Options for Victorian Agriculture in a "New" Climate: Pilot study linking climate change & land suitability modelling

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Abstract: This pilot project determines the potential for growing cool climate grapes, high yield pasture and blue gum across Gippsland (Victoria), and the likely shift in that potential as projected climate change occurs in the region. It provides an indication of the information that can be generated combining land suitability analysis and climate change scenarios. By considering the changing suitability of a few key agricultural enterprises in this region, the project offers an important direction for the agricultural elements of the Victorian Greenhouse Strategy. This pilot project utilises Land Suitability Analysis (LSA) developed by the former Victorian Department of Natural Resources and Environment (DNRE) under the National Land and Water Resources Audit of Australia and further enhanced with Local Government and Catchment Management Authorities across Victoria. This modelling technique allows for an assessment of impacts on a wide range of commodities beyond the historic focus of cropping and pasture models. Following a series of workshops with agronomists, soil scientists, climate scientists, strategic planners and growers, a series of maps/overlays were prepared for Gippsland showing potential suitability of blue gum plantations, cool climate grapes and high yield pasture, as an initial illustration of the methodology. This potential suitability has since been adjusted/modified using a variety of climate change scenarios developed by CSIRO Climate Impacts Group, resulting in an assessment of the change in potential suitability for each enterprise at years 2020 and 2050. The resultant work can be analysed using Geographic Information Systems (GIS) to consider change over time and space in the region. Combined with changes in water availability, this may act as an innovative and powerful decision support tool for policy makers in government and industry.

Keywords: *Climate change; Expert systems; Modelling Climate Change; Land Suitability Analysis; Agricultural Commodities; Victorian Greenhouse Strategy, Ecologically Sustainable Agriculture Initiative; Climate Impact Scenarios.*

1. INTRODUCTION

1.1. Background

The Victorian Greenhouse Strategy (DNRE, 2002) highlighted the need for a range of response actions to deal with the goals of raising awareness of greenhouse issues, limiting greenhouse emissions, living in a carbon-constrained society, building capacity within industry and better understanding climate change impacts and the development of adaptation options. This project set out to implement some of those response actions.

1.2. Project Design

The pilot study utilises a specific Land Suitability Analysis (LSA) tool that was created as an integral part of the "Gippsland Model", a broader regional strategic planning model developed under the National Land and Water Resources Audit of Australia (NLWRA, 2002). The LSA is considered useful at this early phase of regional impact assessment for agriculture for several reasons:

1. It enables scaling up to regional and strategic levels where data paucity and computing costs often limit more complex dynamic plant, catchment or farm models.
2. It is based on an "expert systems" approach and the associated communication effort

delivers a range of peripheral outcomes for the project including raising awareness about climate change.

3. It is highly flexible and can be adjusted depending on the "question being asked".

4. The tool is simple to manipulate and interrogate, providing a highly transparent modelling framework throughout the process.

For this pilot study, LSA uses discrete spatial datasets of soil, landscape and climate attributes. The climate factors introduced into the model are developed using OzClim, a climate change scenario generator developed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) Earth Systems Modelling Program.

Figure 1 outlines the full extent of the study. For the purposes of this paper only the shaded boxes will be discussed in detail, while the dashed sections indicate future directions of the project.

2. CLIMATE SCENARIO TOOLS

Climate scenarios are generated using a combination of greenhouse gas emission scenarios and global circulation models (GCMs).

2.1. SRES – Emissions Scenarios

This pilot study employs the latest set of emissions scenarios issued by the Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2000). The Special Report on Emission Scenarios (SRES) produced 40 future emission scenarios for greenhouse gases and sulfate aerosols. These scenarios cover a wide range of the main driving forces of future emissions, from demographic to technological and economic developments. Six of the 40 SRES emissions scenarios (A1B, A1T, A1F1, A2, B1 and B2 representing the families of technology-population-economy futures) are shown in Figure 2. Further details of these can be found at the SRES website (http://www.sres.ciesin.org).

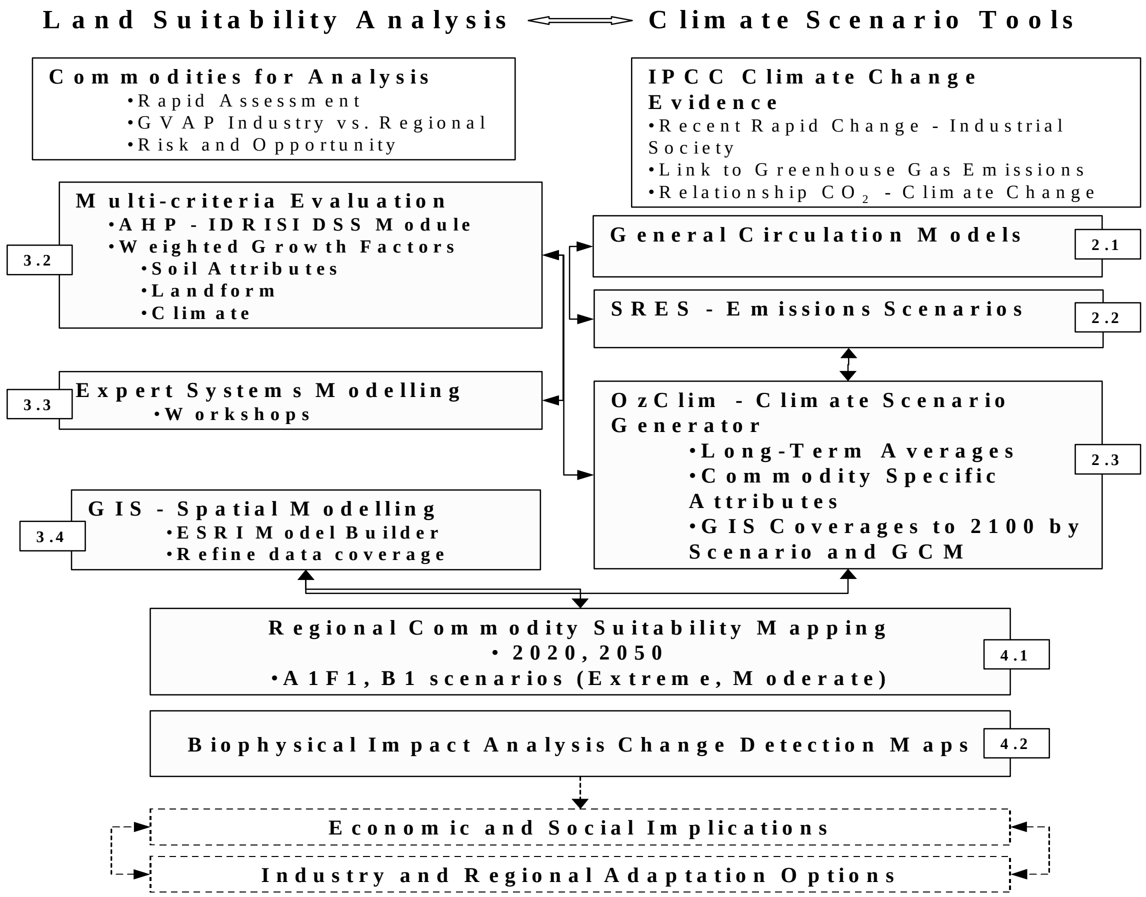

Figure 1: Project Design (relevant text sections indicated)

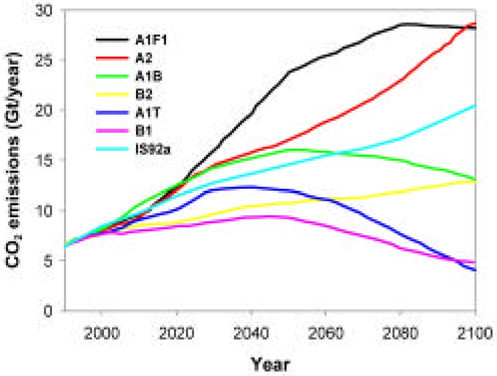

Figure 2: Six of the SRES emission scenarios (Giga-tonnes per year) for carbon dioxide (CO_2), plus the IS92a mid-case scenario used by the IPCC in 1996 (IPCC, 2001).

2.2. General Circulation Models

The IPCC (2001) provides estimates of global-average warming based on 35 of the 40 SRES emission scenarios (Figure 3). These estimates were determined using simple models tuned to match the global performance of GCMs. The two inner lines represent the variation in results according to emission scenarios averaged across all models, while the two outer lines allow for model to model variation.

GCMs are the best available tools to study possible future climate and include complex equations to represent processes that govern atmospheric and oceanic circulations, temperature, precipitation etc. Most GCMs satisfactorily simulate observed temperature, precipitation and mean sea-level pressure patterns over south-eastern Australia (Whetton, et al., 2002).

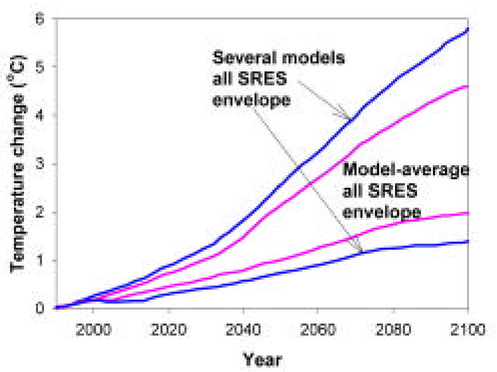

Figure 3: Projections for global-average warming relative to 1990 for an envelope of SRES greenhouse gas and sulfate aerosol emission scenarios. (IPCC, 2001).

2.3. OzClim Climate Scenario Generator

OzClim is a PC-based regional climate scenario generator for Australia that simplifies the process of calculating future climate change for application to impact models. It is chiefly used as a research tool for climate sensitivity studies, and it features a graphical user interface and point and click technology for ease of use, fast calculations and visualisation capabilities (Page and Jones, 2001). OzClim also allows comparison of output from a range of climate models and construction of future climate change scenarios for risk assessment.

CSIRO Atmospheric Research has “tailored” a version of the OzClim scenario generator for the Department of Primary Industry (DPI) to describe how the Victorian climate may change during the next 100 years. This has been achieved by combining a range of projected global warming as given by IPCC (2001) (low-middle-high climate sensitivity derived from Figure 3) with projected regional climate changes (Victorian region) obtained from a range of atmosphere-ocean general circulation models (AOGCM’s) and also high horizontal resolution atmospheric general circulation models (AGCM’s) forced by the output of the AOGCM’s.

OzClim is grid-based, and in this pilot study it employs an array of about 20,000 points (Victorian region), producing a grid spacing of about 5 km over Victoria. Climatic variables such as maximum and minimum temperature, and rainfall were augmented by evaporation, solar radiation and relative humidity. In addition, deciles for daily and monthly maximum and minimum temperature, and rainfall are available and can be modified according to selected emissions scenarios and climate sensitivities.

OzClim also has the capacity to ‘plug in’ a range of impact models to explore the sensitivity of impacts to different emissions scenarios and climate sensitivities. Impact models for the Victorian region developed for this pilot study included simple water balance (precipitation minus potential evaporation), heating degree days, Branas index and frost frequency. Models of effective rainfall, heat stress and chilling units are currently under development.

3. LAND SUITABILITY ANALYSIS

3.1. The Land Suitability Framework

The land suitability framework was developed by the Food and Agriculture Organisation of the United Nations (FAO). Unlike land capability assessment, which essentially focuses on the limitations to land use in an area, LSA assesses the suitability of land for a specific use or commodity (Conacher and Conacher, 2000). LSA can be used to assess potential climate change impacts by using spatial datasets and analysing the various elements based on a function of interaction between them and/or through a multi-criteria analysis method. Due to its probabilistic nature, LSA lends itself well to assessing the impacts of climate change as it can provide with assessments of changing potential for production.

3.2. Multi-criteria evaluations tools and concepts

This pilot study used LSA developed by the former DNRE under the National Land and Water Resources Audit of Australia. The methodology incorporates a Multiple Criteria Evaluation (MCE) within a Geographic Information Systems (GIS) environment. MCE has been developed to improve spatial decision making when considering multiple objectives and conflicting preferences (or priorities). MCE can be an effective decision-making tool for complex issues, using both qualitative and quantitative information. It combines the information from several criteria to form a single composite index of evaluation, and has been utilised around the world for Land Use Suitability modelling.

The Analytical Hierarchy Process (AHP) is a MCE method that orders critical factors into a hierarchy of importance. This improves the representativeness of the mapping because not all factors have an equal weighting of importance. It also allows criteria to trade-off with each other depending on the importance weights assigned to them. Furthermore, AHP can deal with criteria that are interdependent, both from the effect on land and in the interaction between spatial units.

3.3. Expert Systems Modelling – Workshops

To develop the LSA for this pilot study, each commodity was analysed using a series of expert systems model workshops involving agronomists, growers and soil scientists with expertise in the Gippsland region.

The workshops had several objectives:

1. To build awareness of current climate change science.
2. To define the goal of the modelling exercise in the context of the project.
3. To develop a model using Analytical Hierarchy Process – Multi-criteria Evaluation.
4. To verify and fine-tune outputs following GIS modelling

The final model was developed in the form of a weighted hierarchy, as illustrated in Figure 4.

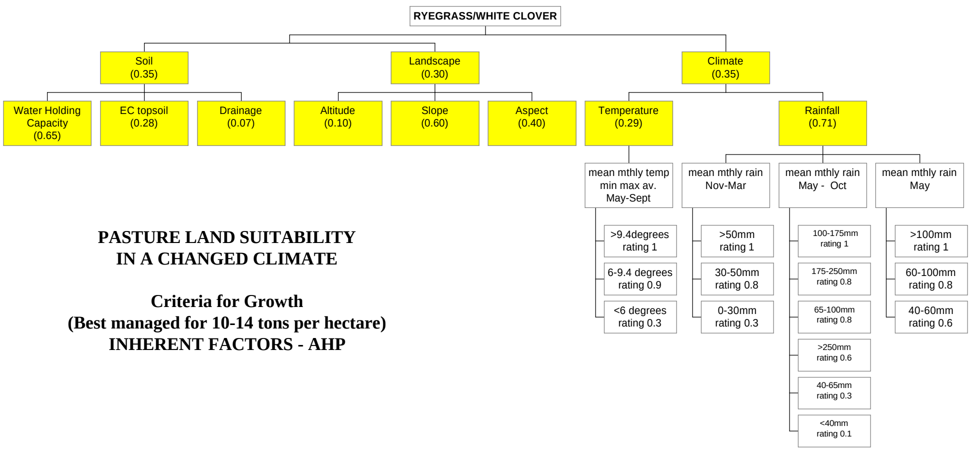

Figure 4. Example of the Analytical Hierarchy Process in the pilot project, showing the model used for high yield pasture(numbers in brackets represent criteria weighting).

3.4. Geographic Information Systems – Spatial Modelling

In order to use the scenarios generated by OzClim as an input into the Multi-criteria Land Suitability Model; a suitable link between the two models was necessary. For the purposes of this pilot study, macros have been developed that take the scenarios generated by OzClim and convert them to a format readable by the Land Suitability models that have been developed using the ArcView Model Builder. The process involved:

1. Generation of all required scenarios using OzClim
2. Exporting these scenarios in 16 bit IDRISI format
3. Application of the interface macros, developed using IDRISI, to convert these IDRISI files to ArcView 32 bit Binary Raster format
4. Importing the Binary rasters into ArcView and converting them to ArcView grid layers
5. Including these grid layers as inputs to the Land Suitability Models

The selected OzClim climate change GCM was CSIRO MK2 utilising both the B1 and A1F1 greenhouse gas emission scenarios. CSIRO MK2 B1 scenarios were created for the years 2000 (base year), 2020 and 2050. MK2 A1F1 scenario was only employed for the year 2050.

4. OUTPUTS OF THE PILOT PROJECT

4.1. Regional commodity suitability mapping

Three commodities were selected for analysis based on the commodities currently produced, new commodities that could be introduced into the region according to potential market demand and advice from agronomists and other relevant experts. The three commodities selected were cool climate grapes, high yield pasture and blue gum plantations.

Initially, land suitability with base climate data (potential for the year 2000) was assessed and a series of maps prepared. Factors considered in this assessment were climate, landscape and soil. Land suitability outcomes were ranked in twelve categories covering high, moderate, low and very low suitability for commercial production and restrictive areas, which were deemed unsuitable for commercial production of the commodity.

The process was repeated using LSA and different climate change scenarios, with a series of maps produced for the years 2020 and 2050. An example of these maps is shown is Figure 5. A panel of experts in a series of workshops assessed the accuracy of these maps. The base climate (2000) maps were verified at this stage.

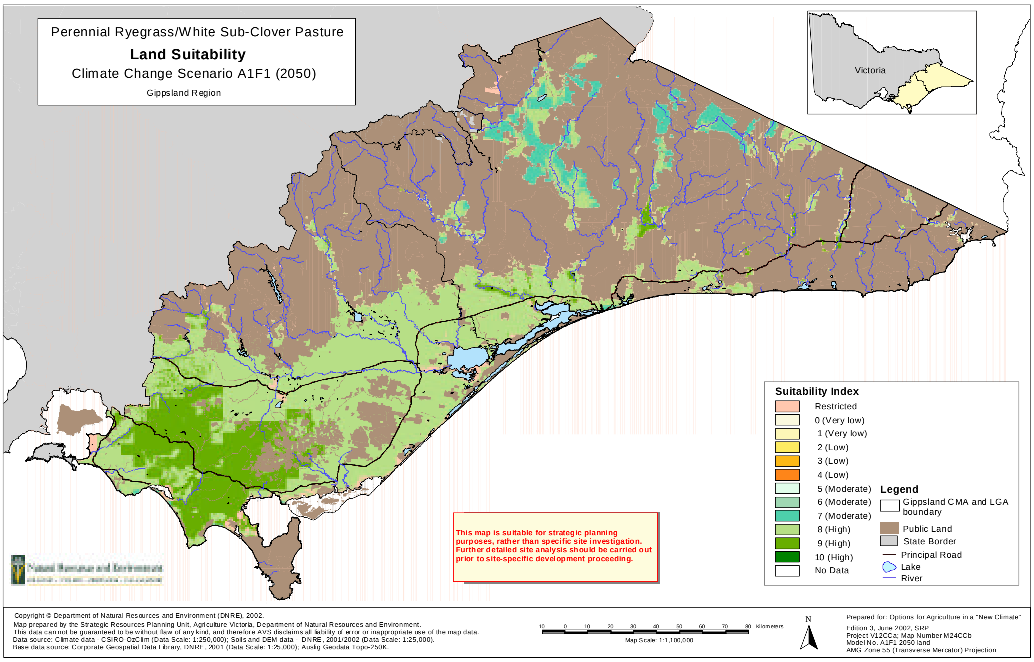

Figure 5. Future Land Suitability (2050) for Cool Climate Grapes under an extreme emissions scenario

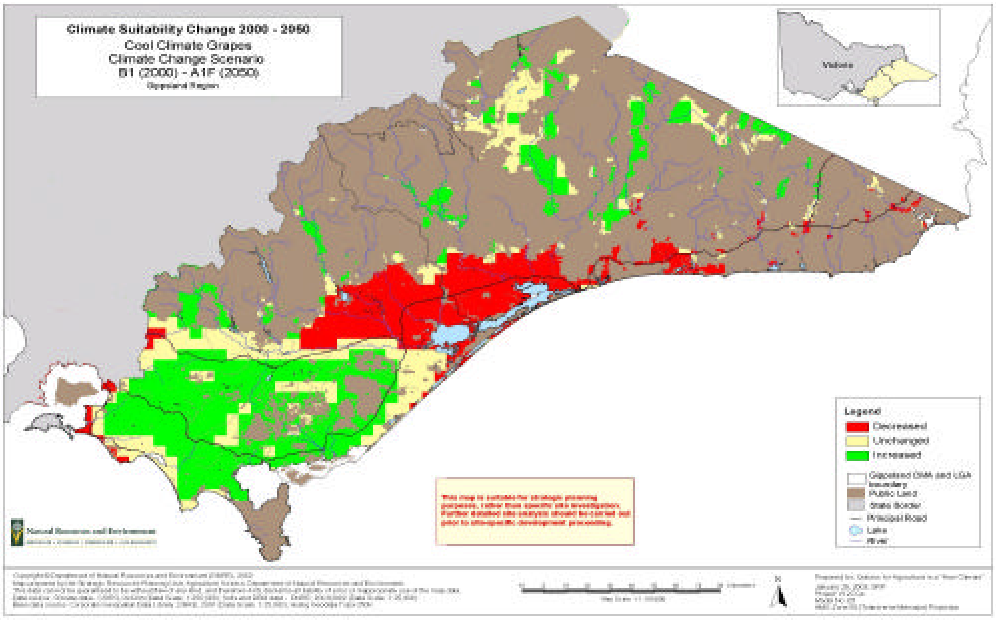

Figure 6. Change in Climate Suitability for Cool Climate Grapes under an extreme emissions scenario

4.2. Biophysical Impact Analysis Change Detection Maps

A further step in this pilot study was to develop change detection maps, using the land suitability maps created for the years 2000, 2020 and 2050 (Figure 6). These maps further enhance the information portrayed in the land suitability maps and clearly indicate areas where land suitability may increase, decrease or remain unchanged in the Gippsland region. Initial maps produced in the LSA were analysed using GIS, and consider temporal and spatial change in the Gippsland region. Change detection maps were produced for each of the commodities studied.

5. ACKNOWLEDGMENTS

The Ecologically Sustainable Agriculture Initiative (EASI), Victoria and the Victorian Greenhouse Policy Unit supported the pilot study.

OzClim is a stand-alone climate change scenario generator that has been developed by CSIRO Atmospheric Research and the International Global Change Institute at the University of Waikato in New Zealand.

http://www.dar.csiro.au/publications/ozclim.htm

6. REFERENCES

Conacher, A. and J. Conacher, *Environmental Planning and Management in Australia*, Oxford University Press, South Melbourne, Victoria, 2000.

DNRE, *Victorian Greenhouse Strategy*, Department of Natural Resources and Environment, Melbourne, 110, 2002.

http://www.greenhouse.vic.gov.au

IPCC, *Climate Change 2000: The Science of Climate Change. Summary for Policymakers and Technical Summary of Working Group*, Cambridge University Press, 98 pp, 2001.

IPCC, *Special Report on Emission Scenarios - A special report of Working Group III of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, 2000.

NLWRA, *Australians and Natural Resource Management 2002*, National Land and Water Resources Audit, ACT, 2002.

Page, C. M., and R.N. Jones, *OzClim: the development of a climate scenario generator for Australia*. Proceedings of MODSIM 2001, International Congress on Modelling and Simulation: Australian National University, F. Ghassemi, and others (editors). Canberra, ACT: p. 667-671, 2001

Whetton, P. H., R. Suppiah, K. L. McInnes, K. J. Hennessy and R. N. Jones, *Climate change in Victoria: High resolution regional assessment of climate change impacts.*, Victorian Department of Natural Resources and Environment, Melbourne, 2002.