Model driven visualisation of climate change scenarios

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Abstract: Climate change will affect us all. In addition to the projected temperature rise, models suggest changes in other climatic averages (e.g., rainfall, sunshine) and also more frequent incidence of special events (e.g., frost, deluge, high winds). These will affect the capacity of the land to support different agricultural or forest products and different modes of production. Land managers need to understand what these changes may be. With this understanding they can better plan their future farm management to be ready and robust in the face of change. This paper introduces regionalised climate change modelling in south-western Victoria, Australia. Variables from the regional climate models become inputs into comprehensive land suitability analysis for each of a range of agricultural commodities. We then describe some experimental approaches to landscape visualisation which map out the possible changes in land suitability and effective management options for dealing with these. We describe the development and application of a GIS-driven interactive approach to visualisation using a real-time virtual environment augmented by special tools for exploring, in space and time, mapped and statistical data through a video game-like interface. The system, called SIEVE, is based on ESRI ArcMap as the GIS product and Garagegames' Torque Game Engine supporting the virtual environment development. The environment also supports multi-player participation which allows for collaborative review of options by farmers, their neighbours and their advisors. SIEVE is demonstrated in the context of climate change assessment and understanding in what is currently a high productivity farming area supporting dairy, sheep, crop and hardwood timber production. In a recent workshop with regional planners, catchment managers and extension staff, we simulated a farm which had been managed to respond effectively to a specific climate change scenario and one that had not. We then showed how – through interaction in the GIS environment – the less well managed adjacent farm could also improve its productivity. This was portrayed within the collaborative environment with avatars representing three participants (two farmers and an advisor) in the unfolding environmental decision-making. Among the options discussed and visualised were the use of deep rooted perennials and paddock reorganisation to support higher sheep stocking rates; Eucalyptus globulus plantation, a biozone for habitat conservation and low carbon energy production options. Virtual worlds can provide land managers with an interactive tool to explore and adapt to the consequences of climate change. In a formal survey, workshop attendants agreed that SIEVE would be a very useful tool for communicating future scenarios and getting stakeholder participation. They also had suggestions for improvement.

Keywords: Climate change, farming, visualisation, virtual environments, collaboration

1. INTRODUCTION

We hear a great deal about climate change. The message frequently concerns extreme conditions: longer and more severe droughts, more dangerous fire seasons, more cyclones, more damaging flooding. While these particular critical events are certainly concerning, changes to 'normal' conditions can also have major implications for agricultural systems which are particularly sensitive to weather conditions across a season or throughout a year. While it is relatively simple to create mental images of conditions which lead to loss of life and damage to property, it is less simple to convey messages about the implications of a rise of average temperature of 2.5 Celsius degrees, or 5 extra days per year over 35 degrees. Farmers, for example, are unlikely to wholly understand the implications of the changes for their farm management. It is often argued in the agricultural sector that these changes are less than the year-to-year changes they experience and they are used to dealing with those. These subtle transitions suggest that many can continue with business as usual.

Longer term changes in agricultural environments change the range of productive systems from which a farmer can choose. Annual crops can be easily replaced with others year-to-year. If, on the other hand, the environment in 10 years will be (on average) too dry for blue gums or too hot for viticulture, then that information is required now in the form of land suitability assessment models. In some instances it may be possible to maintain certain. Some land uses can adapt by a change in land management practices – for example changes in stock management. In that case a model is required not only of the land and climate conditions but also of the effect of management options on soil conditions and grass growth. Thus, the land manager is informed by a series of models each of which may be quite complex. The process begins with a climate model which feeds land capability modelling, which is supported by specific management option models. How is all this best communicated to the farmer to allow for informed decision-making?

Researchers and land managers are increasingly using realistic representation of alternative landscape futures as the basis for individual and community discussions about land use options. There are numerous examples within forestry (Sheppard, 2005; Bishop et al., 2005), urban development (Kwartler, 2005; Lindquist and Danahy, 2006), infrastructure (Bishop and Miller, 2007; Ramirez-Rosado et al., 2007), resort management (Gret-Regamey et al., 2007). Flanders et al., (2008) has also used visualisation innovatively for communicating climate change but primarily in the context of sea level rise. In the agricultural context Lovett et al. (2002), Appleton and Lovett (2003), Paar and Relittke (2005) and Stock et al. (2007) have explored a variety of technological options including stills, animation and real-time exploration. In this paper we focus on real-time collaborative virtual environments.

Stock et al. (2008) described development of a software suite for automating the creation of 3D virtual landscapes, merging these with outputs of environmental processes, linking the 3D world in real-time with underlying sources of data, making this virtual world a multi-user collaborative environment and also allowing in-field access through augmented reality (Chen et al., 2006).

With the right data, this process can create a virtual world representation of the present. However, mapped data seldom gives details of the specific agricultural systems in use at any particular time. A degree of local knowledge and artistic license are required to generate a simulation of current conditions. Representing future farming conditions is still more problematic. It begins, as suggested above, with outputs of modelling to identify likely climate trends. Further modelling then projects land suitability which delimits a range of possible land management futures. The actual land management depends then upon the degree to which farmers are innovative or adaptive, the available capital for new infrastructure, and the plausible uses or management approaches. This means that the visualisation is seldom an attempt to portray the future but a vehicle for discussion of alternative futures and for communication of the potential benefits of transition to new management. As such it is appropriate to look beyond realistic portrayal and to include iconic representation of land productivity and other variables. These more specific modelling outputs can be incorporated within the landscape itself or in graphs, charts and images which become overlays for virtual environment visitors.

In this paper, we quickly review the driver models and the visualisation systems, including examples of iconic representation, and then detail a particular case study leading up to a community workshop based on a story-line of climate change and adaptation conducted within a collaborative virtual environment.

2. MODELLING AND VISUALISATION

2.1. Climate models

Models currently used to formulate climate projections have been developed from numerical weather prediction models. These atmospheric global circulation models (GCMs) are usually coupled with ocean and terrestrial models and, hence, are known as *Atmospheric-Ocean General Circulation Models.* AOGCMs are the most comprehensive global-scale climate models; they include dynamical components describing atmospheric, oceanic and land surface processes, as well as sea ice and other components. At present, there are over 20 global climate models from different research centres available for climate simulations of 20th and 21st century climate (see CSIRO and Bureau of Meteorology, 2007, p. 40).

Climate change modelling from CSIRO has been used to estimate key climatic variables such as temperature, rainfall and solar radiation. Such information is extremely important for land managers and farming industries to better understand the likely impact of climate change on rural communities both from a sustainability and productivity perspective. The CSIRO approach downscales global models to a 5 km^2 grid. Key climatic variables can then be a source of inputs into a range of land use suitability and impact models. As an example, Figure 1 shows the average annual temperature for South West Victoria in the Year 2050 for the A1FI emissions scenario (i.e., a fossil fuel intensive future with very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies.
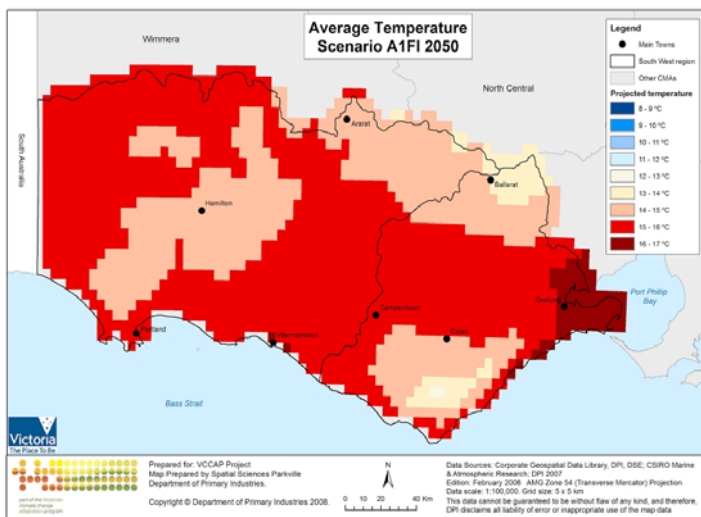

Figure 1. Average annual temperature for South West Victoria, Year 2050, IPCC A1FI Emissions Scenario
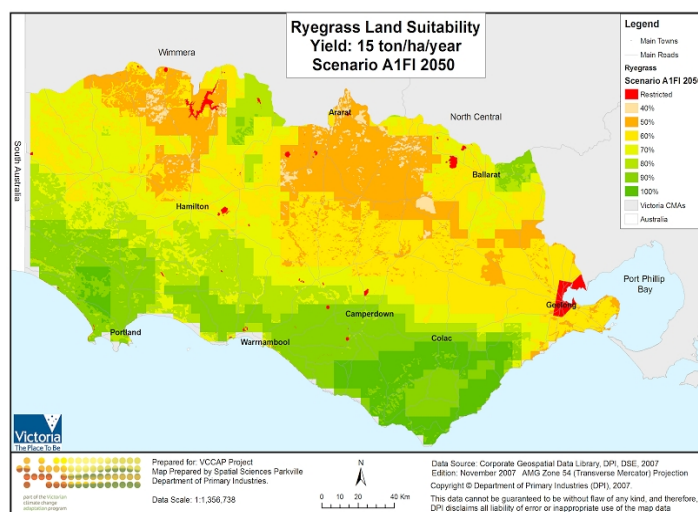
2.2. Land suitability models

In the context of this research the suitability of land (present and future) relates to the relative fitness, or appropriateness, of an area of land to support the growth of a specific agricultural commodity. The land suitability analysis being applied in South West Victoria uses a combination of the Analytical Hierarchy Process (AHP) and weighted linear combination (WLC) multiple criteria evaluation (MCE) techniques (Hossain et al., 2006). The AHP, developed by Saaty (1994), is one of the most widely used MCE methods for land suitability analysis (Carver, 1991; Jankowsky and Richard, 1994; Collins et al., 2001; Duc Uy and Nakagoshi, 2008). In our case, a participatory expert stakeholder approach is used for defining and assigning weightings of importance to a number of input parameters including: climate, soil condition and landscape. The MCE process is implemented within ArcGIS and the main output is a set of maps, one for each land use (or specific agricultural commodity) showing which level of suitability characterises each area of land (Figure 2).

This methodology has been applied by the Victorian Department of Primary Industries for over a decade and has produced more than 50 commodity-based land suitability models to be used by local planners in determining the strategic direction of their municipalities.

Figure 2. Perennial Ryegrass/Sub-clover land suitability in South West Victoria, Year 2000.

More recently the land suitability models have been incorporating climate change modelling parameters to determine likely land suitability into the future.

2.3. Virtual world creation

Three dimensional representations of rural environments can be developed with a number of software products. The software needs the ability to use a grid based digital elevation model and either corresponding aerial imagery or a rule-based approach reflecting the underlying terrain to assign ground textures (e.g., based on elevation and slope). The software also needs to adjust the surface if necessary for special features like roads and then populate the surface with appropriate 3D objects to show vegetation and man-made structures. The options are summarized by Discoe (2005). Surface textures and objects are usually divided into geospecific (as actually exists at the location) and geotypical (as can normally be found in the vicinity). Bishop et al. (2007) extended this distinction to specific, typical, representative and generic and included reference to the precision of object location, as well as appearance, into their definitions.

When a region is to be modelled in great detail, such that familiar viewers can immediately recognise the location and its feature, then a geospecific approach and very detailed positional data and models of objects are required. When projecting future conditions some objects can be expected to change significantly while others (such as the homestead and major sheds) will remain much the same through the years. A new forest plantation, a biozone, horticultural practices or new infrastructure cannot be specific and must be based on what is likely to be typical for the area. This demands the availability of an existing library of objects to be drawn on as appropriate.

The case study work below began with data of this kind. SIEVE Builder (Stock et al., 2008) was used to create the base environment. While some geospecific man-made structures could have been included in the environment, we chose to build two fictional farms and therefore populated the environment with geotypical 3D objects. As discussed, the land use elements can only be geotypical as our intent was to build future scenarios.

2.4. Populating the 3D environment

To build the geotypical surface elements, we used SIEVE Direct (Stock et al, 2008) which links ESRI ArcMap with SIEVE Viewer (Stock et al., 2008) to allow users to place specific 3D models or to fill polygons with replicator billboards representing different land cover types. For our case study environment we built two farmsteads with surrounding paddocks. The paddocks were either supporting sheep farming or wheat crops. The farmstead with the climate change management regime was also bordered by a biozone and a wind farm. Furthermore, this farm featured a biofuel plant and a few wheat silos. The wind farm and bio fuel plant were seen as a combined effort of the catchment to invest into future eco-technology. The biozone was planted across an area that was affected by soil salinity in the past to drop the water level.

The key difference between the two farms in terms of land use was that the better managed farm had replaced annual pasture with a deeper rooted and more heat resilient perennial grass species. This allowed for productive and persistent grass in dryer conditions and at the same time higher sheep stock rates. The farm that did not adapt their management to climate change had poor grass growth and low stocking. Similarly, the wheat paddocks on the better managed farm used a better wheat variety and were more productive.

Figure 3. The linkage between candidate decision polygons in the GIS (left) and the SIEVE expression of chosen land uses (right). The chosen polygon has been filled with a bluegum plantation.

To place elements in our environment, we created shapefiles containing the homesteads and the paddocks. Man-made structures were placed by point files and vegetation areas were mapped by polygon files. Via the live link, attributes in the shapefiles could be changed in the GIS and these changes were instantly visible in the 3D view. This would allow the audience to choose different land use options in the GIS and instantly see the outcome – for example planting a bluegum plantation.

2.5. Use of icon representation and charting

For this project we also created icon images to reflect the productivity levels of different land uses. Both the size and the density of these icons, such as a milk bottle or a loaf of bread, could be varied to indicate both total output and relative efficiency of land management options. This was supplemented by the option of bringing up 2D graphs. Users could look at the science behind the visualisation by bringing up monthly pasture growth rates, wheat yield models and other information. Finally, users were also able to have a look at environmental process model outputs, such as water level tables which were sitting underground and could be revealed by slicing the foreground away.

2.6. Collaborative Virtual Environment

SIEVE Viewer supports a collaborative environment by allowing multiple users to log into the same scenario via a local network or the Internet and interact with each other (Stock et al., 2008). We used this functionality to show the audience how an agronomist or regeneration expert might advise farmers over the Internet using the SIEVE technology. Users participating in a shared environment can communicate via a text box or talk to each other using technology like Skype.

For our case study we also placed numbered flags as special interest location indicators. This way, users could follow the advisor to different locations where the advisor would discuss problems at hand. In particular we used this set-up for the advisor to educate the less adaptive farmer about why the farm was performing poorly and how the neighbour had adapted to changes.
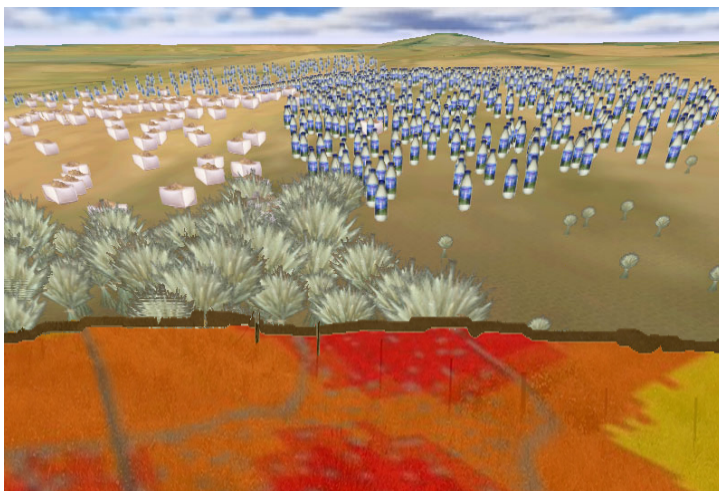
Figure 4. In this case the landscape has been cut away to show the water table under a specific land management scenario. On the land surface the productivity outcomes are illustrated using icons (e.g., wheat sheaves and milk bottles) whose size and density represent outputs and efficiency levels respectively.

3. CASE STUDY

The South West Victoria case study region incorporates both Glenelg Hopkins and Corangamite Catchment Management Authorities (CMAs). It lies south of the Great Dividing Range and extends in the east from the City of Geelong to the South Australian border in the west, and south to the Victorian coastline. The region contains a range of natural assets in the form of its biodiversity, waterways and wetlands, soils, forests and coastal areas. These natural assets support the most important resource-based industries in South West Victoria – agriculture, fisheries and tourism. The region has a diverse and growing economic base. Employment in Corangamite is dominated by the manufacturing and services sectors, especially in the cities of Geelong and Ballarat. Economic activities in Glenelg Hopkins have traditionally been based on grazing, but diversification in the agricultural and non-agricultural economy has been rapid in the past years. A significant diversification in Glenelg Hopkins is that farms have been acquired or leased out to companies growing Blue Gums (*Eucalyptus globulus*) for timber production, This has been quite spectacular over the past decade, with the area under Blue Gum plantations increasing from a low base to around 100,000 hectares today.

Through using the South West Victoria case study approach we have been able to demonstrate and commence testing of model driven visualisations of climate change scenarios. A technical workshop was held in the Council offices of Portland in August 2008. The workshop was attended by a number of council

and catchment management planners, extension staff and researchers. The technical workshop commenced with an overview of land use models currently being developed and applied in South West Victoria as part of the whole of Government Victorian Climate Change Adaptation program (VCCAP). The second part of the workshop explored a possible climate change adaptation storyline and what that might look like at the farm scale. This is where the SIEVE collaborative virtual environment was used to explore future farming systems in South West Victoria. A fictitious farm, rather than a real farm, was visualised as the modelling results are still preliminary and the aim of the visualisation was to explore the potential linkages between models and visual outputs to better communicate climate change scenarios. During the workshop participants formed three groups each associated with a separate computer. An operator on each computer guided the participants through the scenario. Each could see the avatars of the other groups and so begin to explore the potential of the system to support collaboration within the virtual environment.

Feedback from the workshop was clearly promising. Participants believed visualisation to be a powerful tool in communicating the likely impact of climate change and possible adaptation strategies. The promise of the collaborative medium was evident. Feedback also identified that the 'realism' of the visualisation could be improved and there is a need to ensure that the visualisations are properly based on scientific research. These suggestions will be addressed in the next phase of the research.

4. DISCUSSION

One of the key findings of our collaborative modelling and visualisation approach to better understanding climate change futures research, is a clear need for a definitive source of certified climate change models for Australia to inform land management and planning decisions. Recently, the Australian Community Climate and Earth-System Simulator (ACCESS) http://www.accessimulator.org.au/, a joint venture with the Bureau of Meteorology and CSIRO has been established. One of the challenges facing this venture is to be able to generate a definitive set of climate change models which can be applied both at the national as well as regional scale to inform land suitability and impact models. Such outputs can then be visualised using technologies such as the SIEVE virtual collaborative environment to better inform planners, land managers and communities of the likely impacts of climate change on farms and rural landscapes across Australia.

A second key element of effective use of these technologies is better information exchange between elements. In this exercise the climate modellers had to be educated in the specific data formats needed for input to GIS. Once the suitability models had been generated in the GIS it was procedurally an easy task to generate the visualisations – however when we came to do this we realised that we did not have all the necessary objects available to support the visualisation. We needed textures for fat sheep and thin sheep for wheat of different varieties and in different conditions, we needed 3D objects representing wind turbines, a biofuel plant, a barn decked with photovoltaic panels and other symbols of both efficient adaptive farming techniques and traditional approaches. Until a comprehensive and accessible object library exists this bottleneck in the modelling-to-visualisation pipeline will always exist.

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