 5.5 TCI Scores for Summer 2051-2080

Month	May	Jun	Jul	Aug	Sep
TCI Score	60	71	73	70	63

When the temporal visitor arrival distribution is examined (Figure 5.2), these display a similar pattern to the summer-peak TCI curves (despite dip in June); tentatively suggesting the TCI approach does have a valid place in the marketplace. Further correlation research is required in this area.

The findings substantiate the existing body of literature suggesting Ireland will be a country expected to benefit from expected regional shifts in tourist travel under climate change (Amelung et al., 2007, Hamilton and Tol, 2006; Bigano et al., 2006, Perry, 2003). Indeed, Ireland is touted as being a 'Star' of tomorrow by DB Research (2008) on the impact of climate change on global tourism. An increased demand from domestic tourism is also likely to emerge again highlighting the opportunity for tourism industry stakeholders to capitalise on such projections of change.

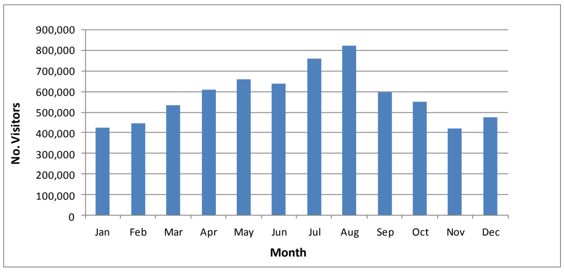


Figure 5.2 Monthly Visitor Arrivals, 2009(Source: CSO, 2013)

5.5 The Importance of Maintaining a High Quality Natural Environment for Tourism

A high quality natural environment is essential for a successful tourism industry (Holden, 2008; Coles, 2003; Mathieson and Wall, 1982) and Mieczkowski (1985) suggests 'the very existence of tourism is unthinkable without a healthy and pleasant environment, with well-preserved landscapes and harmony between people and nature'. From an analysis of Fáilte Ireland's Visitor Attitudes Surveys (2005-2010), it is evident Ireland's rich natural resources and environmental attributes are core visitor demand drivers (Table 5.6). Ireland is perceived by its visitors to have largely unspoilt landscapes and they are our ‘unique selling point’, the primary tourism driver next only to the Irish people. This impression is one which should be maintained so that we continue to attract visitors who want to experience our unique heritage and culture and aesthetical appeal of the landscape. Any change in the quality of the tourist experience (which drives underlying demand) may impact on visitor satisfaction levels and rate of return visits.

	2005	2006	2007	2008	2009	2010
Beautiful scenery	90	90	89	88	89	91
Unspoilt environment	86	85	83	80	80	84
Attractive cities/towns	60	58	54	57	N/A	N/A
Range of natural attractions	N/A	85	80	80	80	82

Table 5.6 Importance of Environmental Factors when considering Ireland as a Destination
(Source: Fáilte Ireland: Visitor Attitudes Surveys)

Potential future extreme climatic events are likely to include increased risk of landslides, bog bursts and scarring of the landscape due to the increased occurrence of prolonged dry periods. The 2006 Derrybrien landslide in south County Galway is an exemplar of such an impact, with visible scars still remaining on the hillside. Popular and lucrative activities undertaken by visitors to Ireland include walking, cycling and golfing and participation is often driven by the desire to experience the natural landscape and environment Ireland has to offer. Such landscapes rely on Ireland's temperate and moist climate so any impacts on the natural environment, such as those posed through climate change, are likely to impact on tourists’ perceptions of Ireland and ultimately impact on the success of Ireland’s tourism product. Therefore, as discussed in Chapter 3, a sustainable landscape management approach should be adopted to augment resilience of ecosystems and natural landscapes into the future.

5.6 Adaptation to Climate Change: Water and Tourism

Water is an essential natural resource for a successful tourism sector and Ireland has an overwhelming proportion (90%) of ‘good’ quality sites which are compliant with EU guide and mandatory values (EPA, 2011). Water is used in accommodation facilities, for activities, during transportation and for personal use. Water consumption by tourists is generally above-average compared with the local population (Holden, 2008). Since a large share of visitors to Ireland stay with ‘Friends and Relatives’ and in small accommodation establishments or city hotels, it can be estimated that each tourist uses approximately 150 litres of water per day (Gössling *et al*., 2011). When tourists stay in more exclusive accommodation facilities and partake in water reliant activities (swimming pools, golfing, spa and wellness centres), the proportion of water use rises significantly. For example, 15,000m³ of water can supply 100 urban families for two years but can only supply 100 luxury hotel guests for 55 days (Salem in Holden, 2008).

Under a changing climate, there is likely to be a general increase in the overall attractiveness of water resources for tourism. At the same time, one must acknowledge the potential negative impacts both from increased usage and also climate change which are dealt with in Chapter 2 of this report. Changes in the quality of water are also likely with a greater risk of eutrophication and increased frequency of low summer flows. Marine ecosystems and fish stocks may also be altered, and increased storminess may impact upon coastal activities (Heritage Council and Fáilte Ireland, 2009). Indeed, coastal infrastructure may become more vulnerable due to sea-level rise and associated storm surge activity (Chapter 6). Construction of new tourist infrastructures should consider exposure levels of the proposed site and build with a changing climate in mind (Chapter 4).

5.7 Tourism Supply-Demand Issues in Water Resource Management

Critically, water supply in Ireland is designed to cater for the permanent resident population as listed in official Census population figures. It generally does not account for increased demand during the peak tourist season when population significantly increases in many areas due to visitor arrivals. For all sectors, climate change will present in serious water resource management issues, as discussed in Chapter 2, with eastern regions particularly affected. Tourism is highly dependent on a reliable water supply and this reliability may be compromised through climate change. Dublin ranks as the most visited tourist region in Ireland, followed by the South West, West and South East. High volumes of visitors to water-stressed regions create additional pressure on the availability of water under the existing supply infrastructure particularly during peak high-season periods (May-August).

Visitor attractions should consider implementing and monitoring water use so that the quality of the attraction is not compromised for future users of the product. Some of the most frequently visited attractions in Ireland are concentrated in the Dublin region and are intensive water users (e.g. Guinness Storehouse, Dublin Zoo, and National Botanic Gardens). An area already under water supply stress, this is likely to be exacerbated into the future as population in the region continues to grow along with additional visitor numbers yet water availability will be reduced. The south and east coasts will become more susceptible to drought periods during summer and early autumn months as the century advances. The need for irrigation of agricultural, recreational and municipal lands will become increasingly necessary and will lead to additional pressures on an already stressed water supply system. All the while, demand from the tourism sector is likely to also be amplified. It is important an upgrade of water infrastructure (Chapter 4) is considered at pivotal tourism centres to allow for a more sustainable consumption of water across all seasons. Local Authorities and tourism boards need to be aware of this issue and will require detailed information on how best to adapt to likely supply-demand issues. Some of these adaptation options are outlined in Chapter 2.

5.8 Adapting to Climate Change

As an industry sensitive to change, tourism must adapt to climate change to reduce risk and vulnerability while augmenting resilience. Over two decades ago, Smith (1990) highlighted the need for immediate planning and adaptation to the impacts of climate change on tourism and more recently the UNWTO has placed the issue firmly on its agenda (UNEP and UNWTO, 2008; UNWTO, 2007). The EU Commission advises that for impacts where we have enough confidence in the projections, adaptation strategies must not be delayed (European Commission, 2009a). Orlove (in Adger *et al.*, 2009) suggests the term ‘adaptation’ contains the promise that problems can be addressed and beneficial opportunities exploited. This can be the case for Irish tourism provided appropriate adaptation planning and implementation measures are taken.

To avoid serious economic and environmental damage to tourism, Dubois and Ceron (2006) advocate the precautionary approach when dealing with climate change adaptation. However, the majority of stakeholders in the industry have yet to take action. Holden (2008) stresses; "as a key stakeholder and catalyst to tourism development, the industry should address its roles and responsibilities to the environment". It is imperative that with a changing climate, a strong environmental ethic is at the heart of Ireland's tourism industry in order to maintain the quality and integrity of the natural environment as its principal tourist asset.

Tourism is a somewhat fragmented sector, composed largely of SMEs. This adds to the existing challenges of successful coordination for adaptation. Owing to this multi-faceted nature of the industry, successful adaptation to climate change will require extensive cross-sector cooperation and integrated governance, an issue further outlined in Chapter 7. Tourism is linked with several other sectors in society. Taking the example addressed earlier, water resource management spans many sectors; agriculture, industry, households, sports grounds, biodiversity etc. Adaptation within tourism can take the form of both soft and hard measures. Soft measures are relatively inexpensive and do not require vast capital investments. Examples include water, energy and waste conservation, raising customer awareness of issues, planning ahead through risk and vulnerability assessments, capacity building, updating disaster risk management strategies and diversifying activities. Hard measures are more costly. They include defence and relocation measures such as sea wall structures to protect coasts, buildings, more efficient, cleaner transportation modes. Hard adaptive measures may be the only solution if delayed action occurs. It is advisable to take the precautionary approach when dealing with climate change adaptation so as to minimise financial burdens on tourism businesses in the long term.

It is generally expected tourism leisure and recreational activities will benefit from warmer summers associated with climate change provided they are managed appropriately. This may help diversification of the Irish tourism product and may include further development of outdoor activities and nature-based destinations (Fischer, 2007). Figure 5.4 in the main report shows popular outdoor activities undertaken by overseas visitors to Ireland which contribute combined revenue of over €800M (Fáilte Ireland, 2010). With a more stable summer climate and greater chance of dry weather conditions, the further expansion of outdoor leisure and recreation activities will be possible. However, while drier, warmer weather may encourage such activities, the quality and satisfaction of these types of visitor experiences may also be jeopardised by climate change as safety concerns for stability of lands, walking trails and the occurrence of extreme events will increase in winter months. Water-based activities such as surfing, boating, water-sports in Ireland's coastal and inland waterways will be given further potential to grow and attract both domestic and overseas users (Heritage Council and Fáilte Ireland, 2009). Furthermore, warmer summer and autumn months may assist the establishment of a continental style 'café' culture which holds strong potential for restauranteurs (McEvoy *et al.,* 2006). A further extension of the diversification of tourism activities may be the development and consumption of sustainable tourism products.

Sustainable tourism, as defined by the Department of the Environment, Heritage and Local Government (DoEHLG, 1997), is a way of "minimising adverse impacts on local communities, our built heritage, landscapes, water resources, habitats and species while supporting social and economic prosperity". Currently, the Irish tourism sector is largely a 'product-led' sector where economic growth of the industry is the central concern. Awareness and conservation of the natural environment is a secondary concern. There are some exceptions to this type of development such as the Greenbox region, Burren-Beo project and the Green Hospitality Programme. Sustainable tourism development must be encouraged in Ireland so that the country's competitive balance in the broader European context is not compromised. Ireland should actively aim to develop a more carbon neutral product offering so that the tourism industry can position itself in the best possible way to act on the opportunities brought from a changing climate and to capitalise on the changing demands of more environmentally conscious consumers. Into the future, Irish tourism must be developed in a manner that is sustainable in the longer term but of course also in a way that will simultaneously reap the economic benefits. This can be achieved through standardised education and training programmes to aid the development of sustainable tourism products

5.9 Conclusions

Climate change will see a warmer, more reliable summer tourist season. The frequency of two very good summer months being experienced will gradually increase. There is a real possibility the tourist season can be successfully extended into shoulder periods of April/May and potentially October as evident from projected changes in Ireland's Tourism Climatic Index. Globally, visitor numbers are projected to increase, further augmenting the significance of the industry for the economy. The emergence of 'green-consumers' represents a shift in the values of a significant sector of the market. Unlike popular Mediterranean regions, heat will not be overly oppressive and therefore, poses an opportunity for Ireland to attract visitors who are migrating away from warmer destinations and to diversify the tourism product further.

However, it is important Irish tourism will have the sustainable product offerings available to reap maximum benefit. The extent of the more negative changes depends greatly on the actions or inactions taken now by all the stakeholders involved; from public and private sectors of the government, industry and community. As discussed in this report and by others (Sweeney *et al.*, 2008), the look and feel of Ireland's landscapes, environment and unique ecosystems and habitats is expected to change. Given these are among Ireland's primary assets and core tourism drivers, it is imperative they are protected and their integrity maintained. The tourism industry should continue to proactively 'address its role and responsibilities toward the [natural] environment' (Holden, 2008). If undue damage is to be avoided, it is imperative forward planning begins immediately and appropriate adaptive measures are implemented and monitored in a sustainable manner. Ultimately, tourism stakeholders and governmental responses to climate change should be integrated into broader risk management plans and policies.

6. Economic Analysis of Impacts and Responses

6.1 Climate Change and Adaptation

The economic impacts of climate change were brought fully to the attention of the public consciousness with the publication of the Stern Review (Stern, 2006). This report suggested that the expected benefits of tackling climate change would far outweigh the expected costs, and that early action would be preferable to reduce and avoid the worst impacts. The key messages from the economic modelling carried out forecast that an increase of global average temperatures of 2-3°C could lead to an equivalent loss of up to 3% in global GDP, with poorer countries suffering the highest costs. (3% of Irish GDP at current prices is approximately €4.8B). With global temperature increases of 5-6°C, the losses in global GDP are estimated to be in the region of 5-10%, with poor countries suffering costs in excess of 10%. However, the risks covered in the assessment cover a very broad range and involve the possibility of much higher losses. Adaptation costs are also discussed in the report with a focus on the additional costs of new climate-resilient infrastructure and buildings. These costs are estimated to range from €11-111B each year in OECD countries (0.05-0.5% of GDP), depending on the warming scenario and would equate to €80-800M in terms of Irish GDP at current prices (Stern, 2006)..

Adaptation in developed countries is considered to still be at an early stage, even though there are well-developed market structures and the capacity to adapt is relatively high. The Stern Review believed that market forces are unlikely to deliver the full response needed to deal with climate risks. It is thus incumbent on governments to provide clear policy frameworks to guide effective adaptation by individuals and organisations in the medium to long term (Stern, 2006). The World Bank warns that global mean temperature increases in the magnitude of 4°C will significantly increase the likelihood of irreversible and potentially catastrophic impacts including extinctions for half of our species worldwide, inundation of up to 30% of coastal wetlands and significant increases in malnutrition (World Bank, 2009). This work forecast that the cost, between 2010 and 2050, of adapting to an approximately 2°C warmer world by 2050 is in the range of €56B to €74B a year.

The study takes a bottom up approach and presents economic case studies on three specific areas: potential sea-level rise (SLR) related impacts, biodiversity impacts along the Irish coast, and inland flooding impacts for selected river catchments. These particular areas of interest are highlighted by the European Commission's Joint Research Centre as areas of concern for Ireland (European Commission, 2009b). These areas also mirror those considered under the United Kingdom Climate Impacts Programme (Jenkins *et al*, 2009) and various regional impacts studies coordinated by ClimateUK (ClimateUK).

6.2 Sectoral Economic Considerations

6.5.1 Sea-level rise

Sea level rise is an issue of significant concern when looking at climate change vulnerabilities at a global scale. It contributes to losses of coastal wetlands, mangroves and increasing damages from coastal flooding (IPCC, 2007a). Rahmstorf projects that a rise of over 1 metre by 2100 for strong warming scenarios (Rahmstorf, 2007). A recent review finds end of century SLR estimates to range from 0.5m to 2.4m (Nicholls *et al*, 2011).

The Irish coastline is 4,577 km in length. More than 50% of the population lives within 15km of the coast, with most of the population concentrated in the major coastal cities of Dublin, Cork, Limerick and Galway. Coastal exposure is the cumulative result of a number of significant factors including, climate-induced SLR, tidal variation, wave climate, currents and non-periodic water movement such as storm surges and coastal geomorphological composition. In Ireland post-glacial isostatic rebound is another factor to consider and results in SLR of a lesser magnitude in the northern half of Ireland compared to the south (Carter *et al*, 1989).

There is a strong variation in topography between the coasts of the Atlantic Ocean and the Irish Sea; the Atlantic coastline is defined by a high relief of approx 500 metres of rocky cliffs interspersed with bays (European Commission, 2009b). In contrast, the Irish Sea coast is composed mainly of low-lying regions with non-consolidated sediment and glacial tills (unsorted glacial sediment). Approximately 20% of Ireland's entire coast is at risk of erosion (European Commission, 2009b) with sea level rise already having a significant impact on the soft boulder clay coasts of the east in the form of erosion. Currently only approximately 4% of the Irish coastline is protected by coastal defences (Devoy, 2008). Counties Dublin, Down, Louth, Wexford and Wicklow are where retreat is fastest occurring, with erosion rates exceeding 3 metres per year in extreme cases. However, the west and south are also affected with low-lying bays and estuaries such as Cork Harbour, Clew Bay, Tralee Bay, and especially the Shannon Estuary, displaying increased exposure to sea level rise (Devoy, 2008; Sweeney *et al*, 2008).

Sea surges can be defined as the difference between predicted and observed still water levels, usually measured at high tide. The extreme 50-year surge heights are approximately 1-1.5 metres on the Irish coast (Orford, 1989; Lennon 1963a; 1963b). Surge events will increase on Irish coastal areas over the next decades with model results indicating an increase in both the frequency and height of extreme storm surges (in excess of 1 metre) (Orford, 1989). The most extreme surges will occur over winter periods on the west and east coasts (Wang et al, 2008). Models suggest that one-in-100-year coastal flood events are likely to become one-in-10-year events (McGrath and Lynch 2008).

Figure 6.1 presents the output of SLR modelling carried out for this study on the Irish coast. The modelling is based on the manipulation of a digital terrain model (DTM) of the Irish Republic. Although the resolution of the DTM is not sufficient for modelling sea level change in a detailed manner at a local level, as there are significant errors in the vertical projections of the model (Coveney *et al*, 2010; Gornitz *et al*, 2002), a number of studies have been carried out using such medium resolution DTMs for regional or national assessments (Li *et al,* 2009; European Environment Agency, 2006; Dobosiewicz, 2001). The modelled output does not account for existing coastal defences. However, this qualification is not especially limiting as currently less than 4% of Ireland's coast is protected by built structures (Devoy, 2008). This study is thus framed as a national estimate exploring some of the potential economic impacts of sea-level and storm surges on the Irish coastline. The modelling uses six projected sea-level rise scenarios from 0.5 metres to 6 metres drawn from the envelope of possible SLR and storm surge scenarios in the literature (Rahmstorf, 2007; Overpeck *et al*, 2006; Hoozemans *et al*, 1993, Nicholls *et al*, 2011). Table 6.1 displays the vulnerable percentage of land in each coastal county. Louth, Dublin and Wexford face the greatest percentage losses ranging from over 1% in the first scenario (0.5m) to over 6% in the sixth (6m)

Building on the initial modelling of vulnerable land areas, the An Post Geo Directory (a database listing all postal addresses in the Irish republic along with associated x,y coordinates) was then used in conjunction with the projected sea level scenarios to estimate the number of addresses that would be potentially impacted under a SLR/storm surge event. Figure 6.2 presents a representation of the Dublin Bay area displaying residential and commercial addresses overlaid on the six sea-level rise scenarios. Figure 6.3 below displays all vulnerable addresses in Leinster.

Case study one: Irish sea-level rise modelling and results

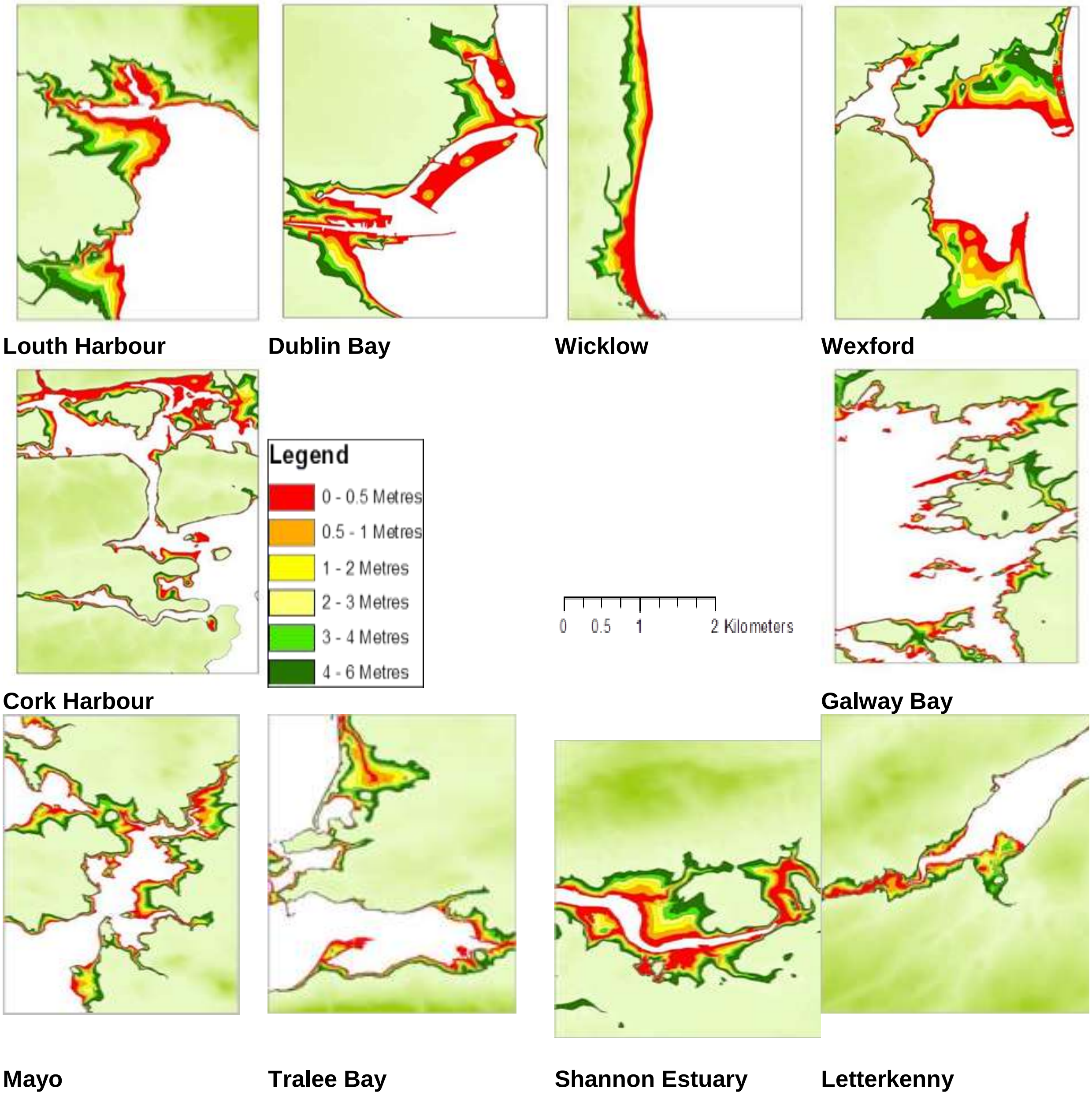


Figure 6.1 Sea-level rise scenarios on the Irish coast employing a digital terrain model

Table 6.1 Exposed percentage of land in each county under the six scenarios

	Sea Level Rise Scenarios					
	0.5m	1m	2m	3m	4m	6m
Provinces/Counties						
Leinster	Exposed Percentage of Land per County					
Louth	1.2	2	2.7	3.5	4.3	6.1
Meath	0.1	0.1	0.2	0.2	0.3	0.3
Dublin	1.6	2.2	2.8	3.4	4	5.4
Wicklow	0.3	0.4	0.6	0.7	0.9	1.2
Wexford	1.1	1.6	2.3	2.8	3.4	4.6
Munster						
Waterford	0.3	0.6	1	1.3	1.7	2.7
Cork	0.4	0.5	0.7	0.9	1.1	1.5
Kerry	0.5	1	1.5	2.1	2.6	4
Limerick	0.4	0.6	0.9	1.1	1.3	1.8
Clare	0.5	0.8	1.2	1.7	2.1	3.1
Connaught						
Galway	0.4	0.6	0.8	1	1.4	2.2
Mayo	0.3	0.5	0.7	0.9	1.2	1.7
Sligo	0.4	0.5	0.7	0.8	1.1	1.6
Leitrim	0	0	0	0	0.1	0.1
Ulster						
Donegal	0.4	0.8	1.1	1.5	1.9	2.7

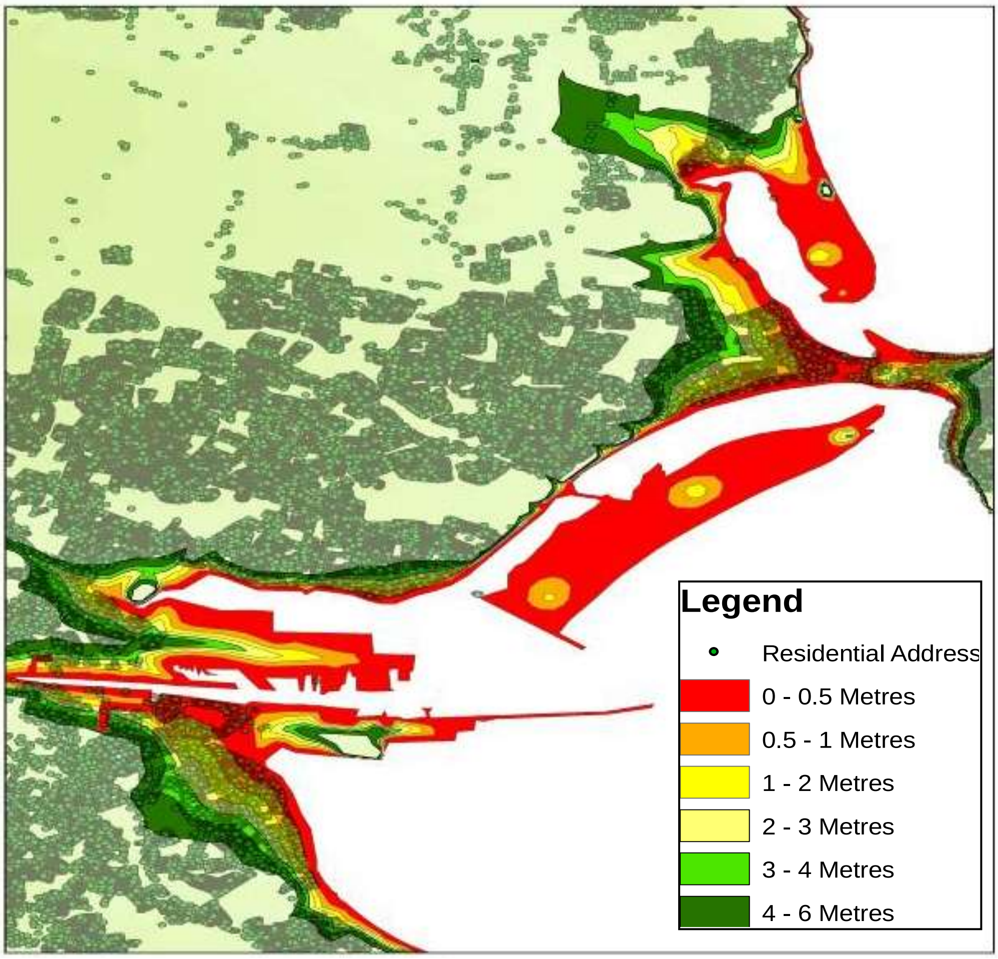


Figure 6.2 Residential addresses displayed over sea-level scenarios in Dublin Bay area

Table 6.2 Cost of November 2009 and October 2011 flooding by claim type(Source: IIF, 2010; 2012)

Claim Type	No of Claims Nov 09'	Oct 11'	Cost of Claims Nov 09'	Oct 11'
Household	4,629	3,532	€76.8M	€58M
Commercial	1541	1,251	€158.9M	€59M

At a national level Dublin, Cork and Galway have the most vulnerable addresses ranging from 500 addresses in Galway, 5,000 in Dublin and over 6,000 in Cork under the first scenario. Using the information on vulnerable addresses determined from the modelling results and in conjunction with flood claim costs a generalised damage cost estimate of SLR and storm surge events was calculated.

Figures released by the Irish Insurance Federation (IIF) in 2010 and 2012 uncovered the insurance costs relating to flood damages from the substantial November 2009 and October

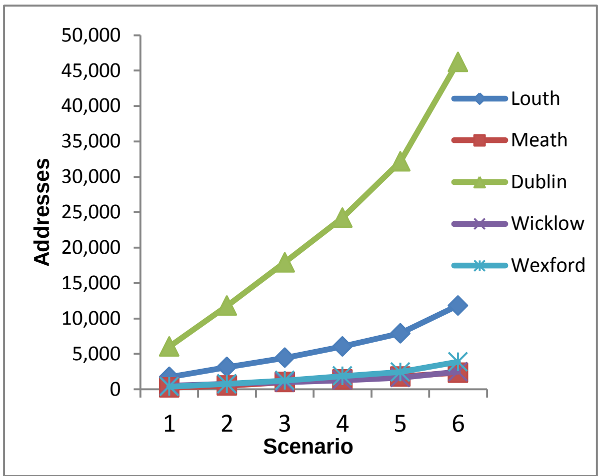


Figure 6.3 Total exposed addresses in Leinster under the six scenarios

2011 flood events (Table 6.2). The majority of the November 2009 flood costs were realised in Munster, the West and the Midlands. The three counties worst hit were Cork, Galway and Clare. Dublin was the main county impacted in the October 2011 flood events. Using the figures presented as a guideline, an estimate of the average claim was calculated for residental and commercial properties over the two events. (Residential: €16,500, Commercial €75,000). Joint use properties were estimated at €46,000. Table 6.3 shows the potential cost for all claims under each of the scenarios. However, it must be noted that the specific nature and timeframe of any SLR or storm surge event will be reflected in the typical insurance claim costs. These costs should therefore be considered as potential costs that would occur if any one of these scenarios transpired in the medium term without significant adaptation measures.

Under the one metre SLR scenario one can see that Cork and Dublin would be are impacted to the greatest extent with projected costs of €361M and €303M respectively (Table 6.3).

6.5.2 Ecosystem Goods and Services

Ecosystems are dynamic and complex communities of plants, animals and micro-organisms and their non living environments, which include air, soil, water and sunlight and acts as a functioning unit (Campbell and Reece, 2002). Deserts, wetlands, rain forests, urban parks and cultivated farmlands are examples of ecosystems. Ecosystem services, also known as environmental services or ecological services, are the "benefits" that people obtain from ecosystems (Tietenberg and Lewis, 2012). The total value of the world's ecosystem services was conservatively valued in 1997 to be in the range of €12-40 Trillion (10^{12}) per year with an average of €24 Trillion (T) per year (Costanza *et al*, 1997). Most of this value is not captured directly within existing markets and this is considered a minimum estimate because of the level of uncertainties involved (Pimm, 1997). The estimated total marginal value of ecosystem services in Ireland is €2.6B per annum. This qualified total captures the value of ecosystem services in terms of their contribution to productive output and human "utility". (Bullock *et al*, 2008).

Coastal Wetlands and their valuation

Wetlands provide an array of important services to human society and are highly ecologically sensitive systems. The Ramsar working definition of a wetland is: 'areas of marsh, fen, peatland or water, whether natural or artificial, permanent or temporary, with water that is static or flowing, fresh, brackish or salt including areas of marine water, the depth of which at low tide does not exceed 6m'. Little work exploring the economic valuation of wetlands has been completed in the Irish context to date with the exception of Devoy (2008). The following analysis is an estimate of some of the potential economic losses resulting from modelled SLR impacts on Irish wetlands. A direct value transfer method was used to capture order of magnitude costs. This method holds the advantage of avoiding the time consuming and expensive primary valuation studies but due to the generalised nature the valuations are subject to error (Brander *et al*, 2006).

The following case study explores the potential economic impacts of three sea–level rise scenarios (0.5m, 1m and 2m) on three Irish coastal wetland systems. Beaches, dunes and sand wetlands are explored along with coastal lagoons and salt marshes using the CORINE 2006 dataset. Figure 6.4 displays the distribution of salt marshes along with the vulnerable percentages loss under the three scenarios. Table 6.4 provides a breakdown of the total area occupied by the three wetland habitats. The vulnerable area of each type, is expressed as a percentage. A gross economic estimate of the vulnerable area of each wetland type is determined using the average European wetland value per hectare of 9,000US$ (approx €6,700) as calculated by Brander *et al* (2006). Total percentage losses of the wetlands under the 1 metre scenario range from 14 to 49%. This compares with estimates of global wetland losses in the range of 25-50%, also based on a 1 metre SLR scenario (Watson *et al,* 1995). The

Table 6.3 Potential insurance claims for all coastal counties under six scenarios

	Sea Level Rise Scenarios					
	0.5m	1m	2m	3m	4m	6m
Provinces/Counties						
Leinster		€M for All Claims				
Louth	43	80	111	153	197	294
Meath	5	12	22	30	37	46
Dublin	151	303	458	607	806	1,194
Wicklow	16	22	28	39	50	77
Wexford	11	21	36	54	72	114
Munster						
Waterford	13	23	38	61	78	121
Cork	267	361	439	510	582	737
Kerry	11	19	31	46	68	148
Limerick	50	75	97	112	130	184
Clare	10	19	34	65	119	226
Connaught						
Galway	12	33	58	89	125	234
Mayo	5	10	13	16	21	37
Sligo	4	11	18	24	29	47
Leitrim	0	0	1	1	1	1
Ulster						
Donegal	18	35	48	66	82	132
Total	**617**	**1,025**	**1,431**	**1,872**	**2,399**	**3,592**

assumption is made, in the modelling results, that once a particular wetland is submerged as a result of increasing sea levels it will not be replaced. However, temporary inundation, due to

Figure 6.5 Distribution and potential loss of salt marshes under 3 SLR scenarios

storm surge events, also creates significant damage to wetland flora and fauna as a result of increased salinity levels (Hart et al, 1990). The most vulnerable coastal beaches, dunes and sandy shores can be found in Dublin, Waterford and Wexford. Dublin is at risk of losing its Bull Island wetland (150ha) where increased SLR could lead to losses of over 80% for a half metre rise, up to 90% for a 2 metre rise. Due to the much greater area of Wexford's coastal beaches, dunes and sand of approximately 1,000 hectares, its possible losses at approximately 40% for a metre SLR will lead to the greatest loss of this wetland type in the country. These coastal features may not be entirely destroyed but rather displaced. The coastal lagoons of Wicklow (42ha) and Wexford (293ha) are at the greatest risk with possible losses of over 90% a one metre SLR scenario. For Ireland's salt marshes the greatest percentage losses occur in Wicklow (Figure 6.4) (60% for a 1 metre scenario) and Waterford (54% for a 1 metre scenario) where salt marshes make up 180ha and 84ha respectively. It is probable that the greatest area lost will occur in Clare and Kerry at over 30% salt marsh loss with a 1 metre SLR occurring on existing salt marsh areas of 1,303ha and 760ha respectively.

Table 6.4 Impact of Sea Level Rise on salt marches

Salt Marshes			
Scenario	0.5m	1m	2m
County	Exposed % Loss		
Kilkenny	22	34	44
Waterford	35	54	68
Sligo	21	31	40
Wicklow	38	60	83
Limerick	26	27	28
Donegal	25	37	44
Galway	27	34	39
Dublin	45	52	57
Cork	31	40	49
Louth	28	29	29
Wexford	12	15	19
Kerry	23	32	40
Clare	24	31	36

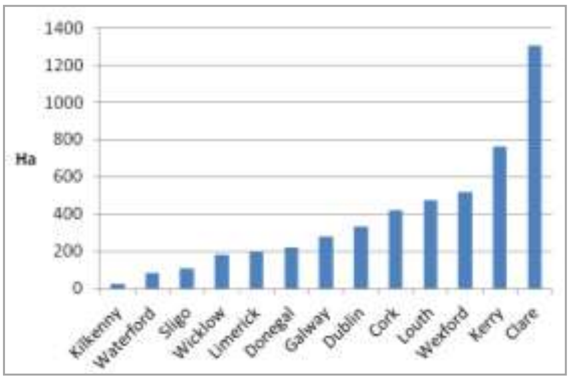


Figure 6.4 Loss of Sea Marsh area by county for 1m SLR

Table 6.5 Irish wetlands; displaying total area of each wetland, exposed % of total land for each wetland under the 3 scenarios along with € M value per hectare per year			
Wetland Feature	**Total Area (ha)**	**Exposed % of total**	**€ M Value $ha^{-1} yr^{-1}$**
Beaches, Dunes and Sand	10,890		
0.5m Scenario		10	7.6
1m Scenario		14	10.4
2m Scenario		17	12.8
Salt marshes	4,907		
0.5m Scenario		26	8.5
1m Scenario		33	10.9
2m Scenario		39	12.9
Coastal lagoons	820		
0.5m Scenario		47	2.6
1m Scenario		49	2.7
2m Scenario		50	2.7

6.5.3 Irish Inland flooding case study

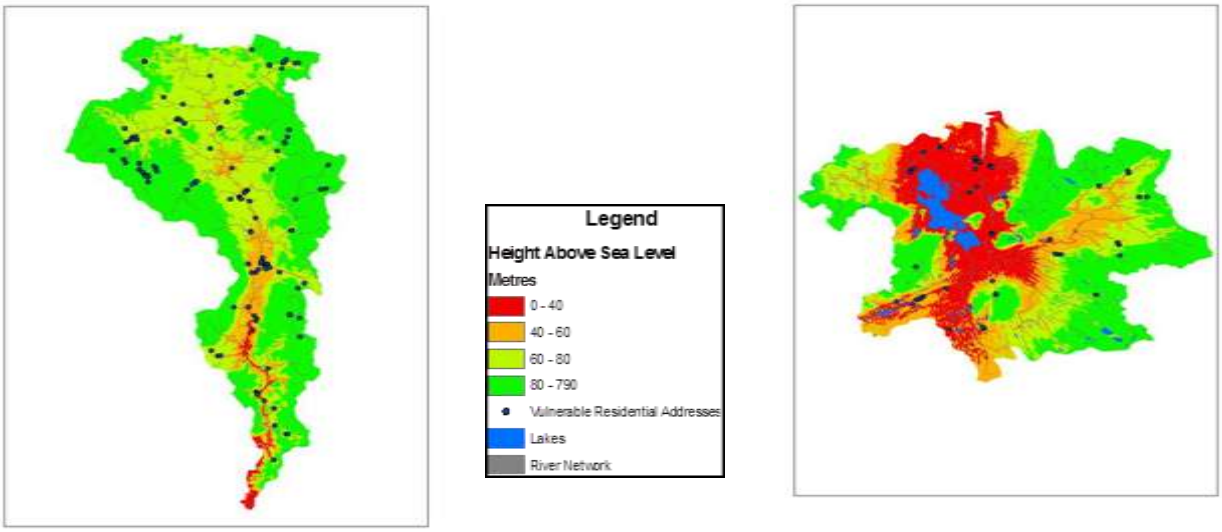
It is likely that Irish river flow will increase by approximately 20% in winter and spring by mid to late century. In turn, flood events are predicted to become more frequent, with a current 50-year event moving closer to a 10-year return period (Murphy & Fealy, 2010). Future flood events will necessitate construction of significant defences. The Office of Public Works is the lead agency on flood risk assessments and flood mapping in Ireland with their Catchment Flood Risk Assessment and Management Studies Plan (CFRAMS) to be carried out for each river catchment in and their Flood Hazard Mapping Programme (FHMP). The CFRAMS programme began in 2011.

Detailed costs relating to flooding in Ireland are not available. However, the estimates of the insurance costs of the November 2009 and October 2011 floods by the Irish Insurance Federation (IIF) provide useful data on economic impacts for inland flooding (Table 6.6) (IIF, 2010; 2012). This report presents some indicative modelling results for four Irish catchments. Hydrologically adjusted DTMs of the case study catchments were used to determine the major river networks in each catchment. A hydrologically adjusted DTM is an adjusted elevation raster in which any depressions in the source DTM have been eliminated (filled), but which allows for internal drainage since some landscapes contain natural depressions. A series of elevation buffers (1m, 2m and 3m) were then fitted to each river network. Point data

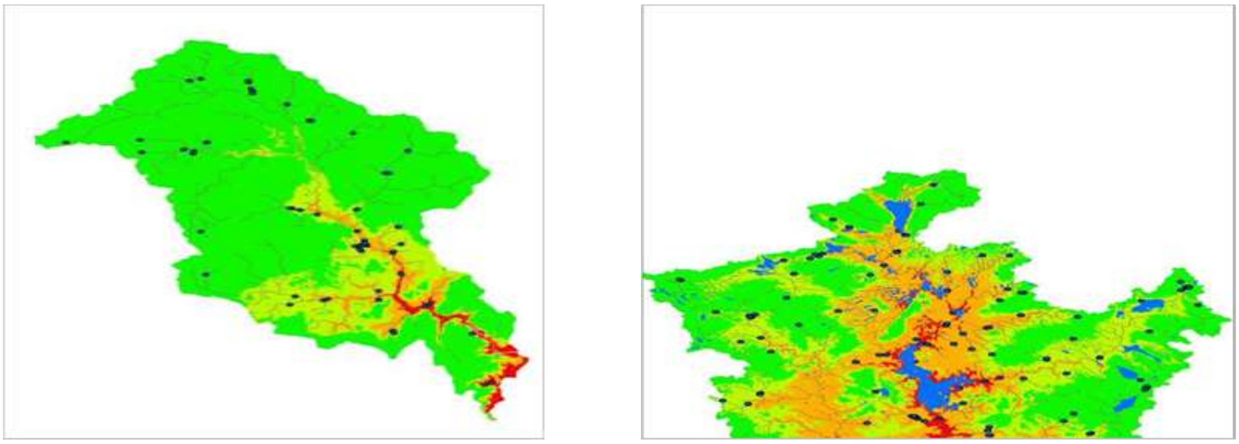
Table 6.6 Potential flood costs for four sample catchments

Residential Addresses					**Commercial Addresses**			
	Buffer					**Buffer**		
Catchment	**1m**	**2m**	**3m**		**Catchment**	**1m**	**2m**	**3m**
Barrow	571	618	697		**Barrow**	62	66	78
Shannon Upr.	403	457	559		**Shannon Upr.**	79	88	103
Nore	193	210	229		**Nore**	59	64	73
Moy	229	262	299		**Moy**	48	52	57
	€ Thousands					**€ Thousands**		
Barrow	9,422	10,197	11,501		**Barrow**	4,650	4,950	5,850
Shannon Upr.	6,650	7,541	9,224		**Shannon Upr.**	5,925	6,600	7,725
Nore	6,650	3,465	3,779		**Nore**	4,425	4,800	5,475
Moy	3,779	4,323	4,934		**Moy**	3,600	3,900	4,275

providing Irish addresses from the An Post Geo



Barrow catchment Moy Catchment



Nore catchment Shannon Upper catchment

Figure 6.6 Irish catchment modelling displaying exposed addresses and potential costs

Database were then overlaid on the catchments to create an indicative assessment of vulnerable residential and commercial properties under the three buffer scenarios. The results (Figure 6.5) signify that the Barrow has the greatest number of exposed residential addresses under a one metre buffer at approximately 571 and the Shannon Upper catchment has the greatest number of exposed commercial addresses at approximately 79 with potential losses of €9.4M and €5.9M respectively.

6.3 Conclusion

Economic impacts of climate change are estimated to range between just over 1% of global GDP to over 10% per year depending on the economic model employed, discount rate assumptions and climate scenario. An impact of 2.5% of GDP would equate to, mid century, economic impacts in Ireland of approximately €4B per year at current prices. Estimated global adaptation costs range from €36-127B per year with Irish adaptation costs estimated at between €80-800M per year in terms of Irish GDP at current prices. Caveats of assumed discount rates along with the timing and extent of climate change impacts and indeed adaptive responses are important to consider when looking at such figures. Nonetheless these figures convey the message that climate change impacts far outweigh adaptation costs. This argument is strengthened further when factors such as the non-substitutability of natural systems are fully considered.

This chapter considered three areas vulnerable to climate change impacts in the Irish context informed by work produced by the European commission and the UK Climate Impacts Programme. Potential economic impacts relating to SLR and human capital were explored along with impacts on coastal wetland systems under a range of SLR scenarios. Impacts of inland river flooding were also considered under a range of scenarios. The modelling results are subject to the quality of the input datasets and methodologies explored. Approximately 350km^2 of land is exposed under a 1 metre SLR with potential economic costs relating to property insurance claims in the region of €1B. Impacts relating to wetlands under a 1 metre SLR are modelled at 14-49% of potential losses dependant on wetland type with economic losses estimated at approximately €24M per year. Modelling relating to inland flooding carried out on four Irish river catchments under a 2 metre river network elevation buffer found over 1,800 exposed properties with potential insurance claims in the region of €46M.

These impact results highlight the importance of Integrated Coastal Zone Management (ICZM) along with ongoing and future Catchment Flood Risk Assessment and Management Studies (CFRAMS) in working towards managing and adapting to the climate change impacts most likely to occur in Ireland. Despite extensive existing national and international legislation Irish wetlands are experiencing significant losses. The mounting pressures posed by climate change impacts on our wetlands can only be tackled by both adhering to existing protective legislation and further strengthening wetland conservation in Ireland.

7. Governance and Climate Change

7.1 Introduction

The National Adaptation Framework was published in December 2012. Prior to this Ireland's national policies did not address adaptation. The National Climate Change Strategies (2000, 2007) set mitigation targets and acknowledged the importance of adaptation; however, the only included adaptation was flooding. Similarly, other instruments (such as the Planning and Development Amendment Bill 2009, National Spatial Strategy, the National Development Plan, the National Sustainable Development Plan) acknowledged the links between climate change and other sectors but deferred to the National Climate Change Strategies for specifics.

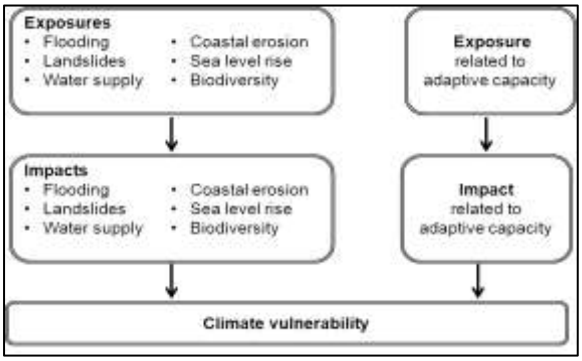


Figure 7.1 Methodology for first research phase

This research draws conclusions about how to advance subnational climate adaptation through a multi-step climate change vulnerability assessment, and stakeholder engagement including nationwide surveys (2009 and 2011) and interviews with governmental staff.

7.2 Methodology

Each local authority's climate change vulnerability was assessed through five steps (Figure 7.1)

Step 1: physical exposures were evaluated at the county level using national datasets for flooding, landslides, water supply, coastal erosion, sea level rise, and biodiversity. The sectors were selected based on previous research on climate impacts in Ireland (Sweeney *et al.*, 2003). This section of the work aims to increase adaptive capacity of local authorities and this chapter limits the focus to these six sectors.

Step 2: exposure related to adaptive capacity levels was evaluated using council development plans, climate change strategies, and forward planning staff numbers.

Step 3: the potential impact on population (Ireland's sensitivity to climate change) was evaluated by weighting the exposure results with 2011 Census population data.

Step 4: for overall physical climate, the physical exposures and impacts were weighted, as shown in Figure 7.2a, based on stakeholder input from the 2009 survey. Then the weighted values for each sector were averaged to derive the combined exposure and impact.

Step 5: climate vulnerability was evaluated using a matrix with physical impacts on the horizontal axis and adaptive capacity on the vertical axis.

Stakeholder engagement included two surveys and interviews with governmental staff, carried out in 2009 and 2011 with all city and county council planning offices. The interviews were carried out with staff members of local authorities, regional authorities, and national government. Four local authorities were selected for interviews based on the following criteria: 1) county/city authorities, 2) located in different regions, 3) physical exposure levels, and 4) adaptive capacity levels. The interviews with local authority staff members explored perceptions and practices beyond what is included in formal policy documents. Interviews with regional authority/national government staff members explored plans to advance climate measures at all levels.

7.3 Results

Results are presented in two parts: 1) exposures, impacts, and vulnerability and 2) local authority barriers/opportunities and high-level government plans.

Exposure levels vary throughout the country, with different counties have 'very high exposure' for the six sectors due to local physical characteristics. Flood exposure is very high in Cork, Dublin, Galway, Mayo and Waterford.

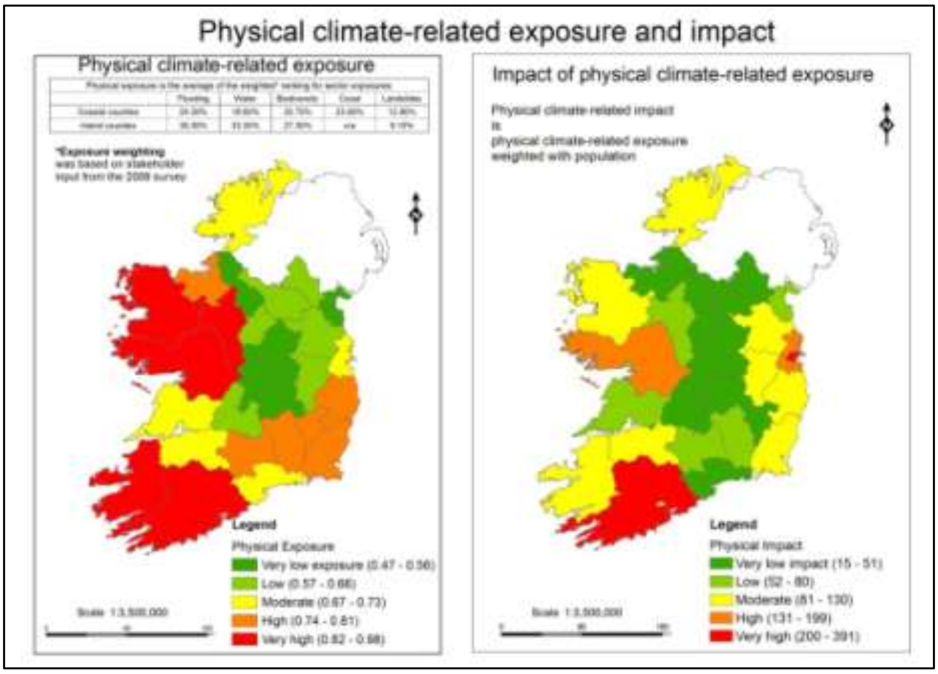


Figure 7.3 a: physical exposure and 7.2b: physical impact

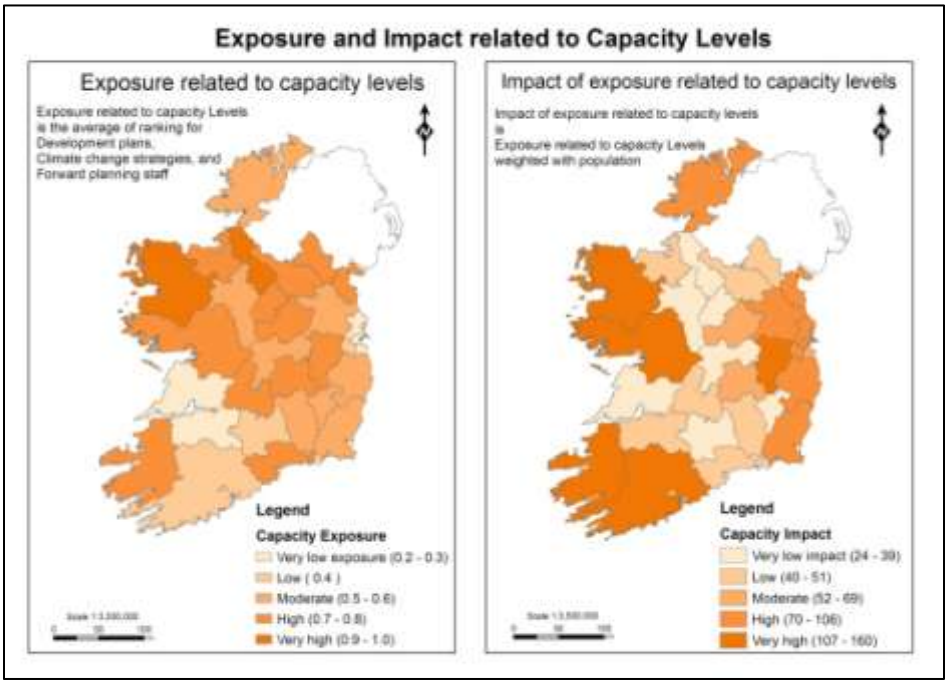


Figure 7.2 a Exposure, and 7.3b Impact related to capacity levels

Landslide exposure is very high in Kerry, Mayo, and Wicklow. Water supply exposure is very high in Cork, Roscommon, and Wicklow. Coastal erosion exposure is very high in Cork, Galway, Kerry and Mayo. Sea level rise exposure is very high in Clare, Galway, Kerry, and Sligo. Biodiversity exposure is very high in Carlow, Cork, Dublin, Kildare, Kilkenny, and Meath. Meanwhile, there is 'very high impact' for all sectors in the greater Dublin area (hereinafter referred to as 'Dublin') due to its high population density. Coastal erosion is the only sector with 'very high *impact*' in an additional county, Louth, as well as Dublin. Detailed results of this vulnerability assessment are included McGloughlin and Sweeney (2013).

As a separate exercise, each council's overall climate exposure and impact was assessed. Exposure (Figure 7.2a) varies, with very high exposure in Cork, Galway, Kerry, and Mayo, whereas, impact (Figure 7.2b) is greatest in Dublin City and County Cork (very high impact) followed closely by Dun Laoghaire-Rathdown, Fingal, South Dublin, and County Galway (each high impact). Further assessments are recommended as lead agencies (the OPW, GSI and NPWS) together with local experts (city and county councils) are best placed to fully assess climate exposures and impacts as a basis for resource allocation.

Adaptive capacity, the second type of exposure, refers to how prepared councils are to address anticipated climate impacts. Even though most local authorities anticipate high impacts for flooding (61%), water supply (42%), biodiversity (39%) and coastal issues (48%), few are prepared. Based on publicly available information, Galway City, Leitrim and Tipperary NR have very high exposure, i.e. are least prepared for climate change (Figure 7.3a). However, when considering population, Limerick City has very high impact, and there is high impact for Cork and Waterford Cities (Figure 7.3b).

A closer look at the formal policies, shown below in Figure 7.4, reveals that there is no standardised approach to climate change at the local level. Development plans vary in how many and which sectors are linked with climate change. Some plans link climate change with as many as six sectors, while others link few or none. However, there was no significant increase in climate measures between the plans adopted in 2004 and those adopted in 2010. Considering the sectors, many local authorities link climate change with flooding (56%), transport (38%), and energy (53% for renewable energy and 47% for energy demand reduction). Even so, few local development plans address the same combination of sectors. Since all the local authorities operate under the same legislative framework, the extremely varied development plans indicates a lack of vertical integration between the national and local levels.

Similarly, subnational climate change strategies have been adopted in an *ad hoc* manner with local circumstances controlling the level of progress and the comprehensiveness of the strategy. As Figure 7.5 shows, seven local authorities and two regional groupings have published climate change strategies, some of which are more detailed than others. Twenty-four other councils are working toward their strategies, but have not published their strategy as yet (Association of Irish Energy Agencies, accessed 16/4/10 and personal communication with councils in Cavan, Dun Laoghaire, Galway City, and Sligo). The remaining three councils indicated they are not currently working on a strategy.

As shown inFigure 7.5, all the published climate change strategies include aims and specific actions (potential and/or completed). These specific actions include staff trainings, staff transportation policies, awareness campaigns, demonstration projects, and quantified targets/indicators to assess progress.

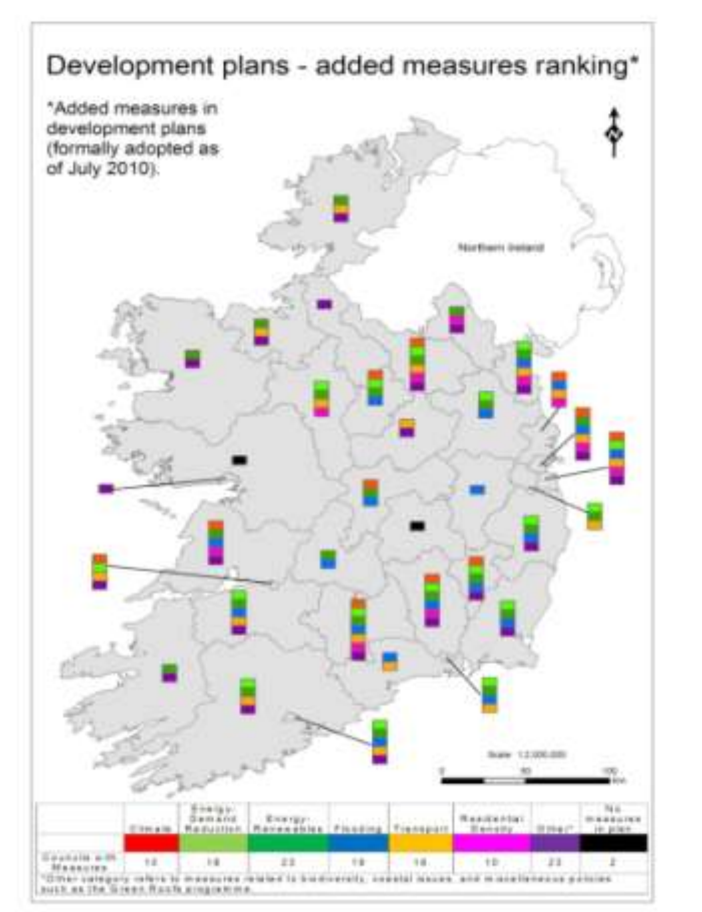
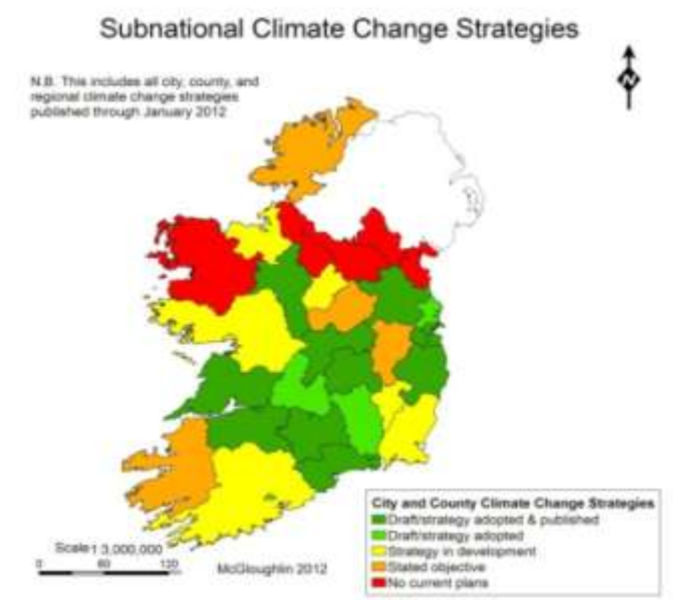


Figure 7.5 Development Plan review



Subnational climate change strategies details

Strategy Date/ Period	Jurisdiction	Aims/ Objectives	Specific Actions	Quantified Emissions	Quantified Targets
2010-2012	Clare County Council	X	X	X	X
2008-2012	Dublin City Council	X	X		
2009 review	Dublin City Council	X	X	X	X
2009-2012	Laois County Council	X	X		
2006	Limerick Clare Energy Agency	X	X	X	X
2011-2012	Meath County Council	X	X	X	
2008	Mid-West Regional Authority	X	X	X	X
2009-2014	Offaly Local Authorities	X	X		
2011-2013	Roscommon County Council	X	X		
2009	South Dublin County Council	X	X		
2008	South Tipperary County Council	X	X	X	
2011	Waterford City Council	X	X	X	
2008-2012	Waterford County Council	X	X	X	

Figure 7.4 Subnational Climate Change Strategies

Climate vulnerability is the relation between physical climate and adaptive capacity, taking into account exposures and impacts (Figure 7.6). Climate exposure is shown on the left, impact of climate exposure is shown on the right. Each city and county (hereafter referred to as ‘councils’) is represented by a point. On the left graph, councils at the top have taken few actions and therefore have high exposure related to their adaptive capacity. Conversely, councils at the bottom have taken more actions and have low exposure related to their adaptive capacity. The left graph also shows physical climate exposure, which is the combination of the previously discussed flooding, landslides, water supply, coastal erosion, sea level rise, and biodiversity. Councils on the left side of the graph have relatively less exposure and councils on the right side have relatively greater exposure. Combining the two axes (the actions on the vertical and the physical processes on the horizontal axis) illustrates each council's relative vulnerability. they have low population. Similarly, the impact of a council's physical exposure is reduced when they have low population. Because Leitrim has the lowest exposure (in relation to other councils), they are still at the lowest end of the range. However, in councils with greater population, such as Dublin City (D) their low exposures on the left graph translate to higher impact on the right graph because of the greater

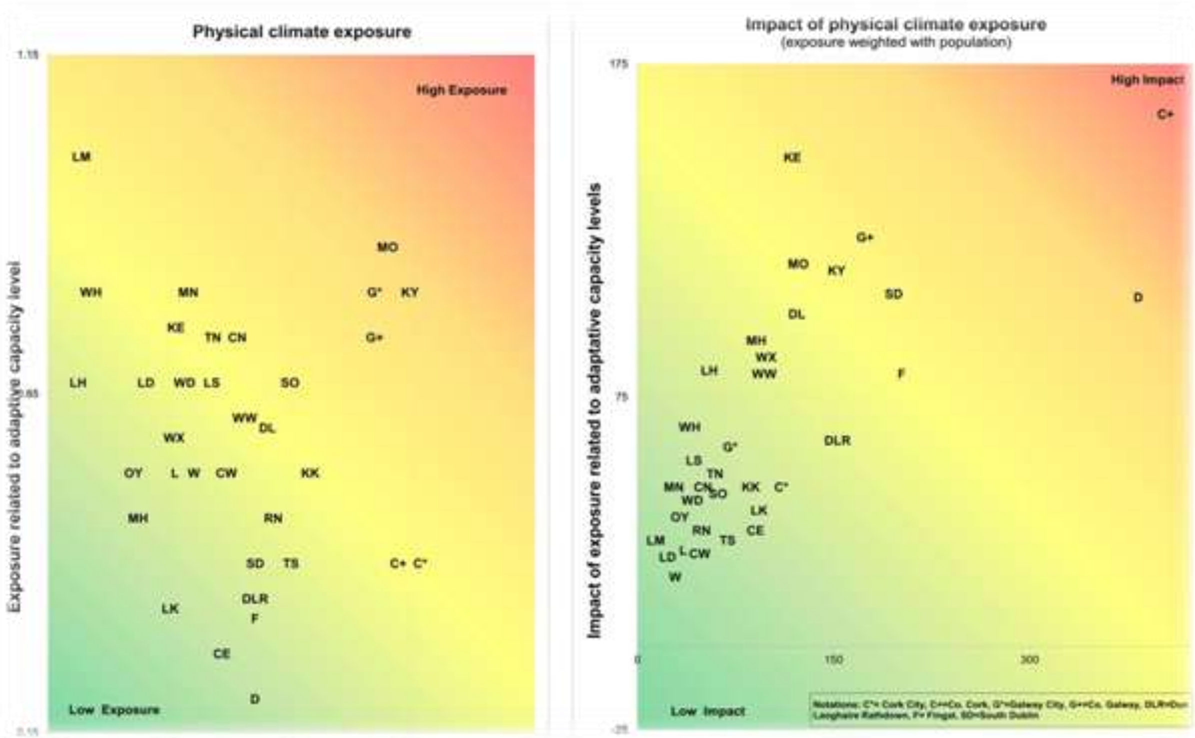


Figure 7.6 Climate vulnerability Climate exposure on the left represents the likely climate effects that need to be addressed. Climate impacts on the right represent the number of people likely to be impacted by these exposures

For example, Leitrim (LM) has taken few actions (high exposure related to adaptive capacity) but has very low physical exposures. Therefore, they may have less to deal with regarding climate change; but may be unprepared to deal with things that do occur.

On the right graph, the focus is shifted to impacts and the number of people likely to be affected. The exposure scores on the left graph are multiplied by the population in each council. Therefore, the impact of a council's exposure related to adaptive capacity is reduced when number of people likely to be affected.

To address the existing climate change vulnerability status, input was collected from stakeholders about challenges and opportunities related to climate change adaptation and specific to local, regional and national levels of government.

Challenges

The actions detailed above suggest that barriers are impeding action. Local authorities confirmed this in their responses and in the case study interviews. The three most common barriers were resource shortages, competing priorities, and integration. Resource shortages and competing priorities were each cited by 77% as a current problem, and lack of a nominated champion was cited by 71%. These barriers have been overcome by some councils who have incorporated climate change into their development plans. In addition, some councils with fewer forward planning staff (proxy for funding) incorporate more measure for climate change into their development plans than those more forward planning staff members.

In terms of competing priorities, most respondents felt that there was apathy from both elected officials and the public. Case study interviews confirmed this when staff members noted that adaptation is hindered by two types of circumstances. First, pressures from local circumstances, such as development issues and agricultural concerns, can inhibit local actions. Secondly, elected officials sometimes prioritise the local economic agenda over environmental protection. However, in three of the four councils interviewed, elected officials supported local flood measures and adaptation is moving forward.

A third type of barrier, integration (horizontal and vertical), was also cited by 65% of survey respondents and featured prominently in the interviews. Both types of integration relate to imperfect coordination resulting in policy gaps and/or detrimental overlaps in responsibilities. Horizontal integration relates to the links at a given level of government, both internally within an organisation, and externally among organisations at that level. Vertical integration focuses on integration between different levels of government (mainly local and national). Both types of integration were noted extensively by the case study interviewees: 71 statements (31%) related to integration. In addition, 29 statements (13%) highlighted the potential for integrated policies and structures to enhance adaptive capacity and move adaptation forward.

Opportunities

Some innovative local authorities are taking action even though there is no direct statutory requirement to do so. The following illustrative examples are not meant to be comprehensive. Irish local authorities are adapting by leading by example, building capacity, and promoting individual behavioural changes. Good practice examples include energy reduction in council properties (Office for Local Authority Management, 2008). Councils are building capacity through internal administrative structures and policies, and external policies for flooding. Ten councils (Clare, Dublin City, Fingal, County Galway, Kilkenny, Limerick City, Mayo, Roscommon, County Waterford, and Wicklow) have established cross-departmental teams with a specific remit to address energy and/or climate change. External policies for flooding include increased standards in North Tipperary and Waterford City development plans.

Dublin City Council is proactively addressing climate change as shown by its climate change strategy and one-year review (CCS) and the Greater Dublin Sustainable Drainage Study (GDSDS). The CCS prioritises “adaptation strategies that initiate, modify and enhance existing policies rather than solutions that require new funding/staffing” (Dublin City Council, 2009). The CCS include a range of actions with specific baseline indicators, and specific actions from each council department, such as the Environment & Engineering Department promoting the use of “grey” water where appropriate. The GDSDS adopts the precautionary principle and has been incorporated into the Dublin City Development Plan. The GDSDS is an important example because this local innovation has been incorporated into other council development plans (Carlow, Dublin City, Dun Laoghaire Rathdown, Kildare, Kilkenny, Louth, Meath, South Tipperary, and Wicklow). However, other councils, such as Cork City and Longford have not made this transition and, instead, defer flood risk assessments to the OPW, the national lead agency.

Lastly, some local authorities are promoting individual behavioural changes. They are raising awareness both internally with staff information and externally through public awareness campaigns (Carlow, Kildare, Kilkenny, County Limerick, Sligo, Waterford City, and Wexford). For example, there were two nationwide conferences in 2008, and on-going local public awareness campaigns include bi-weekly radio spots, information days in public libraries, and an interactive environmental learning centre. Additionally, councils are working to increase public transport use by promoting cycling and walking routes, requiring mobility management plans for new builds, and conducting traffic and transportation studies. These examples highlight the councils' ability to affect individual behaviours where they have direct influence (planning) and where they have a less prescribed role (transportation). To conclude, these good practice examples are ways that local authorities can move forward in addressing climate change even in the absence of central government requirements.

Regional authorities have a limited role in Ireland and a corresponding limited staff and funding: their role is to facilitate a coordinated regional approach. Some examples of regional authority projects are broadband initiatives, micro-projects for renewable energy, and in one case a regional craft centre.

National government has departments that each specialise in particular sectors, and this has resulted in a fragmented approach for mainstream issues as well as climate change considerations. Ireland has placed climate change under the remit of the DECLG. Even within the DECLG, there is a fragmented approach in that there is a climate change unit, which designs policies with a high-level strategic approach, and a local government unit, which implements these policies at the subnational level and adopts a more pragmatic approach.

Interviews with the principal officers of the DECLG's Climate Change Unit and Local Government Unit provided insights into national government perspectives on adapting to climate change. The Climate Change Unit clarifies policy principles and builds consensus in order to be able to put the adaptation agenda on a "statutory footing." However, this requires a high level of horizontal integration (funding for climate change comes from the exchequer) and vertical integration (strong links between national government and local authorities). With regard to horizontal integration, there are committees set up between the DECLG and CCMA, and through the advisory County Development Boards. Therefore, the Local Government Unit would be equally important in adapting to climate change.

7.4 Conclusions

This research has illustrated that Ireland is vulnerable to climate change even though some proactive local authorities are advancing climate measures. At the same time, a review of local plans and strategies, coupled with stakeholder perceptions, has revealed that climate change is not adequately mainstreamed into local policies or institutional practices. Overall, the role of central government is to set goals and to incentivise or regulate minimum standards. Local authorities would welcome increased regulations and guidance – one local authority criticised central government regulations as too lax, or too late, thereby making it difficult to enact a higher standard because elected officials cite central government regulations as justification for a lower standard.

In order to adapt to climate change, Ireland will need to overcome challenges inherent in the current government structures. There are challenges due to lack of integration and challenges specific to each tier of government. Integration needs to be improved both vertically with improved links between the levels and horizontally to decrease breakdowns within each level.

7.5 Recommendations

While Ireland's climate change response needs an integrated approach to avoid gaps and maladaptation, the existing government structures do have potential to address climate change. Local government should expand on existing good practice examples; regional government should coordinate local actions with a mid-level strategic approach, and national government should steer policies and provide statutory backing to advance action at all levels.

7.5.1 Local authorities

By acting on climate change, local authorities can contribute to a more comprehensive climate change policy throughout Ireland. If they do not take action, they will be forced to adapt reactively, i.e. responding to events after the damage has been caused, without becoming prepared for future events. Local authorities can address climate change in the following ways:

- Build adaptive capacity by sharing information among local authorities through web-based tools and databases, published reports, and targeted conferences.
- Establish structures such as a climate change team, a climate change strategy and specific measures in general policies. The climate change team should include Directors of Services, be accountable to the County Manager, and report progress in the monthly council meetings. The climate change strategy should include concrete measurable actions for both climate mitigation and adaptation. General policies should incorporate specific climate change criteria into relevant areas such as development control, flood management, and amenity.
- Monitor progress by publishing specific, measurable targets for climate mitigation and adaptation. Initial requirements could be less rigorous, if necessary, such as a specific objective to prepare a climate change strategy within the lifespan of their current development plan.
- Report progress within annual council reports and budgets.

7.5.2 Regional authorities

Regional government has potential to advance climate measures, even in their current role as facilitators, in the following ways:

- Serve as an information clearinghouse for local authorities.
- Oversee local authority climate change strategies and explore the possibility of regional climate change strategies.
- Establish directly elected regional representatives, with a remit solely for regional level policies. These posts are

the European norm and they require additional resources and structure.

7.5.3 National government

National government, with the statutory power that is lacking at local and regional levels, can join with the other two levels of government by establishing enforceable minimum standards and facilitating an integrated response in the following ways:

- Create legislation that will clearly signal climate change as a priority and advance climate measures.
- Establish and enforce specific, actionable standards (for mitigation and adaptation) for regional and local governments.
- Include climate change criteria and concrete climate adaptation measures in national policy documents to increase transparency in the decision-making process.
- Continue raising awareness to build public consensus. Without a public consensus to move forward on climate change, there will be no mandate for the elected representatives to prioritise this issue. This will leave Ireland in their current position of reactive management largely driven the EU Directives and sanctions.
- Monitor progress through specific measures including baselines, benchmarks and annual targets.
- Report national progress annually by each Department and in the annual address by the Taoiseach. Annual reporting will increase accountability, provide national government an opportunity to highlight their progress, and build further public support. Alternatively, if progress is not being made, then annual accountability will provide opportunity for early intervention and adjustments.

7.5.4 Integration

There needs to be a coherent approach, which should be integrated both vertically and horizontally.

Vertical integration should:

- Maintain the Climate Change Working Group, which includes "representatives from local authorities, energy management agencies, OLAM and the DoEHLG" (OLAM, 2008: 5).
- Incorporate explicit references to other tiers of government within policy documents at each level.

Horizontal integration should:

- Establish an internal climate change team at each level to oversee the directorates' address of climate change with specific responsibilities for each department.
- Establish cross-sectoral forums at all levels (national, regional, and local). This will minimise maladaptation, increase knowledge transfer, and increase potential synergies between the different agencies with their separate agendas.
- Establish formal links among similar authorities in different jurisdictions at each level to address climate change. This will build capacity through knowledge transfer and increase potential synergies between adjacent jurisdictions.
- Establish climate change criteria to be incorporated into annual assessments.

7.7.5 Future prognosis

Ireland has begun laying the groundwork to address climate change and will need to continue on this path with increased commitment. This will require national government to establish clear priorities through legislation with specific requirements by local authorities and private entities. Without this, Ireland will remain unprepared for the upcoming challenges related to climate change and general environmental issues

8. Integrating Adaptation: A Case Study of Co. Mayo

8.1 Introduction

Mayo is the third largest county in Ireland, with an area of just under 5,600km^2 and a population of 130,552 in 2011. It is a county characterised by major variations in landscape, ranging from the rugged mountainous areas around Killary Harbour in the south to the vast flat expanses of blanket bog in Erris in the north west, and from the lake studded interior to the Atlantic cliffs of Achill. Its geological heritage has resulted in a complex mosaic of landscapes and ecosystems. Each of these require different levels of management, and each exhibit different degrees of robustness and sensitivity to forthcoming climate change.

Model-based scenarios for future climate change (McGrath *et al,* 2008*;* Sweeney *et al,* 2008*)* project that Co. Mayo, in common with the rest of Ireland, can expect warming of 3-4^{o}C over the current century. This would bring mean July temperatures to around 18^{o}C and mean January temperatures to the level currently experienced throughout Co. Mayo in an average April. Though regional details for precipitation are less certain, most models agree that summers will be significantly drier, though with higher intensity rain events likely to punctuate more frequent drought periods. Winters are likely to be significantly wetter, perhaps by as much as 25%. Sea level along the Mayo coast can be expected to continue to rise, by 0.5 - 1m over the century, with an additional, as yet uncertain, influence on coastal processes expected as a result of changes in storminess.

Mayo is exposed to adverse climate change impacts. The county has a history of landslides and flooding events. It is also exposed to risks associated with sea level rise and consequent increased coastal erosion. Other areas of concern centre on biodiversity and tourism, though in the case of some sectors, positive impacts can be expected.

This chapter seeks to provide a case study at an individual county level integrating the overall research findings to examine where and how Co. Mayo may best adapt to climate change pressures.

8.2 Scoping Exposures

Reports on climate-related hazards experienced in the county were reviewed together with strategic documents such as the current County Development Plan, the current County Council Corporate plan, energy agency publications etc. Preliminary observations concerning adaptive capacity were also drawn from the county's responses to two nationwide surveys (2009 and 2011) as well as face-to-face interviews with four staff members of Mayo County Council. Physical exposures were evaluated using data for land attributes, recorded hazardous events, and/or designated protected spaces and species (Table 8.1). The data for each indicator was aggregated to the county level, and converted to a unit-less scale using the Jenks natural breaks method. These categories were labelled with a range from one (very low exposure) to five (very high exposure). Figure 8.1 shows a compilation characterisation for Co. Mayo.

8.3 Vulnerability and Adaptation for Surface Water Supplies

8.3.1 Methods and Tools

Climate change will alter catchment hydrology in Co. Mayo over medium and long time scales. It is also important to recognise that climate change is but one challenge to future water resources and management. Factors that are independent from climatic change but also need to be considered in future water resource management include: population changes, changes in water demand, legislative changes (e.g. the Water Framework Directive or
introduction of water charges) as well as water infrastructural changes driven by policy incentives (e.g. leakage reduction).

Table 8.1 Sector, Indicators and Data Sources for Exposure Scoping

Sectors	Indicator List	Data Source
Flooding	Recorded flood events	OPW National Flood Archive
	Winter rainfall % increase	C4I modelling
Landslides	Peat areas as % of land area	CORINE 2000
	> 15° slope as % of land area	EPA Digital Elevation Model
	Recorded landslides 1900–2009	GSI National Landslide Database
Water Supply	Public Water Supply at risk	EPA Remedial Action List 2010
	Summer rainfall % decrease	C4I modelling
Coastal Erosion	Coast at risk	ECOPRO
	Erosion trends	EUROSION (EEA)
Sea Level Rise	Elevation less than 1 metre	EPA Digital Elevation Model
	Storm surge	Ireland in a Warmer World, C4I
	Coastal aquifers	GSI Groundwater Aquifers
Biodiversity	**Protected sites as % of land area**	**NHAs, SACs and SPAs (NPWS)**
	Protected species	Protected Species (NPWS)

Sources for Exposure Scoping

The adaptation methodology described in Chapter 2 was applied to Co. Mayo. A number of surface water abstraction points were analysed (Table 8.2, Figure 8.2). In general, the points assessed show a low level of vulnerability to future changes in climate. Two abstraction points were selected for further investigation; Cuilmore and Kiltimagh, the results of which are detailed below.

Table 8.2 Abstraction Points Analysed

Scheme Name	Scheme Code	Population Served	Volume (m^3/day)
Cuilmore GWS	2200PRI2039	420	400
Kiltimagh WSS	2200PUB1017	1555	616
Laghta GWS	2200PRI2079	203	145
Louisburgh WSS	2200PUB1020	1480	400
Newport WSS	2200PUB1022	803	273
Rathnacreeva GWS	2200PRI2099	164	128

Kiltimagh WSS

Kiltimagh WSS abstracts water from the River Glore catchment. Results based on the URR were analysed with respect to the 0.05-quantile, the median and the 0.95-quantile of all model outcomes for each water scenario. For the 2020s and the 2050s, no water stress was detected in the 0.05-quantile and in the median of all flows, indicating the low levels of vulnerability to the majority of future projections (Figure 8.3). There are, however a number of simulations that indicate water stress at the 0.95-quantile. For the 2020s, low-water-stress was detected for 11 out of 360 months in the investigated business-as-usual scenario A. The demand reductions in scenario B result in a reduction in the number of simulations falling within this category and were further reduced following implementation of scenarios C and D. The number of months indicating water stress increases for the 2050s where ~14% of months indicate low water stress or higher. This is in line with progressive decreases in flow simulated for summer months under the climate change scenarios used. The adaptation options examined are successful in reducing the occurrence of water stress, where for example, the leakage reduction in scenario C reduces the number of months indicating low levels of water stress to 6.94%. All adaptation scenarios show a robust performance under the uncertainties incorporated in this modelling framework.

Cuilmore GWS

Figure 8.4 shows the Water Use-to-Resource Ratio for Cuilmore over coming decades. An increasing trend in low water stress for the summer months is evident. The plots represent the ranges of outcomes from the climate change scenarios sampled, with some simulations showing high water stress. The median of all simulations is marked by the black horizontal line for each year. While vulnerability is small, the results point to an increased risk of low levels of water stress, particularly for the latter decades considered.

Results for summer were further analysed using the RRV analysis described above. Results are shown for Scenario D – combined reductions in demand and leakage (Figure 8.5). The threshold used is the URR 10% threshold which marks the difference between no and low water stress. Results show that for dry summers there are significant reductions in reliability though overall the resilience and duration vulnerability is low.

8.3.2 Recommendations

In comparison to other parts of the country there is a relatively low level of vulnerability evident for Co. Mayo. Robust approaches to climate change adaptation that result in win-win solutions, both now and in the future are likely to be sufficient to cater for the majority of scenarios considered. Such strategies include demand and leakage reduction. It is recommended that such robust, flexible strategies should form an important aspect of adaptation planning.

8.4 Climate Change Adaptation in Co Mayo: Conserving Biodiversity

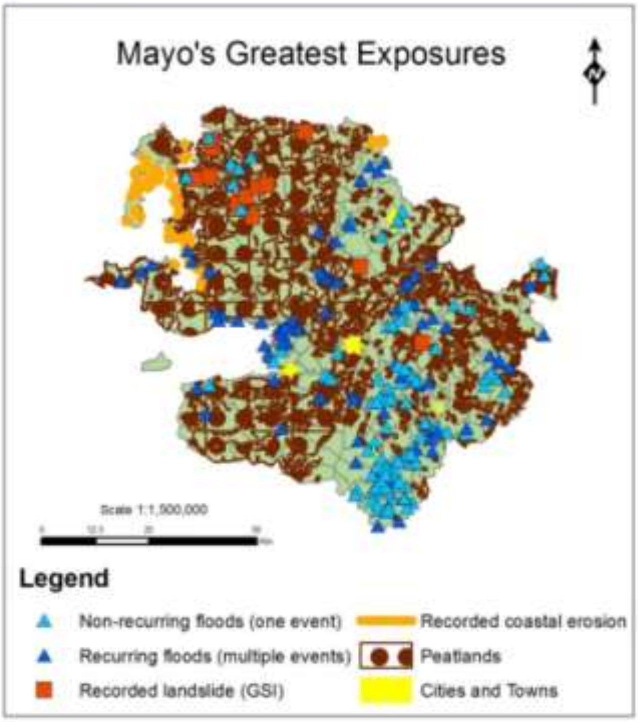
8.4.1 Biodiversity and Natura 2000 Sites in Co. Mayo

Mayo is an important regional repository of biodiversity. Over 25% is designated for nature conservation in the *Co Mayo Biodiversity Action Plan (BAP).* Natura 2000 sites account for the majority of designated sites protected by the European Habitats and Birds Directives. These are composed of 52 Special Areas of Conservation (SAC) and 18 Special Protection Areas (SPA), covering 30% and 10% of the county, respectively (Figure 8.6).

SACs in Co Mayo have been designated in some cases to protect a specific habitat type (e.g. turloughs such as Skealoghan); while others are home to a high diversity of habitats (e.g. Mweelrea/Sheeffry/Erriff Complex and Mullet/Blacksod Bay Complex). Many of these sites contain priority habitats which Ireland has a particular responsibility to protect (Table 8.3). Some of them contain a relatively large proportion of the national range of these habitats e.g.; Mullet/Blacksod Bay, Owenduff/Bellacorick Bog.

Mayo

Greatest Exposures:
- Floods
- Coastal erosion
- Landslides
- Adaptive Capacity



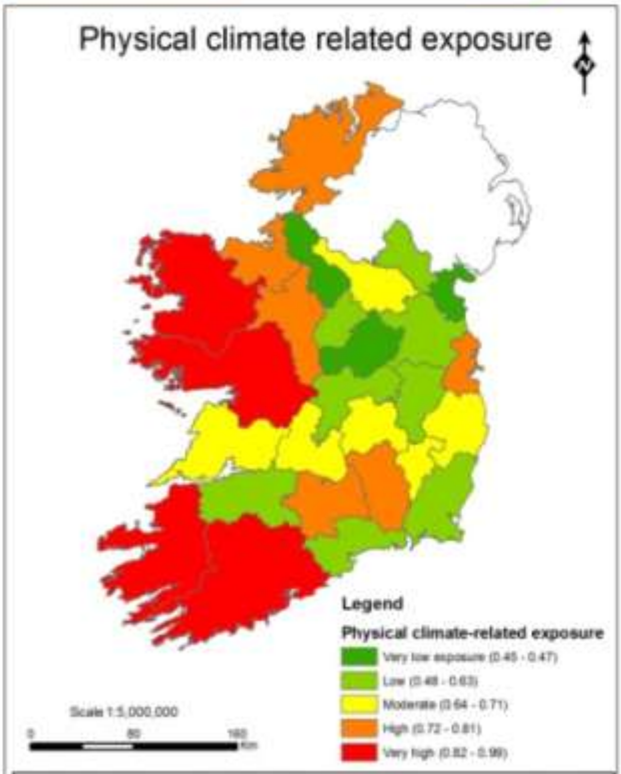
Exposures

Average of exposure rankings shown in top right figure

Sector Exposures:	Mayo	Ireland
Floods * Flood events * Precipitation 2021-2040	4.0	2.8
Landslides * Recorded events * > 15° slope (% area) * Peatlands (% area)	4.7	2.3
Water Supply * Public water supply at risk * Precipitation 2021-2040	3.5	2.8
Coastal Erosion * Coast at risk * Erosion trends	4.5	2.7
Sea Level Rise * Elevation less than 1 metre * Storm surge * Aquifers	3.7	3.1
Biodiversity * Protected sites (% area) * Protected species	2.5	3.1
Adaptive Capacity * Added measures in plan * Climate change strategy * Forward planning staff	0.9	0.6

	Classes				
Exposures	Very low	Low	Moderate	High	Very High
Floods	1.5 - 2.0	2.1 - 2.5	2.6 - 3.0	3.1 - 3.5	3.6 - 4.5
Landslides	1.0 - 1.3	1.4 - 2.3	2.4 - 3.0	3.1 - 3.7	3.8 - 4.7
Water supply	1.0 - 1.5	1.6 - 2.0	2.1 - 3.0	3.1 - 3.5	3.6 - 4.5
Coastal erosion	1.0	1.1 - 1.5	1.6 - 2.5	2.6 - 3.5	3.6 - 4.5
Sea level rise	1.7 - 2.0	2.1 - 2.3	2.4 - 2.7	2.8 - 3.7	3.8 - 4.3
Biodiversity	2.0	2.1 - 2.5	2.6 - 3.0	3.1 - 3.5	3.6 - 4.5
Adaptive capacity	0.2 - 0.3	0.4	0.5 - 0.6	0.7 - 0.8	0.9 - 1.0

*For example, floods sub-index value is the average of (Flood events and Projected precipitation)



Sectoral weighting based on 2009 survey of local authorities

	Floods	Water	Biodiversity	Coast	Landslides
Coastal counties	24.3%	18.6%	20.7%	23.6%	12.9%
Inland counties	30.3%	33.3%	27.3%	n/a	9.1%

Figure 8.1 Co. Mayo Exposure to Climate

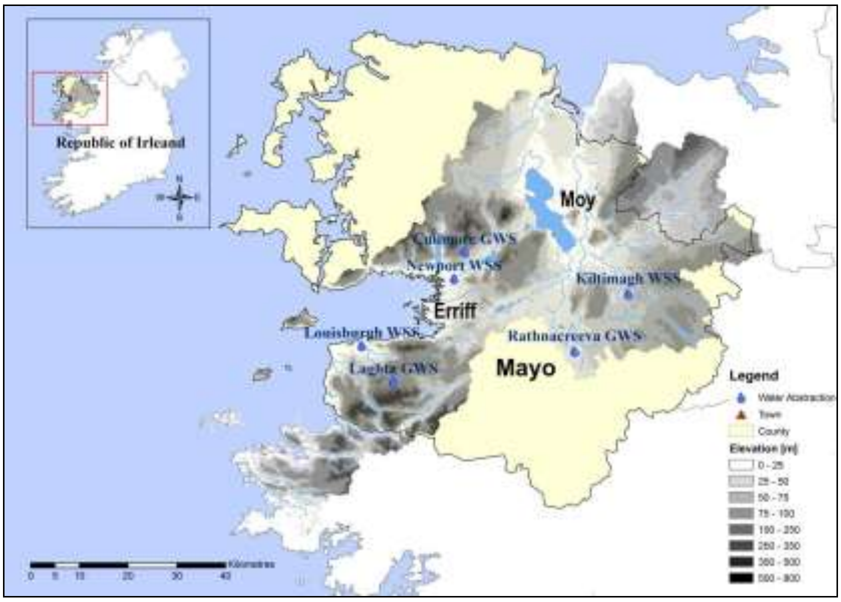


Figure 8.2 Location of the Surface Water Abstraction Points Analysed

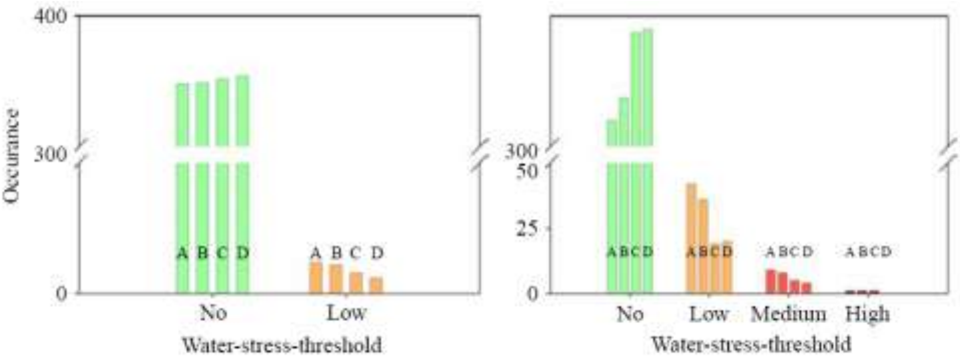


Figure 8.3 Kiltimagh water-stress-threshold exceedance (number of months out of 360) of the 0.95-Quantile for the 2020s (left) and 2050s (right) for each scenario analysed

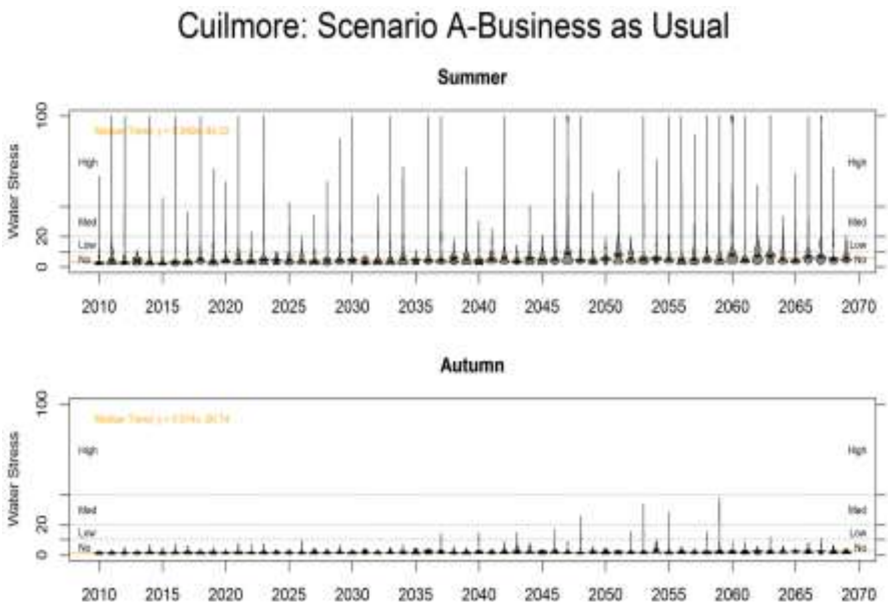


Figure 8.4 Water Use to Resource Ratio for Cuilmore under the Business as Usual Scenario

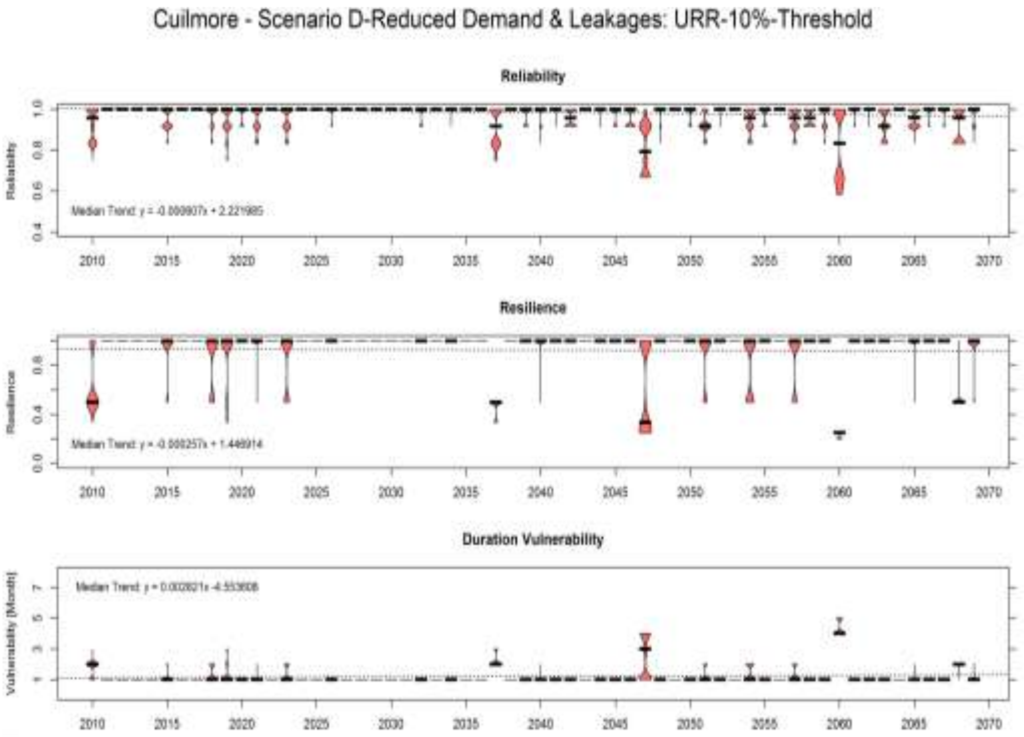


Figure 8.5 Cuilmore RRV analysis under scenario D combining strategies of combined demand and leakage reduction

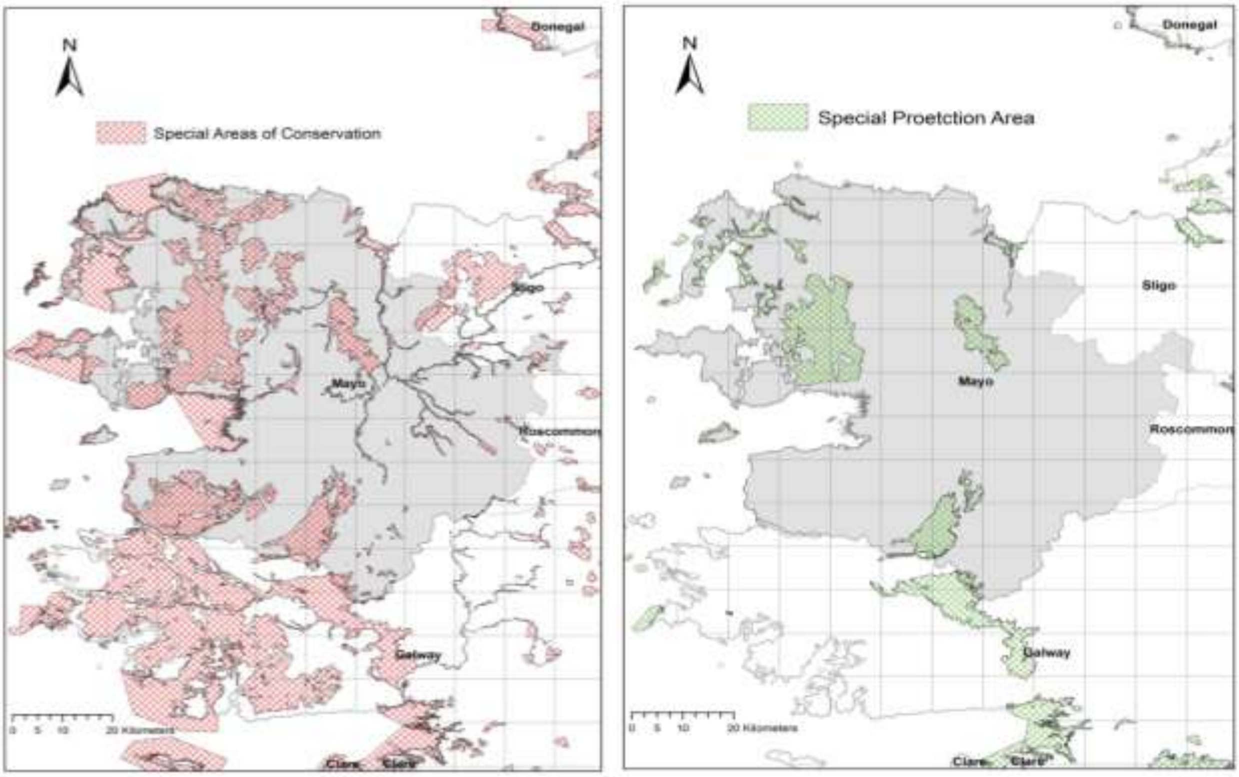


Figure 8.6 (a)Special Areas of Conservation and (b) Special Protection Areas in Co Mayo

Table 8.3: List of SACs in Co Mayo, including habitats richness at each site and the number of priority habitats found at each site as defined by the EU Habitats Directive.

Special Area of Conservation	Habitat Richness	No. of Priority Habitats
Mweelrea/Sheeffry/Erriff Complex	24	5
Lough Corrib	14	6
Mullet/Blacksod Bay Complex	10	3
Clew Bay Complex	9	1
Killala Bay/Moy Estuary	9	1
Owenduff/Nephin Complex	9	1
Glenamoy Bog Complex	8	2
Lough Carra/Mask Complex	8	4
River Moy	6	2
Bellacorick Bog Complex	5	1
Broadhaven Bay	5	0
Lacken Saltmarsh and Kilcummin Head	5	1
Ox Mountains Bogs	5	1
Corraun Plateau	4	0
Achill Head	3	0
Clare Island Cliffs	3	0
Flughany Bog	3	1
Keel Machair/Menaun Cliffs	3	1
Lough Cahasy, Lough Baun and Roonah Lough	3	1
Bellacragher Saltmarsh	2	0
Carrowmore Lake Complex	2	1
Clyard Kettle-holes	2	2
Erris Head	2	0
Lough Gall Bog	2	1
Lough Hoe Bog	2	1
Oldhead Wood	2	0
Ardkill Turlough	1	1
Balla Turlough	1	1
Brackloon Woods	1	0
Carrowkeel Turlough	1	1
Cloonakillina Lough	1	0
Cloughmoyne	1	1
Croaghaun/Slievemore	1	0
Cross Lough (Killadoon)	1	0
Doocastle Turlough	1	1
Doogort Machair/Lough Doo	1	1
Greaghans Turlough	1	1
Inishkea Islands	1	1
Kilglassan/Caheravoostia Turlough Complex	1	1
Mocorha Lough	1	1
Shrule Turlough	1	1
Skealoghan Turlough	1	1
Slieve Fyagh Bog	1	1
Urlaur Lakes	1	0

(Data Source: http://www.npws.ie/protectedsites/specialareasofconservationsac/ December 2011).

Table 8.4: Frequency of protected habitat types found at Natura 2000 sites in Co Mayo

NATURA 2000 Habitat^	No. of SACs containing protected habitats
Blanket bog (*active only)	9
Depressions on peat substrates of the *Rhynchosporion*	9
Turloughs	9
Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*)	6
Oligotrophic waters containing very few minerals of sandy plains (*Littorelletalia uniflora*	6
Northern Atlantic wet heaths with *Erica tetralix*	6
Alkaline fens	6
Shifting dunes along the shoreline with *Ammophila arenaria* (white dunes)	6
Alpine and Boreal heaths	6
Machairs (* in Ireland)	6
Natural dystrophic lakes and ponds	5
Mudflats and sandflats not covered by seawater at low tide	5
Old sessile oak woods with *Ilex* and *Blechnum* in British Isles	5
Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*	4
Perennial vegetation of stony banks	4
European dry heaths	4
Transition mires and quaking bogs	4
Juniperus communis formations on heaths or calcareous grasslands	4
Large shallow inlets and bays	4
Embryonic shifting dunes	3
Fixed coastal dunes with herbaceous vegetation (grey dunes)	3
Salicornia and other annuals colonizing mud and sand	3
Active raised bogs	3
Water courses of plain to montane levels with the *Ranunculion fluitantis* and Callitricho-*Batrachion* vegetation	3
Limestone pavements	3
Reefs	3
Mediterranean salt meadows (*Juncetalia maritimi*)	3
Annual vegetation of drift lines	3
Coastal lagoons	3
Vegetated sea cliffs of the Atlantic and Baltic coasts	3
Degraded raised bogs still capable of natural regeneration	3
Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp.	3
Calcareous rocky slopes with chasmophytic vegetation	2
Alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior* (*Alno-Padion, Alnion incanae, Salicion albae*)	2
Petrifying springs with tufa formation (*Cratoneurion*)	2
Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco Brometalia)*(*important orchid sites)	2
Atlantic decalcified fixed dunes (*Calluno-Ulicetea*)	2
Siliceous rocky slopes with chasmophytic vegetation	2
Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*	2
Estuaries	1
Bog woodland	1
Humid dune slacks	1
Natural euthrophic lakes with Magnopotamion or Hydrocharition-type vegetation	1
Dunes with *Salix repens* ssp.argentea (*Salix arenariae*)	1
Submerged or partly submerged sea caves	1
Molinia meadows on calcareous, peaty or clavey-silt-laden soils (*Molinion caeruleae*)	1

*Priority habitats are indicated with an asterisk.
^Description of the habitat types. Please refer to the 'The Interpretation Manual of European Union Habitats - EUR27' for further information (http://ec.europa.eu/environment/nature/legislation/habitatsdirective/docs/2007_07_im.pdf)
(Data Source: http://www.npws.ie/protectedsites/specialareasofconservationsac/ December 2011).

Co Mayo therefore has a responsibility to protect various habitat types. Those most vulnerable to climate change impacts at a national scale are:

- upland habitats comprising siliceous and calcareous scree, siliceous and calcareous rocky slopes, alpine and subalpine heath;
- peatland habitats including blanket bog and raised bog;
- coastal fixed dunes.

These all have a substantial representation in Co Mayo (Tables 8.3 and 8.4):

8.4.2 Projected changes to constituent plant species

Species at higher latitudes and altitudes are likely to experience the largest range contractions. These contractions are often significantly greater in Co Mayo compared to the national projections (Table 8.5), suggesting that Co Mayo may have to be more proactive in implementing targeted conservation initiatives

Table 8.5 Assessments of climate space winning and losing plant species from peatland, heath and coastal habitats of high conservation value in Co Mayo.

Blanket Bog (Active)

Overall Assessment: Species show a variable response to climate change with shifts in the composition of communities possible**.** Species such as *Drosera intermedia* see projected local losses of suitable climate space in Co Mayo contrary to projected increases nationally. Current pressures such as overgrazing, drainage and peat extraction will remain critical to the status of this habitat in Co Mayo and govern its overall resilience to climate change. This habitat of national and European importance requires prioritisation, with many important sites found in Co Mayo.

Species	Gain	Loss	Stable	Range change (%) - Mayo	Range change (%) - Nationally
Campylopus atrovirens	0	30	7	-81	-67
Cladonia portentosa	0	0	0	0	25
Drosera intermedia	17	37	20	-35	94
Drosera rotundifolia	0	13	64	-17	5
Erica tetralix	0	3	74	-4	9
Eriocaulon aquaticum	9	41	1	-76	12
Eriophorum angustifolium	0	3	74	-4	6
Eriophorum vaginatum	2	14	56	-17	-2
Lobelia dortmanna	19	37	19	-32	-34
Myrica gale	0	24	53	-31	11
Narthecium ossifragum	0	15	62	-19	5
Pinguicula grandiflora	30	0	0	0	100
Pinguicula lusitanica	0	36	14	-72	-49
Pleurozia purpurea	0	22	15	-59	-50
Racomitrium lanuginosum	0	13	18	-42	-17
Rhynchospora alba	0	22	55	-29	-7
Schoenus nigricans	0	7	70	-9	22
Sphagnum papillosum	0	28	4	-88	-54
Sphagnum subnitens	10	27	20	-36	10
Sphagnum tenellum	0	21	6	-78	-56
Trichophorum cespitosum	1	14	62	-17	3
Vaccinium myrtillus	0	3	29	-9	-3

Raised Bog (Active)	**Overall Assessment:** While most species show little change or small increases in suitable climate space nationally (other than *Andromeda polifolia*), at the local scale these species are projected to experience greater losses of suitable climate space in Co Mayo, possibly due to raised bogs being at the edge of range in Co Mayo. Future deterioration of the hydrological regimes of these bogs will be central to their ability to withstand climate change.				
Species	**Gain**	**Loss**	**Stable**	**Range change (%) - Mayo**	**Range change (%) - Nationally**
Andromeda polifolia	0	0	0	0	-88
Cladonia portentosa	0	0	0	0	25
Drosera intermedia	17	37	20	-35	94
Drosera rotundifolia	0	13	64	-17	5
Erica tetralix	0	3	74	-4	9
Eriophorum angustifolium	0	3	74	-4	6
Eriophorum vaginatum	2	14	56	-17	-2
Sphagnum cuspidatum	6	34	9	-65	39

Wet Heath	**Overall Assessment:** Variable response overall nationally, in particular from *Sphagnum* spp. although little change from important species such as *Erica tetralix* and *Trichophorum cespitosum.* Similar trends projected for Co Mayo, although losses of suitable climate space increase at the local scale for most Wet Heath species. Cumulative threats of overgrazing and climate change pose a risk to this habitat.				
Species	**Gain**	**Loss**	**Stable**	**Range change (%) - Mayo**	**Range change (%) - Nationally**
Cladonia portentosa	0	0	0	0	25
Erica tetralix	0	3	74	-4	9
Pleurozium schreberi	0	0	21	0	1
Sphagnum capillifolium	1	31	13	-68	-24
Sphagnum papillosum	0	28	4	-88	-54
Sphagnum subnitens	10	27	20	-36	10
Sphagnum tenellum	0	21	6	-78	-56
Trichophorum cespitosum	1	14	62	-17	3

Dry Heath	**Overall Assessment:** Widespread habitat with dominant species showing a variable response at the national and local scale. *Ulex gallii* is projected to see large increase in suitable climate space while *Vaccinium vitis-idaea* is projected to experience serious losses of suitable climate in Co Mayo. Shifts in the composition of communities possible.				
Species	**Gain**	**Loss**	**Stable**	**Range change (%) - Mayo**	**Range change (%) - Nationally**
Erica cinerea	3	2	72	1	32
Ulex gallii	38	0	2	1900	53
Vaccinium myrtillus	0	3	29	-9	-3
Vaccinium vitis-idaea	0	5	1	-83	-23

Alpine and Subalpine Heath	**Overall Assessment:** Many of its most important species showing serious range contractions at national level and in Co Mayo. This highly sensitive habitat mostly found above 350m requires prioritisation, with many important sites found in Co Mayo.				
Species	**Gain**	**Loss**	**Stable**	**Range change (%) - Mayo**	**Range change (%) - Nationally**
Carex binervis	6	7	60	-1	39
Diphasiastrum alpinum	0	5	1	-83	-62
Racomitrium lanuginosum	0	13	18	-42	-17
Salix herbacea	0	6	2	-75	-73
Vaccinium myrtillus	0	3	29	-9	-3
Vaccinium vitis-idaea	0	5	1	-83	-23

Coastal Habitats

Fixed Dunes

Overall Assessment: A variable climate change response overall, with contrasting trends in projected suitable climate space changes at the local (Co Mayo) and national scales. Nationally, *Viola tricolor subsp curtisii* is projected to experience significant increases in suitable climate space while in Co Mayo is projected to lose all suitable climate space. Extreme events, increased storm frequency and sea level rise may pose greater risks to these communities than the direct impacts of temperature and precipitation changes. Local planning and coastal adaptation and protection policies will be important in Co Mayo to protect these species and habitats.

Species	Gain	Loss	Stable	Range change (%) - Mayo	Range change (%) - Nationally
Anacamptis pyramidalis	23	5	0	360	-59
Carex arenaria	1	21	4	-80	-7
Viola tricolor subsp curtisii	0	9	0	-100	48

Marram Dunes

Overall Assessment: A variable climate change response overall. At the local scale in Co Mayo, species such as *Ammophila arenaria*, *Carex arenaria* and *Eryngium maritimum* are projected to experience significantly larger losses in suitable climate space than are projected nationally. Extreme events, increased storm frequency and sea level rise may pose greater risks to these communities than the direct impacts of temperature and precipitation changes. Local planning and coastal adaptation and protection policies will be important in Co Mayo to protect these species and habitats.

Species	Gain	Loss	Stable	Range change (%) - Mayo	Range change (%) - Nationally
Ammophila arenaria	0	19	3	-86	-12
Carex arenaria	1	21	4	-80	-7
Eryngium maritimum	0	13	5	-72	-5
Euphorbia paralias	1	0	5	20	20
Otanthus maritimus	0	0	0	0	178

Vegetated Sea Cliffs

Overall Assessment: Most species showing range expansions or little change at national level. Local losses of suitable climate space in Co Mayo are projected for species such as *Lavatera arborea* and *Plantago maritima*. Extreme events, increased storm frequency and sea level rise may pose greater risks to these communities than the direct impacts of temperature and precipitation changes. Local planning and coastal adaptation and protection policies will be important in Co Mayo to protect these species and habitats.

Species	Gain	Loss	Stable	Range change (%) - Mayo	Range change (%) - Nationally
Armeria maritima	2	13	21	-32	-2
Coclearia officianalis	0	13	10	-57	-3
Crithmum maritimum	1	0	6	17	29
Inula crithmoides	3	0	0	0	-14
Lavatera arborea	0	2	2	-50	34
Plantago maritima	4	20	50	-23	31
Scilla verna	0	0	0	0	261
Sedum rosea	0	8	5	-62	-59

8.4.3 Projected changes to wetland habitat climate space

Habitat modelling was undertaken using the methodology described in Chapter 3. For each of the wetland habitat types these are summarised as the change relative to the baseline and the gain/loss in absolute numbers relative to the baseline (Table 8.6).

Table 8.6: Summary of suitable climate space changes (for Co. Mayo wetland habitats relative to the baseline simulation for the 10 x 10 km grid subset for County Mayo

Habitat type and code	Model 61-present	Model 2050s present	Gain	Loss	Net Change
Wet Heath (4010)	63	41	0	22	**-22**
Degraded Raised Bog (7120)	6	8	3	1	**+2**
Active Blanket Bog (7130)	56	40	1	17	**-16**
Rynchosporion Depressions (7150)	77	69	0	8	**-8**

The greatest loss of climate space is associated with the wet heath habitats with a projected loss of ~28.6% of suitable climate space compared to the baseline simulation. This compares to projected losses of ~22.1% and ~10.4% for the active blanket bog and rynchosporion depression habitats respectively. By contrast the climate space associated with the degraded raised bog is projected to increase slightly relative to the baseline. However, the detail of the projected changes for the County Mayo subset differs from the country-wide projections. At the national scale e.g. the projected changes indicate some of the greatest losses of climate space are associated with low-elevation coastal cells in the west. The relatively large losses of climate space projected for the wet heath and active blanket bog habitats is merely likely to be reflecting a relatively high proportion of these low-elevation cells in the County Mayo data subset.

8.4.4 Recommendations for Climate Change adaptation in Co. Mayo: Biodiversity

Maintaining strong links between local and national levels: National implementation of the Habitats Directive requires regular assessment and reporting on the conservation status of species and habitats listed in the Directive's Annexes I, II, IV, and V. To date, data concerning climate change projections have not been incorporated into these assessments. Future assessments should ensure that the latest data and modelling techniques are used to project climate change impacts and that they feed directly into these assessments.

Invasive species: Climate change will increasingly facilitate the spread of invasive species and this is acknowledged in the Co Mayo BAP ("*Continue efforts to eradicate Gunnera*"). Key invasive species found in Co Mayo include Giant rhubarb, Japanese knotweed, Rhododendron, and the zebra mussel. Local authorities and conservation groups will play a central role in minimising the damage to native biodiversity.

Hedgerows and landscape connectivity: Species will experience changes in their ranges, moving to higher latitudes and altitudes. The maintenance of and promotion of connectivity in the landscape and between Natura 2000 sites is vital to ensure species can reach new areas of suitable climate space. The creation of green infrastructure will help facilitate dispersal to these new areas. Utilising the Co Mayo Hedgerow Survey (2007 and implementing relevant actions in the Co Mayo BAP will be central to achieving this aim.

Habitat restoration: Restoration of degraded habitats will improve the extent, integrity and resilience of vulnerable habitats such as blanket and raised bogs with knock-on benefits for species dependent on such habitats. Several sites in Co Mayo have been involved in the EU Life /Coillte project to restore degraded blanket bogs and this work will ideally need to be continued and extended.

Flexible site designation and protection: Future biodiversity management will require a more dynamic approach to conservation site designation and protection at the local level. The identification of current sites where species will be able to persist in the future, sites where species will migrate to, and areas that connect these sites should underpin long term planning.

Planning and cumulative effects: Co. Mayo's species and habitats currently face a multitude of threats including land-use change, habitat fragmentation and the introduction of non-native species. Sustainable land use planning and local development by Mayo Co. Council are critical to addressing these pressures.

Assisted migration: Some species will not be capable of migrating to new areas of suitable climate and habitat or adapting to new conditions. If future conservation objectives deem these species to be a priority then assisted migration (translocation) to areas with suitable climate and habitat may be necessary..

Prioritise limited resources: It is recommended to focus limited conservation resources on those species and habitats in Ireland that are most vulnerable. This report will help identify many of these habitats and help fulfil the actions outlined in the Co Mayo BAP.

County level monitoring: Long term monitoring of species distribution, habitat quality, etc is central to detecting and quantifying climate change impacts on Ireland's vulnerable species and habitats. This will aid appropriate conservation management actions. The Co Mayo BAP aims to: *Collect and make accessible biodiversity/natural heritage information.* Implementation of the actions to *Identify areas of local nature conservation importance, Continue to conduct habitat mapping projects* and *maintain the County Mayo Biological Database* will be central to achieving this.

Local scale modelling: Future biodiversity modelling requires further refinement of the techniques used. More research and a retention and extension of the capacity developed here are needed to deliver the tools required to provide the conservation sector with the best available projections.

8.5 Climate Change Adaptation in Co Mayo: the Built Environment

In common with other parts of the Western Region, the built environment and human infrastructure in Co. Mayo is generally more widely dispersed than in other areas of Ireland. 71% of the population of the county currently reside in rural parts (CSO, 2012). In construction terms, Mayo is experiencing the same decline occurring nationally. For example, in 2005 at the height of housing construction in Mayo 2,795 residential units were commenced. In 2010 this figure had fallen to 351 (DECLG, 2011b). By mid 2011 there were 128 unfinished estates in the county (Western People, 2011) and a vacancy rate of just under 25% (CSO,2012).

Weather significantly affects many activities in the building and construction sector Once constructed, buildings continue to be subjected to weather related stresses. Due to its location on the western fringes of Ireland, Mayo is exposed to more extreme weather events than many other counties, and consequently its built structures experience proportionally greater weathering than those further inland. The importance of this is that climate change is likely to have a more significant impact on buildings in Mayo than in more eastern and inland areas. Therefore, it is of great importance to quantify likely changes in climatic conditions at the local scale and to identify adaptation strategies to manage them.

8.5.1 Wind-driven Rain

The Irish Standard IS EN ISO 15927-3:2009 'Hygrothermal performance of buildings – calculation and presentation of climatic data – part 3: Calculation of a driving rain index for vertical surfaces from hourly wind and rain data' (NSAI, 2009) was employed to calculate new driving rain indices for Co. Mayo for the periods 1961-1990, 2021-2040 and 2041-2060. A combination of observed and modelled wind and rainfall data was used. For the future periods, modelled output from the C4I project (McGrath et al, 2008) was processed to provide

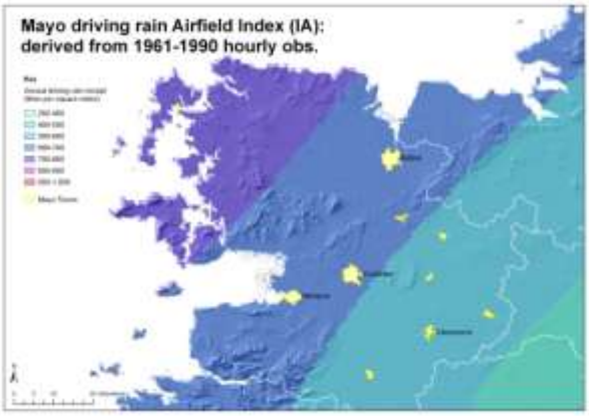


Figure 0.1 Mayo driving rain 1961-1990

10km^2 resolution dynamically downscaled scenario outputs.

Current wind-driven rain conditions in Mayo for the period 1961-1990 can be seen in Figure 8.7. Westport, Ballina and Claremorris are subject to annual values of wind-driven rain in the range of 600-700 litres/m^2 of precipitation on vertical surfaces. Predictably, amounts are greatest on the western seaboard and decrease inland. Using downscaled output from global climate models, projected changes in these quantities can be computed. Figure 8.8 illustrates the projected wind-driven rain amounts for the period 2041-2060. Of particular note is that the principal urban centres of Westport, Ballina and Castlebar are in, or near to, a band of wind-driven rain featuring values between 700-800 litres/m^2 per annum. The overall result is that increases in wind-driven rain in the order of 14% will be experienced by structures in the Mayo region.

The increase in wind-driven rain will impact on construction through a reduction in numbers of sites suitable for construction, tighter planning regimes and the necessity of employing increasingly resilient materials. Materials used in construction, particularly in the north west of the county, will need to be appropriate for current and future conditions in terms of maintaining building envelope integrity and resistance to moisture. This has implications for the industry in terms of cost, work schedule planning and maintaining industry best practice.

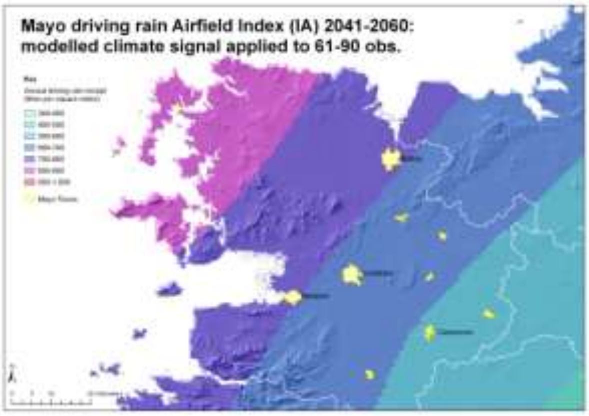


Figure 0.2 Mayo driving rain 2041-2060

Also of interest in Mayo is higher terrain such as the Nephin Beg range. Increased wind-driven rain intensity with height will mean that effects are accentuated with altitude, which will necessitate further consideration both in terms of materials used and planning policy. That said, it is anticipated that very little construction will take

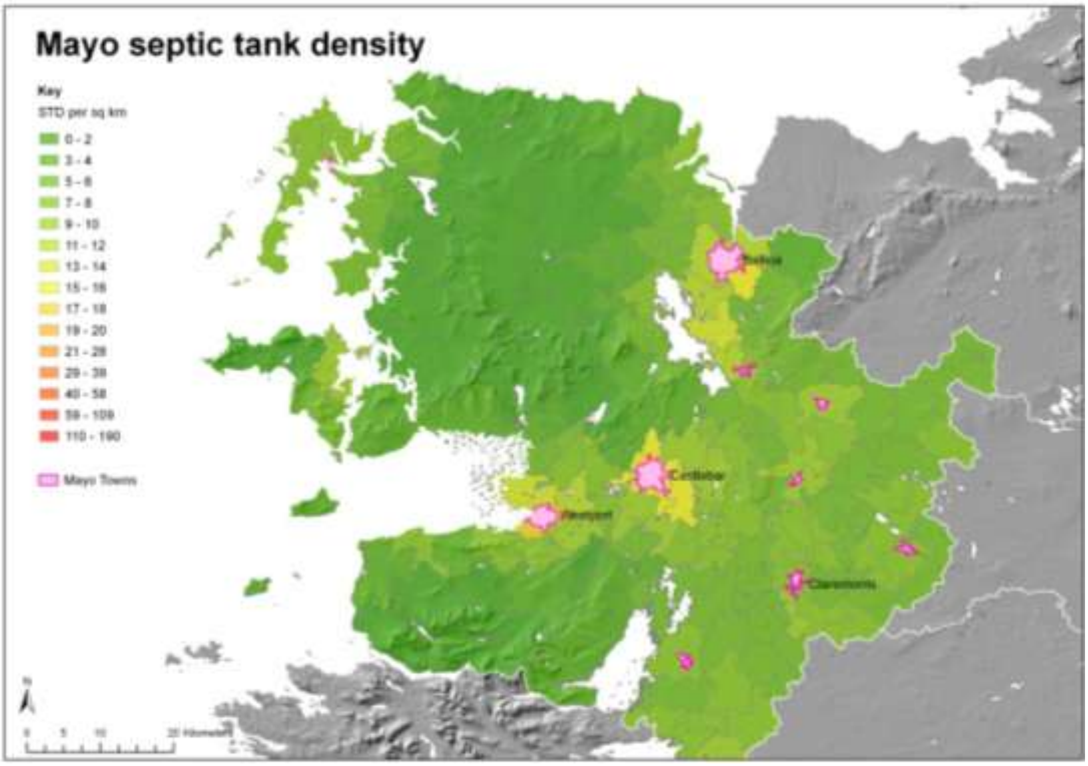


Figure 0.3 Mayo septic tank density

place in these zones due to planning restrictions and their Natura 2000 status.

From a regulatory stand-point, recommendations regarding Technical Guidance Documents A (Structure) and C (Site Preparation and Resistance to Moisture) from Chapter 4 should be implemented with due regard to Mayo's regional variability. Furthermore, due to increased wetting, the thermal properties of envelopes will also be compromised. To mitigate for this, high specification insulation should be incorporated throughout as per guidance in TGD L (Conservation of Fuel and Energy), complemented by ventilation such as that recommended in TGD F (Ventilation) to reduce the likelihood of mould growth and occupant health hazard.

In terms of adaptation, a stricter planning regime should limit construction in exposed zones. Where construction is permitted, materials of higher specification should be used as prescribed in the Technical Guidance Documents, and work carried out to standards set out in relevant Actual Construction Details.

8.5.2 Recommendations for Construction

1. Tighter planning policies must be enforced in the more exposed zones if structural integrity is to be maintained throughout the lifetime of the structure.

2. Self-certification of construction projects should be prohibited. Competent Local Authorities only should sign off the relevant stages.

3. In general, no single leaf building construction should be permitted. Double leaf, or construction such as meets or exceeds double leaf performance, should be used in all zones of County Mayo unless in an extremely well sheltered environment. ISO 15927-3:2009 should be used for site-specific evaluation.

4. Higher tolerances to wind loading and a more integrated materials approach should be incorporated to enhance structural and thermal performance.

8.5.3 Septic tanks

In a county where 71% of the population live in a rural setting, it would be reasonable to expect high septic tank densities with a consequent threat to groundwater quality. However, due to Mayo's relatively small population, spread over a large area, septic tank density outside the urban centres is low (Figure 8.9).

Although overall distribution reflects the national trend of higher densities in peri-urban zones, septic tank density values within urban environs, with the exception of Westport at 17/km^2, do not exceed the 16/km^2 level determined to be indicative of potential zones of contamination. The next highest STD values are for the suburbs of Ballina and Castlebar at 15/km^2. Other areas in Mayo register densities well below the significant contamination risk threshold, with low concentrations in the east in the order of 6/km^2 and very low densities in the west of <2/km^2.

minimum depth for adequate effluent purification of 1.5m of unsaturated subsoil and gravel, measured from the base of the percolation pipes. It can reasonably be suggested that every septic tank within the vicinity of the monitoring station, at the very least, was discharging partially treated effluent directly to groundwater during this period.

In the context of climate change, Mayo is threatened with the possibility of rising winter water tables due to increased winter

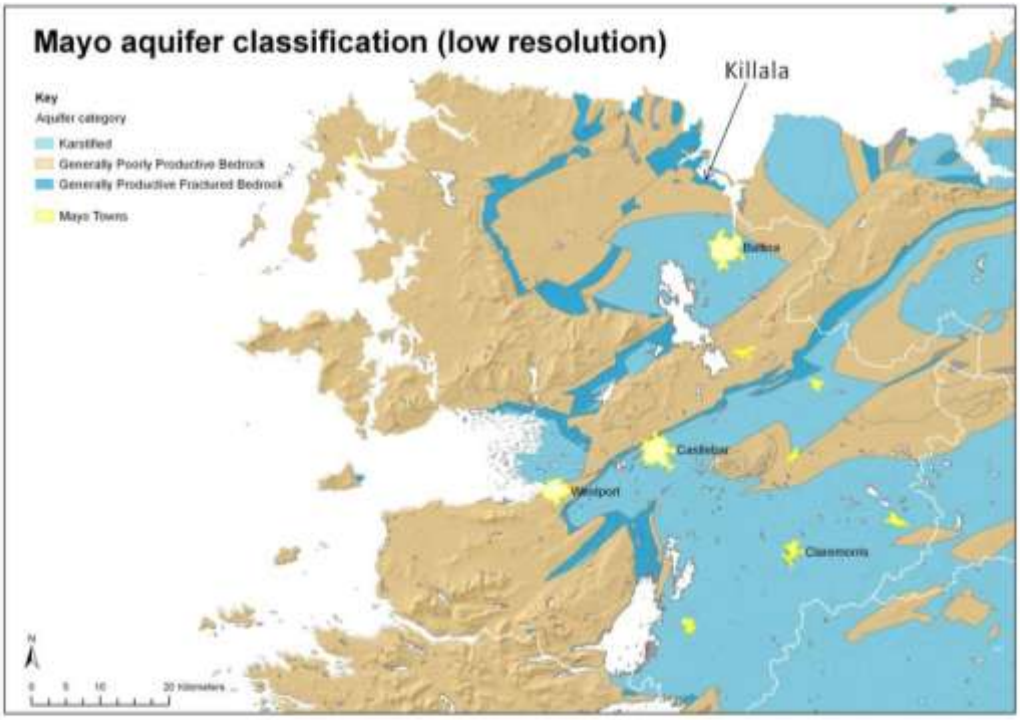


Figure 0.4 Mayo aquifer category

Although septic tank density is an important aspect of the potential impacts of climate change on groundwater vulnerability, it is not the only factor. Depth to water table is also crucial. For example, Killala lies above an aquifer classified as Generally Productive Fractured Bedrock (Figure 8.10). According to the EPA's groundwater level reading at the site, the depth to water table in November 2009 was 0.7m. This encroaches well inside the EPA's recommended

precipitation. Considerable uncertainty surrounds the regional details of future precipitation and Figure 8.11 should be taken only as indicative of an expected increase in winter precipitation. However, any increase in winter precipitation will endanger groundwater quality as the water table rises in response to the increased recharge toward septic tank zones of purification.

Figure 8.11 Modelled December January February percentage precipitation increase

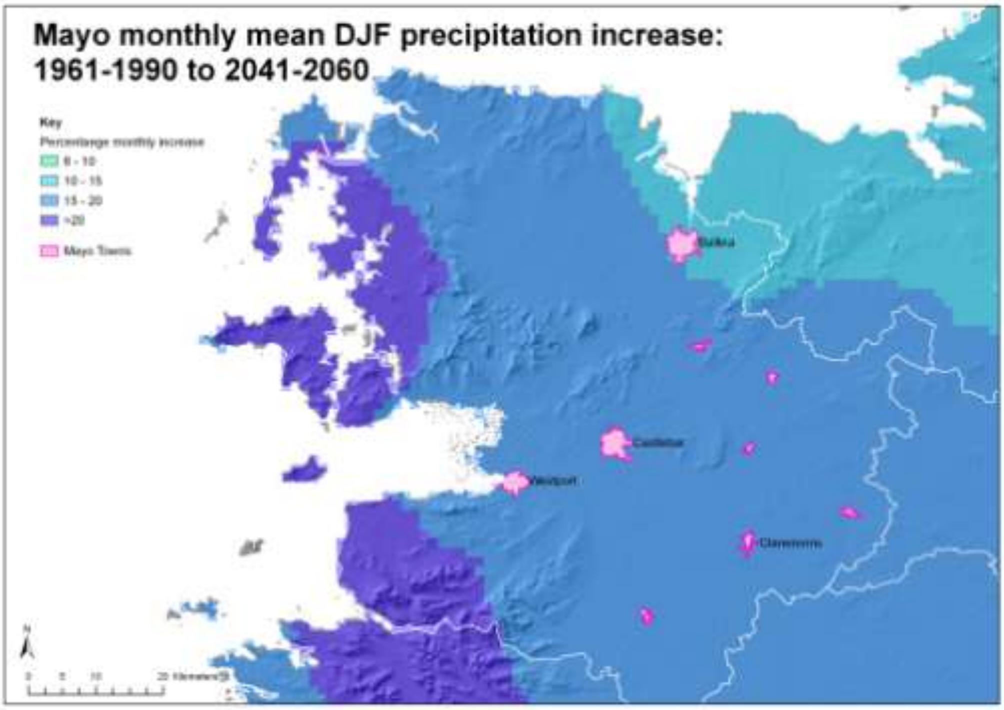


Figure 0.5 Modelled December January

Although the greatest increase is in the west where septic tank density is low and where the aquifers are classified as Generally Poorly Productive Bedrock, in the central and eastern areas there is still a significant increase of between 15-20%. As such, groundwater levels will require careful monitoring to provide warning of encroachment into septic tank purification zones, particularly around the urban centres of Castlebar, Ballina and Westport where septic tank densities are higher. The west of Mayo features generally unproductive bedrock and low septic tank density and it is the threat to surface water that is evident. For example, location of septic tanks on impermeable subsoil could lead to contamination of surface waters that eventually merge with groundwater sources, thereby polluting aquifers hitherto unaffected by direct contaminant loading.

According to the Vulnerability Index illustrated in Chapter 4, Mayo is rated 2 ('moderate risk of groundwater contamination'). However, as is shown here, local considerations such as high water tables greatly enhance vulnerability, with the result that the only way to provide a comprehensive analysis of actual groundwater vulnerability is further study by the Local Authority.

8.5.4 Recommendations for Septic Tanks

1. Septic tank installation to be severely curtailed in zones with an STD of near to or greater than $16/km^2$.
2. Further development in peri-urban areas should be conditional on provision of wastewater management other than septic tank systems.
3. Groundwater protection schemes to be set up around aquifers with high winter water tables.
4. Funds should be allocated to enable the Local Authority to take an increasingly active role in assessing groundwater vulnerability prior to approving new septic tank installations.

8.5.5 General Remarks and Conclusions

The volume and value of construction in Mayo is not as high as in other, more densely populated areas of Ireland. However, this case study highlights the necessary steps that will ultimately have to be taken to adapt to climate change through the present century. While the primary strategies in a construction context revolve around planning regimes and materials usage, governance and responsibility at local level are also important tools with which to handle climate change issues.

Communication and co-ordination are vital in this regard. Ensuring seamless adaptation management at local level between sectors as diverse as construction, water, biodiversity, tourism, economics and planning requires strong linkages horizontally between Local Authorities and cooperation vertically with high-level government. If these links are, as they should be, supported by relevant policies, Mayo can be seen as leading the way in terms of implementing national strategies to manage climate change.

8.6 Climate Change Adaptation in Co Mayo: Tourism

The West region (Galway, Mayo, Roscommon) received approximately 1,148,000 overseas tourists in 2010 (19.6% of total national figure (Fáilte Ireland, 2011a) generating revenue of €348M (Table 8.7). Mayo’s share of overseas visitors was 322,000 in 2010, generating €89M in revenue. Domestic tourism is also an important feature of tourism in Mayo. The West region is the second most visited region by domestic visitors accounting for 18% of all domestic trips (Fáilte Ireland, 2010).

Table 8.7: Overseas Visitors to West Region in 2010

Data: Fáilte Ireland (2011b).

Table 0.1 Overseas Visitors to West Region in 2010

	Britain	Mainland Europe	North America	Other Areas	Total Overseas Tourists
Numbers	394,000	422,000	255,000	77,000	1,148,000
Revenue (€M)	127	111	92	17	348

Almost 82% of visitors to the West region arrived in Ireland by air (Fáilte Ireland, 2011a; CSO, 2012) thus emphasising the importance of Knock International Airport. While currently Knock Airport has a low rate of holiday arrivals, it does have the potential to contribute to the future development, expansion and success of tourism in Mayo and surrounding regions.

County Mayo has a large accommodation stock for visitors (Table 8.8) with hotels the most preferred type of accommodation facility for overseas visitors. Therefore, it is suggested that the tourism authorities in the region promote sustainable consumption in these premises.

Table 0.1 Mayo's Tourism Accommodation Stock and Visitor Choice 2010

Accommodation type	Premises	Beds	Visitor choice
Hotels	52	4851	31%
Guesthouses/ B&Bs	154	1717	22%
Self-Catering	117	468	6%
Camping & Caravan	9	2,304	2%
Hostel	5	232	11%
Friends/Relatives/Other	-	-	28%
TOTAL	337	9572	100%
Data: Fáilte Ireland, 2011c and TAMS, 2010			

National initiatives such as the Green Hospitality Programme can be beneficial in ensuring the long-term environmental and economic sustainability of accommodation premises.

Table 8.8: Mayo's Tourism Accommodation Stock and Visitor Choice 2010

Data: Fáilte Ireland, 2011c and TAMS, 2010.

In terms of visitor attractions, Mayo is rich with natural and built visitor attractions, ranging from indoor museums to outdoor activity sites and natural scenic landscapes. It has the longest coastline in Ireland (1,168km) and has two national pilgrimage sites at Croagh Patrick and Knock. Mayo is also home to the 5000-year old Neolithic farmstead at the Céide Fields. The Great Western Greenway through Westport, Newport, Mulranny and Achill has become one of the leading cycling/walking trails in the country (ITIC, 2011) and is a positive development within the sustainable/eco-tourism sector. These activities and attractions along with the more intangible assets and experiences such as heritage are central to the successful and sustainable development of Mayo tourism into the future.

Tourism in Mayo is centred on niche markets; outdoor leisure, adventure, angling, water-sports and heritage towns which span from the centre hubs of Castlebar, Ballina, Westport and Ballinrobe. The conservation of these is critical for the success of tourism in the area. For example, the River Moy is one of the main and hosts an annual Salmon Festival, centred in Ballina. Under projected climate change, water quantity and quality will become an issue of concern and so it is important the integrity and quality of vital tourist amenities such as the River Moy is maintained.

In 2011, Mayo was awarded 13 Blue Flag Beach Awards, among the highest of any county in Ireland (An Taisce, 2011). All 15 designated bathing areas in Mayo achieved good water quality status and complied with the EU guide and mandatory values (EPA, 2011). Both of these successes are crucial to the success of tourism in the county and it is important this standard is upheld given the increased likelihood of extreme weather events along with challenges of potentially diminishing water quality from increasing temperatures under climate change.

A cursory Strengths/ Weaknesses/ Opportunities/ Threats analysis for tourism in the county can identify climate change as a significant threat to many of its tourism assets based around the natural environment, operating through the medium of water, biodiversity, sea level rise etc. (Table 8.9). However as shown later, positive tourism benefits are also likely.

TABLE 0.2 SWOT ANALYSIS OF MAYO'S TOURISM PRODUCT

SWOT	Characteristic
Strengths	International airport, Existing tourism product, Several heritage towns, range of visitor attractions, scenic location, Ballycroy National Park, upgraded road and rail networks and accessibility
Weaknesses	Area of county, long travel distances between tourist hubs
Opportunities	Diversification into niche tourism markets (outdoor, adventure, water, fishing), sustainable tourism products (ecotourism), further development of airport and other transport facilities
Threats	Lack of investment, withdrawal of key businesses, price perception, competing counties, dominance of Dublin, **climate change**

Table 8.9: SWOT Analysis of Mayo's Tourism Product

8.6.1 Establishing a Tourism Climatic Index for Mayo

Using the methodology described in Chapter 5 a Tourism Climatic Index (TCI) for Mayo was calculated. Using the future climate model projections, one can see the likely changes in suitability of climate in the Mayo region for general tourist activity (Tables 8.10, 8.11, Figure 8.12, 8.13). TCI scores were constructed for the synoptic stations of Belmullet and Claremorris and are in line with national TCI changes. These show the climate suitability of the county improving as the century advances.

Table 0.3 Monthly TCI Scores for Belmullet synoptic station

Belmullet	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TCI Score
1961-1990	26	38	38	53	54	56	54	54	46	37	34	32	**43.5**
2021-2050	32	34	42	53	56	60	56	52	46	37	32	32	**44.3**
2051-2080	32	34	46	51	60	64	63	59	55	39	32	32	**47.3**

Table 0.4 Monthly TCI Scores for Claremorris synoptic station

Claremorris	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TCI Score
1961-1990	31	39	38	50	51	59	61	57	49	38	34	32	**45**
2021-2050	33	36	42	50	59	63	65	61	49	37	32	33	**47**
2051-2080	34	36	46	50	59	68	70	66	59	41	32	34	**50**

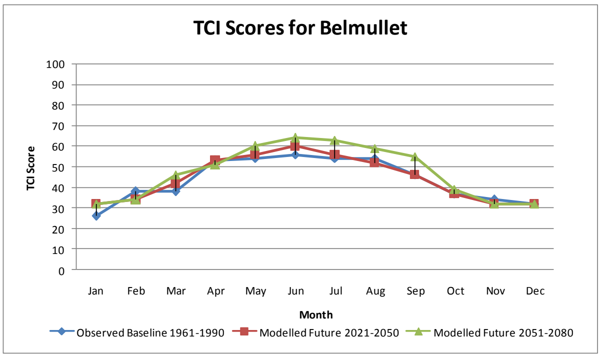


Figure 0.1 TCI Curve for Belmullet over three time periods

Table 8.11: Monthly TCI Scores for Claremorris Synoptic Station

8.6.2 Interpreting the TCl for Mayo and Recommendations

The mid-century projections (2021-2050) serve as a guide for regional scale action and adaptation while the late-century projections (2051-2080) serve as an eye to the long term future where long term adaptation strategies can be developed and implemented. Mayo's Tourism Climatic Index over the three time periods analysed illustrates a 'Summer Peak' distribution which becomes more pronounced later into the century. This affirms the statistical data, highlighting that 36% of overseas visitors and 37% of domestic visitors to the West region arrive in the peak tourist months of July, August and September (Fáilte Ireland, 2010). The TCI scores from the shoulder seasons (late-spring and autumn) are projected to broadly increase thereby offering the potential to extend the

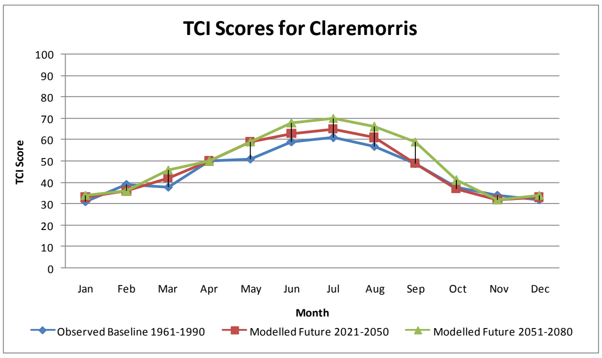


Figure 0.2 TCI Curve for Claremorris over three time periods

currently short summer high-peak season. This would be particularly beneficial to the tourist economy in the county. Such changes in reliability of the climate and expansion of the tourist season will not be immediate, but will probably become clearly evident within 25-35 years. The earliest beneficiaries will be tourism facilities outside of Mayo, along the southern and eastern areas of Ireland which are projected to have the significantly drier and sunnier conditions earlier than the west coast.

the Ireland West strategy, it would be viewed as an important reference point for tourism stakeholders in Mayo to have a county-specific plan with local knowledge embedded into it. Through co-operative work, impacts of climate change on Mayo tourism can be optimised and the commercial potential of the county's tourism better realised through a comprehensive adaptation strategy.

Table 0.4 Analysis of County and Local Area Development Plans

Development Plan	Tourism References	Climate Change/Global Warming References
Mayo County 2009-2015	22	None
Castlebar Local Area 2008-2014	5	None
Ballina Local Area 2009-2015	35	None
Westport Local Area 2010-2016	26	None
Ballinrobe Local Plan 2010-2016	14	None
Ballyhaunis Local Area 2010-2016	5	None

Climate change is likely to impact upon the tourism industry in county Mayo through impacts on visitor attractions: both built and natural. Consequently, tourism development decisions must be made with climate change specifically on the agenda.

It is encouraging to see in Fáilte Ireland West's Regional Tourism Development Plan 2008-2010 there is an aim on developing the region as Ireland's primary outdoor and adventure destination, while focusing on environmental sustainability. While tourism plans are briefly outlined in Mayo County Development Plan and some of the Local Area Plans, there is no evident specific tourism development strategy for Mayo and a content analysis shows no mention of climate change in these plans (Table 8.12).

There is a need to develop such a strategy, which should be in line with the guidelines set out in Fáilte Ireland West's Regional Development Plan. While this may seem like a duplication of

8.7 Climate Change Adaptation in Co Mayo: Economic Perspectives

Economic aspects of three subjects were considered for Co. Mayo. These centred on potential sea-level rise (SLR) related impacts, biodiversity impacts along the Mayo coast and inland flooding impacts for selected river catchments.

8.7.1 Sea Level Related Aspects

Coastal exposure is the cumulative result of a number of factors including: climate-induced Sea Level Rise (SLR), tidal variation, changes in wave climate, currents, and storm surges, and coastal geomorphological composition. Although the Mayo coast is predominantly hard-rock dominated, there are significant areas of soft low-lying coastline vulnerable to increased inundation and accelerated coastal erosion. Model results suggest an increase in both the frequency and height of extreme storm surges on the west coast in winter (Wang et al, 2008). Although considerable uncertainties remain, (McGrath and Lynch 2008) suggest that a 30% increased frequency in surge elevations in the range 0.5-1m are likely by mid century for Clew Bay and Sligo Bay.

Table 0.5 Exposed percentage of land, exposed addresses and €M potential insurance claims for County Mayo

Sea Level Rise Scenarios					
0.5m	**1m**	**2m**	**3m**	**4m**	**6m**
Exposed Percentage of Land					
0.3	0.5	0.7	0.9	1.2	1.7
Exposed Addresses					
166	354	480	615	779	1,367
€ M for All Claims					
6	12	15	19	23	41

Using a medium resolution Digital Terrain Model (DTM) the extent of land lying at various heights above sea level can be estimated (Figure 8.14). Land exposed under the SLR scenario mapping makes up 0.3% of land in Co. Mayo under the 0.5m scenario and increases up to 1.7% under the 6m combined SLR and storm surge scenario. A further dataset of residential addresses and commercial addresses can be overlain on this (Figure 8.15) and the potential liability of properties estimated.

Average residential and commercial property claims were obtained from the Irish Insurance Federation. These were based on actual claims data from the major flood events that took place in November 2009 (IIF, 2010). On this basis, approximate potential insurance claims from the 0.5m scenario to the 6m scenario for Co. Mayo would range from €6M to €41M (Table 8.13). It should be stressed that this is a 'first pass estimate' and further refinement of the DTM and property values would be required to provide a more reliable set of figures. However, it does indicate the scale of potential property costs associated with sea level change for the county.

Figure 8.14. Sea-level rise exposure on the coast of Mayo ranging from 0.5m to 6m employing a medium resolution Digital Terrain Model (DTM).

(Clockwise from top left: The Mullet Peninsula, Rossport, Ballycastle and Lacken Bay, Clew Bay, Achill)

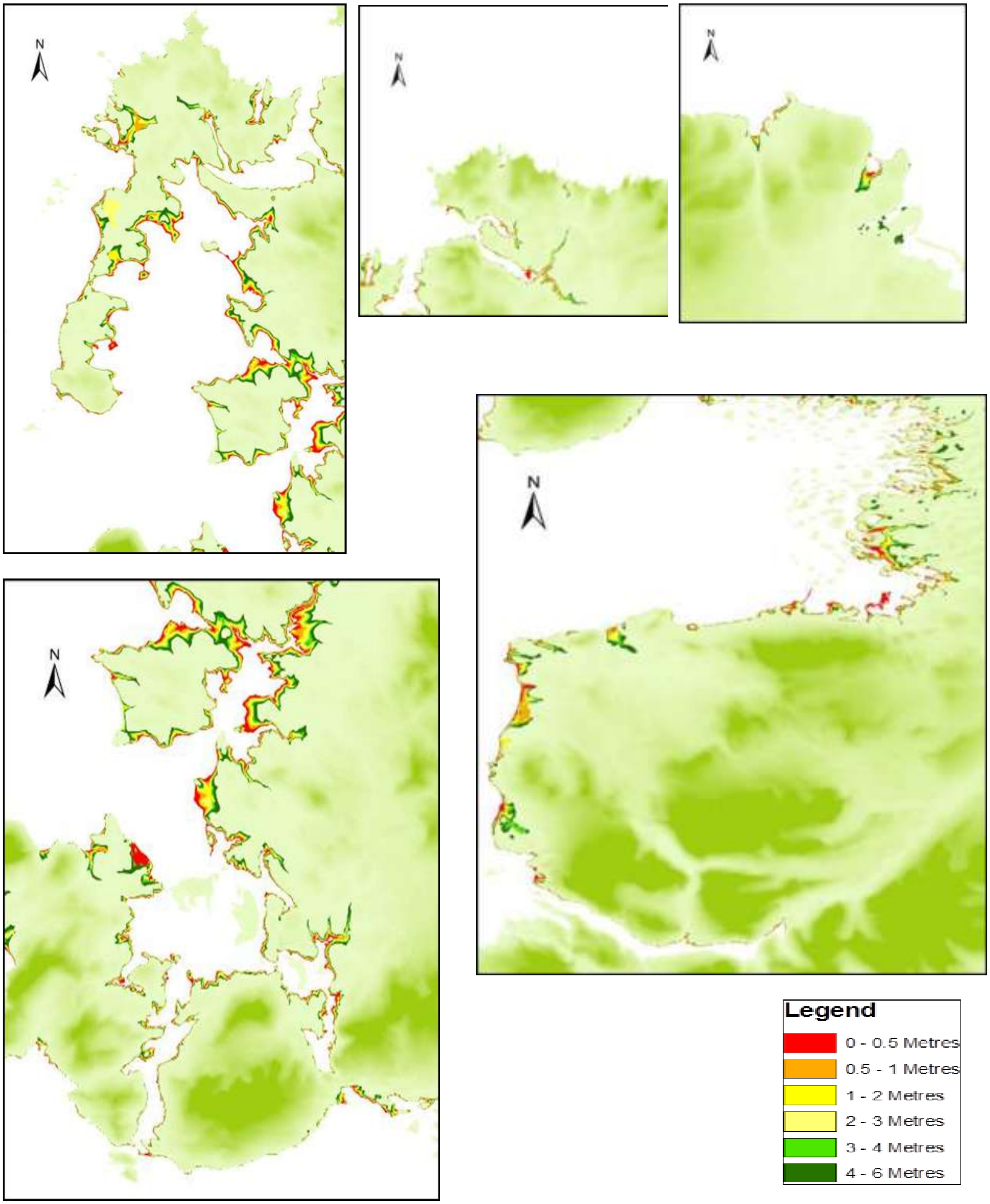


Figure 0.3 Sea-level rise exposure on the coast of Mayo ranging from 0.5m to 6m employing a medium resolution Digital Terrain Model (DTM). (Clockwise from top left: The Mullet Peninsula, Rossport, Ballycastle and Lacken Bay, Clew Bay, Achill)

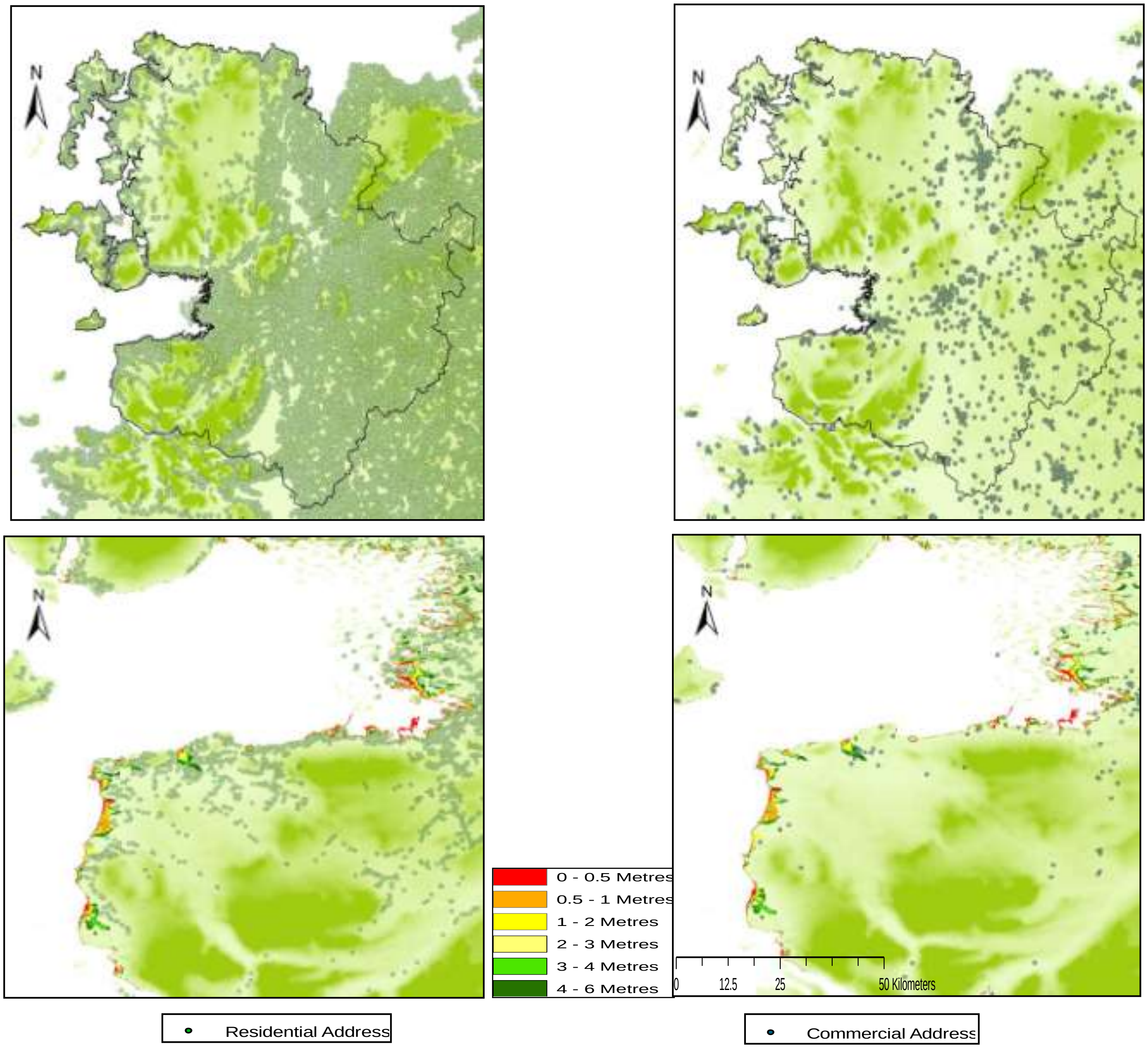


Figure 0.4 Residential and commercial addresses for Co. Mayo extracted from An Post Geo-Directory. The 6 SLR scenarios are overlain for a sample area (Clew Bay).

8.7.2 Coastal Wetlands

The extent of coastal wetlands exposed to SLR in County Mayo, comprising beaches, dunes and sand was determined from the CORINE 2006 database (CORINE, 2010) (Figure 8.16). The three SLR scenarios of 0.5m, 1m and 2m were explored in relation to the exposure of this coastal wetland subgroup. Estimated potential percentage losses range from 7% under the 0.5m scenario to 14% under the 2m scenario. Placing monetary valuations on the loss of such habitats is not possible and the subject of considerable debate. Employing an established valuation methodologies the €M Value per hectare per year relating to these losses was estimated as ranging from €1.2-2.3M. (Brander *et al*., 2006).

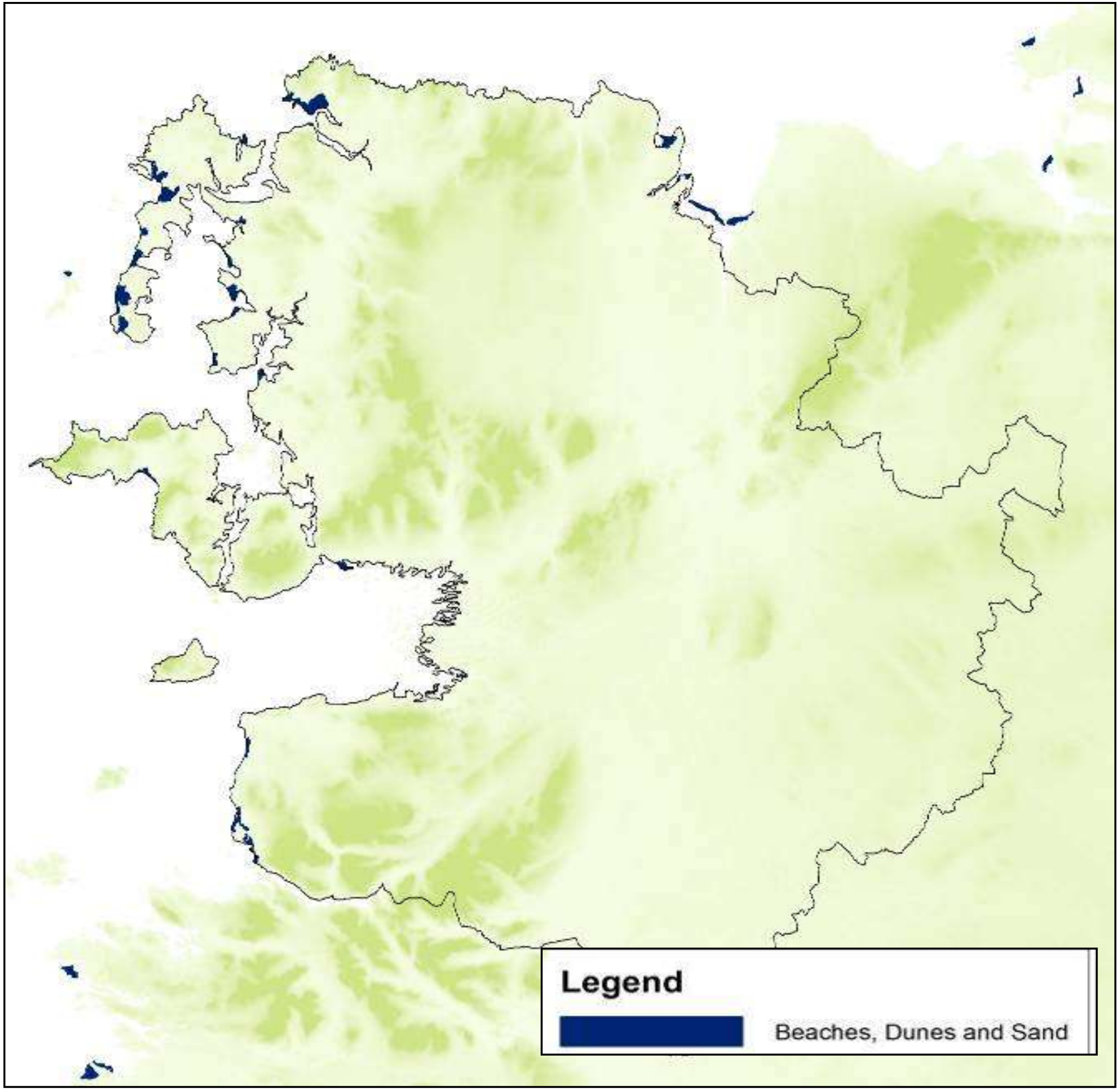


Figure 0.5 CORINE 2006 indentified Beaches, dunes and sand in County Mayo along with exposed potential percentage area loss, area loss and €M value per hectare per year under 3 SLR scenarios.

8.7.3 Riverine Flooding

In the absence of detailed floodplain maps it is not possible to quantify the extent and potential costs of climate change-related flooding. A provisional estimate may be made for a catchment by applying elevation buffers around the river channel and quantifying the number of properties at risk as a result. This was done for the Moy catchment for heights of 1, 2 and 3m above the channel height. Potentially exposed commercial and residential addresses as well as associated insurance claim costs were estimated (Figure 8.17). Under a 2m flood scenario, potentially exposed residential addresses stand at 262 with insurance claims of €4.3M. 52 commercial addresses are exposed under a 2m scenario equating to insurance claims costs of €5.2M.

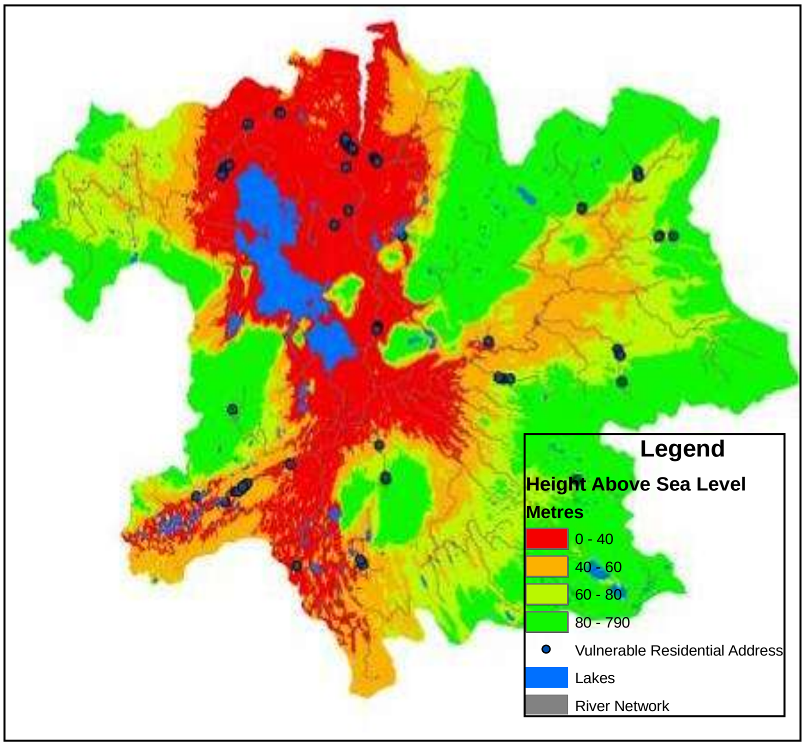


Figure 8.17 Potentially exposed commercial and residential addresses and associate Insurance claim costs in the Moy Catchment under 3 flood scenarios.

Buffer		
1m	2m	3m
Residential Addresses		
229	262	299
€ M		
3.7	4.3	4.9
Commercial Addresses		
48	52	57
€ M		
4.8	5.2	5.7

8.7.4 Conclusions

This case study would suggest that a typical Irish county faces substantial potential costs from sea level rise, loss of biodiversity and flooding. While the methodology and models employed display considerable uncertainty, and cannot be considered the final product in terms of quantitative cost estimation, they do convey the message that that climate change impact costs are likely to far outweigh adaptation costs.

Economic quantification of natural assets is particularly difficult. Who can quantify the loss of the Moy Salmon or the blanket bogs of Erris? What can be concluded is that these results highlight the importance of Integrated Coastal Zone Management (ICZM) along with ongoing and future Catchment Flood Risk Assessment and Management Studies (CFRAMS) in working towards managing and adapting to climate change impacts. It is clear though that that in making the hard choices necessary to address climate change impacts, a strengthening of governance structures at local and national level is required.

8.8 Climate Change Adaptation in Co Mayo: Governance/ Planning

There are two types of climate-related exposures: physical exposures and exposure related to adaptive capacity. The physical exposures which fall under the remit of local authorities include flooding, landslides, coastal erosion, sea level rise, water supply, and effects on biodiversity. These exposures have been outlined both in Section 8.1 and for selected sectors relevant to Mayo throughout this report.

It is evident that Mayo has very high exposure for floods, landslides and coastal erosion as well as high exposure for water supply and sea level rise. Concerns also exist in key areas of biodiversity. Overall, Mayo has very high physical exposure to climate change as evaluated by combining each of the foregoing sectors.

Mayo has also very high exposure related to adaptive capacity because there have been few actions regarding climate change adaptation. This will present challenges for Mayo as climate-change related events increasingly occur. Although, as a rural county with low population density, Mayo will be impacted less than some other areas, this does not render the need to plan for adaptive action less pressing..

Early adaptation minimises the need to repair damages, allows for incremental changes, and increases available options. First, acting now can prevent damages from future extreme events. Second, acting now allows entities to make small changes to day-to-day practices and investments that will better position them to withstand the effects of climate change. Third, acting now increases the future available options. Climate change considerations need to be mainstreamed into county level plans, which may require specific national regulations and dedicated funds for climate adaptation

8.8.1 Climate Adaptation: Local Government Actions

Mayo Co. Council acknowledges the likelihood of climate-related impacts, but has no climate change strategy and limited measures in the County Development Plan and other policy documents. The Development Plan only addresses sea level rise and renewable energy. Sea level rise is explicitly acknowledged with a 30-metre hoizontal setback and a planning policy that applications "must demonstrate that any development would not be subject to potential rising sea levels as a result of global warming" (MCC, 2008:150). Measures for flooding, water supply, and biodiversity are also needed. This will require a shift from generic acknowledgements of "climatic conditions" to detailed plans to address climate change.

8.8.2 Key challenges and opportunities

Generalised goals for sustainable development and climate change need to be translated into specific measures for transport, land use planning and energy consumption.

Stronger environmental regulations from central government are needed to reduce the effects of local development pressures. For example, a national level regulation for "no building on benefiting lands" would provide higher-level support to minimise pressures to develop in flood-prone areas. In addition, specific guidance from central government would help local authorities to implement national policies. For example, central government guidance in areas such as public lighting, energy for water services etc would likely result in greater energy reductions, and be of benefit to the overall climate change agenda.

Dedicated climate change resources would greatly help local authorities be proactive about climate change. Because central government funding represents a significant portion of local budgets, there is little latitude for local authorities to move forward without financial support. Without dedicated resources, any climate adaptation must be pursued under other agendas. Additionally, current budget allocations are based on demonstrated risk and do not include future risks.

Detailed risk assessments are urgently needed to provide necessary information to adequately prepare for climate change. Council staff rightly argue that these risk assessments require resources that are beyond the scope of local authorities and should be carried out by national lead agencies, as in the case of the OPW and flood risk assessments

Support from councillors is necessary to move forward. Without this, development pressures are compromising environmental protection measures such as implementing river basin management plans and limiting development in risk-prone areas such as flood plains and those with high landslide risk.

8.8.3 Governance Recommendations

- Establish a cross-sectoral climate change team, including all directors from all key departments within the local authority.
- Prepare a climate change strategy with indicators for each department. This should include a range of actions: existing measures that benefit climate change adaptation, potential measures possible within the current administrative framework, necessary measures requiring additional staffing or changes in administrative structures. A template for action is shown in Table 8.14 below.
- Raise awareness with elected officials by providing information regarding local climate change impacts.

	Necessary actions	Timeline
Climate mitigation	• Collect baseline data, broken down by department, on energy use and emissions • Set clear objectives and targets for reducing energy use	

Risk Assessment	• Identify potential local climate change issues • Identify which risks will require a response • Identify sectors requiring a more detailed risk e ○ built environment ○ cultural and religious heritage ○ local business, industry, and economy ○ energy generation and distribution system ○ health-care facilities ○ land use ○ transportation system ○ parks and natural environment ○ tourism
Building capacity	• Council staff members to attend worksh mainstreaming climate change into their specif • Hold a series of workshops to build knowle government leaders, chief executives, and el foster unity of purpose
Establishing structures	• Establish a cross-departmental team, staffed with responsibility for taking action on climate c • Establish a framework for evaluating, mea progress
Monitoring progress	• Incorporate reports from the climate chan monthly Council meetings • Incorporate departmental reports about clima the local authority's annual report
Building public consensus	• Designate responsibility with an individu communicating climate change messages • Carry out public information campaigns announcements, leaflets, schools, and commu

Table 8.13 A Template for Local Authority Action on Climate Change

8.9 Overall Recommendations

- Planning for adaptation will always be conducted in a situation of uncertainty. Robust, flexible strategies will be required in Mayo based on what is considered at the time to be an acceptable level of risk. Major investments e.g. for water infrastructure should be subjected to a sensitivity analysis of performance under the full range of climatic uncertainty likely during their effective lifetime.
- Successful implementation of the Habitats Directive will require greater understanding of the impacts of climate change on species and habitats, especially invasive species and species close to their current climatic boundaries. To ensure Co. Mayo's unique biodiversity is not any more adversely affected than necessary, the creation of green infrastructure and actions to maintain a

heterogeneous landscape require to be formally integrated into landscape management approaches. For protected sites, future designations will require effective planning for this, while in the wider landscape, appropriate agri-environmental measures are required.

- A conservation focus on those species and habitats identified in this work as most vulnerable is recommended. Future research efforts are required to incorporate dispersal, biotic interactions and land use change scenarios to ensure that the conservation sector is equipped with the best available projections on which to base adaption decisions. Long term monitoring and the research in climate-biodiversity must be supported to achieve this.
- For construction, design standards should be based on climate conditions which can be reasonably expected to occur during the expected lifetime of the structure. This means planning permissions in the County should take greater account of materials proposed for building fabric as well as location exposure. Double leaf housing construction should be considered as a requirement for those areas most exposed to higher winter rainfall with hollow-block single leaf construction only permissible in sheltered locations.
- Higher winter water tables in Co. Mayo pose increased pollution potential for poorly located or defective septic tanks. Stricter planning guidelines in vulnerable areas are therefore recommended with connections to mains wastewater systems the preferred strategy where possible.
- The most recent model climate scenarios should be utilised when reviewing building regulations, and issuing new Technical Guidance Documents, particularly in terms of projected increases in wind-driven rain and consequent increases in moisture ingress. A strengthening of the functions of Mayo Co. Council in monitoring and enforcing the building control system is necessary to achieve the required adaptive response.
- The potential for tourism expansion in Co. Mayo be investigated further using survey and focus group techniques in conjunction with climate change scenarios incorporated into the Tourism Climatic Index. Specific adaptation options require examination using detailed cost-benefit analysis. In particular, water and waste water treatment projections require to be incorporated into tourism infrastructure calculations for Mayo's tourism towns.
- Economic costings of potential climate change impacts require to be considered when protective infrastructure is being contemplated by Mayo Co. Council. Under almost all scenarios, potential impact costs far outweigh adaptation costs. An extension of the Catchment Flood Risk Assessment and Management Studies (CFRAMs) and of Integrated Coastal Zone Management to incorporate the most up to date climate change scenarios is recommended. Difficult to quantify losses in ecosystem goods and services require also to be incorporated in economic quantification of adaptation strategies.
- It is recommended that Mayo Co. Council build adaptive capacity by establishing a high level climate change team responsible for developing and overseeing the implementation of a climate change strategy. Climate change should be integrated into the current Development Plan.

8.10 Overall Recommendations

- Planning for adaptation will always be conducted in a situation of uncertainty. Robust, flexible strategies will be required in Mayo based on what is considered at the time to be an acceptable level of risk. Major investments e.g. for water infrastructure should be subjected to a sensitivity analysis of performance under the full range of climatic uncertainty likely during their effective lifetime.
- Successful implementation of the Habitats Directive will require greater understanding of the impacts of climate change on species and habitats, especially invasive species and species close to their current climatic boundaries. To ensure Co. Mayo's unique biodiversity is not any more adversely affected than necessary, the creation of green infrastructure and actions to maintain a

heterogeneous landscape require to be formally integrated into landscape management approaches. For protected sites, future designations will require effective planning for this, while in the wider landscape, appropriate agri-environmental measures are required.

- A conservation focus on those species and habitats identified in this work as most vulnerable is recommended. Future research efforts are required to incorporate dispersal, biotic interactions and land use change scenarios to ensure that the conservation sector is equipped with the best available projections on which to base adaption decisions. Long term monitoring and the research in climate-biodiversity must be supported to achieve this.
- For construction, design standards should be based on climate conditions which can be reasonably expected to occur during the expected lifetime of the structure. This means planning permissions in the County should take greater account of materials proposed for building fabric as well as location exposure. Double leaf housing construction should be considered as a requirement for those areas most exposed to higher winter rainfall with hollow-block single leaf construction only permissible in sheltered locations.
- Higher winter water tables in Co. Mayo pose increased pollution potential for poorly located or defective septic tanks. Stricter planning guidelines in vulnerable areas are therefore recommended with connections to mains wastewater systems the preferred strategy where possible.
- The most recent model climate scenarios should be utilised when reviewing building regulations, and issuing new Technical Guidance Documents, particularly in terms of projected increases in wind-driven rain and consequent increases in moisture ingress. A strengthening of the functions of Mayo Co. Council in monitoring and enforcing the building control system is necessary to achieve the required adaptive response.
- The potential for tourism expansion in Co. Mayo be investigated further using survey and focus group techniques in conjunction with climate change scenarios incorporated into the Tourism Climatic Index. Specific adaptation options require examination using detailed cost-benefit analysis. In particular, water and waste water treatment projections require to be incorporated into tourism infrastructure calculations for Mayo's tourism towns.
- Economic costings of potential climate change impacts require to be considered when protective infrastructure is being contemplated by Mayo Co. Council. Under almost all scenarios, potential impact costs far outweigh adaptation costs. An extension of the Catchment Flood Risk Assessment and Management Studies (CFRAMs) and of Integrated Coastal Zone Management to incorporate the most up to date climate change scenarios is recommended. Difficult to quantify losses in ecosystem goods and services require also to be incorporated in economic quantification of adaptation strategies.
- It is recommended that Mayo Co. Council build adaptive capacity by establishing a high level climate change team responsible for developing and overseeing the implementation of a climate change strategy. This should be integrated into the current Development Plan.

9. Conclusions

9.1 Introduction

The European Commission's White Paper: Adapting to Climate Change in Europe-options for EU action highlighted the need for early action in implementing climate change adaptation strategies. It argued that such strategies, if acted on now, would bring about clear economic benefits and minimise the threats to ecosystems, health, economic development, property and infrastructure. Competitiveness on the international stage is essential for both medium term economic recovery and longer-term prosperity for Ireland, and adaptation to imminent climate change is an essential ingredient in this.

This study has addressed this need through a multidisciplinary integrated assessment of the drivers and impacts of climate change and the development of information systems and outreach tools which address priority adaptation areas. It employs an integrated framework, incorporating observation systems, previous research outputs, new analysis and modelling, to provide decision support tools and guidelines in support of cross-sectoral adaptation decision making, at local, regional and national level. It also contributes to coordinated efforts at developing adaptation strategies at the EU level. Significant interactions exist between the sectors studied and an integrated assessment has been prepared in tandem with this study to provide a case study of the adaptation challenges and opportunities facing an individual Irish county.

Significant outcomes from the project include the enhancement of national research capacity in this area and a capability to provide, on an integrated basis, information and analytical tools to support, test, and validate policy development and adaptive responses to climate change.

9.2 Water

A combination of population change and climate change will render many parts of Ireland vulnerable to water stress over coming decades. Adapting to these requires coping with inherent uncertainties in both climatic and non-climatic factors. The tools developed in this work allow the identification of vulnerability within individual water supply systems at local catchment level. This enables the assessment of robust adaptation options through an exploratory scenario-based modelling approach.

In the short term, many, low-regrets or no-regrets, forms of adaptation planning can be suggested. These would include demand management and leakage control, and clearly, these offer a relatively low cost initial strategy. Over longer time scales, however, approaches based on risk assessment which integrate 'vulnerability thinking' into forward planning is advocated. Prior to major new water infrastructure investments a sensitivity analysis of performance under the full range of climate change uncertainty then prevailing is recommended. A flexible tool capable of achieving this is provided.

9.3 Biodiversity

It is clear that potential climate change impacts now need much greater priority in the assessment and management of Natura 2000 sites in Ireland if appropriate actions to protect vulnerable species and habitats are to be implemented in time. Irish plant communities and habitats are likely to show dynamic responses to projected climate change and rethinking of conservation objectives and practices will be required. Climate change will also facilitate invasive species as well as significant changes in the ranges of native species. A move to higher latitudes and higher altitudes will require issues such as spatial connectivity to be more actively planned for.

Particular attention is required for vulnerable habitats such as blanket and raised bogs, with consequent implications also for their dependent species. Tools are provided here for the identification of most vulnerable areas to enable prioritisation of conservation efforts and the maintenance of migration corridors. Adaptation will require effective incorporation of such considerations into planning and management strategies and it may be necessary to designate some new sites or extend existing ones to achieve these objectives. Much remains to be understood regarding the interrelationships between biodiversity, ecosystem functioning, ecosystem service provision and environmental change in Ireland.

The current work has identified those species and habitats which are most vulnerable and provided a useful insight into what the conservation sector requires to do to enable adaptation of Ireland's natural landscape. Long term monitoring and a more integrated approach incorporating dispersal models, biotic interactions and land use change scenarios are essential ingredients for the forward-looking, flexible and dynamic approach to nature conservation that will be required for the future management of climate change impacts on Irish biodiversity.

9.4 Building and Construction

Ireland's unique position on Europe's north-western extremity increases its relative vulnerability to precipitation extremes and wind-driven rain. These are significant considerations for building and construction activities which should incorporate climate change contingencies into design specifications. Apart from new build, adaptation offers significant opportunities for the industry, as structures are designed and built or retrofitted to higher specifications to meet the projected climate extremes.

When revising Technical Guidance Documents and associated Building Regulations, the opportunity should be taken to incorporate the best available future climate model projections. In particular, winter wind driven rain is likely to become a more important issue especially in western areas due to expected increases in wind speeds and rain. Due to projected increases in these parameters, double-leaf housing construction should be used in most cases. Hollow-block single-leaf construction should only be used in the least exposed zones where significant shelter is evident. Exterior materials specifications and maintenance requirements may require reassessment. A tool for estimating changes in wind driven rain has been developed as part of this work to identify where tailoring of building regulations to anticipated future conditions is facilitated. These may be revised as new high resolution climate scenarios emerge.

Higher winter water tables have implications for septic tank-related pollution of groundwater. A much more conservative planning policy will be required in vulnerable areas where an increased risk of contamination exists. Connection to mains sewerage where possible is recommended and, in the absence of this, more monitoring of septic tank functioning will be required. Extension of the groundwater monitoring network is also recommended both for quality and levels.

Since it is generally more cost-effective to incorporate climate mitigation and adaptation measures at the design and build phase, a persuasive argument exists for adopting 'no-regrets' construction-related policies and embodying these in revisions of the Building Regulations. Local authorities will be central in implementing such measures and ensuring that design and construction should be based on an awareness of what conditions can reasonably be foreseen during the lifetime of the structure.

9.5 Tourism

Based on an analysis of tourism-climate relationships, it is concluded there is a likelihood of Ireland's tourist season extending into the current shoulder months of April/May, and potentially October, over the next several decades. The significance of the industry for the Irish economy is likely to grow accordingly and the relative absence of heat extremes is likely to provide an opportunity to exploit new markets in more heat-affected areas further south and east. A growing sector in environmentally responsible tourism is also likely to enable Ireland to increase market share provided it protects adequately the environmental assets underpinning tourism.

A sustainable product will require adaptation measures to be successful in other areas, most notably in landscape management and biodiversity. While some success stories are evident in this area, much more emphasis on minimising adverse impacts on built heritage, landscapes, water resources and biodiversity is required. As a fragmented, multi faceted sector, successful adaptation will require cross sectoral cooperation and integrated governance. Integration of tourism adaptation with future water infrastructure is particularly important due to the seasonal nature of tourist-related demand in some urban centres.

9.6 Economics

Estimates of economic impacts of climate change vary widely depending on the sectors considered, the scenarios used and ethical and economic considerations such as the discount rate employed. Although the methodology employed in the Stern Report suggests unabated climate change could cost the world at least 5% of global GDP each year, the main costs are likely to be experienced in developing countries. Even a value of 2.5% of Irish GDP, however, would equate to costs of approximately €4B per year. Irish adaptation costs are estimated at €80-800M per year by contrast, indicating that the benefits of strong, early adaptation action considerably outweigh the costs

Digital Terrain Modelling was used in this study in conjunction with a range of datasets to examine potential economic vulnerabilities relating to coastal, commercial and residential property addresses. This was based on known insurance claim costs. Approximately 350km2 could be considered exposed to a sea level rise of 1m with a potential property insurance exposure of just over

€1B. These may be considered provisional estimates, with analysis of a range of factors such as coastal defences requiring to be integrated into more detailed analysis. But they do indicate the need for integrated coastal zone management as an adaptive response to climate change. Provisional modelling relating to inland flooding on four Irish river catchments under a 2m river elevation buffer identified 1,800 exposed properties with potential insurance claims of close to €46M.

Quantification of economic losses from losses in ecosystem goods and services is difficult to refine. However, potential losses of three coastal wetland systems with a metre rise in sea level were estimated at approximately €24M per year using average European wetland valuations. The soft coastlines of eastern Ireland are particularly at risk, though in some cases inland displacement may occur.

9.7 Governance

Coping with climate change to safeguard competitiveness and protect people, natural environments, and their infrastructure will require active governance at local, regional and national levels. Procrastination will necessitate reactive adaptation, essentially repairing damage to infrastructure and ecosystems after severe weather events.

Notwithstanding the actions of some proactive local authorities, a detailed review of local plans and strategies, coupled with stakeholder perceptions, has revealed that climate change is not adequately mainstreamed into Ireland's local policies or institutional practices. At local level the formation of a climate change team, a climate change strategy and the incorporation of climate change considerations into areas such as development control, flood management and amenity planning is recommended. Measurable targets for mitigation and adaptation are required. Regional authorities should provide oversight and facilitation. It is however at national level that governance can be most effective. Legislation and the establishment and enforcement of standards for both mitigation and adaptation are necessary for effective climate change adaptation. National government can facilitate this also by leadership which includes climate change criteria and concrete adaptation measures in national programmes and policies. A continuing drive to build a public consensus on the issues is also essential and accountability and ownership of the issue should be demonstrated at the highest political levels.

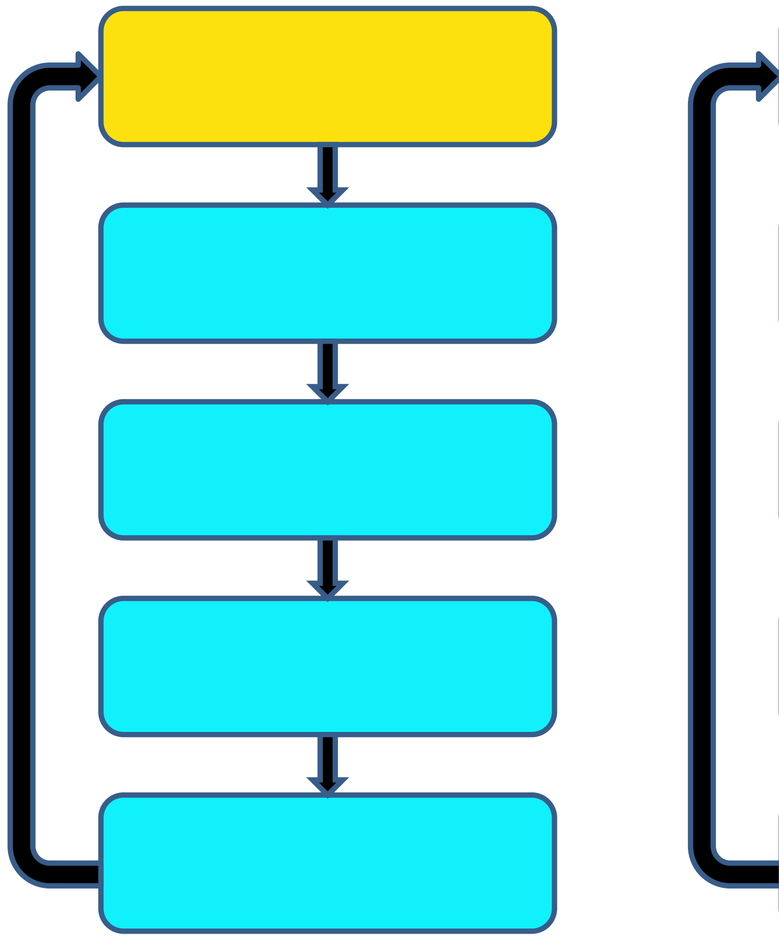
Vertical integration in governance must be accompanied by horizontal integration in the form of cross sectoral linkages. This entails specific responsibilities in a range of Departments, better liaison between them, and sharing of experience and approaches to building capacity and establishing best practice. Ultimately adaptation will require national government to establish clear priorities and requirements for those under their jurisdiction which is backed by effective legislation.

9.8 Concluding Comments

In coming decades Ireland will have to cope with a wide range of climate change impacts. As a mid latitude country, its temperature changes can be expected to be close to the global average. Increased confidence from model outputs suggest warming of approximately 2-4oC relative to the 1961-90 period is likely by the later decades of the present century. International efforts to arrest this are so far quite slow and unlikely to change the global temperature trajectory over the next few decades. Adapting to this forthcoming change poses many challenges for Ireland in economic sectors which are strategically important for the country. Investments in longer term enterprises such as infrastructure, housing, and forestry are particularly vulnerable if steps are not taken today to adapt them to tomorrow's climate. Concepts such as return periods, historically used for design purposes, are not reliable for future conditions.

Through the course of this study, concepts of adaptation have evolved considerably in response to a recognition that a top down climate scenario-led approach does not always offer the best strategy. While such an approach has characterised most assessments internationally, they do not offer opportunities for integration of risks and opportunities across sectors, a point made in the recent review of the UK Climate Change Risk Assessment (Wilby, 2012).

Ultimately, adaptation can take many forms and this work provides a number of tools to enable the adjustments necessary to cope with an uncertain future to be taken on a 'no regrets' basis. It does not offer a comprehensive vulnerability analysis, nor a detailed risk analysis. However it does point to where adaptive action should be focused to ensure Ireland rises to the challenge of climate change and safeguards the economic competitiveness of the country on which long term prosperity will be dependent.



(Adapted from: Wilby 2012)

Figure 9.1 Evolution of adaptation strategies from a 'top down' to a bottom-up approach

9.9 Final recommendations

- Planning for adaptation will always be conducted in a situation of uncertainty. Robust, flexible strategies will be required based on what is considered at the time to be an acceptable level of risk. Major investments in infrastructure e.g. for water resource management should be subjected to a sensitivity analysis of performance under the full range of climatic uncertainty likely during their effective lifetime.
- Successful implementation of the Habitats Directive will require greater understanding, and incorporation, of the impacts of climate change on species and habitats, especially invasive species and species close to their current climatic

boundaries. To ensure Ireland's biodiversity resources are not any more adversely affected than necessary, the creation of green infrastructure and actions to maintain a heterogeneous landscape require to be integrated into landscape management approaches. For protected sites, future designations will require effective planning for this, while in the wider landscape, appropriate agri-environmental measures are required.

- Given limited resources, a conservation focus on those species and habitats identified in this work as most vulnerable is recommended. Future research efforts are required to incorporate dispersal, biotic interactions and land use change scenarios to ensure that the conservation sector is equipped with the best available projections on which to base adaption decisions. Long term monitoring and the maintenance of research capacity in climate-biodiversity must be supported to achieve this.
- For construction purposes, design standards should be based on climate conditions which can be reasonably expected to occur during the expected lifetime of the structure. This means planning permissions should take account of materials proposed for building fabric as well as location exposure more overtly. Double leaf housing construction should be considered as a requirement for those areas most exposed to higher winter rainfall conditions with hollow-block single leaf construction only permissible in sheltered locations.
- Higher winter water tables pose increased pollution potential for poorly located or defective septic tanks. Stricter planning guidelines in vulnerable areas are therefore recommended with connections to mains wastewater systems the preferred strategy where possible. The extension of the groundwater monitoring network is recommended.
- Current model climate scenarios should be used when reviewing building regulations, and issuing new Technical Guidance Documents, particularly in terms of changes in wind-driven rain and consequent increases in moisture ingress. A strengthening of the functions of local authorities in monitoring and enforcing the building control system is necessary to achieve the required adaptive response.
- The potential for tourism expansion be investigated further using survey and focus group techniques in conjunction with climate change scenarios incorporated into the Tourism Climatic Index. Specific adaptation options require to be examined using detailed cost-benefit analysis. In particular, water and waste water treatment projections require to be incorporated into tourism infrastructure calculations.
- Economic costings of potential climate change impacts require to be considered when protective infrastructure is being contemplated. Under almost all scenarios, potential impact costs far outweigh adaptation costs. An extension of the Catchment Flood Risk Assessment and Management Studies (CFRAMs) and of Integrated Coastal Zone Management to incorporate the most up to date climate change scenarios is recommended. Difficult to quantify losses in ecosystem goods and services require also to be incorporated in economic quantification of adaptation strategies.
- Local authorities build adaptive capacity by establishing structures such as a high level climate change team responsible for developing and overseeing the implementation of a climate change strategy. Climate change should be integrated into current Development Plans. Regional authorities should oversee the integration of these local climate change strategies at a regional level.
- The 2013 EU Adaptation Strategy lays the groundwork for monitoring and review through indicators for member states with links to European Structural and Investments funds in the period 2014-2020. This study has identified a number of obstacles to any adaptation strategy. These centre on the lack of policy underpinned by legislation. A lack of awareness and urgency on the part of decision makers at all levels of governance is accompanied by a lack of capacity and expertise which limits worthwhile individual initiatives in some key sectors. It is recommended that national government must create the conditions for mainstreaming of climate change considerations into general policy development and legislation. The National Climate Change Adaptation Framework is a start and needs to be expanded by integrating adaptation and mitigation into all levels of governance. Cross sectoral teams working on sectoral target-led objectives are essential to achieve this. Most importantly, management 'buy in' at the highest level of government must be evident in the reporting structures to provide the essential leadership necessary for the climate

adaptation process to succeed. A ‘wait and see’ approach to adaptation is not an option.

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An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce;
- dumpáil mara.

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

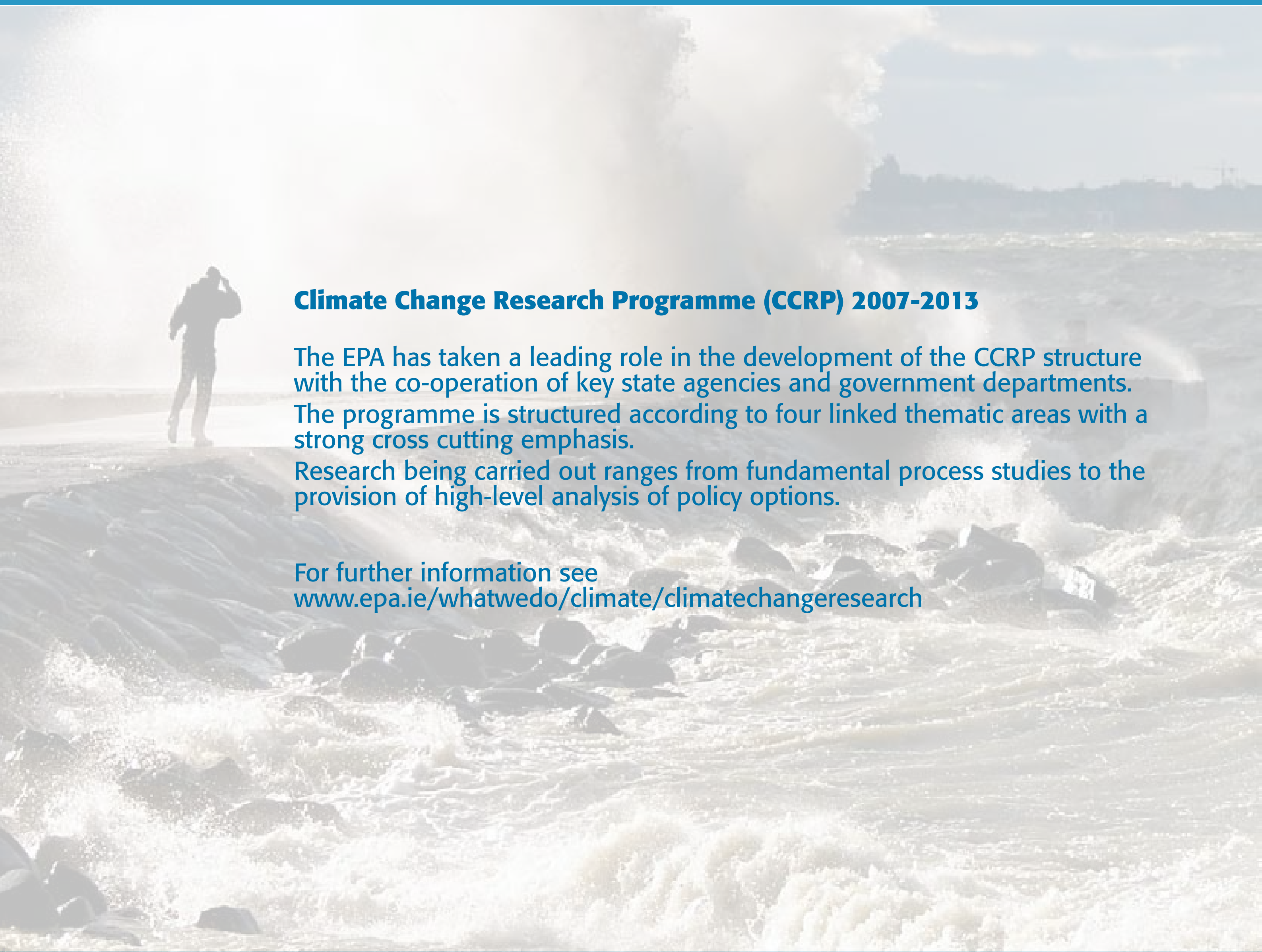
STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.



Climate Change Research Programme (CCRP) 2007-2013

The EPA has taken a leading role in the development of the CCRP structure with the co-operation of key state agencies and government departments.
The programme is structured according to four linked thematic areas with a strong cross cutting emphasis.
Research being carried out ranges from fundamental process studies to the provision of high-level analysis of policy options.

For further information see
www.epa.ie/whatwedo/climate/climatechangeresearch

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