# A web based systems simulator for climate governance

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**Abstract:** In helping local authorities in Ireland to adapt to climate change we have developed a prototype socio-ecological systems simulator which we believe can be applied as a governance tool in many domains. We outline the consultation process which was developed in order to engage members of local communities in the production of adaptation plans. We explain the reasons for adopting an ICT driven approach to further this engagement and how the prototype web-based tool was implemented. We describe how this tool is currently being adapted in order to help implement the Irish government's national climate adaptation framework. We discuss how the tool may be enhanced in the future by the addition of more sophisticated modeling tools based on artificial intelligence.

## 1 Introduction

Ireland's response to global climate change has required a multidisciplinary and multi-scale approach to consultation, social modelling, and policy design. At the local level, the CLAD project dealt with adaptation for coastal communities based on consultation, experimentation and modeling. The desire to scale this approach to a national audience led naturally to an ICT mediated approach through the IASESS prototype, which allowed individual cognitive models to be easily created, combined and analysed to provide an important tool for thinking through the consequences of change as a group. With ClimateIreland, Ireland's climate information platform, this prototype is currently being deployed as a means to translate national policy into local action by combining local, national and global knowledge. Further research will advance upon the fuzzy cognitive mapping techniques employed in all these projects in order to provide a picture of Ireland's resilience to climate change. Eventually, we hope to generalise this toolset to deal with a wide variety of social issues.

# 2 CLAD - local scale coastal climate adaptation

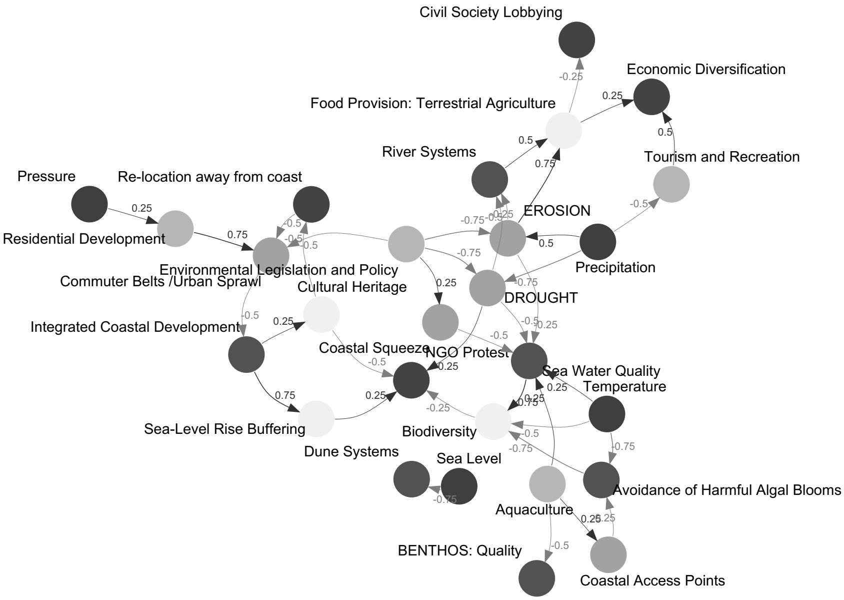


Figure 1: Individual Graph View

In 2009 Ireland's Environmental Protection Authority (EPA) funded a three year project, led by the Coastal and Marine Research Centre (CMRC) to provide methodological and informational support for decision-makers and stakeholders regarding sustainable adaptation to climate change in Irish coastal areas. The project assessed governance models for effective coastal zone management in Ireland, and designed a toolkit to allow effective stakeholder participation in adapting planning at all levels of the decision-making process [GGG+13].

The project's outcomes include a set of guidelines aimed at local scale coastal management practitioners, at individuals and groups from local communities who have an interest in coastal matters, and at employees of national agencies [GFOG12]. The guidelines embody extensive practical experience in conducting stakeholder workshops and were arrived at through the evaluation of numerous competing tools and methodologies. The driving ethos was to approach adaptation to changing circumstances through constant effort, reflection and a willingness to treat adaptation decisions as flexible experiments rather than immovable objects of policy.

Designing appropriate adaptations to climate change involves negotiating a complex landscape of choices and risks with a high degree of dependence on local context. This context is generally embedded in tacit knowledge, and needs to be drawn out if an adaptation response is to have a chance of success. Furthermore, any given group of individuals will

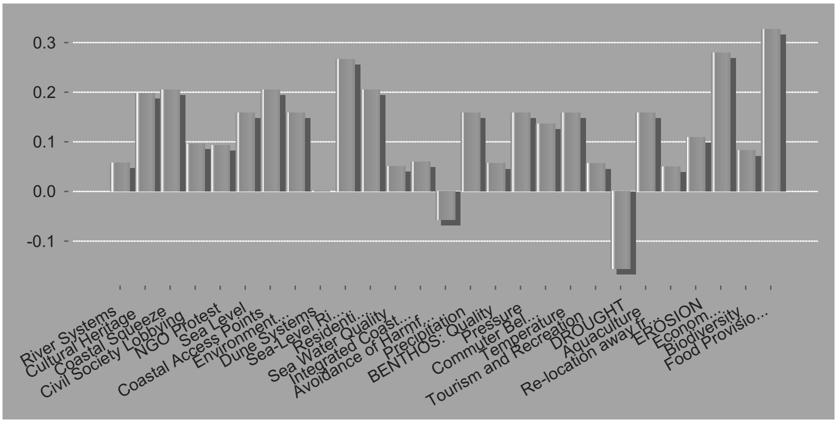


Figure 2: Steady state

have a different set of contexts in mind, and a mediation process is necessary in order to establish basic ground rules to avoid unnecessary friction and channel discussion productively.

With this in mind a systems modelling approach was selected based on Fuzzy Cognitive Mapping (FCM). In FCM, a map is constructed between elements in a system, as in Figure 1. The strength of the relationships between the elements is analysed using fuzzy logic to determine the strength of impact of the elements [Kos86], which can be plotted in a bar chart as shown in Figure 2. FCM has been successfully used to integrate stakeholder knowledge in socio-ecological decision making [GCCJ12]. The modelling approach helps to frame the discussion and orient the participants towards discussing the consequences of action, or inaction, rather than trying to push favoured solutions.

The stakeholder workshops were very effective at local scale. They involved using whiteboards to construct a group model of a particular context, e.g. the coastal region around Dingle, Ireland, as seen from the perspective of local authorities, stae agencies, NGOs and community groups. The models developed were captured in a spreadsheet and run through the FCMapper software (FCMappers.org) to produce the baseline model results, indicating the state to which the system as modeled would converge after a number of iterations. These results were then used by the group facilitator to produce a group model which could then provide a starting point for further discussion.

In order to streamline the process of capturing the individual models and producing the results, a prototype system was built in Visual Basic™. This built on the FCMappers software[WBA+10], written in Excel™to provide a more visual and user-friendly interface.

# 3 IASESS - Ireland's Adaptive Socio-ecological Systems Simulator

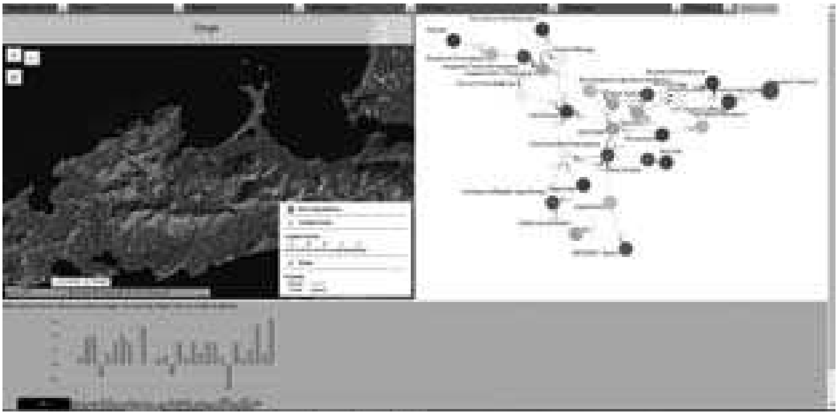

Figure 3: Iasess screenshot

The next stage in developing the prototype was to provide a web front-end. While the workshop approach worked well on a local scale, and the desktop tool greatly facilitated the creation of model and their analysis, the deployment of the system on the web was felt to be a necessary step in assessing how the approach could be broadened to accommodate as many different mental models as possible.

A prototype was designed and implemented which could allow an individual to model the system (http://www.github.com/CMRC/coastal-resilience). A user registration system allows the individual user to register in order to maintain a set of models which can be accessed online using only their username and password. The individual modeling view Figure 3 shows a context window detailing the geographical area (www.mangomap.com, maps ©Microsoft), an editable network graph showing causal relationships and their strengths, and a bar chart showing the baseline model results which is recalculated continuously as new concepts and causal relationships are added.

In order to make integration easier, we rewrote both the server and client sides. The server side was written in Clojure, an open source programming language using the JVM. This generated images and HTML which were rendered on the client side, with additional javascript in order to make them interactive.

The network graph was rendered in SVG on the server using GraphViz (www.graphviz.org). This allows us to leverage the power of GraphViz to automatically place nodes, route lines and deconflict labels, while providing a DOM structure which can be manipulated on the client side using javascript. The D3.js fisheye distortion is used, for example, to zoom in on features of interest.

Each user has the ability to create an individual account which holds all their individual models. The user-generated data is stored in a CouchDB document database. This allows for fast creation and retrieval of graph data, and also makes it easier to scale the database across multiple nodes without joins or complicated sharding. The ability to scale is an important design criterion and a major motivation for moving from a desktop to a web-based system. It is hoped that moving to user base of potentially millions of users will allow for the creation of combined models to solve many different problems and eventually provide a powerful knowledge base for policy modelling of all kinds.

## 4 ClimateIreland and the National Climate Adaptation Framework

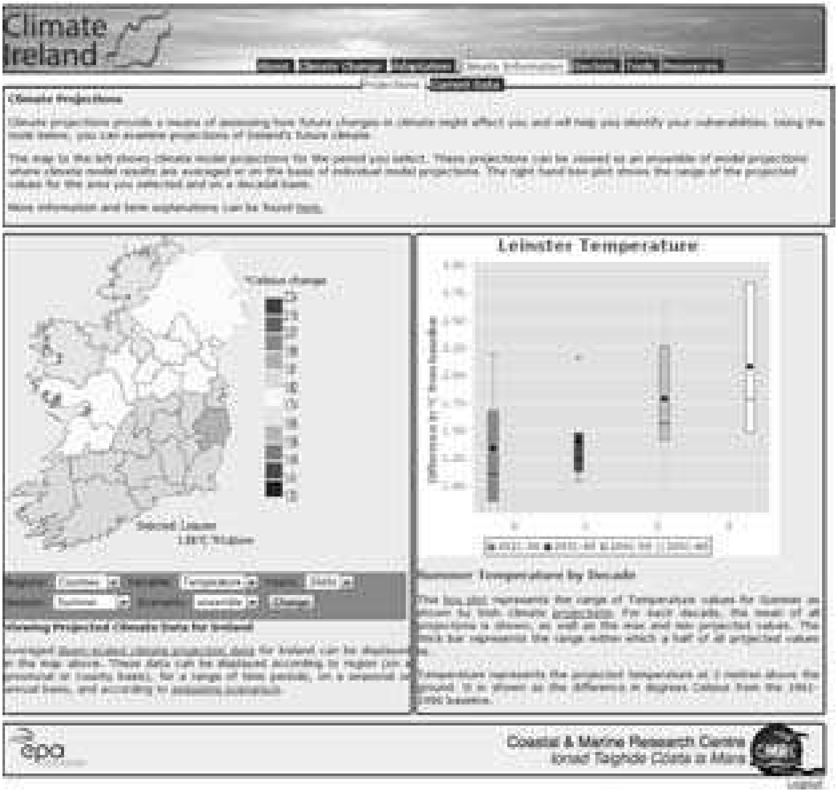


Figure 4: ClimateIreland screenshot

Ireland's Climate Information Platform (www.ClimateIreland.ie) is another EPA project funded under the Climate Change Research Programme. This project is aimed at providing a 'one-stop-shop' for climate information aimed at local authorities, industry and representatives of a wide variety of sectors likely to be affected by climate change. Figure 4 shows part of the ClimateIreland interface which includes choropleth [1] maps and plots

[1] A choropleth map is a thematic map in which areas are shaded or patterned in proportion to the measurement

of downscaled climate projection data, summarised at the level of internal administrative boundaries. ClimateIreland will play a key role in translating the National Climate Adaptation Framework into action, by providing sector specific actionable advice. In order to do this effectively, the Iasess systems modelling tool will be deployed as part of the platform. Its core functionality will be expanded with the aim of allowing individual practitioners to pool their collective experience and local knowledge to provide effective implementation responses to the national policy.

The strategy for using Iasess within ClimateIreland is based on three levels of knowledge; local and regional tactical knowledge, national strategic knowledge, and national and global scientific knowledge. The first two categories represent tacit knowledge. The local practitioners at whom the tool is aimed have a wealth of knowledge which Iasess will capture in the form of cognitive maps. This knowledge will be supplemented by knowledge captured from national experts and policy makers on the effects of climate change variables on a scale of five to fifty years, captured during a series of expert workshops conducted during the ClimateIreland project [O'D12]. The changes in physical variables which drive the system will then be applied to this tacit knowledge, to gauge the likely outcomes of various future climate change scenarios. This scientific knowledge comes from downscaled climate models developed specifically for Ireland, e.g. ([NLM$^+$11],[FS07],[MLD$^+$08]).

In order to apply the levels of knowledge we create geographical contexts based on geospatial correlations of essential climate variables. The local experts will create a cognitive map for each of these contexts, which will be aligned to administrative regions. For each region, a set of climate scenarios will be chosen, represented by regional summaries of downscaled climate projection data. The knowledge from the national experts will then be applied, by creating relationships between the physical variables and key elements within the local models, and setting the strengths of those relationships according to the opinions of the national experts. By running the FCM analytics on the resulting system, a result can be obtained which takes into account the three levels of knowledge in showing the likely impacts of future climate change.

## 5 Current status and future directions

The prototype system (Iasess) described above has been built. Initial testing has been successful, and the individual modelling view, map view and information panel, including model results are operational. The model merging functionality has been tested, but is not yet incorporated into the user interface. The map view is currently fixed to the area of South West Ireland used for the workshops, and we are experimenting with the best way of allowing a group facilitator to easily create an individualised view.

In addition to the *expert-based methods* used so far in our prototype, we are currently investigating the use of *computational methods*, also known as *inductive methods*. The objective of this research is to expand upon the knowledge of the experts in order to explore the full problem surface. In the current Iasess prototype, the system is run forward from

of the statistical variable being displayed on the map (wikipedia).

a starting point determined by the present knowledge of the system. The model created by the local expert is assumed to be valid for that starting point and for a finite region of the multidimensional space defined by the modelled elements. Any point within that region is assumed to take a trajectory which ends up, after a finite number of iterations, at the same point. In order to fully understand the dynamics of the system, we need to map the boundaries of this region. This will allow us to understand how far the system can be pushed in any given direction before the dynamics of the system change and the system defaults to a new steady state. This will give us a measure of the resilience of the system. In order to fully understand resilience, we are currently exploring options for more efficient FCM learning, which will allow us to run the system in reverse and map out the set of possible starting points.

## 6 Conclusion

The prototype and associated research described here build firmly on existing techniques applied successfully to a variety of problem domains. We believe it is innovative in that it provides an end-to-end solution capable of being used by large groups of people with a minimum of technical knowledge of the techniques involved and how they are implemented. It allows the individual user to assemble a cognitive model using easy simple actions on a web page, while viewing both the context of the model and the modelled results. It allows the group facilitator to easily combine individual models in order to form a model of the thought processes of the group as a whole and does this in a way that can scale easily to large groups of users. Functionality under development will allow the facilitator to easily combine concepts and create filtered views of the cognitive graph in order to explore specific aspects in more detail. Further research in automated reasoning will allow better and faster feedback on the consequences of the chosen model, thus allowing it to be used for more detailed exploratory analysis of a given problem domain.

The system under development has the potential to be developed into a highly scalable tool for turning individual thought processes into a representation of group thought. This can be used to model how the group would respond to external events. As such it can be used to model complex systems with a high degree of dependency on human responses, such as policy, economics or ecology.

## References

[FS07] Rowan Fealy and John Sweeney. Statistical downscaling of precipitation for a selection of sites in Ireland employing a generalised linear modelling approach. *International Journal of Climatology*, 27(15):2083–2094, 2007.

[GCCJ12] Steven Gray, Alex Chan, Dan Clark, and Rebecca Jordan. Modeling the integration of stakeholder knowledge in social-ecological decision-making: Benefits and limitations to knowledge diversity. *Ecological Modelling*, 229(0):88 – 96, 2012. Modeling Human Decisions.

[GFOG12] S.R.J. Gray, M. Falaleeva, C. O'Mahony, and J. Gault. Local Scale Coastal Climate Adaptation: Practitioner Guidelines. *Unpublished manuscript*, 2012.

[GGG+13] S.R.J. Gray, A.S. Gagnon, S.A. Gray, B. ODwyer, C. OMahony, D. Muir, M. Falaleeva, and J. Gault. Are coastal managers detecting the problem? Assessing stakeholder perception of climate vulnerability using Fuzzy Cognitive Mapping. *Manuscript submitted for publication*, 2013.

[Kos86] B. Kosko. Fuzzy cognitive maps. *International Journal of Man-Machine Studies*, 24:65–75, 1986.

[MLD+08] R McGrath, P Lynch, S Dunne, J Hanafin, E Nishimura, P Nolan, V Ratnam, T Semmler, C Sweeney, and S Wang. Ireland in a warmer world. *Scientific Predictions of the Irish Climate in the Twenty-First Century. Final Report of C4I, Dublin*, 2008.

[NLM+11] Paul Nolan, Peter Lynch, Ray McGrath, Tido Semmler, and Shiyu Wang. Simulating climate change and its effects on the wind energy resource of Ireland. *Wind Energy*, 15(4):593–608, 2011.

[O'D12] B O'Dwyer. Consultation Workshop, Ireland's Climate Information Platform: Assessin the Information Required for Climate Change Adaptation Planning. *Unpublished manuscript*, 2012.

[WBA+10] M Wildenberg, M Bachhofer, M Adamescu, G De Blust, R Diaz-Delgadod, KGQ Isak, F Skov, and V Riku. Linking thoughts to flows-Fuzzy cognitive mapping as tool for integrated landscape modeling. In *Proceedings of the 2010 International Conference on Integrative Landscape Modelling. Symposcience, Cemagref, Cirad, Ifremer, Inra, Montpellier. http://www. symposcience. org/exl-php/articles/651-article. htm. Accessed*, volume 20, 2010.