

# A SPATIAL DECISION SUPPORT SYSTEM FRAMEWORK FOR CLIMATE CHANGE ADAPTATION IN VICTORIA

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### ABSTRACT:

Climate Change has been acknowledged as one of the single greatest threats to global social, environmental and economic well-being. Climate change poses significant threats to existing urban infrastructure, current water use practices and agricultural industries to name a few. In the State of Victoria in Australia, there is an e-Science initiative to mobilise cross-organisational expertise in order to underpin policy-making as it relates to climate change adaptation. An underpinning Spatial Decision Support System Framework has been designed to support integrated systems modelling across a number of modelling domains including climate, hydrological, crop and land suitability modelling. A number of core datasets serve as inputs in the spatial decision support system framework including land utilization, soil, geology, climate prediction (historical and forecasts) and many others. These datasets feed into a number of system models, which are used to better understand the present and future land suitability, hydrological processes, agricultural productivity and sea level changes. The climate change models align with the Intergovernmental Panel on Climate Change (IPCC) scenarios and have been downscaled to a regional level. In this research we present an e-Science based virtual collaborative workspace which has been developed to support the exchange of data, models, within a secure cross-organisational data grid. Also, we examine the use of a geographical visualisation as a front end to complex multi-disciplinary scenario modelling to enable end users to better understand the policy and on the ground implications of climate change to the Victorian landscape.

## 1. INTRODUCTION

With the global human population expected to reach 8 billion people by 2030 and 9 billion by 2050 the anthropogenic influence of climate change will no doubtably escalate, as will the pressure placed on land use practices. According to the IPCC (2007, p5) "most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations." Economist Lord Nicholas Stern stated that global warming is the major environmental and economic threat in the 21<sup>st</sup> Century with major biophysical and socio-economic ramifications (Stern, 2006). This report prepared for the British Government highlights the need for economic global action, and puts forth a figure of 1 percent of global gross domestic product (GDP) which will be required to mitigate the risk that global GDP could otherwise fall by 20 percent (Stern, 2006). Such findings highlight the clear need for research and responses to climate change both from an adaptation and mitigation perspective. In this paper we describe a spatial decision support system (SDSS) framework to aid policy-makers, planners, researchers, industries and communities to collaboratively work towards viable climate change adaptation scenarios. The SDSS framework has been developed to support government and universities to better work together in sharing data and models for addressing climate change adaptation within South West Victoria.

## 2. CLIMATE CHANGE ADAPTATION RESEARCH IN VICTORIA

There is increasing recognition of the roles and responsibility of Governments at all levels to address both climate change mitigation and adaptation. Mitigation focuses on actions to reduce our carbon footprint in order to meet international targets set by policies and protocols, for example the Kyoto Protocol (UNFCCC, 1997). Adaptation focuses on actions to address the impending impacts of climate change due to increasing temperature, sea-level rises and extreme events such as fire, flood and drought. The research presented in this paper is focused on climate change adaptation, specifically on the impacts of climate change on agriculturally productive landscapes.

In Victoria there are a number of Government led climate change research initiatives which have been established. The first of the initiatives is the Department of Primary Industries lead Victorian Climate Change Adaptation Program (VCCAP) - <http://www.greenhouse.unimelb.edu.au/vccap.htm>. VCCAP is an across Government initiative involving a number of State Government Departments including: Primary Industries (DPI), Sustainability and Environment (DSE), Premier and Cabinet (DPC), Human Services (DHS), and Innovation, Industry and Regional Development (DIIRD). The second Government program is the Victorian eResearch Strategic Initiative (VeRSI) - <http://versi.edu.au/index.html>. VeRSI is a joint venture between Multimedia Victoria (MMV), DPI and Melbourne, Monash and La Trobe Universities. The Ecoinformatics Platform and Climate Change Application Demonstrator is one

of the capability projects of VeRSI apart from Life Sciences capability projects  
<http://versi.edu.au/activities/ecoinformatics.html>.

Ecoinformatics can briefly be described as the study of ecosystem and environmental data and information products. This project is using ecoinformatics to better demonstrate a new approach to natural resource research using climate change as a pilot/demonstrator application. The research discussed in this paper draws upon results from both of the inter-related initiatives with a focus on south west Victoria as a pilot region.

### 2.1 South West Victoria pilot study

Between 2007-2010 resources from both the VCCAP and VeRSI initiatives are being focused to undertake research in the south west region of Victoria. The extent of this study area includes both the Glenelg-Hopkins (<http://www.glenelg-hopkins.vic.gov.au/>) and Corangamite Catchment Management Authority (CMA) regions (<http://www.ccma.vic.gov.au/>) as illustrated in Figure 1. The south west Victoria region comprises a population of around 455,000 people and encompasses approximately 30,000km<sup>2</sup>. Land uses from of agricultural practices include: dairy, grains, forestry, fisheries and broad acre grazing. The study area includes both irrigated and dryland dairy systems. The south west region of Victorian has an active community representative group known as the South West Climate Change Forum (SWCCF) that represents over 70 percent of all community and industry stakeholder groups situated within the region. Also, there are a number of planners and natural resource manager from both CMAs and Local Government Authorities (LGAs) that are interested in a number of climate change adaptation questions such as: which agricultural land use practices are sustainable into the future? what are the options for renewal energy? what will be the impact of sea level rises and increases in extreme events such as floods, droughts and fire?



Figure 1. South west Victoria region including Glenelg-Hopkins and Corangamite Catchment Management Areas.

The project team assembled to address these critical questions span across a number of government departments and universities including those government organisations previously listed plus the University of Melbourne, Monash University and La Trobe University. There are a multitude of skills and expertise required to develop a truly integrated systems approach to climate change adaptation. The research team draws from a pool of scientists with have expertise in the

following fields: climatology, agronomy, pedology, hydrology, geology, geomatics, information communication and technology (ICT), regional planning and social sciences. With such a multidisciplinary team there is a need to develop a generic ecoinformatics platform that connects collaborating researchers across disciplines and organisations.

## 3. AN E-SCIENCE APPROACH TO SUPPORTING COLLABORATIVE RESEARCH

### 3.1 e-Science

Coined by Sir John Taylor as referred by Hey & Trefethen (Hey et al., 2002), e-Science refers to the large scale science that is increasingly been carried out through geographically distributed collaborations enabled over the Internet. Taylor (Hey et al., 2002) also stated that e-Science is about global collaboration in key areas of science, and the next generation of infrastructure that will enable it. e-Science is also known as cyber infrastructure (CI), which can serve as an online technology platform to collaborate and undertake multi-disciplinary research. In the broader context it is known as e-Research which is about multi-disciplinary research collaboration by using a spectrum of advanced ICT capabilities. At its highest level global e-Science is an enhanced scientific endeavour by communities of researchers from organizations that span national boundaries. With collaboration being the key to next generation research and development, enabling e-Science technology infrastructure is paramount. With the 21<sup>st</sup> century computing and information science revolution, geographically distributed and heterogeneous resources have become the driving components for collaboration. This is observed with the rise of 'Geocollaboratory' based decision support systems such as the Human-Environment Regional Observatory (Machren, 2006).

Grid computing (Foster et al., 1999) is envisaged as the backbone for e-Science that provides software and hardware infrastructure. Initiatives have been taken world-wide notably the Open Sciences Grid (OSG) <http://www.opensciencegrid.org/>, and the Enabling Grids for e-Science (EGEE) URL: <http://public.eu-egee.org/> to establish virtual organisation (Foster et al., 2001) for research utilizing these types of infrastructure. However, large scale projects like the Cancer Biomedical Informatics Grid (CaBIG) URL: <https://cabig.nci.nih.gov/>, and the Earthquake Engineering Simulation (NEES) URL: <http://www.nees.org/>, often require cross organisations involvement and multidisciplinary research efforts. Grid computing is considered to be a significant component to e-Science infrastructure (Russel et al., 2006) and within the context of the Victorian Ecoinformatics Climate Change project. The high performance computing (HPC) and data storage facilities located within DPI, Monash University, University of Melbourne and La Trobe University will form part of the supporting technology infrastructure. Below is a list of some known international e-Science initiatives which are natural resource specific:

- Long Term Ecology Research (LTER) - <http://lternet.edu/>
- Eco Info - <http://ecoinformatics.org>
- Geosciences network (GEON) - <http://www.geongrid.org/>
- Water Resources Observatory Network - <http://www.wron.net.au/>

- Project Vulcan - <http://www.purdue.edu/eas/carbon/vulcan/index.php>

### 3.2 Ecoinformatics

Ecoinformatics is an e-Science platform that provides policy and public access to and interrogation of natural resource data, information and knowledge products through a web-enabled interface. In this research our aim is to provide an open “ecosystem” data and knowledge infrastructure to support complex policy and decision making. This is to be achieved where possible, through the use of open source applications and open standards and thus maximising the benefits of system interoperability.

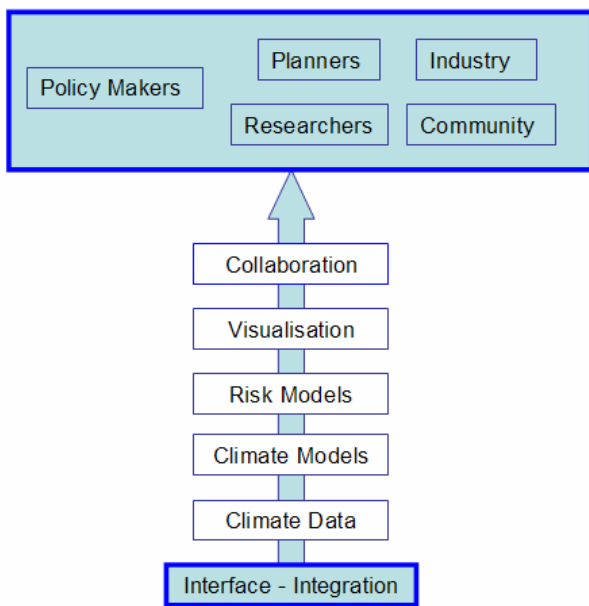


Figure 2. Ecoinformatics platform providing spatial planning and decision support

The first step in realising this ambitious vision is the conceptualisation of the ecoinformatics platform. Figure 2 illustrates the data, information and knowledge framework to realise an ecoinformatics platform to support climate change adaptation research. Underpinning this platform is a number of fundamental data inputs including: soil, land use, topography, slope, aspect, elevation, and historical climate data. These datasets are used as inputs into both the climate change and risk modelling components. Dual scale climate models are applied. Firstly a general circulation model (GCM) is run to obtain climate change scenarios for 2050 at a resolution of 200km<sup>2</sup>. This scale of information is too coarse to support regional planning decisions so the model is downscaled to a resolution to a raster cell of 6.7km<sup>2</sup>. This has been achieved through a regional dynamic downscaling model run by Monash University on their e-Research computing facility. Once the resolution of the climate models has been scaled down a number of output variables including, temperature, rainfall, solar radiation, and predicted number of frost days are used as inputs into a number of risk models.

These Risk models are used to understand the likely impact of climate change on the landscape. Under the umbrella of risk a

number of models have been run to understand the impact of climate change scenarios on both the built and natural environment comprising the south west Victoria up until 2050. The risk models available to date include: land suitability models, hydrological models, and crop and grazing productivity models. Once these models have been run their results need to be shared with the research team and other end users including: decision-makers, planners, industry and the community. Both geographical and scientific visualisation interfaces enable complex information to be easily communicated and provide a front end to both the climate change and risk models. Finally, there is a collaboration component which enables shared access to all data, models and visualisation products. The collaboration component also supports more informal information exchange and interactions amongst the project team through the use of next generation web 2.0 collaboration tools such as Wikis.

## 4. THE VIRTUAL E-RESOURCE CENTRE

### 4.1 Platforms for collaboration

Platforms for collaboration can shape Victoria’s adaptation to global climate change. Cross institutional involvement is the driving principle of large scale research. These often require establishing virtual organisations (VOs) to make complex collaborative decisions. A Virtual Organisation (VO) is a group of people and/or organisations who share resources and skills to achieve a common goal. Within the VO decisions can be on how to limit the social, economic and environmental risk associated with climate change. A virtual collaborative workspace is a platform which supports the VO, allowing users from cross organisations to share data, ideas, analysis, reports, models and outcome. To enable such capability we have designed and implemented a virtual collaborative workspace known as the Virtual e-Resource Centre (VRC) to support multidisciplinary and cross organisational research.

### 4.2 System design

The VRC is a virtual collaborative workspace designed specifically to support Victorian Climate Change Adaptation research and has been developed on the top of the Atlassian confluence wiki platform (<http://www.atlassian.com/software/confluence/>). The VRC offers a secure virtual collaborative environment where data, information, knowledge and ideas can be shared across organisations and locations. As illustrated in Figure 3, the VRC homepage provides access to the steering committee, technical advisory committee and the VCCAP research team. Different access privileges are assigned to the various users. For example members of the steering committee have access to the steering committee section to access committee meeting minutes, presentations and relevant contents. Likewise the technical advisory committee has access only to their respective area and also similar access control policy applies for the VCCAP research team. The site has initially been set-up to support up to 500 users of which there are currently over 50 registered users. However, this is expected to increase over the duration of the project as the research team expands to include involvement from other organisations.

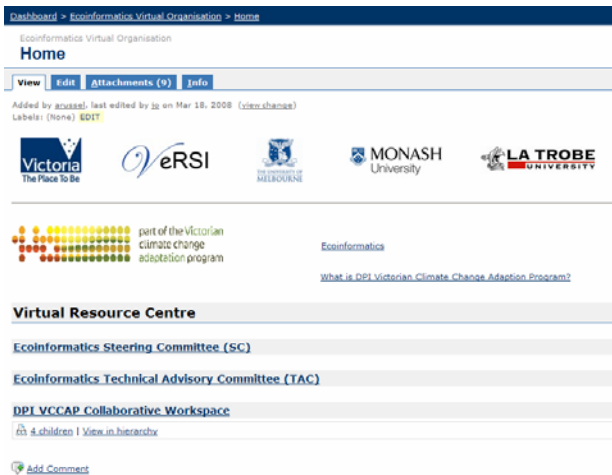


Figure 3. VRC Homepage with access links for both governance committees and research users.

### 4.3 Security and access

The VRC is a secure collaborative space for allowing experts to make decision in a managed environment. One of the key advantages of the VRC is a de-centralised identity provider solution with an identity federation governed by AAF (Australian Access Federation) [www.aaf.edu.au](http://www.aaf.edu.au). This allows the provision of services to users who have their identity attributes managed by their own organisation. This reduces the cost of managing many users' accounts while still providing a high level of shared services. Moreover, it makes sure that the users are valid and coming from a trusted identity provider. All back channel communications are trusted via Public Key Infrastructure (PKI) mechanism. Any front channel communication is also protected by a well known certificate authority.

The VRC is protected to authorized users and uses Shibboleth technology (<http://shibboleth.internet2.edu/>) to achieve this. It consists of three major components:

1. Service providers: All services within VRC which are protected via common interface.
2. Identity providers: Identity providers for all members of the VRC.
3. Federation: A federation of listing all identity providers and registering services.

When any valid member wants to access the VRC, the service interface redirects the request to the federation WAYF (Where Are You From) service where the user can choose their own identity provider. If the given credentials by the user are valid, the identity provider releases the user attributes to trusted services to authorizing access. Upon receiving the attributes the service provider, in this case, VRC validates all rights and allows access to services. The entire VRC can also be extended for Grid certificate (X.509) based protected services. Moreover, the VRC is using Single-Sign-On (SSO) capability. This means that any collaborator needs to provide credentials only once to access all services within VRC.

### 4.4 Functionality and services

The principle user of the VRC is the VCCAP research team. The VRC has been set up to support the six research modules

which include (i) farming systems scenario development, (ii) impacts modelling and land suitability, (iii) institutional adaptation, (iv) policy research, (v) communications and utilisation, and (vi) visualisation. As the VRC applies a Wiki structure each module research team has control on the 'look and feel' of their respective module layout and content. For example, the visualisation module team has set up a visualisation toolbox area. This will be discussed in more detail in the next section of this paper.

There is a set of generic services which have been developed to support information sharing across the research team. A virtual library has been established so that all researchers can share relevant journal papers, conference proceedings and technical reports. An online forum is available with various discussion threads and a calendar service has been implemented so that all participants can receive notifications of upcoming presentations, workshops and meetings. Additional services which are being considered include an online chat service so participants may interact within the VRC within one another in real-time, RSS feeds so participants can choose to receive updates when new content is uploaded and a virtual map library powered by Google maps.

## 5. GEOGRAPHICAL VISUALISATION

The communication of climate change scenarios can be enhanced through the use of three-dimensional (3D) geographical visualisation technologies. Visualisation provides a powerful front-end for sophisticated and complex climate and risk models (Pettit et al., 2006). Through the use of visual media we can better inform communities, stakeholders, planners and managers of the implications of climate change and subsequent land use change scenarios. Through 3D geographical visualisation, we can move beyond the use of traditional flat maps and create virtual landscapes where users can collaboratively explore past, present and future land use scenarios. Visualisation allows us to (i) present the landscape in realistic or near realistic ways, (ii) bring large data sets to life to enable people to become part of an interactive decision-making process. There are a range of geographical visualisation technologies now available to assist in the communication of complex landscape processes. For example, standard GIS packages such as ArcGIS, photorealistic landscape visualisation tools such as Visual Nature Studio (VNS), digital globes such as Google Earth and computer gaming engines such as Torque. In this research we apply a number of visualisation products for communicating regional climate change scenarios for the South West Victoria. End users for these visualisation products include state policy-makers, regional planners for local government municipalities, industry groups and ultimately the local community.

### 5.1 Visualisation toolbox

A visualisation toolbox has been developed within the VRC. The toolbox includes a number of geographical visualisation products as shown in Figure 4. The Collaborative for Advanced Landscape Planning (CALP) Scenario Viewer is a java interface developed out of The University of British Columbia (Salter, 2005). This interface has been customised to include access to a range of IPCC Scenarios and related land suitability analysis models. The Spatial Information Exploration Visualisation Environment (SIEVE) gaming engine tool developed by Stock et al. (2008) is being applied to create

collaborative virtual environments for small scale 15 kilometres areas with the South West Victoria study area. The hybrid VNS/digital globe product provides a Google Earth representation of the South West Victoria region with embedded photorealistic landscape simulations of current and possible future land use. This product will be discussed further in the next section of this paper.

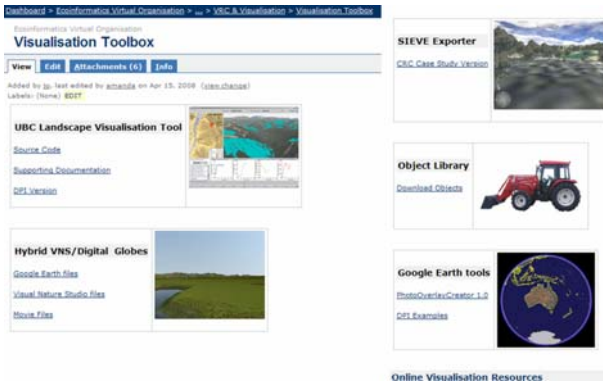


Figure 4. The VRC Visualisation toolbox

The visualisation toolbox includes a 3D object library comprising vegetation, buildings and infrastructure which can be used to create 3D landscape models for the south west region of Victoria. A public version containing a subset of these objects can be accessed via the Victoria Resources Online (VRO) geographical visualisation portal <http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/geovis>. These objects feed into visualisation products such as SIEVE, VNS and Google Earth. Embedded 3D panoramic views have also been developed and embedded within Google Earth so that end users can visit points of interest within the region and undertake virtual tours. All of these visualisation products are currently available to researchers and policy-makers within the DPI Victorian Climate Change Adaptation Program (VCCAP).

## 5.2 Visualisation a front end to climate change models

Geographical visualisation provides a powerful front end to a number of landscape models. One such visualisation tool that has been created to support decision makers in understanding the impact of climate change on future land suitability combines the photorealistic prowess of VNS with the easy to use Google Earth digital globe. Figure 5 illustrates the overlaying of land suitability models within Google Earth combined with photorealistic representation of the baseline landscape in 2000 and possible future landscape scenarios in 2050. Land suitability for two commodities (i) blue gums for plantations and phalaris for grazing has been modelled. These models have been developed using a GIS based multiple criteria evaluation (MCE) approach that applies both Weighted Linear Combination (Voogd, 1983) analytical hierarchy processing (AHP) (Saaty, 1980) for obtaining expert weighting for variables for a number of biophysical factors including soil, climate and topography (Hossain et al., 2006). This approach has been previously developed and applied in north western Victoria to determine the biophysical factors for the growth of winter wheat under three IPCC scenarios (low, medium, high climate change) (Sposito, 2006). The development of such visual interfaces enables decision makers to better understand complex landscape interactions so that informed decisions can

be made with respect to how industries and communities adapt to a changing climate and what policies are needed to assist with this adjustment.

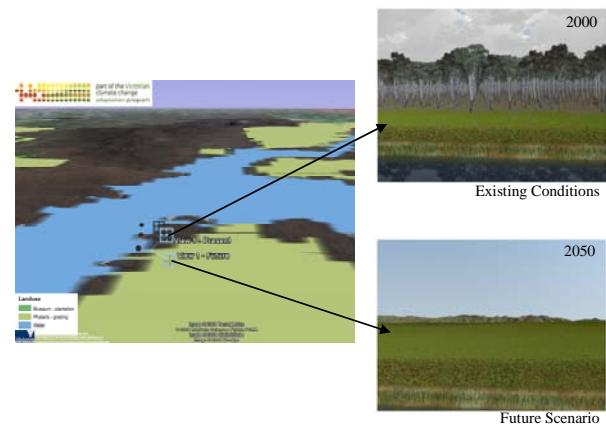


Figure 5. Google Earth visualisation front end to land suitability models with links to photorealistic current and future climate change scenarios

## 6. FUTURE RESEARCH

Ongoing research is required to develop and evaluate both the VRC and visualisation components presented in this paper. With respect to e-Science further work is required to better share data assets and link modelling systems. The coupling of models through workflow engines such as Kepler (<http://kepler-project.org/>) and the implementation and application of Grid computing are critical steps forward as it is often considered the backbone of an e-Science platform. Large scale decision making process often requires massive computational power for analysis. The exponential increase of digital data being produced across the cross-organisational domain also requires high speed data transfer capability and distributed federated storage. We are therefore planning to integrate distributed federated storage and large computing infrastructure within the VRC to facilitate near real-time decision support.

Further work is required to refine and evaluate the suite of visualisation products available via the visualisation toolbox. Evaluation is considered an important next step as there is the need to understand which visualisation products best represent particular climate change impacts and which tool best support policy and collaborative decision making. Also, further work is underway to continue building objects which accurately represent the vegetation, animals built infrastructure and rural landscape comprising the south west Victoria region.

## 7. CONCLUSION

Global e-Science is increasingly becoming a fundamental building block used to support collaborative research and support both regional and state decision-making. A key objective for our research has been to realise the latent energy, synergies and cost-savings of true collaborative systems research and multidisciplinary approach toward climate change science. In order to achieve this we have developed a virtual e-resource centre (VRC) to support climate change adaptation

research in Victoria, Australia. Contained with the VRC are a number of tools and services which are a move towards web 2.0, which endeavours to enhance creative research solutions, promote information sharing and support collaboration amongst users. The visualisation toolbox presented in this paper is one such service available on the VRC to assist researchers in communicating between disciplines and to communicate often complex landscape processes to policy and decision-makers.

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