DEPARTMENT OF PLANNING, INDUSTRY & ENVIRONMENT

Climate change impacts in the NSW and ACT Alpine region

Integrated assessment using the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) tool

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Cover photo: Winter landscape in Kosciuszko National Park. John Spencer/DPIE

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ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ACT	Australian Capital Territory
ACTPLA	ACT Territory Plan dataset
ACLUMP	Australian Collaborative Land Use and Management Program
ALUM	Australian Land Use and Management
CMIP	Coupled Model Intercomparison Project
DPIE	Department of Planning, Industry and Environment
EHF_nf13	Excess Heat Factor Index
GCM	Global Climate Model
GIS	geographic information system
IDW	Inverse Distance Weighted
LSC	Land and Soil Capability
LUMAP	Land-Use Mapping Program
MBE	mean bias error
MCAS-S	Multi-Criteria Analysis Shell for Spatial Decision Support
MM	Murray-Murrumbidgee state planning region
MGA	Map Grid of Australia
NARCliM	NSW/ACT Regional Climate Modelling project
NetCDF	Network Common Data Form
NSW	New South Wales
OEH	Office of Environment and Heritage
RCM	Regional Climate Model
SCALD	Standard Classification for Attributes of Land
SEED	Sharing and Enabling Environmental Data
SET	South East and Tablelands
SRTM	Shuttle Radar Topographic Mission
WRF	Weather Research and Forecasting

Summary of findings

Integrated assessment using the Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) tool

1. This work integrated spatial outputs from the climate change impacts in the NSW and ACT Alpine region projects with other data.
2. Data was converted into a standardised format called a ‘datapack’ that allowed it to be used in the free, user-friendly modelling software Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) to inform climate change adaptation and support land management and land-use planning decisions.
3. MCAS-S is a powerful, easy-to-use decision support tool designed to help visualise and combine spatial data in an interactive way.
4. Two MCAS-S datapacks were developed at different spatial scales and resolutions. The large scale (100 m pixel), datapack covered the full project study area while the smaller scale (30 m pixel), datapack was built to support the analysis and environmental management of Kosciuszko National Park.
5. MCAS-S datapacks integrated outputs from 12 Global Climate Model/Regional Climate Model simulations as well as climate change impacts modelling projects, with other contextual data.
6. Datapacks include 782 datasets covering themes such as administration and statuary boundaries, climate, European and Aboriginal culture, population, geology, land form, land use, land class, soil properties, tenure, vegetation and water.
7. MCAS-S datapacks increased the computational efficacy and resources were able to be allocated to the other important steps in the multi-criteria analysis (MCA) decision support process.
8. The interactivity and data visualisation features of MCAS-S improved participatory modelling, an approach that has been shown to improve stakeholder understanding, acceptance and adoption of modelled outputs and decisions.
9. Although the technical challenge of building the MCAS-S datapacks more efficiently has been met, further work will improve the documentation, useability and utility of the data and facilitate the sharing of lessons learnt.

1. Introduction

1.1 Background

The New South Wales (NSW) and Australian Capital Territory (ACT) Alpine region is located in the south-eastern corner of mainland Australia and is the highest mountain range in Australia. Though it comprises only about 0.16% of Australia in size, it is an important region for ecosystems, biodiversity, energy generation and winter tourism. It forms the southern end of the Great Dividing Range, covering a total area of 1.64 million hectares that extend over 500 kilometres. The highest peak, Mount Kosciuszko, rises to an altitude of 2228 metres.

This report is a part of a larger project delivered by the NSW Department of Planning, Industry and Environment (DPIE) on the various impacts from climate change on the NSW and ACT Alpine region, hereafter referred to as the Alpine region. The full study region covers the Murray-Murrumbidgee region (MM), South East and Tablelands (SET) and the ACT, bordering the Victorian border in the south (Figure 1).

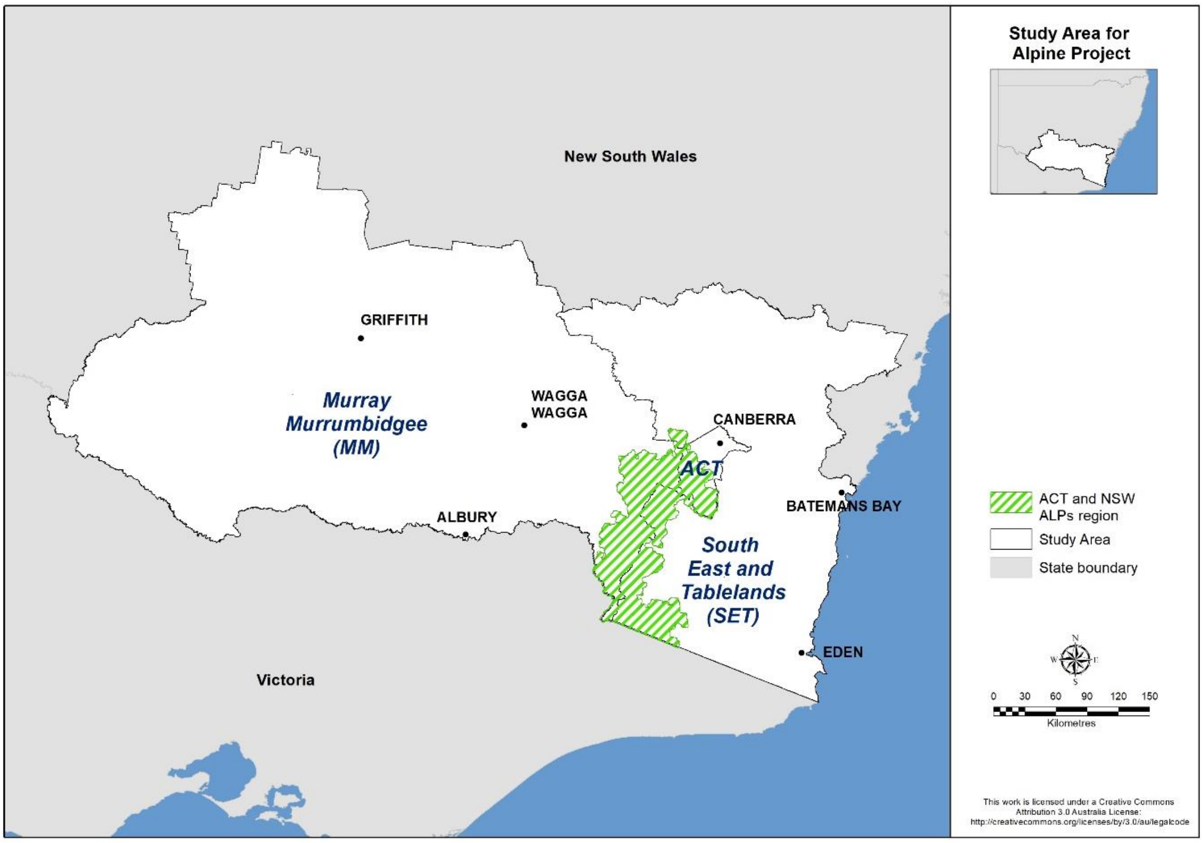


Figure 1 The study area for the Alpine project, including the NSW and ACT Alpine region, Murray-Murrumbidgee region and South East and Tablelands

1.2 Objectives

Most climate change adaptation problems are technically and socially complex and there is no one correct solution. Tackling complex climate adaptation problems requires the integration of different types of information and knowledge including: bio-physical (e.g. ecology, soils, hydrology, climate), cultural (e.g. cultural heritage, cultural health), economic (e.g. farm income and profitability, commodity prices) and social (e.g. wellbeing, health, behaviour). These types of complex problems benefit from involving stakeholders in the modelling and decision-making process, herein referred to as 'participatory modelling' (see Davies et al. 2015).

Using a participatory modelling approach to address complex problems is a growing field of research (Bousquet & Voinov 2010; Oteros-Rozas et al. 2015; Kabaya et al. 2019). Participatory modelling supports the integration of scientific and contextual or local knowledge (Pahl-Wostl et al. 2007). Participatory modelling facilitates processes that combine scientific knowledge development and political decision-making processes, increasing trust and adoption of model outcomes (Becu et al. 2008). The Multi-Criteria Analysis Shell for Spatial Decision Support (MCAS-S) software and supporting tools facilitate the integration of different types of spatial data. This improves capacity to support land-use and land management decisions, especially when tackling complex problems. Being interactive and flexible makes MCAS-S an ideal platform for undertaking participatory planning and decision-making.

In this project, we imported the spatial outputs from the following climate change impacts modelling projects: Projected climate in the NSW and ACT Alpine region, Impacts on fire weather, Impacts on water availability, Impacts on soil erosivity and hillslope erosion, and Impacts on biodiversity, as well as contextual data, into two 'datapacks' for use in MCAS-S. This technical report documents the process of building the datapacks, and the different types of input data. It also uses some examples to demonstrate the five steps involved in undertaking multi-criteria analysis (MCA) decision support using MCAS-S.

The aim of this project was to develop tools that help stakeholders answer specific spatial questions using the outputs from the other climate change impacts projects. One of the major advantages of the NARCliM models, and most of the climate change impacts models, is that they produce spatially explicit data outputs at a finer scale than the coarser (10 km) Global Climate Models. This means it is possible to use these spatial outputs to support spatial planning and prioritisation decisions at landscape or sub-regional scales.

1.3 Outputs

Output	Key user
Report	Users of the MCAS-S datapack and those considering downloading and trialling the MCAS-S software and datapacks
MCAS-S datapack	Researchers, planners, land managers, students

1.4 Focus region

MCAS-S datapacks were built for two study areas at different scales (Figure 2). The first covers the entire climate change impacts in the Alpine region study area and is based on a one hectare or 100 metre pixel. The second is a higher resolution, 30 metre pixel, covering Mount Kosciuszko and adjacent national park areas.

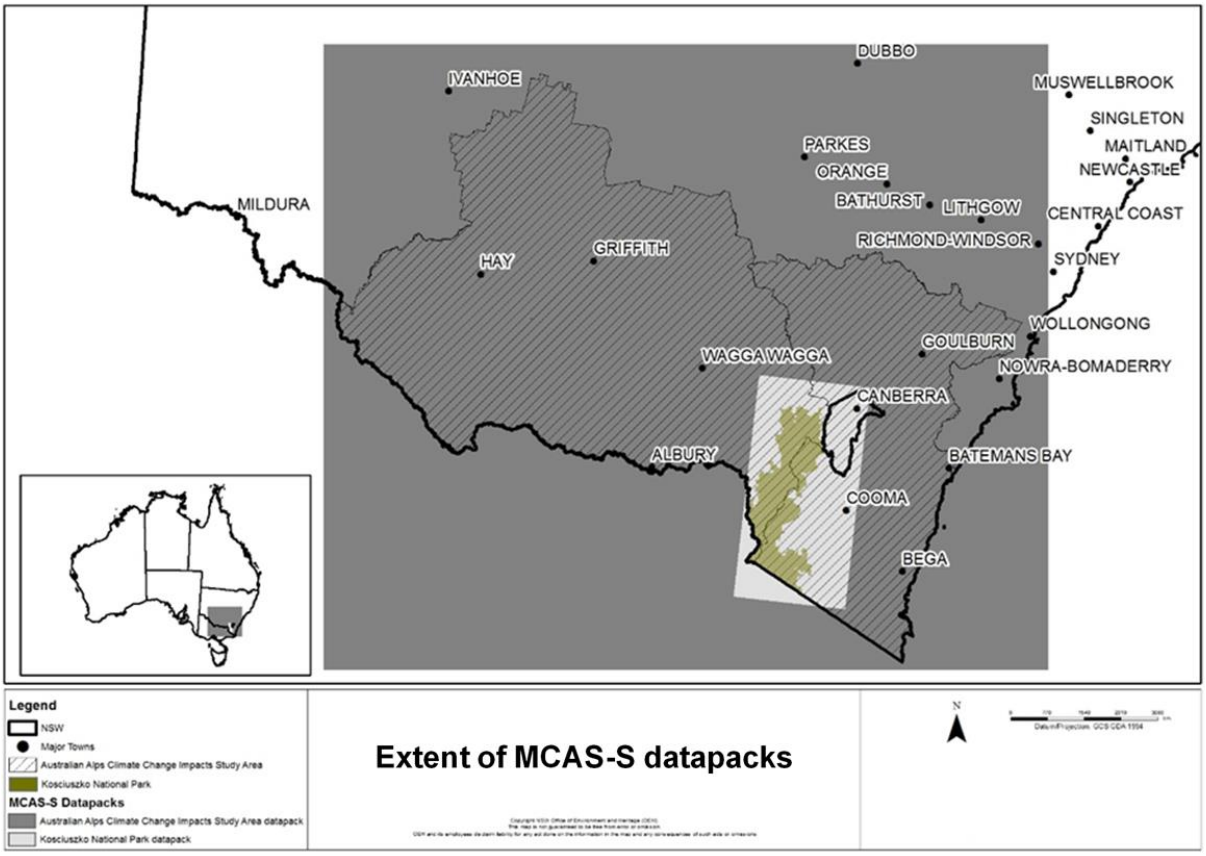


Figure 2 Climate change impacts in the NSW and ACT Alpine region study area and the extent of the MCAS-S datapacks

2. Methods

This section provides an overview of the MCAS-S software, the spatial data and the steps involved in reformatting the data for inclusion in the two MCAS-S datapacks.

2.1 Use and advantages of MCAS-S software for spatial decision support

Created by the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), MCAS-S is a powerful and user-friendly spatial decision support tool designed to help visualise and combine spatial data in an interactive way (Hill et al. 2005; MCAS-S Development Partnership 2018). Relative to conventional geographic information systems (GIS), spatial models are displayed more rapidly using MCAS-S. This rapid visual display of spatial data greatly improves participatory modelling workshops because users can immediately see results of different modelling scenarios and the potential impacts of their decisions. The visual layout of the data and models is well structured and when clearly documented can increase decision-making transparency and repeatability (MCAS-S Development Partnership 2018). Other advantages of the MCAS-S software include:

- access, combine and analyse a large range of spatial datasets
- simultaneously deal with categorical and continuous variable formats
- it is user-friendly – non-GIS experts can easily build special models
- ability to view why a pixel has a value provides transparency
- flexibility – allows for improvements as new data or knowledge becomes available
- scalable – a model can be built at one scale then replicated at a different spatial scale or in a different study area (assuming the input data is available).

MCAS-S software and user manuals are free to download from the ABARES MCAS-S webpage.

The multi-criteria analysis (MCA) process is widely used to address a variety of complex problems across disciplines such as health, land-use planning and natural resource management (Malczewski 2007; Ishizaka & Nemery 2013). The following five steps in the MCA process (MCAS-S Development Partnership 2018) are described in Section 2.3:

1. Define the objective and decision criteria
2. Assemble data inputs (build MCAS-S datapack)
3. Explore and combine data
4. Develop options
5. Review and report.

There are several Australian natural resource studies that demonstrate the successful application of MCAS-S software. The software has been used as a planning tool for mapping revegetation priorities (Hill et al. 2006; Lesslie & Cresswell 2008; Lesslie 2012), estimating water loss vulnerability (ABARES 2010), identifying land at risk of acidification (Wilson et al. 2009), assessing the sustainability of livestock grazing in rangelands (Lesslie et al. 2008), mapping soil loss through wind erosion (Smith & Leys 2009; Leys et al. 2017), and for identifying potential areas of soil carbon content enhancement (Baldock et al. 2009).

The DPIE Science Division is actively involved in MCAS development and provides funding for improvements to the MCAS-S software. New features include time-series data analysis, improved useability and help to automate the process of building datapacks. This report outlines step 2 of the MCA process, assemble data inputs, and provides examples of the other steps to help guide users of the climate change impacts MCAS-S datapacks.

The DPIE Science Division is actively involved in building the MCAS-S datapacks.

2.2 Building the MCAS-S datapacks

Building the MCAS-S datapacks involved undertaking the following auditing and spatial data processing tasks, which are described in more detail below:

1. Spatial parameters – Decide on spatial parameters for the datapacks and build raster ‘template’.
2. Data sources – Identify and source spatial data outputs from the other climate change impacts sub-projects. Identify all GIS contextual data on the DPIE spatial P-drive with statewide coverage.
3. Import data into MCAS-S datapacks – Convert GIS data into a standard raster format (template) used by the MCAS-S datapack.
4. Metadata – Source all GIS metadata and build the MCAS-S tip metadata files.

Task 1. Spatial parameters

Spatial parameters for the MCAS-S datapacks are the data projection, alignment or origin, cell or pixel size, and extent (see Table 1).

Data projection

MCAS-S calculates areas and reports on proportions by counting pixels. For the calculations to be accurate each pixel must represent the same area on the ground, i.e. be of equal area and require an equal area projection (MCAS-S Development Partnership 2018). For this reason, we used the ‘Australian Albers’ equal area projection for the larger study area datapack, which is the projection used by ABARES and the Australian Government

(MCAS-S Development Partnership 2018). For the smaller Kosciuszko National Park datapack we chose the Map Grid of Australia (MGA) zone 55 projection, as this is the recommended projection when the study area lies within a single MGA zone (NSW Department of Finance, Services and Innovation Map projections).

Alignment or origin

We aligned the MCAS-S datapack data with the environmental variable grids sourced from the NSW vegetation mapping project (OEH 2017). These grids were aligned with the commonly used one-degree (~30m) Shuttle Radar Topographic Mission (SRTM) Digital Elevation Model (Geoscience Australia 2011); therefore the pixels align with the environmental variables and the vegetation maps derived from this DPIE statewide vegetation modelling program.

Cell or pixel size

When using the 64-bit version of MCAS there is no upper limit to the number of pixels in an MCAS-S datapack; however, there is a trade-off between the number of pixels and the time it takes for MCAS-S to recalculate when building models. To be interactive and view the real-time effect of changes in the models, larger study areas require larger pixels compared with smaller study areas. To maintain a tractable number of pixels (<50 million) we chose a 100 metre pixel size for the larger study area datapack and 30 metres for the smaller Kosciuszko National Park datapack.

Extent

The extent for the larger MCAS-S datapack was selected to include the full climate change impacts in the Alpine region study area and was extended slightly to ensure it also covered the same region as the Alps Bogs and Alpine Icons and Threats datapacks (National Environmental Research Program (NERP) Landscapes and Policy Hub; Magierowski et al. 2014; Porfirio et al. 2014). The Kosciuszko National Park MCAS-S datapack extent covers the Kosciuszko National Park as well as adjacent nature conservation.

Table 1 Summary of the spatial parameters for the two MCAS-S datapacks

Datapack	Size	Projection	Pixel size	Columns / rows	Total pixels
Australian Alps Climate Change study area	721 km x 650 km	Australian Albers	100 m x 100 m	7,210 x 6,500	46,865,000
Kosciuszko NP	111 km x 222 km	MGA Zone 55	30 m x 30 m	3,700 x 7,400	27,380,000

Task 2. Data sources

Over 3400 spatial data layers were imported into the MCAS-S datapacks. The data came from five different sources:

1. DPIE corporate spatial drive
2. raster grids of environmental variables compiled for the NSW native vegetation mapping program
3. climate change impacts in the Alpine region sub-projects
4. NARCliM modelled climate variables
5. DPIE Sharing and Enabling Environmental Data (SEED) portal.

The total number of data layers sourced for the datapacks is summarised in Table 2 for these five sources and by theme in Table 5 in Appendix A.

Table 2 Summary of data sources imported into the MCAS-S datapacks

Data source	Number of data layers
DPIE spatial P-drive	197
DPIE vegetation mapping project	84
Climate change impacts in NSW and ACT Alpine region project outputs	175
NARCliM outputs	3,024
From SEED data portal	2
Total	**3,482**

GIS statewide data on the DPIE spatial P-drive

We included statewide data from the DPIE corporate spatial P-drive. This is a combination of data derived by DPIE and sourced from other state agencies. This will enable us to achieve a longer-term objective of automating the generation of MCAS-S datapacks for other regions in New South Wales.

Environmental variables used in NSW vegetation mapping program

Environmental data was collated from several statewide vegetation modelling sources including DPIE, Bureau of Meteorology and CSIRO (OEH 2017). A total of 84 environmental variables were imported (see Appendix B, Table 6) and grouped into the following folders and sub-folders: climate (energy, rainfall and temperature), land (drainage, geophysics, landform and location) and soil (properties).

NARCliM outputs

We developed GIS tools and techniques to reformat the raw outputs from the NARCliM models to allow import into the MCAS-S datapacks. This involved five processing stages:

1. Conversion of the NARCliM NetCDF (nc) file from 'rotated pole' projection to a regular 'geographic' projection. This is performed by a Python script in the Imagery and Remote Sensing (IRS) computer environment using the 'MobaXterm' terminal software and Climate Data Operators (CDO) commands.
2. Extraction of each of the 12 time-slices (raster grids) representing the 12 months of the year. The values in each month are the average for that month across all the months in the time periods. This is done using the Grid Garage NetCDF (Figure 3). These tools are currently in the development version of the Grid Garage and not in the public release version.
3. Cutting the data to the Alpine region climate change impacts study area using batching tools in the Grid Garage Toolbox.
4. Reducing the file size by converting each data layer to an integer type using batching tools in the Grid Garage Toolbox. This may also involve multiplying by a factor, e.g. 10 or 100 or 1000 depending on the range of the original variable.
5. Renaming each raster so that MCAS-S recognises it as a time-series with format YYYYMM using batching tools in the Grid Garage Toolbox.

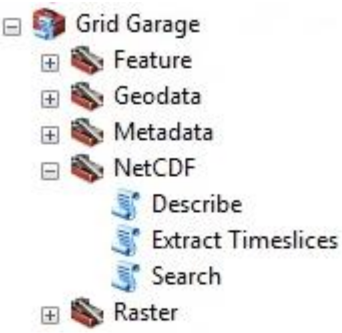


Figure 3 Grid Garage NetCDF tools

To trial these outputs in MCAS-S we imported the seven temperature variables (described in Table 3) for all four GCMs (CCCMA3.1, CSIRO-MK3.0, ECHAM5 and MICRO3.2), the three regional downscaling models (R1, R2 and R3) and for the three time periods (1990 to 2009, 2020 to 2039 and 2060 to 2079). Only one of the variables, EHF_nf13 (Excess Heat Factor Index), could not be projected from the NetCDF format to a regular 'geographic' grid.

These NARCliM model outputs have been imported into MCAS-S as time-series data. This means MCAS-S can calculate statistics such as mean, maximum, minimum and report on areas exceeding a threshold, e.g. area exceeding 40°C (see Figure 4 and Appendix C – MCAS-S work process).

Table 3 NARCliM variables processed for inclusion in MCAS-S

Variable	Full name	Imported into MCAS-S datapack with Grid Garage Tool?
FFDI	Forest Fire Danger Index	Yes
pracc	Precipitation	Yes
tasmean	Mean surface temperature	Yes
tasmax	Maximum surface temperature	Yes
tasmin	Minimum surface temperature	Yes
tasmaxmean	Mean maximum surface temperature	Yes
tasminmean	Mean minimum surface temperature	Yes
prcacc	Convective precipitation	No
prncacc	Non-convective precipitation	No
uasmean	U component of wind	No
vasmean	V component of wind	No
wssmean	Mean wind speed	No
wssmax	Maximum wind speed	No
mrsomean	Soil moisture content	No
hussmean	Surface specific humidity	No
EHF_NF13	Excess Heat Factor Index	No

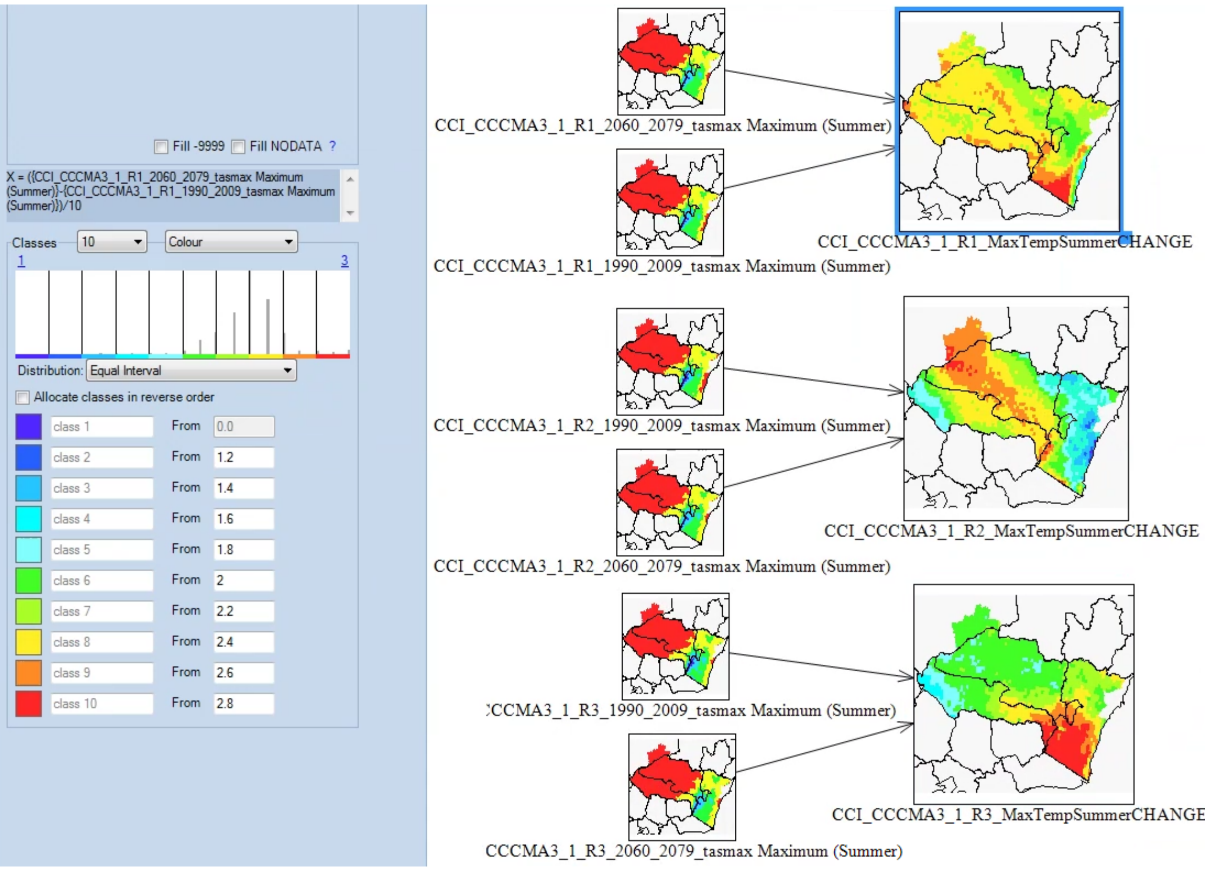


Figure 4 **Example of how a NARCliM monthly mean (for each time period) time-series can be used to compare models**

The three layers (right) represent the predicted difference in mean maximum surface temperature (summer months) for the three RCMs CCMA3.1 (abbreviated to CCI_CCCMA3.1) R1, R2, R3. Note: dark blue=no change between 1990 to 2009 baseline and 2060 to 2079 time period (≥0°C – 1.2°C), lighter blue=small change (>1.2°C – 1.4˚C), red=large change (>2.8°C).

From SEED data portal

After the data from the DPIE spatial P-drive had been imported into MCAS-S a more up-to-date version of the NSW Land Use data became available on the DPIE SEED portal. Because this is often a key model criterion for many land-use and land management decisions we included this data in the MCAS-S datapacks.

Trial of importing DPI crop model outputs into MCAS-S

We received a sample of the spatial outputs from Department of Primary Industries (DPI) crop modelling to test the feasibility of including them in the MCAS-S datapacks. The outputs from the crop models were in the form of a vector point layer with an attribute table that contained the crop yield predictions. To be used in MCAS-S the point data needed to be converted into a continuous raster grid. This can be done using several different interpolation methods. The example shown below (Figure 5) uses the Inverse Distance Weighted (IDW) method of interpolation based on the surrounding 24 points. There was not time in this project to import the crop modelling outputs into the MCAS-S datapack, but this test demonstrates they can be added in the future.

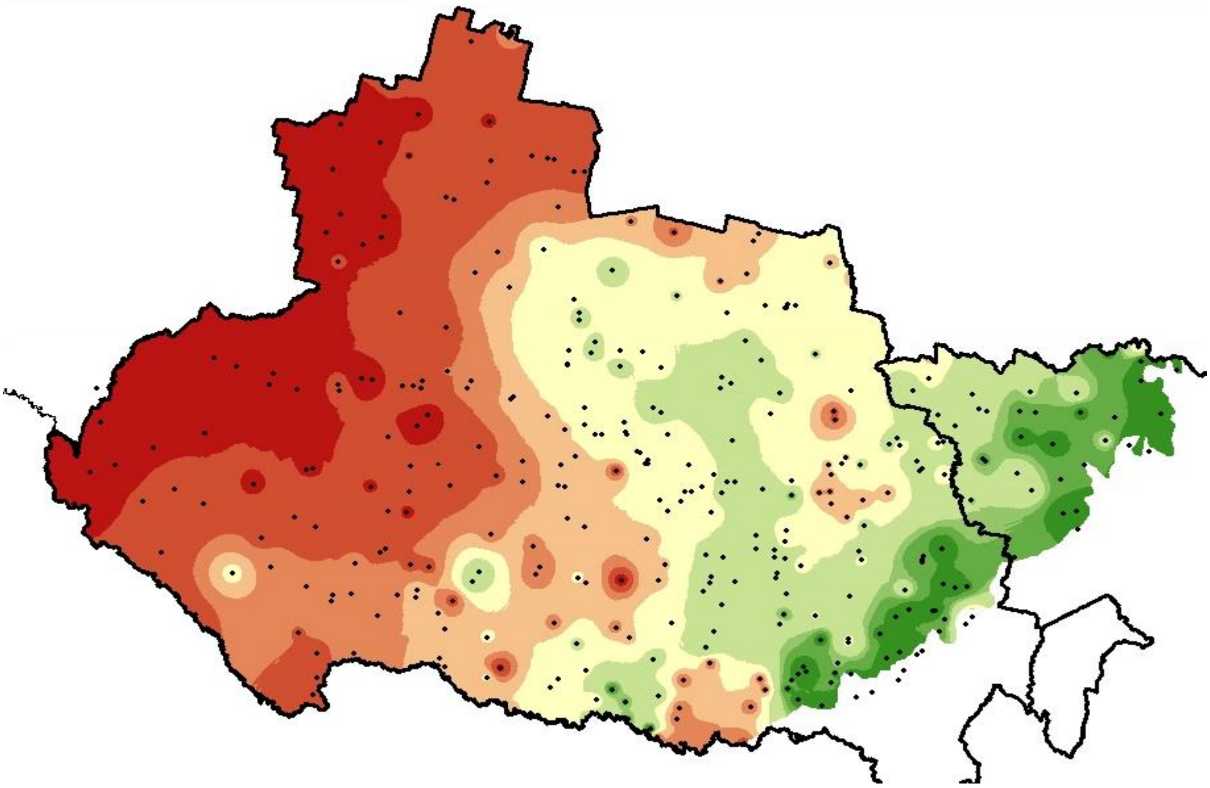


Figure 5 **A spatial raster layer from modelled crop yield values at point locations using the Inverse Distance Weighted interpolation method based on the closest 24 points**

Note: this is an example only and does not represent final model values.

Task 3. Import data into MCAS-S datapack

MCAS-S requires all raster grids in the datapack to be spatially aligned with the same origin, grid cell size and projection (Figure 6). At DPIE we have developed the Grid Garage ArcGIS Toolbox that helps GIS users undertake the tasks required to process GIS data into a standard, spatially aligned format. Grid Garage contains 36 tools designed to save time by batch processing repetitive GIS tasks, diagnosing problems with data and capturing a record of processing steps and errors encountered.

Grid Garage provides tools that function using a list-based approach to batch processing where both inputs and outputs are specified in tables to enable selective batch processing and detailed result reporting. In many cases the tools simply extend the functionality of standard ArcGIS tools, providing some or all the inputs required by these tools via the input table to enable batch processing. This approach differs from normal batch processing in ArcGIS; instead of manually selecting single items or a folder on which to apply a tool or model, you provide a table listing target datasets.

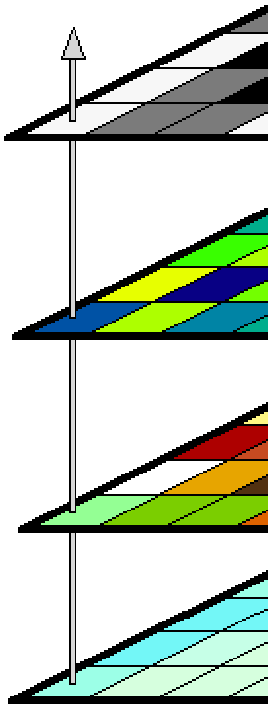


Figure 6 **Illustration of aligned raster grids**

Grid Garage allows you to:

- list, describe and manage very large volumes of geodata
- batch process repetitive GIS tasks such as managing (renaming, describing, etc.) or processing (clipping, resampling, reprojecting, etc.) many geodata inputs including time-series geodata derived from satellite imagery or climate models
- record errors when batch processing and diagnose errors by interrogating the input geodata that failed
- develop your own models in ArcGIS ModelBuilder that allow you to automate any GIS workflow utilising one or more of the Grid Garage tools that can process an unlimited number of inputs.

The Grid Garage is intended for use by anyone with an understanding of GIS principles and an intermediate to advanced level of GIS skills. Using the Grid Garage tools in ArcGIS ModelBuilder requires skills in the use of the ArcGIS ModelBuilder tool. The Grid Garage Toolbox is free to download from the SEED data portal or via the Grid Garage online user guide.

The MCAS-S user guide (MCAS-S Development Partnership 2018) provides instructions on how to build an MCAS-S datapack. Many of the GIS processing tasks, outlined in Table 4 below, can be automated or batch processed, using the tools in the DPIE Grid Garage ArcGIS Toolbox.

Table 4 Summary of the types of GIS processing required to reformat different types of GIS data for use in MCAS-S datapacks

Type of data	GIS processing required
Categorical vector polygons, e.g. land use, geology	Conversion of one or more of the fields into categorical raster grids using the 'Polygon to Raster' Grid Garage tool. See instructions on the Feature Tools Polygon to Raster webpage. The naming protocol for these output rasters is as follows: *'source data set name_field name'*
Raster where grid cell size ≥ datapack template	Resampling the grid cell size to be the same as the datapack, e.g. 100 m or 30 m. If you base all of the ArcGIS 'Geoprocessing > Environments..' settings on the MCAS-S datapack template raster (see the Setting up the Geoprocessing Environment webpage) the Raster Copy function will automatically project and resample your input raster to be the same as the template datapack (Raster Tools Copy).
Raster where grid cell size < datapack template	Decide on a statistic to summarise the pixel values up into the larger pixel. Using tools like 'Aggregate' (Raster Tools Aggregate) or 'Resample' (Raster Tools Resample).
Continuous floating point raster datasets	When the input raster is a floating point (i.e. contains decimal points such as 0.45 or 10.67) we recommend conversion to an integer to reduce file sizes. To maintain accuracy, you may need to multiply the original data by 10, 100 or 1000 before converting into an integer grid. If this was done it was noted in the MCAS-S tip file and was included in the file name. For example, 'cw_prescott_x1000.tif' is the Prescott water balance index multiplied by 1000 before being converted into an integer. We used the Raster Tools Tweak Values Grid Garage tool to perform this and other types of rescaling tasks.

There are many more GIS batching tools available in the Grid Garage ArcGIS Toolbox; refer to the Grid Garage online user guide for more information on how to use them.

Task 4. Metadata

Each data layer in the MCAS-S datapack requires a text file containing metadata called a 'tip file' which has the same name as the data with a '.tip' extension. Users can access this metadata information in MCAS-S by clicking on the [Info] button while the layer is selected in the main MCAS-S project view (Figure 6).

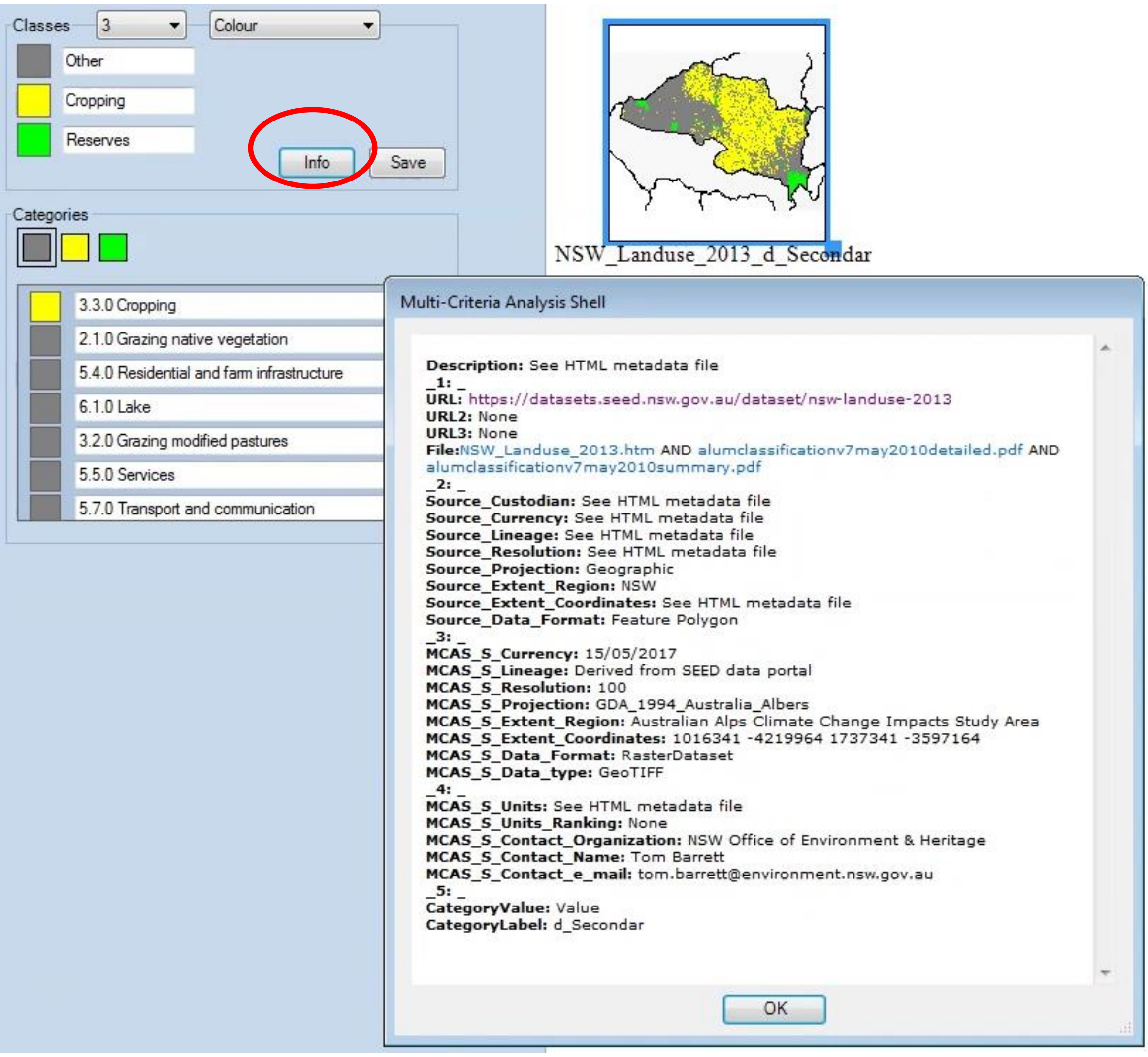
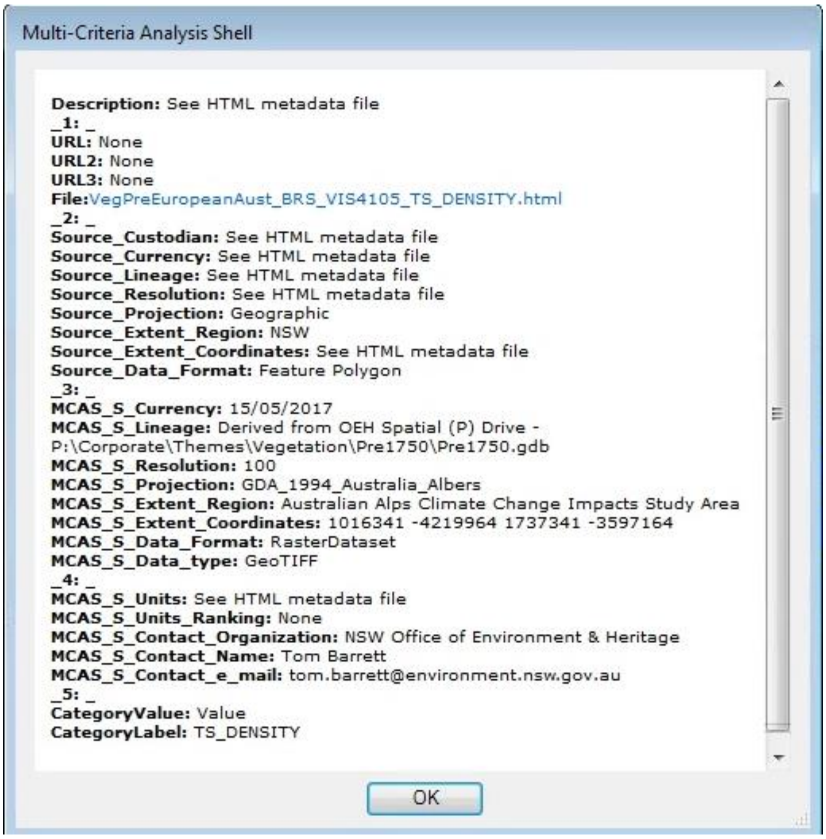


Figure 6 **Example of viewing metadata (tip text file) for 'NSW_Landuse_2013' in MCAS-S by clicking on the [Info] button, circled in red**

As part of the Grid Garage ArcGIS Toolbox we have developed a suite of ArcGIS tools to build and update MCAS-S tip files. These tools were used to build the metadata tip files for all the data imported into the MCAS-S datapack. The Grid Garage Toolbox, containing the MCAS-S metadata creation and management tools, is free to download from the SEED data portal or via the Grid Garage online user guide. Instructions for building the tip files are on the Metadata Tools page of the user guide.

For the 199 datasets from the DPIE spatial P-drive, transferring the metadata from the ArcGIS format to the MCAS-S tip file was too onerous. Instead we built the 'Grid Garage > Metadata > Export Metadata' tool to export the ArcGIS XML metadata as an HTML web file. A link to this file was then included in the MCAS-S tip file. Figure 7 shows an example of what the tip metadata file looks like when viewed in MCAS-S. Figure 8 illustrates the HTML metadata file, displayed in an internet browser. For instructions on how to use this tool see the Metadata Tools Export Metadata page in the user guide.



Multi-Criteria Analysis Shell

Description: See HTML metadata file
_1: _
URL: None
URL2: None
URL3: None
File: VegPreEuropeanAust_BRS_VIS4105_TS_DENSITY.html
_2: _
Source_Custodian: See HTML metadata file
Source_Currency: See HTML metadata file
Source_Lineage: See HTML metadata file
Source_Resolution: See HTML metadata file
Source_Projection: Geographic
Source_Extent_Region: NSW
Source_Extent_Coordinates: See HTML metadata file
Source_Data_Format: Feature Polygon
_3: _
MCAS_S_Currency: 15/05/2017
MCAS_S_Lineage: Derived from OEH Spatial (P) Drive - P:\Corporate\Themes\Vegetation\Pre1750\Pre1750.gdb
MCAS_S_Resolution: 100
MCAS_S_Projection: GDA_1994_Australia_Albers
MCAS_S_Extent_Region: Australian Alps Climate Change Impacts Study Area
MCAS_S_Extent_Coordinates: 1016341 -4219964 1737341 -3597164
MCAS_S_Data_Format: RasterDataset
MCAS_S_Data_type: GeoTIFF
_4: _
MCAS_S_Units: See HTML metadata file
MCAS_S_Units_Ranking: None
MCAS_S_Contact_Organization: NSW Office of Environment & Heritage
MCAS_S_Contact_Name: Tom Barrett
MCAS_S_Contact_e_mail: tom.barrett@environment.nsw.gov.au
_5: _
CategoryValue: Value
CategoryLabel: TS_DENSITY

OK

Figure 7 Example of tip file for data sourced from the DPIE corporate spatial P-drive

Vegetation of Australia Pre-European Settlement, 1788

File Geodatabase Feature Class

Thumbnail Not Available

Tags

There are no tags for this item.

Summary

There is no summary for this item.

Description

The vegetation data was captured from Geoscience Australia's 'Natural Vegetation' at 1:5 million scale map. The map broadly shows the probable state of Australia's vegetation around 1788 when European settlement began.
Vegetation - Pre-European Settlement (1788) depicts areas over 30 000 hectares as well as small areas of significant vegetation such as rainforest. Attribute information includes: growth form of tallest and lower stratum, foliage cover of tallest stratum and dominant floristic types.

For more information see:
Vegetation - Pre-European Settlement (1788) Product User Guide
National Mapping Division, Geoscience Australia.
Published by Geoscience Australia
Department of Industry, Tourism and Resources, Commonwealth of Australia, 2004
For up to date information on Vegetation - Pre-European Settlement (1788) refer to the Geoscience Australia website:
www.ga.gov.au

Figure 8 Metadata statement from the DPIE corporate spatial P-drive, as exported from the ArcGIS Catalogue as an HTML web page

2.3 Using the MCAS-S datapacks

Step 1. Define the objective and decision criteria

Your objective must be a spatial or a 'where' question. It is important to reach a consensus among experts and end-users on the objective question. The question will be determined by a mix of end-user needs, available data and level of knowledge of the systems being modelled.

The decision criteria can be developed and communicated using means-to-end diagrams (MCAS-S Development Partnership 2018) (see Figure 9, Figure 10 and Figure 11 below for examples of means-to-end diagrams used to address objective (spatial) questions using MCAS-S and available data). Software tools are available to help build means-to-end diagrams; for example, the 'Flowchart' graphics tools in Microsoft Word or PowerPoint or the Compendium dialogue mapping software (free to download). We have made a Compendium stencil to build customised means-to-end diagrams that refer to MCAS-S data and functions (Figure 9, Figure 10 and Figure 11). Further instructions and the MCAS-S stencil can be downloaded from the Compendium software page in the Grid Garage online user guide.

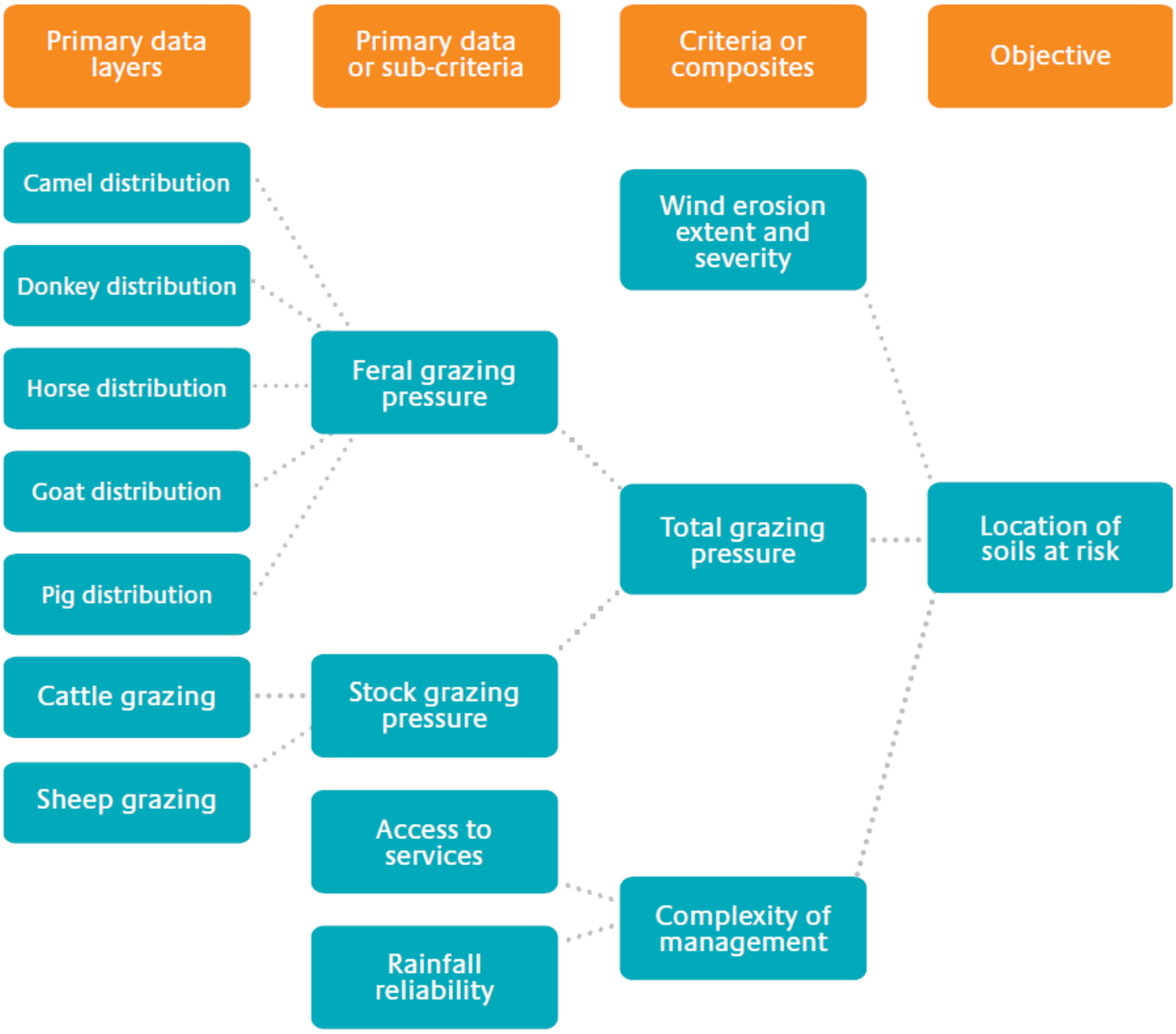


Figure 9 **Example of a means-to-end diagram from the MCAS-S manual addressing the objective question 'Where are soils at risk of wind erosion?'**

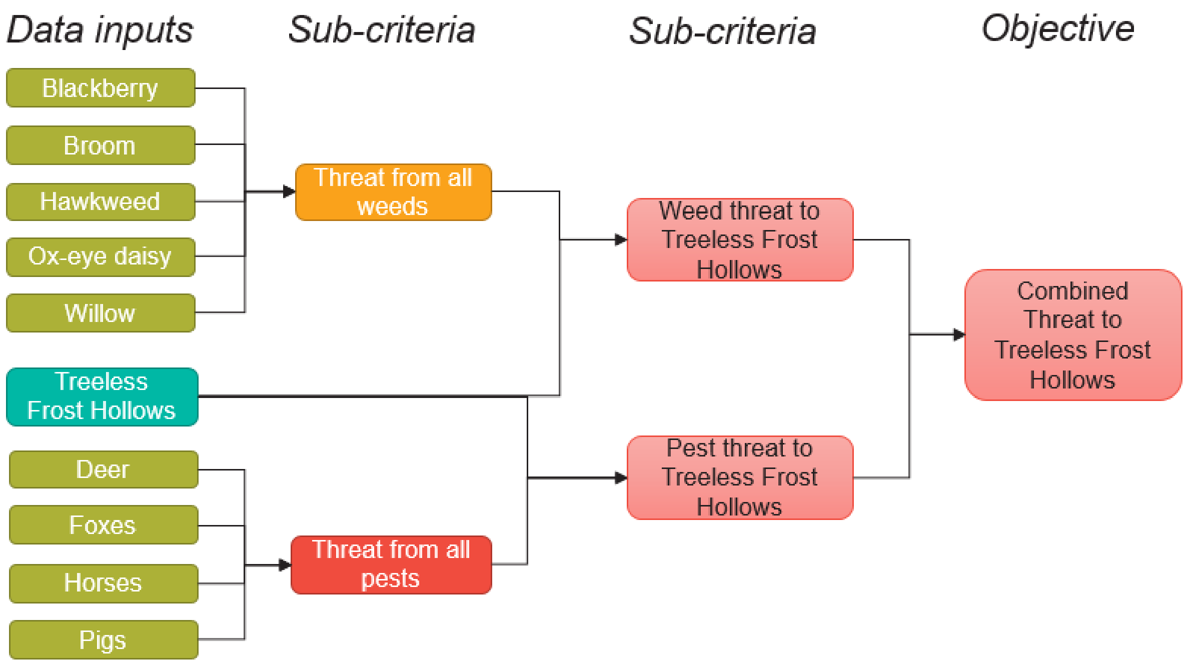


Figure 10 Example of a means-to-end diagram addressing the objective question 'Where are Treeless Frost Hollows [ecosystems] most threatened by pests and weeds?' (from Porfirio et al. 2014)

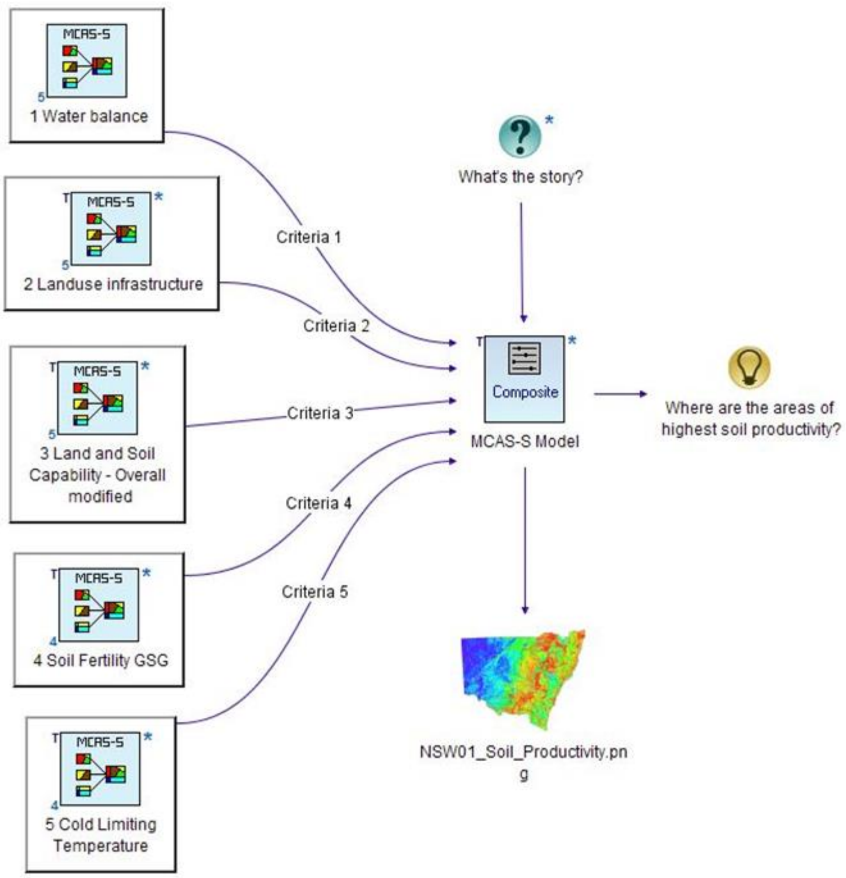


Figure 11 Example of means-to-end diagram built using customised Compendium stencil addressing the objective question 'Where are the areas of highest soil productivity?'

Step 2. Assemble data inputs

The data inputs have already been compiled in the MCAS-S datapacks. If you identify additional data that is not in the datapacks it will need to be imported using the tools in the Grid Garage ArcGIS Toolbox.

Step 3. Explore and combine data

The MCAS-S user manual (MCAS-S Development Partnership 2018) provides instructions on how to use MCAS-S to explore and combine data to answer the objective question. An example based on NARCliM outputs is illustrated in Appendix C.

Step 4. Develop options

MCAS-S provides a flexible modelling environment allowing easy modification of existing models to answer different objective questions; for example, National Parks and Wildlife Service (NPWS) managers at Mount Kosciuszko told us that a question addressed by Porfirio et al. (2014), 'Where are Treeless Frost Hollows most threatened by pests and weeds?' did not meet their planning needs. NPWS undertakes operational planning based on the control of individual weeds, so to address their specific planning needs a more relevant objective question would be 'Where should we prioritise the control of broom to maximise protection of values?'. The new means-to-end model is shown in Figure 12.

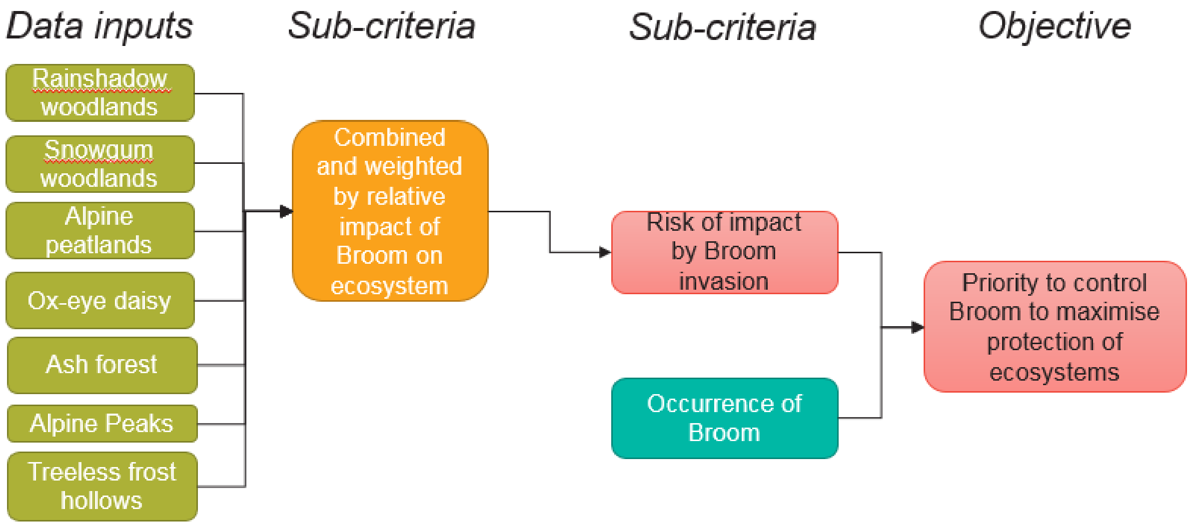


Figure 12 **Example of a means-to-end diagram for the revised objective question 'Where should we prioritise the control of broom to maximise protection of values?'**

Step 5. Review and report

The MCAS-S reporting tools generate tabular or spatial outputs (MCAS-S Development Partnership 2018). MCAS-S allows you to run spatial area reports based on categorical or 'region' data. You can select from any of the categorical datasets stored in the MCAS-S datapack 'Mask' folder. MCAS-S also allows you to report on time-series data (e.g. see Figure 13, Figure 14 and Step 5 in Appendix C).

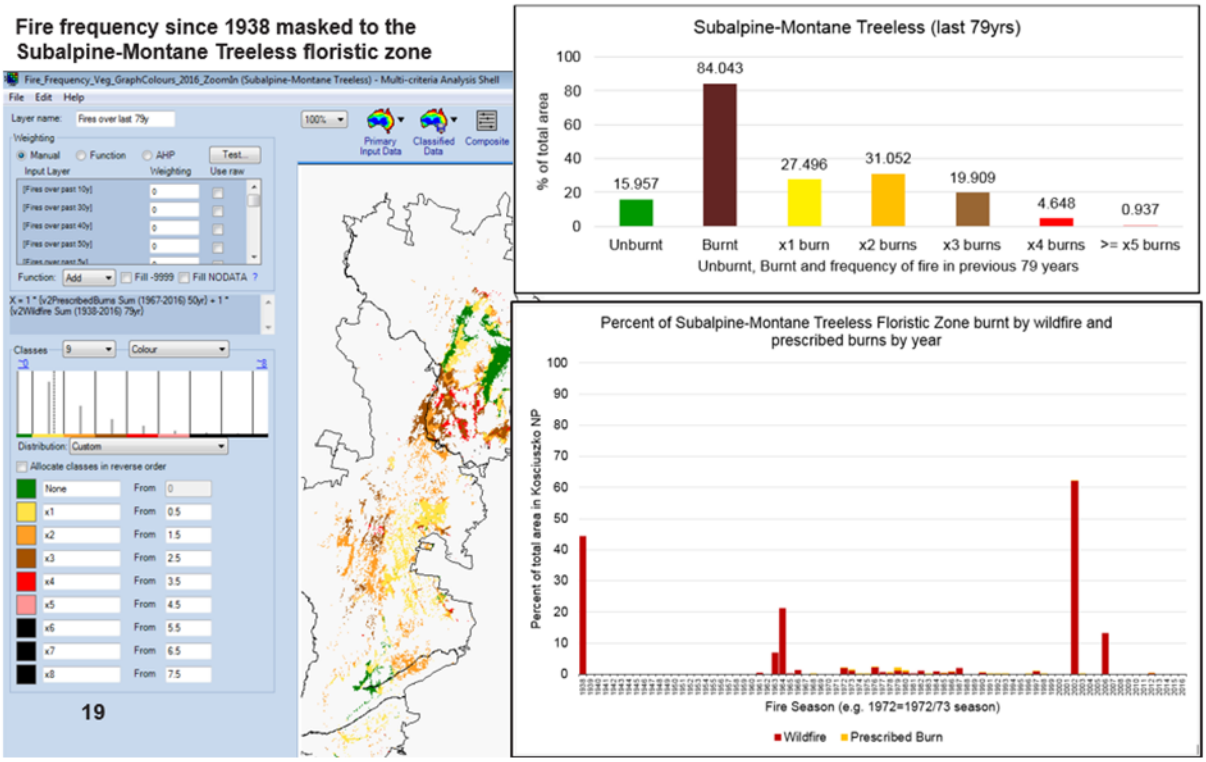


Figure 13 **Example of reporting on the fire frequency in Kosciuszko National Park derived from the mapped fire history database (Barrett & Allen in prep.)**
Tabular reports were run in MCAS-S, exported as text files and imported into Microsoft Excel to generate the graphs. The top graph shows the summary area statistics for different burn history classes in the Subalpine-Montane Treeless floristic zone. The bottom graph shows the area burnt by year for wildfires and prescribed burns in the Subalpine-Montane Treeless floristic zone.

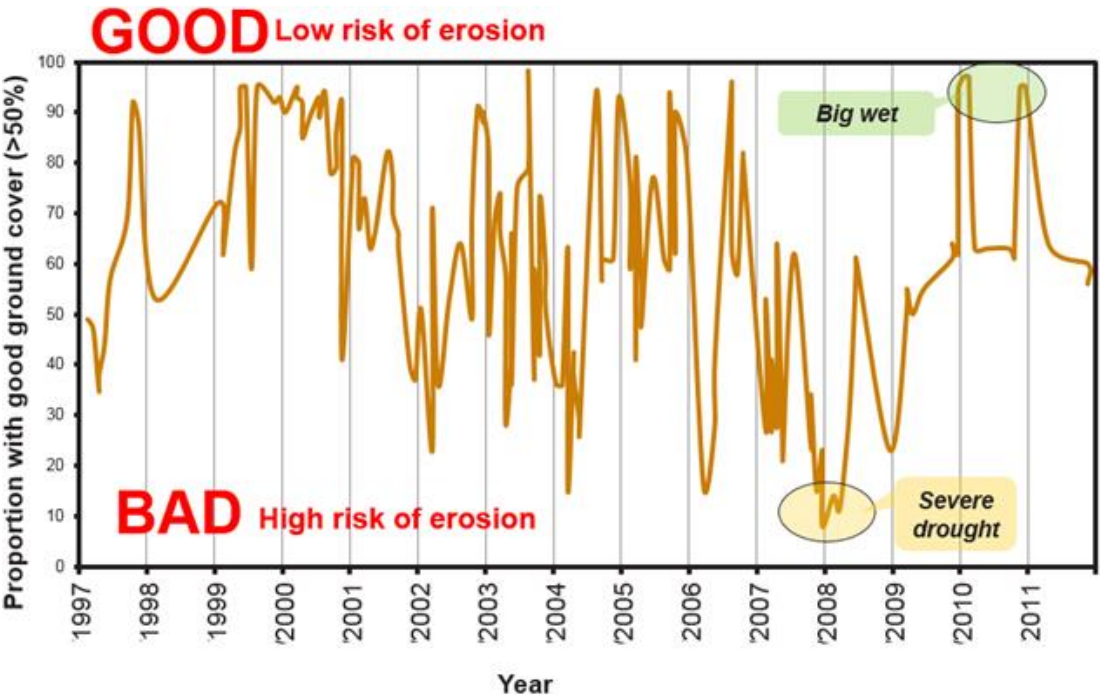


Figure 14 **Example of reporting on a time-series Landsat-derived groundcover dataset in MCAS-S (Booth et al. 2015)**
This graph shows the change in groundcover in the Willandra Lakes World Heritage Area Region since 1997. From this graph it is possible to see the impact on groundcover of the Millennium Drought and the wet period that followed in 2010 and 2011.

Quality control

All spatial data imported into MCAS-S was visually checked and compared with the original data. This included the NARCliM climate variable outputs where the MCAS-S layers were compared with the original datasets visualised in the NARCliM modelling software.

Data storage and access

The datapacks have also been registered in the DPIE Information Asset Register (IAR) and will be made available for the public to download via SEED.

3. Discussion

Anyone with a personal computer can use MCAS-S and the MCAS-S datapacks provided to explore the data and develop their own models to address spatial or 'where' questions. One benefit of making spatial data available in MCAS-S datapacks is that it frees up time and resources that can be allocated to other important steps in the MCA decision support process, such as: developing the objective question, building a conceptual 'means-to-end' model, data exploration and learning, as well as building spatial models to answer the objective spatial question.

An important part of building a conceptual model is identifying criteria and the relationships between them. The onus is on the user to document and justify all decisions made when developing conceptual and MCAS-S models. Understanding the input data used to represent the criteria is crucial to building a robust spatial model. New functions in MCAS-S have improved the links between the data and additional metadata online or in report form. The interactive nature of MCAS-S also facilitates data exploration and can help build an understanding of the strengths and weaknesses of the data.

As new and improved data becomes available it can be added to the MCAS-S datapacks so they can be updated over time. This also includes future, finer-scale NARCliM models and associated impact models derived from NARCliM outputs.

Appendix D lists the research needs identified by stakeholders attending the workshop in Queanbeyan, New South Wales, held on 29 March 2017. For integration-related questions we have provided some comments on the potential for using MCAS-S. Most of the questions were broad and would require more consultation and workshopping to narrow down the focus and develop a spatial objective question.

3.1 Limitations

The limitations of this assessment fall under six themes, detailed below.

Sourcing the single point of truth metadata

We could not source single point of truth metadata links for 60% of the datasets sourced from the DPIE corporate 'P-drive'. These datasets will need to be removed from the datapacks that are made publicly available unless the link to the single point of truth metadata statement can be located or a metadata record is created in the SEED metadata portal.

Recommendation 1: Follow up with data custodians to locate a single point of truth for the data and metadata link.

Improving the utility of data

Metadata, in the form of the MCAS-S 'tip' text files, contain information about the data, its format, history (lineage) and a description of what it represents. For the data 'Description' field, many of the current tip files only refer to a linked report that describes the data in more detail and how it was generated. Adding more useful information into the description field, rather than referring to a report, would improve the utility of the data in MCAS-S.

Recommendation 2: Update the 'Description' field in the MCAS-S tip files to accurately describe the data.

Identifying and importing additional data

Time did not permit all the NARCliM modelled climate variables to be imported into MCAS-S.

Recommendation 3: If it can be demonstrated that these outputs would be useful, and resources become available, the remaining (7 out of the total of 16) NARCliM modelled climate variable grids could be cut to the study area and imported as time-series variables into the MCAS-S datapack.

The larger MCAS-S datapack covers the same region as the Alpine Icons and Threats datapacks generated by the National Environmental Research Program (NERP) Landscape and Policy Research Hub (Magierowski et al. 2014; Porfirio et al. 2014). Some of these datasets were imported into the Kosciuszko National Park MCAS-S datapack, but time did not permit us to import this data into the larger datapack.

Recommendation 4: Future work could involve importing all the data used in the NERP Landscape and Policy Research Hub Australian Alps datapacks into the climate change impacts study area datapack. This would facilitate improving the NERP datapacks and models at a finer scale, i.e. 100 metres instead of 500 metres.

New corporate data on the spatial P-drive or on the SEED web portal should be evaluated for inclusion in the MCAS-S datapacks.

Recommendation 5: Develop and implement a process to update the packs when new statewide data becomes available or when existing data is updated with a new version.

Deriving new data for commonly used criteria (foundational data)

There are some criteria, such as land tenure, that are commonly used in spatial modelling but for which there is no single dataset in the MCAS-S datapacks. These types of data are referred to as 'foundational' data.

Recommendation 6: Identify commonly used criteria that currently do not have a single dataset in the MCAS-S datapacks. Develop sub-models to build these datasets and make them available to users.

User feedback and support

Every new project that utilises the MCAS-S datapacks will identify new and useful data that is not currently included in the datapacks. It would be useful to have a process whereby users could request additional data for inclusion in future releases of the datapacks.

Recommendation 7: Develop and implement a process that allows users to suggest additional data for inclusion in future releases of the datapacks.

Knowing the most suitable and/or current data to import and use in MCAS-S models can be a challenge. There is a need to develop a web-based service that allows data users to share their data-using experiences and help others to make decisions about which data to use for their own spatial modelling projects.

Recommendation 8: Investigate options and opportunities for developing a web-based service that allows data users to share their data-using experiences and help others make decisions about which data to use for their own spatial modelling projects.

Data processing tool development

All bar one of the NARCliM output NetCDF files were successfully reprojected into a regular LAT/LONG grid.

Recommendation 9: Investigate why there were errors in the projection of the Excess Heat Factor (EHF_NF13) NetCDF file from Rotated Pole to a regular LAT/LONG grid and update the Python script to fix the error.

Conversion from the NetCDF format into raster grids is still a highly technical and complex task. If future outputs from the NARCliM modelling project need to be converted to regular GIS raster layers, it would be beneficial to develop a more user-friendly software tool (or tools) to undertake this conversion task.

Recommendation 10: Investigate options for the development of a more user-friendly software tool (or tools) to undertake and automate the NetCDF to regular GIS raster layers conversion task.

The tools in the Grid Garage ArcGIS Toolbox can be used to automate the GIS tasks required to batch process spatial data inputs and generate an MCAS-S datapack for any region in New South Wales.

Recommendation 11: Using ArcGIS ModelBuilder develop models using the Grid Garage Tools to automate the process of building MCAS-S datapacks for any region in New South Wales, at any scale (within the limits set by MCAS-S and computer hardware requirements).

Initial investigations and the trial of importing the DPI crop model outputs demonstrated that it was feasible to import and use the models in MCAS-S.

Recommendation 12: In collaboration with DPI scientists, collate crop model outputs and import into an MCAS-S datapack when time and resources permit. Also identify the best method to spatially interpolate from the point data to a continuous raster grid.

3.2 Future work

Participatory planning and modelling is a growing field of social research. There is a need to test the assumption that participation in the spatial modelling process (one of the promoted strengths of MCAS-S) leads to improved stakeholder understanding, acceptance and adoption of the modelled outputs. This type of social research could be conducted on selected case studies where stakeholders participate in the development of the objective question, the conceptual 'means-to-end' and MCAS-S modelling process.

Recommendation 13: Investigate opportunities to undertake social research that tests the hypothesis that participatory modelling results in improved stakeholder understanding, acceptance and adoption of the modelled outputs.

4. Conclusion

This project has demonstrated that DPIE now has the technical capability to efficiently build large MCAS-S datapacks for any region in New South Wales that includes NARCliM model outputs and Climate Change Impact model outputs. The MCAS-S software provides a free and relatively easy-to-use spatial modelling tool for use by the research community as well as interested members of the public.

We hope that building and providing the MCAS-S datapacks will free up time and resources for undertaking other important steps in the MCA decision support process, such as developing the objective question, building a conceptual 'means-to-end' model, data exploration and learning as well as building MCAS-S spatial models that address the problem and help answer the objective question.

Although the technical challenge of building the MCAS-S datapacks more efficiently has been met, there is still more work to do to meet the challenge of improving the documentation, useability and utility of the data. This would help to ensure users have a sufficient level of understanding of the data including strengths and weaknesses.

5. References

ABARES 2010, *Indicators of community vulnerability and adaptive capacity across the Murray-Darling Basin—a focus on irrigation in agriculture*, ABARE–BRS Client Report, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

Baldock J, Grundy M, Wilson P, Jacquier D, Griffin T, Chapman G, Hall J, Maschmedt D, Crawford D, Hill J and Kidd D 2009, *Identification of areas within Australia with the potential to enhance soil carbon content*, report to the Australian Government, Caring for Our Country, Sustainable Agriculture Flagship.

Barrett T and Allen W in prep., 'Evaluating impact of fire on broad floristic zones in Kosciuszko National Park', project report to the NSW National Parks and Wildlife Service.

Becu N, Neef A, Schreinemachers P and Sangkapitux C 2008, Participatory computer simulation to support collective decision making: potential and limits of stakeholder involvement, *Land Use Policy*, vol.25, pp.498–509.

Booth S, Barrett T, Ridges M, Simpson G, Goggin L, Bye D, Green R, Leys J and Heidenreich S 2015, 'Sustaining Willandra – Integrated Land Management Framework', MU9057, Final report to Western Local Land Services (unpub.).

Bousquet F and Voinov A (eds) 2010, Modelling with stakeholders, *Environmental Modelling & Software*, vol.25, no.11.

Davies KK, Fisher KT, Dickson ME, Thrush SF and Le Heron R 2015, Improving ecosystem service frameworks to address wicked problems, *Ecology and Society*, vol.20, no.2, p.37.

Geoscience Australia 2011, *1 second SRTM Derived Products User Guide v1.0.4*, accessed online at d28rz98at9flks.cloudfront.net/72759/1secSRTM_Derived_DEMs_UserGuide_v1.0.4.pdf.

Hill MJ, Lesslie R, Barry A and Barry SM 2005, A simple, portable, spatial multi-criteria analysis shell — MCAS-S, in *MODSIM 2005: International Congress on Modelling and Simulation*, University of Melbourne, Australia.

Hill P, Cresswell H and Hubbard L 2006, *Spatial prioritisation of NRM investment in the West Hume area (Murray CMA region)*, CSIRO Water for a Healthy Country National Research Flagship, CSIRO, Canberra.

IPCC 2000, *Special Report on Emissions Scenarios: A Special Report of Working Group III of the Intergovernmental Panel on Climate Change*, published for the Intergovernmental Panel on Climate Change by Cambridge University Press, Cambridge, UK.

Ishizaka A and Nemery P 2013, *Multi-Criteria Decision Analysis: Methods and Software*, Wiley, UK.

Kabaya K, Hashimoto S, Fukuyo N, Uetake T and Takeuchi K 2019, Investigating future ecosystem services through participatory scenario building and spatial ecological–economic modelling, *Sustainability Science*, vol.14, p.77, doi.org/10.1007/s11625-018-0590-1.

Lesslie R 2012, 'Mapping our priorities – innovation in spatial decision support', in P Figgis, J Fitzsimons and J Irving (eds), *Innovation for 21st Century Conservation*, Australian Committee for IUCN, Sydney, pp.156–163.

Lesslie R and Cresswell H 2008, Mapping priorities: planning re-vegetation in southern NSW using a new decision-support tool, *Thinking Bush*, vol.7, pp.30–33.

Lesslie RG, Hill MJ, Hill P, Cresswell HP and Dawson S 2008, 'The application of a simple spatial multi-criteria analysis shell to natural resource management decision making', in C Pettit, W Cartwright, I Bishop, K Lowell, D Pullar and D Duncan (eds), *Landscape Analysis and Visualisation: Spatial Models for Natural Resource Management and Planning*, Springer, Berlin, pp.73–95.

Leys J, Chappell A, Mewett J and Barson M 2017, *Wind Erosion Assessment for National Landcare Program Report to the Department of Agriculture and Water Resources,* Office of Environment and Heritage, Sydney, NSW.

Magierowski R, Wild A, Anderson G, Gaynor S, Lefroy T and Davies E 2014, *MCAS-S Datapack for Alpine Bogs of the Australian Alps Bioregion: A worked example using the MCAS-S tool to map the coincidence of threats in the Australian Alps*, University of Tasmania.

Malczewski J 2007, GIS-based multicriteria decision analysis: a survey of the literature, *International Journal of Geographical Information Science*, vol.20, no.7, pp. 703–726.

MCAS-S Development Partnership 2018, *Multi-Criteria Analysis Shell for Spatial Decision Support MCAS-S version 3.2 User guide*, CC BY-ND 4.0, Australian Bureau of Agricultural and Resource Economics and Sciences, Canberra.

OEH 2017, *The NSW State Vegetation Type Map: Methodology for a regional-scale map of NSW plant community types*, NSW Office of Environment and Heritage, Sydney, available online at www.environment.nsw.gov.au/resources/vegetation/nsw-state-vegetation-type-map-methodology-170134.pdf

Oteros-Rozas E, Martín-López B, Daw T, Bohensky EL, Butler JRA, Hill R, Martin-Ortega J, Quinlan A, Ravera F, Ruiz-Mallen I, Thyresson M, Mistry J, Palomo I, Peterson GD, Plieninger T, Waylen KA, Beach EM, Bohnet IC, Hamann M, Hanspach J, Hubacek K, Lavorel S and Vilardy SP 2015, Participatory scenario planning in place-based social-ecological research: insights and experiences from 23 case studies, *Ecology and Society*, vol.20, no.4, art.32.

Pahl-Wostl C, Craps M, Dewulf A, Mostert E, Tabara D and Taillieu T 2007, Social learning and water resources management, *Ecology and Society*, vol.12, no.2, art. 5.

Porfirio L, Hugh S, Carter L and Mackey B 2014, *The Australian Alps Icons and Threats MCAS-S datapack,* Landscapes and Policy Hub, Hobart, Tasmania.

Smith J and Leys J 2009, *Identification of areas within Australia for reducing soil loss by wind erosion*, Bureau of Rural Sciences, Australian Government, www.brs.gov.au.

Wilson PL, Baldock J, Grundy M, Jacquier D, Griffin T, Moody P, Chapman G, Hall J, Maschmedt D, Crawford D, Hill J and Kidd D 2009, *Identification of land with a risk of acidification*, CSIRO Land and Water Science Report, Commonwealth Scientific and Industrial Research Organisation, Canberra, ACT.

Appendix A – Input data for MCAS-S datapacks

Table 5 Summary of the sources of spatial data used to build the MCAS-S datapacks

Data from the Bureau of Meteorology, CSIRO and Geoscience Australia were part of the package of environmental data compiled by the DPIE native vegetation mapping team.

	Data custodian					
Primary data folders	DPIE	DPIE spatial drive	Bureau of Meteorology	CSIRO (Soil and Landscape Grid of Australia)	Geoscience Australia	Grand total
Admin		**57**				**57**
Corporate		32				32
IndexMaps		4				4
Statutory		21				21
Climate	**17**		**12**	**2**		**31**
Energy	4					4
Rainfall	4		6	2		12
Temperature	9		6			15
ClimateChangeImpacts	**499**					**499**
Biodiversity	13					13
Hydrology	20					20
HydroSalinity	22					22
SoilErosion_Change_Grids	20					20
SoilErosion_ExtrRain_Change	28					28
SoilErosion_ExtrRain_Mean	42					42
SoilErosion_Mean_Grids	30					30
NARCliM_Outputs_1990_2009	**108**					**108**
CCI_CCCMA3_1_R1_1990_2009_tasmax	12					12
CCI_CCCMA3_1_R1_1990_2009_tasmean	12					12
CCI_CCCMA3_1_R1_1990_2009_tasmin	12					12
CCI_CCCMA3_1_R2_1990_2009_tasmax	12					12
CCI_CCCMA3_1_R2_1990_2009_tasmean	12					12
CCI_CCCMA3_1_R2_1990_2009_tasmin	12					12
CCI_CCCMA3_1_R3_1990_2009_tasmax	12					12
CCI_CCCMA3_1_R3_1990_2009_tasmean	12					12

Primary data folders	Data custodian DPIE	DPIE spatial drive	Bureau of Meteorology	CSIRO (Soil and Landscape Grid of Australia)	Geoscience Australia	Grand total
CCI_CCCMA3_1_R3_1990_2009_tasmin	12					12
NARCliM_Outputs_2020_2039	**108**					**108**
CCI_CCCMA3_1_R1_2020_2039_tasmax	12					12
CCI_CCCMA3_1_R1_2020_2039_tasmean	12					12
CCI_CCCMA3_1_R1_2020_2039_tasmin	12					12
CCI_CCCMA3_1_R2_2020_2039_tasmax	12					12
CCI_CCCMA3_1_R2_2020_2039_tasmean	12					12
CCI_CCCMA3_1_R2_2020_2039_tasmin	12					12
CCI_CCCMA3_1_R3_2020_2039_tasmax	12					12
CCI_CCCMA3_1_R3_2020_2039_tasmean	12					12
CCI_CCCMA3_1_R3_2020_2039_tasmin	12					12
NARCliM_Outputs_2060 to 2079	**108**					**108**
CCI_CCCMA3_1_R1_2060_2079_tasmax	12					12
CCI_CCCMA3_1_R1_2060_2079_tasmean	12					12
CCI_CCCMA3_1_R1_2060_2079_tasmin	12					12
CCI_CCCMA3_1_R2_2060_2079_tasmax	12					12
CCI_CCCMA3_1_R2_2060_2079_tasmean	12					12
CCI_CCCMA3_1_R2_2060_2079_tasmin	12					12
CCI_CCCMA3_1_R3_2060_2079_tasmax	12					12
CCI_CCCMA3_1_R3_2060_2079_tasmean	12					12
CCI_CCCMA3_1_R3_2060_2079_tasmin	12					12

	Data custodian					
Primary data folders	DPIE	DPIE spatial drive	Bureau of Meteorology	CSIRO (Soil and Landscape Grid of Australia)	Geoscience Australia	Grand total
Cultural		**32**				**32**
Aboriginal		2				2
Aboriginal_ASDST		13				13
Population		14				14
Tourism		3				3
Fire		**1**				**1**
FirePlanning		1				1
Geology		**31**				**31**
Structural		31				31
Land	**23**	**26**			**5**	**54**
Drainage	4					4
Geophysics					4	4
LandClass		9				9
Landform	17	5			1	23
Landuse		12				12
Location	2					2
Soil		**8**		**25**		**33**
Properties				25		25
Salinity		3				3
SoilFertility		1				1
SoilType		4				4
Tenure		**11**				**11**
Conservation		7				7
CrownEstate		4				4
Vegetation		**10**				**10**
Extent		6				6
Pre1750		2				2
VegClassification		2				2
Water		**23**				**23**
Classification		11				11
Drainage		12				12
Grand total	**539**	**199**	**12**	**27**	**5**	**782**
Grand total (excluding NARCliM outputs)	**215**	**199**	**12**	**27**	**5**	**458**

Appendix B – Environmental data from the NSW vegetation mapping project

Table 6 List of environmental data layers sourced from the NSW vegetation mapping project team

Group 1	Group 2	Grid name	Description
Climate	Energy	ce_radiation_seasonality_x100.tif	Radiation of seasonality: coefficient of variation (bio23)
Climate	Energy	ce_radiation_lowest_period_x1000.tif	Lowest period radiation (bio22)
Climate	Energy	ce_radiation_highest_period_x1000.tif	Highest period radiation (bio21)
Climate	Energy	ce_radiation_ann_mean_x1000.tif	Annual mean radiation (bio20)
Climate	Rainfall	cw_rain_summer_winter_ratio_x1000.tif	Average rainfall – summer winter ratio
Climate	Rainfall	cw_rain_ave_winter_x10.tif	Average rainfall – winter
Climate	Rainfall	cw_rain_ave_summer_x1.tif	Average rainfall – summer
Climate	Rainfall	cw_rain_ave_spring_x10.tif	Average rainfall – spring
Climate	Rainfall	cw_rain_days_over_1mm_x10.tif	Average number of days with rainfall greater than 1mm annual
Climate	Rainfall	cw_prescott_index_x1000.tif	Prescott index
Climate	Rainfall	cw_precipitation_wettest_period_x10.tif	Precipitation of wettest period (bio13)
Climate	Rainfall	cw_precipitation_seasonality_x100.tif	Precipitation of seasonality: coefficient of variation (bio15)
Climate	Rainfall	cw_precipitation_driest_period_x100.tif	Precipitation of driest period (bio14)
Climate	Rainfall	cw_precipitation_ann_x1.tif	Annual precipitation (bio12)
Climate	Rainfall	cw_evapotranspiration_ave_ann_areal_pot_x10.tif	Average areal potential evapotranspiration – annual
Climate	Rainfall	cw_evapotranspiration_ave_ann_areal_act_x10.tif	Average areal actual evapotranspiration – annual
Climate	Temperature	ct_temp_ave_daily_min_winter_x100.tif	Average daily max temperature – winter

Group 1	Group 2	Grid name	Description
Climate	Temperature	ct_temp_ave_daily_min_summer_x100.tif	Average daily min temperature – summer
Climate	Temperature	ct_temp_ave_daily_min_ann_x100.tif	Average daily min temperature – annual
Climate	Temperature	ct_temp_ave_daily_max_winter_x100.tif	Average daily max temperature – winter
Climate	Temperature	ct_temp_ave_daily_max_summer_x100.tif	Average daily max temperature – summer
Climate	Temperature	ct_temp_ave_daily_max_ann_x100.tif	Average daily max temperature – annual
Climate	Temperature	ct_temp_seasonality_x1000.tif	Temperature seasonality: coefficient of variation (bio4)
Climate	Temperature	ct_temp_max_warmest_period_x100.tif	Max. temperature of warmest period (bio5)
Climate	Temperature	ct_temp_min_coldest_period_x100.tif	Min. temperature of coldest period (bio6)
Climate	Temperature	ct_temp_isothermality_x10000.tif	Isothermality 2/7 (bio3)
Climate	Temperature	ct_temp_diurnal_range_x100.tif	Mean diurnal range (mean(period max.– min.)) (bio2)
Climate	Temperature	ct_temp_ave_ann_x100.tif	Annual mean temperature (bio1)
Climate	Temperature	ct_temp_ann_range_x100.tif	Temperature annual range: difference between bio5 and bio6 (bio7)
Climate	Temperature	ct_frostdays_below_2deg_x10.tif	Number of days/annum with minimum temperature less than 0 degrees
Climate	Temperature	ct_frostdays_below_0deg_x10.tif	Number of days/annum with minimum temperature less than 2 degrees
Land	Drainage	dl_distance_to_streams_6order_andabove_x1.tif	Euclidean distance to 6th order streams and above
Land	Drainage	dl_distance_to_streams_4order_andabove_x1.tif	Euclidean distance to 4th order streams and above
Land	Drainage	dl_distance_to_streams_2order_andabove_x1.tif	Euclidean distance to 2nd order streams and above
Land	Drainage	dl_distance_to_streams_all_x1.tif	Euclidean distance to all streams (i.e. all orders: 1 to 9)

Group 1	Group 2	Grid name	Description
Land	Geophysics	gp_u_filtered_uranium_x10.tif	Filtered uranium (U), gaps filled in using geographically weighted regression model and spline function
Land	Geophysics	gp_total_dose_rate_x1.tif	Total dose rate, gaps filled in using geographically weighted regression model and spline function
Land	Geophysics	gp_th_filtered_thorium_x10.tif	Filtered thorium (Th), gaps filled in using geographically weighted regression model and spline function
Land	Geophysics	gp_k_filtered_potassium_x100.tif	Filtered potassium (K), gaps filled in using geographically weighted regression model and spline function
Land	Landform	lf_topographic_position_index_2000m_radius_x100.tif	Topographic position index using neighbourhood of 2000 m radius
Land	Landform	lf_topographic_position_index_1000m_radius_x100.tif	Topographic position index using neighbourhood of 1000 m radius
Land	Landform	lf_topographic_position_index_0500m_radius_x100.tif	Topographic position index using neighbourhood of 500 m radius
Land	Landform	lf_topographic_position_index_0250m_radius_x100.tif	Topographic position index using neighbourhood of 250 m radius
Land	Landform	lf_topographic_position_index_0120m_radius_x100.tif	Topographic position index using neighbourhood of 120 m radius
Land	Landform	lf_slope_degrees_x100.tif	Slope in degrees
Land	Landform	lf_roughness_1000m_radius_x10.tif	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 1000 m neighbourhood. Derived from DEM-S

Group 1	Group 2	Grid name	Description
Land	Landform	lf_roughness_0500m_radius_x10.tif	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 500 m neighbourhood. Derived from DEM-S
Land	Landform	lf_roughness_0100m_radius_x100.tif	Neighbourhood topographical roughness based on the standard deviation of elevation in a circular 100 m neighbourhood. Derived from DEM-S
Land	Landform	lf_cold_air_drainage_x1000.tif	Cold air drainage
Land	Landform	lf_exposure_to_NW_x1000.tif	Exposure to the NW (low = exposed (drier forests); high = sheltered (moister forests)).
Land	Landform	lf_dem_1sec_smoothed_x1.tif	1 sec SRTM smoothed DEM (DEM-S)
Land	Landform	lf_curviture_slope_of_slope_x1000.tif	Curvature or slope of the slope: defines concave, convex and flat. A positive curvature indicates the surface is upwardly convex at that cell. A negative curvature indicates the surface is upwardly concave at that cell. A value of 0 indicates the surface is flat
Land	Landform	lf_curviture_in_profile_x10000.tif	Curvature in profile (the direction of the maximum slope)
Land	Landform	lf_curviture_in_plan_x10000.tif	Curvature in plan (is perpendicular to the direction of maximum slope)
Land	Landform	lf_compound_topographic_index_x100.tif	Compound topographic index or CTI also known as wetness index, topographic wetness index. Based on DEM-H (for flow direction and accumulation)
Land	Landform	lf_aspect_x10.tif	Derived by DPIE from 1 sec SRTM DEM (see URL for DEM metadata)

Group 1	Group 2	Grid name	Description
Land	Landform	lf_aspect_beers_x1000.tif	Beer's Aspect – transformation of aspect to a continuous scaled variable. Changed for the southern hemisphere by setting maximum value (2) to SE slopes (coolest) and minimum (0) to NW slopes (warmest)
Land	Location	dl_longitude_grid_x100.tif	Longitude (surrogate for location, dispersal, isolation)
Land	Location	dl_latitude_grid_x1000.tif	Latitude (surrogate for location, dispersal, isolation)
Soil	Properties	sw_weathering_intensity_x1000.tif	A weathering intensity index using airborne gamma-ray spectrometry and digital terrain analysis
Soil	Properties	sp_organic_carbon_100_200_prop_x1000.tif	Organic carbon
Soil	Properties	sp_organic_carbon_000_100_prop_x1000.tif	Organic carbon proportionally combined depths from 0–100 cm
Soil	Properties	sp_sand_content_100_200_prop_x100.tif	Sand content (%) (100–200 cm)
Soil	Properties	sp_sand_content_000_100_prop_x100.tif	Sand content proportionally combined depths from 0–100 cm
Soil	Properties	sp_silt_content_100_200_prop_x100.tif	Silt content (%) (100–200 cm)
Soil	Properties	sp_silt_content_000_100_prop_x100.tif	Silt content proportionally combined depths from 0–100 cm
Soil	Properties	sp_total_phosphorus_100_200_prop_x10000.tif	Total phosphorus (%) (100–200cm)
Soil	Properties	sp_total_phosphorus_000_100_prop_x10000.tif	Total phosphorus proportionally combined depths from 0–100 cm
Soil	Properties	sp_ph_calc_chloride_100_200_prop_x1000.tif	pH (calcium chloride) (100–200cm)
Soil	Properties	sp_ph_calc_chloride_000_100_prop_x1000.tif	pH (calcium chloride) proportionally combined depths from 0–100 cm
Soil	Properties	sp_total_nitrogen_100_200_prop_x10000.tif	Total nitrogen (%) (100–200 cm)

Group 1	Group 2	Grid name	Description
Soil	Properties	sp_total_nitrogen_000_100_prop_x10000.tif	Total nitrogen proportionally combined depths from 0–100 cm
Soil	Properties	sp_cation_exchange_capacity_100_200prop_x100.tif	Effective cation exchange capacity (100–200 cm)
Soil	Properties	sp_cation_exchange_capacity_000_100prop_x100.tif	Effective cation exchange capacity proportionally combined depths from 0–100 cm.
Soil	Properties	sp_depth_soil_profile_000_200_x1000.tif	Depth of soil profile (A and B horizons) 0–200 cm depths
Soil	Properties	sp_clay_content_100_200_prop_x100.tif	Clay content (%) (100–200 cm)
Soil	Properties	sp_clay_content_000_100_prop_x100.tif	Clay content proportionally combined depths from 0–100 cm
Soil	Properties	sp_bulk_density_100_200_prop_x10000.tif	Bulk density (100–200 cm)
Soil	Properties	sp_bulk_density_000_100_prop_x10000.tif	Bulk density proportionally combined depths from 0–100 cm
Soil	Properties	sp_avail_water_capacity_100_200_prop_x100.tif	Available water capacity
Soil	Properties	sp_avail_water_capacity_000_100_prop_x100.tif	Available water capacity proportionally combined depths from 0–100 cm
Soil	Properties	sm_clay_smectite_0-20_x10000.tif	Relative abundance of smectite clay minerals in surficial topsoil (0–20 cm)
Soil	Properties	sm_clay_kaolinite_0-20_x10000.tif	Relative abundance of kaolinite clay minerals in surficial topsoil (0–20 cm)

Appendix C – MCAS-S work process

Step 1. Define the objective and decision criteria

To demonstrate the use of MCAS-S time-series analysis capabilities the following spatial objective question is addressed:

'Which local government areas are predicted to have the largest increase in average monthly maximum surface temperatures for summer months between 1990 to 2009 and 2060 to 2079?'

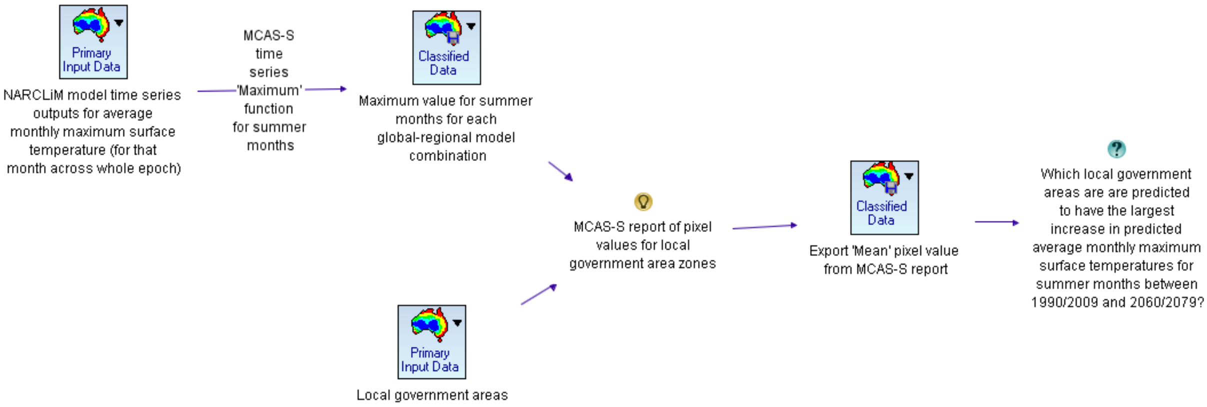


Figure 15 **Means-to-end diagram used to identify criteria (inputs) and plan the MCAS-S model, generated using Compendium software**

Step 2. Assemble data inputs (build MCAS-S datapack)

As this is a simple model there will only be a small number of required data inputs. In the zip file we have included an empty 'template' datapack. Copy across the NARCliM models for 'tasmax' into the 'Primary' folder, in the template datapack, for the 2000 baseline (1990 to 2009 time period), shown in Figure 17. Do the same for the 2070 time period (2060 to 2079 abbreviated to 2070) for each of the three regional models (R1, R2, R3). Also copy the Local Government Areas dataset into the 'Mask' folder, shown in Figure 17.

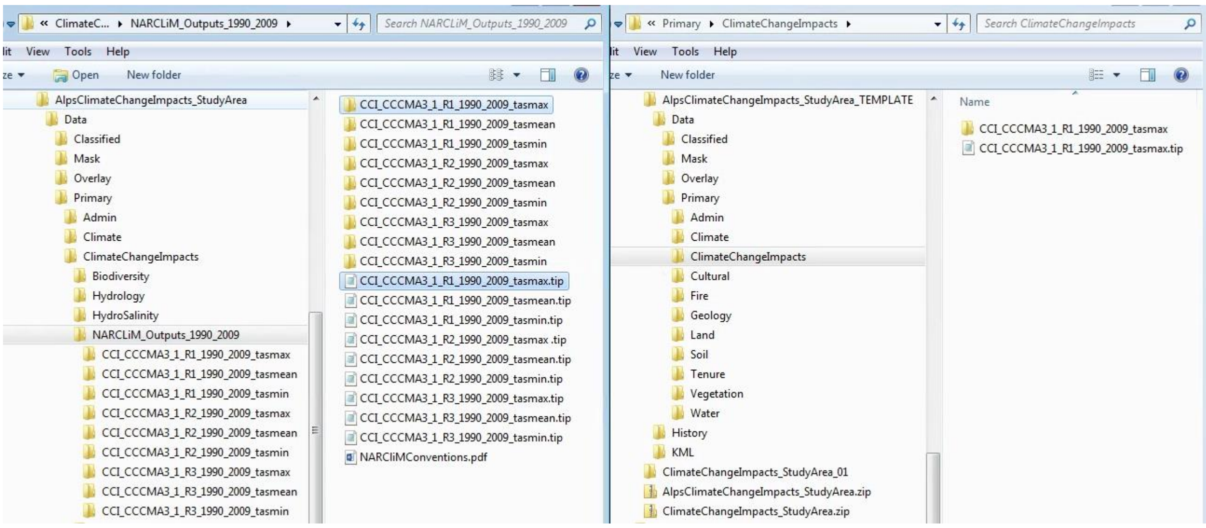


Figure 16 **Example of how to build a custom MAS-S datapack containing only the datasets you need for your model**

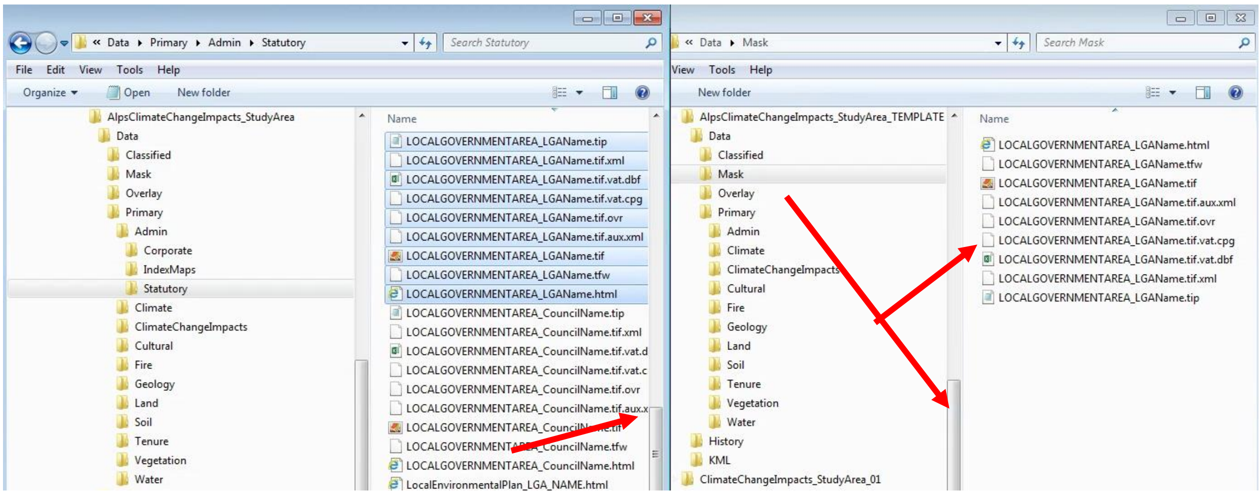


Figure 17 Example of how to use a dataset from the Primary folder (Primary>Admin> Statutory in this case) for reporting, by copying it into the 'Mask' folder

Be sure to sort the Primary data by 'Name' so you copy all the required data files.

Once you have copied the required data into the blank MCAS-S datapack template you can open the MCAS-S project 'MCAS-S PROJECT Blank.mcas', shown in Figure 18, to view the data and build a model. Be sure to save the MCAS-S project using a new name before exiting MCAS-S.

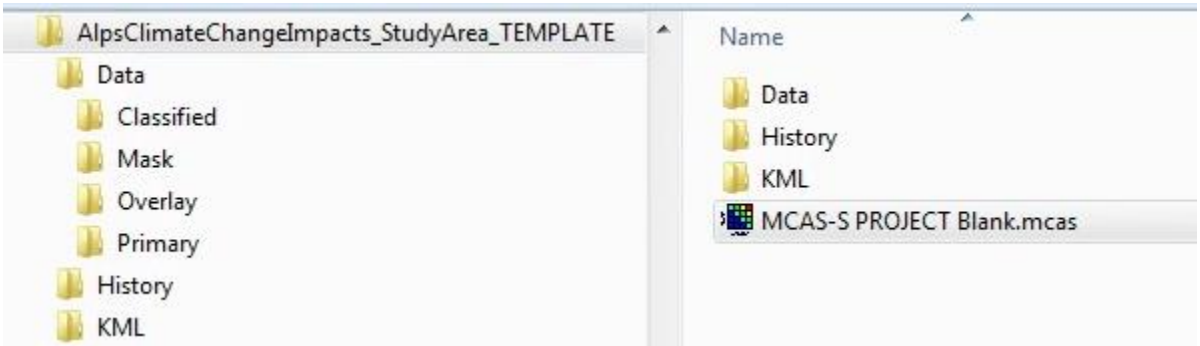


Figure 18 When the data has been copied over to the empty template datapack you can open the MCAS-S project called 'MCAS-S PROJECT Blank.mcas' to view the data

Step 3. Explore and combine data

The NARCliM outputs are a time-series and represent the average monthly value across all months in each time period. When you drop them into the MCAS-S project window you can select the summer months (December, January and February) and choose the [Maximum] button to calculate the maximum value across all these summer months. Do this for the 2000 baseline (1990 to 2009 baseline time period abbreviated to 2000) and the 2070 time period for each of the three regional models (R1, R2, R3). This is illustrated in Figure 19 for R1, 1990 to 2009 time period. Figure 20 shows the six time-series analysis outputs that can be accessed by selecting them from the MCAS-S [Classified Data] drop-down list and dragging and dropping them into the MCAS-S project window.

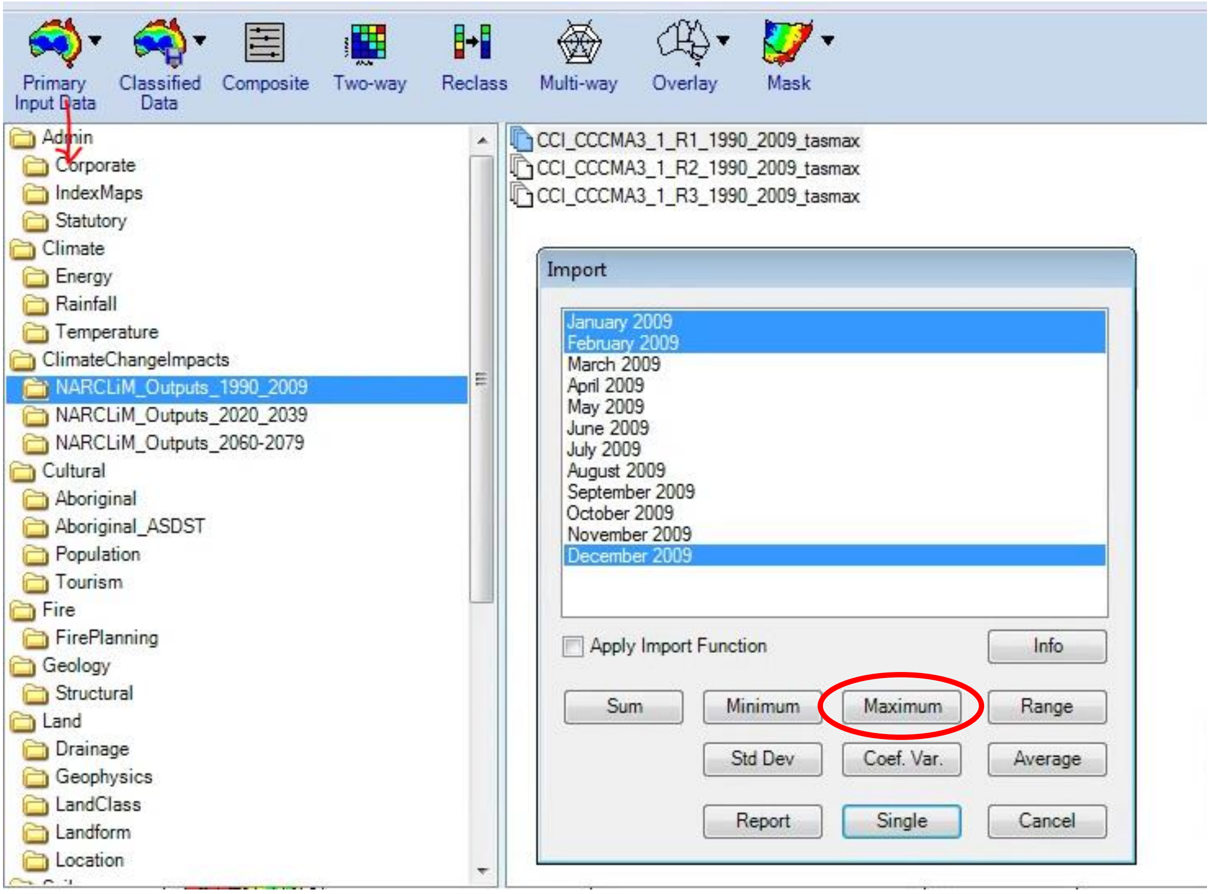


Figure 19 **Calculating the maximum value from the three summer months using the NARCliM time-series dataset**

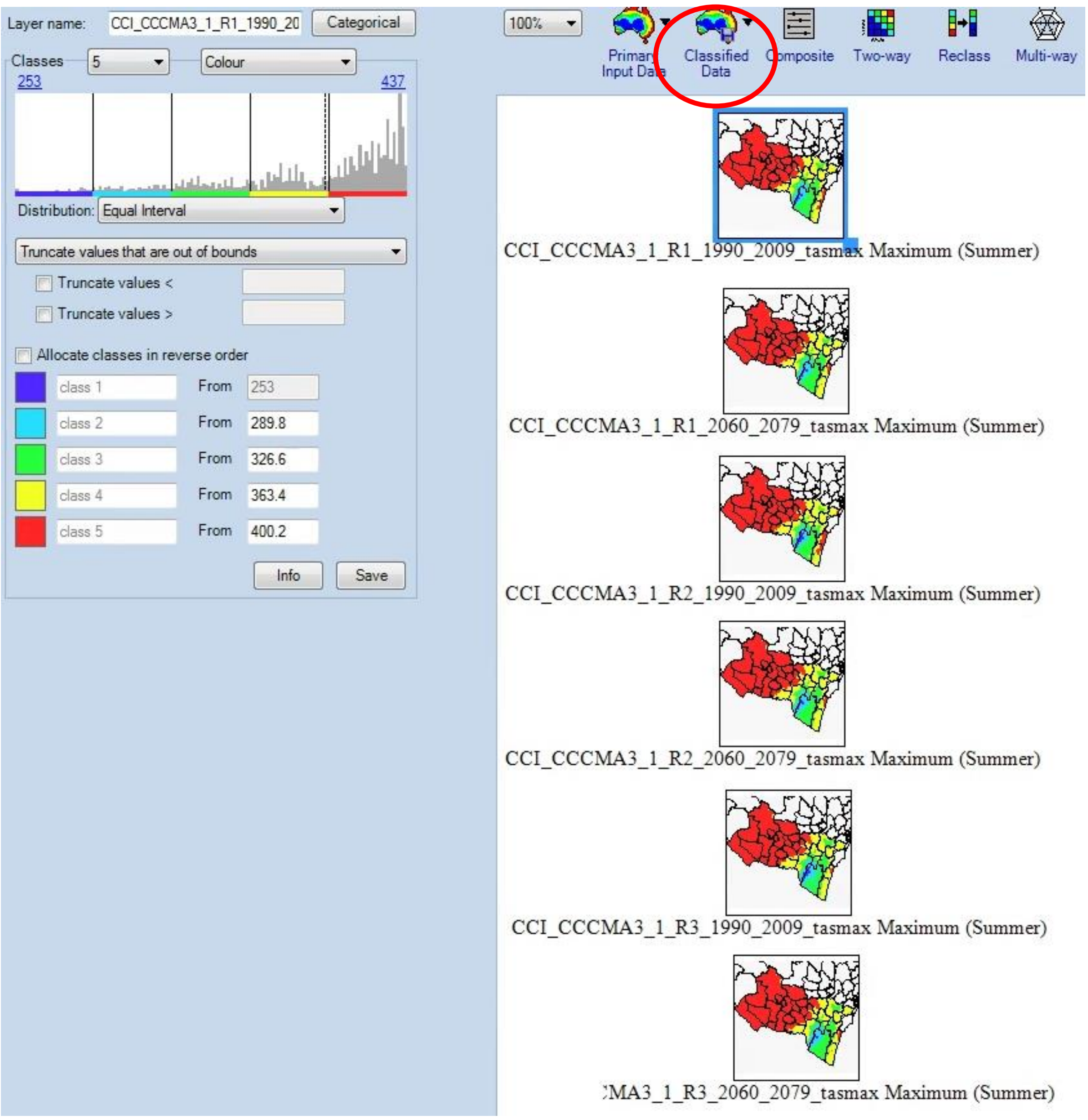


Figure 20 **Six time-series outputs representing maximum average surface temperatures for summer months across all summer months in each time period**

Time-series analysis outputs are available in the [Classified Data] MCAS-S button.

To calculate the change in maximum summer surface temperature you use the MCAS-S [Composite] tool to build a function 'future value minus baseline value', illustrated in Figure 21 below. Figure 22 shows this process completed for the three regional models R1, R2 and R3.

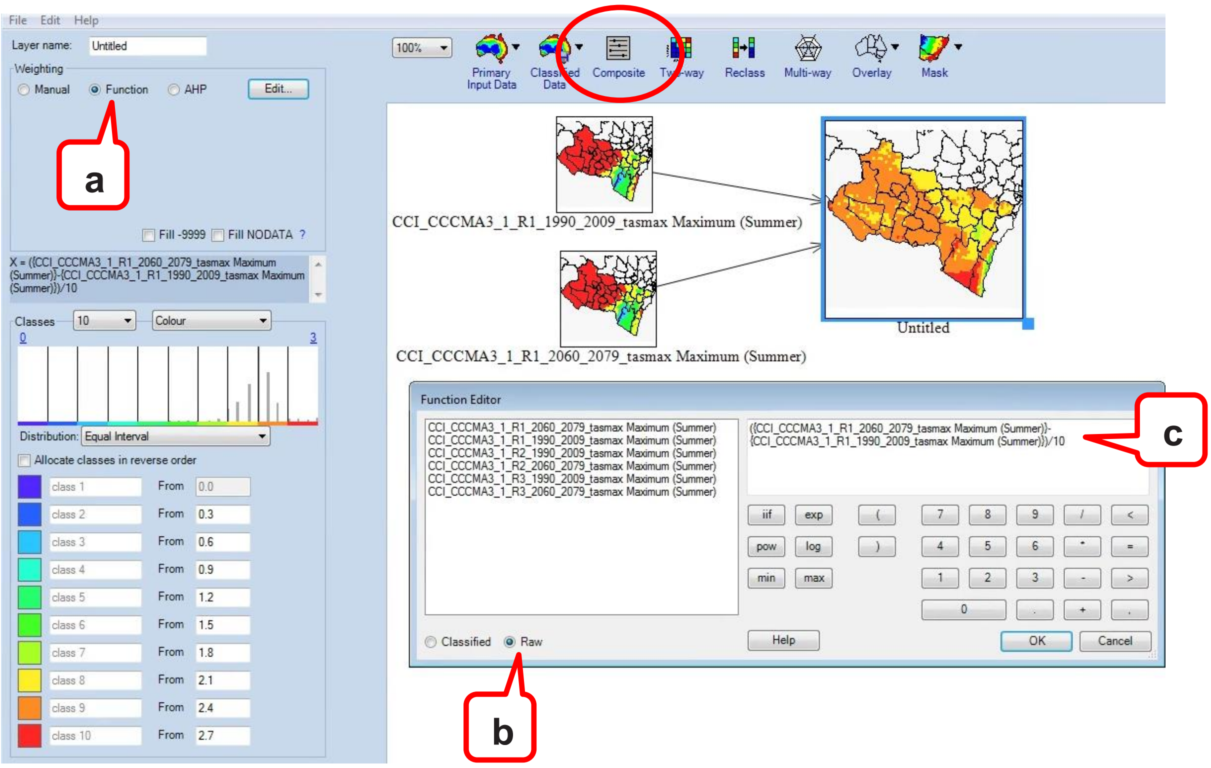


Figure 21 **Screenshot showing how to build the MCAS-S [Composite] function to calculate the difference between 1990 to 2009 and 2060 to 2079 maximum summer surface temperatures**

Once you have dropped the [Composite] function into the MCAS-S project window click on the Function radio button (a) and ensure the 'Raw' option is selected (b), when you build the difference equation (c). The difference value is divided by 10 because the original NARCliM output data is multiplied by 10 to convert it into an integer type to reduce the file size.

Step 4. Develop options

The three different regional models R1, R2 and R3 shown in Figure 22 represent three different versions of the NARCliM future climate forecast. If we were undertaking this modelling in closer collaboration with end users, and imported more of the NARCliM outputs, we might decide to look at more options or NARCliM variables, model and time period scenarios.

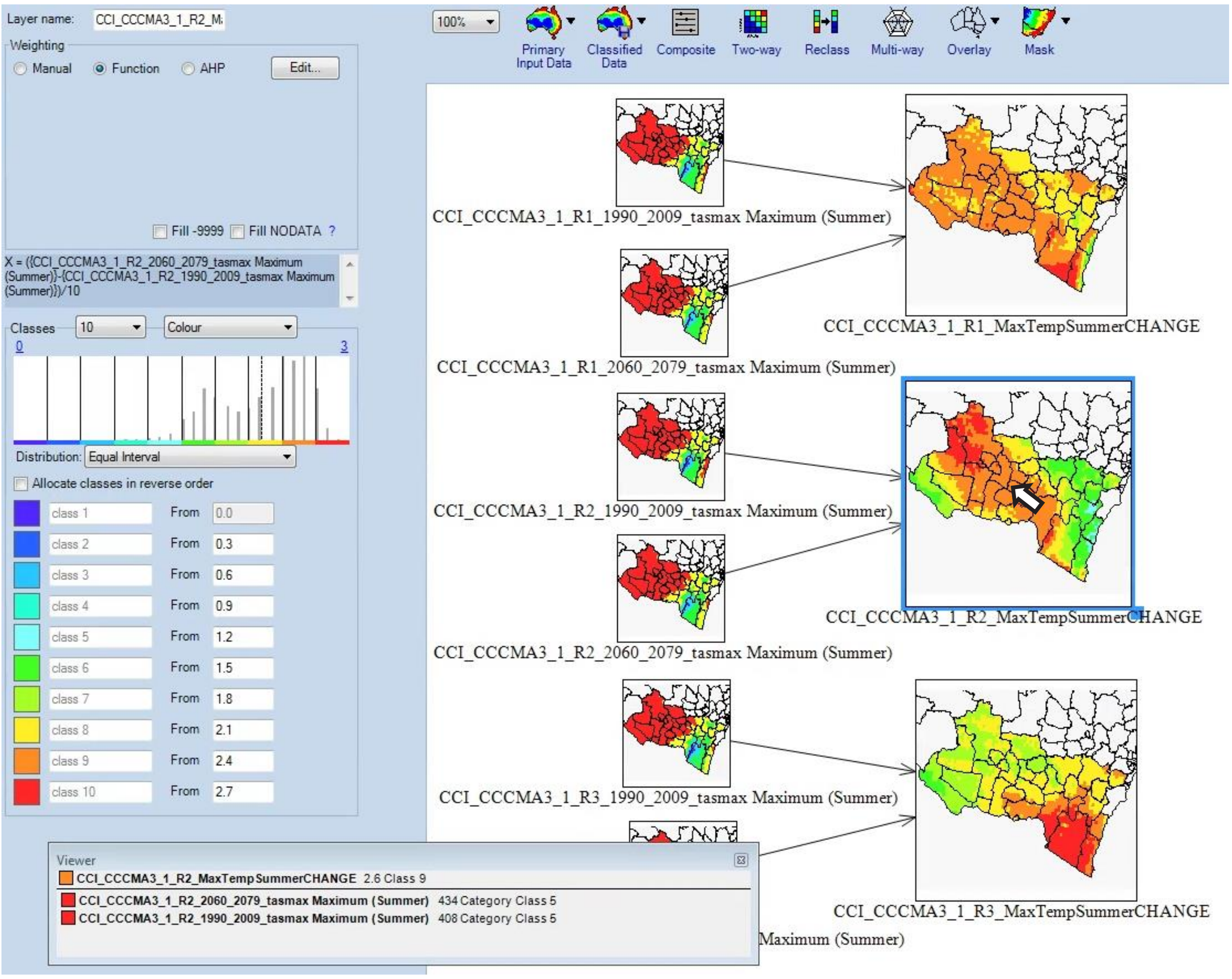


Figure 22 **MCAS-S project showing the three composite functions that represent change from baseline of maximum summer surface temperature for the three RCMs CCMA3.1 (abbreviated as CCI_CCCMA3_1 followed by R1, R2 and R3)**

Note the viewer is displaying the final value and the input values for the pixel under the mouse pointer in the highlighted (middle) layer.

Step 5. Review and report

MCAS-S allows you to run spatial area reports based on a categorical or 'region' data. You can select from any of the categorical datasets stored in the MCAS-S datapack 'Mask' folder. In this example, shown in Figure 21 and Figure 22, we are reporting based on local government area regions. You can then create new MCAS-S layers based on the summary statistics (see Figure 23 and Figure 24) or save the report as a text file for further analysis and/or graphing in Microsoft Excel.

From this reporting (shown in Figure 25) we can see that the Snowy Valleys LGA is the only LGA where all models predict an average rise in maximum surface temperature of ≥2.4°C.

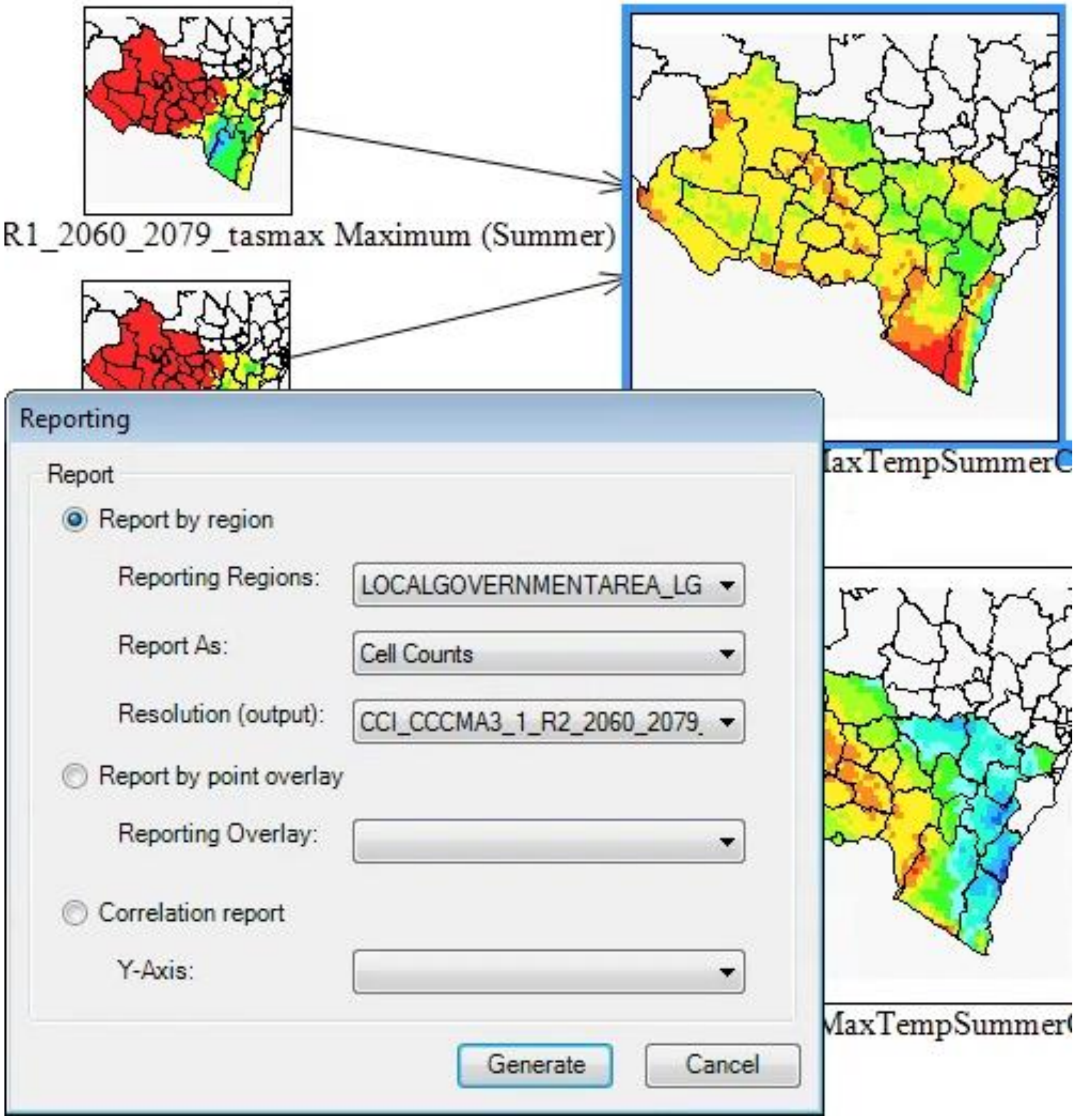


Figure 23 **In MCAS-S a right-mouse-click over the data layer gives you the options for running a report**

The report options window allows you to select the regions (from the data in the MCAS-S datapack Mask folder) you want to report on. In this case we are reporting on local government areas.

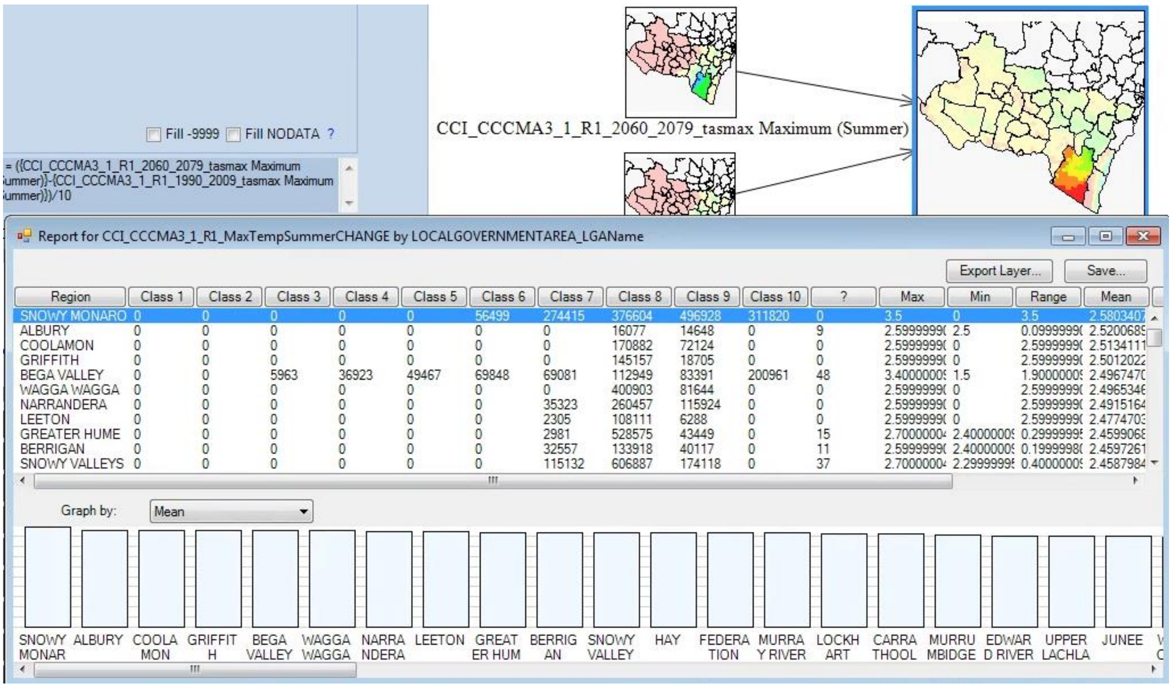


Figure 24 Result of the MCAS-S report

If you select an LGA region (Snowy Monaro in this case) it will be highlighted in the map view. You can export this table as a comma-delimited text file, by clicking on the [Save] button, which can then be graphed in an application like Microsoft Excel.

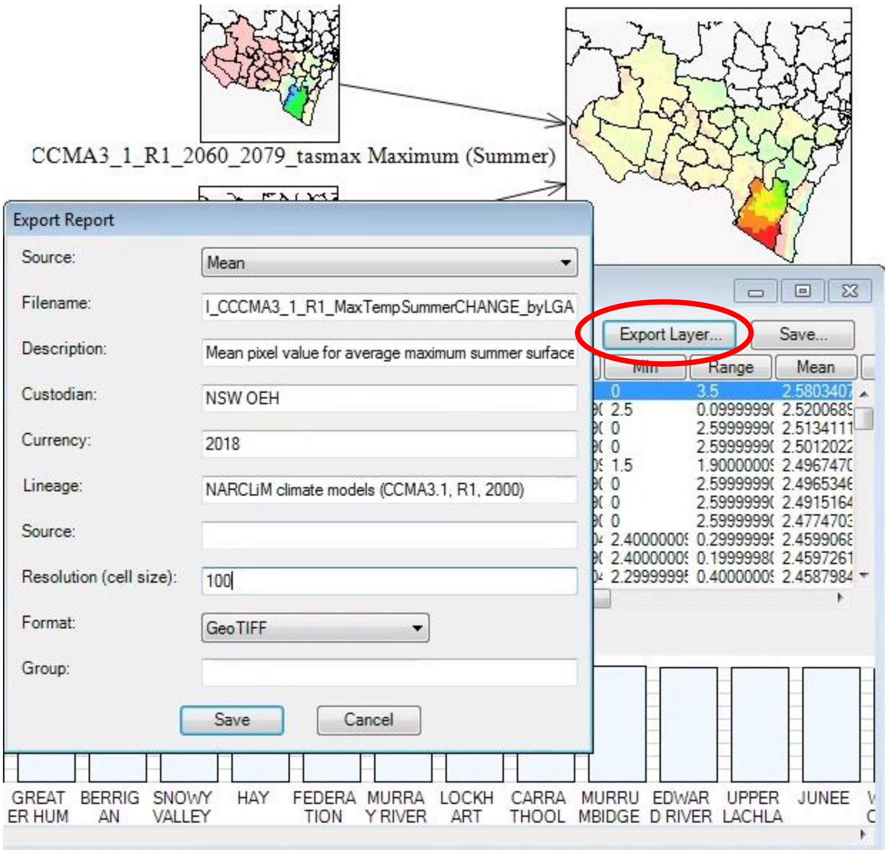


Figure 25 You can create a new MCAS-S layer based on any of these report statistics by selecting the [Export Layer] button and then selecting the 'Source' statistic to create the new layer

The new layer will be available to add to your MCAS-S project from the [Classified] button drop-down list.

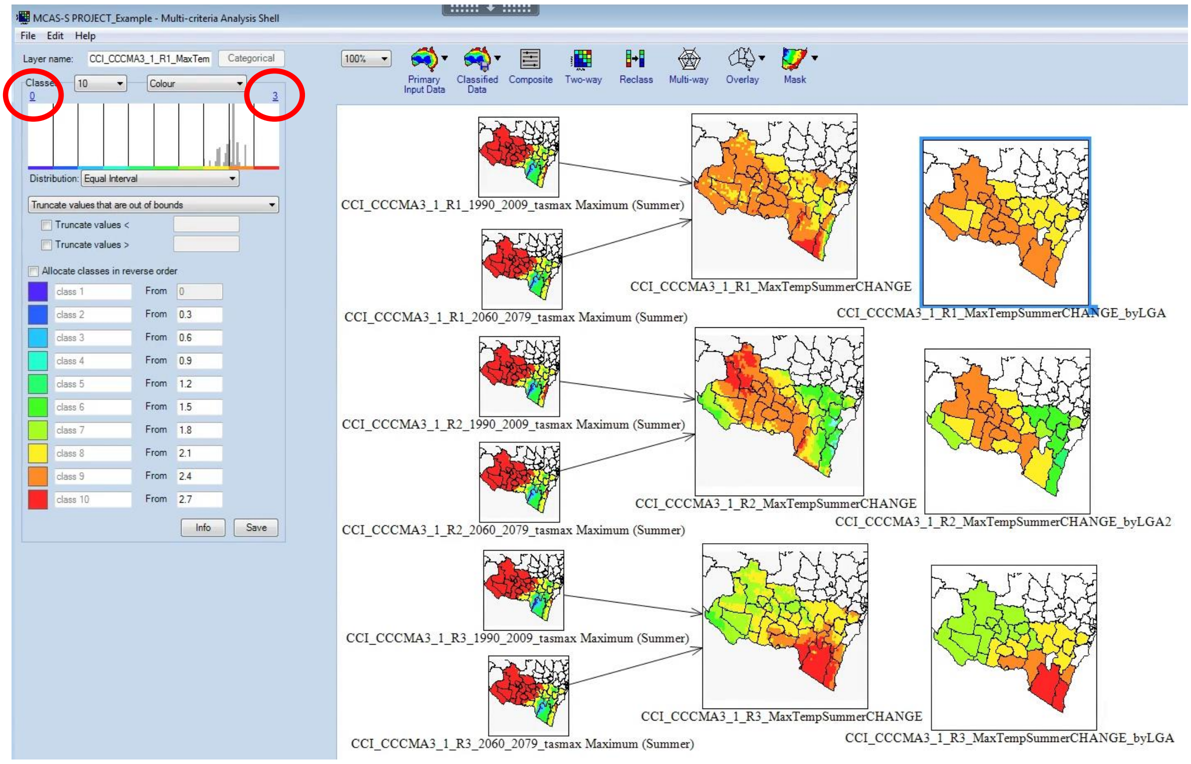


Figure 26 **The three layers on the right of the MCAS-S project window show the ‘average’ pixel value (change in maximum summer surface temperature between 1990 to 2009 and 2060 to 2079) for each LGA region**

To compare these outputs visually set the minimum and maximum display value (see red circles in top left) to be the same in all layers, 0 and 3 in this case.

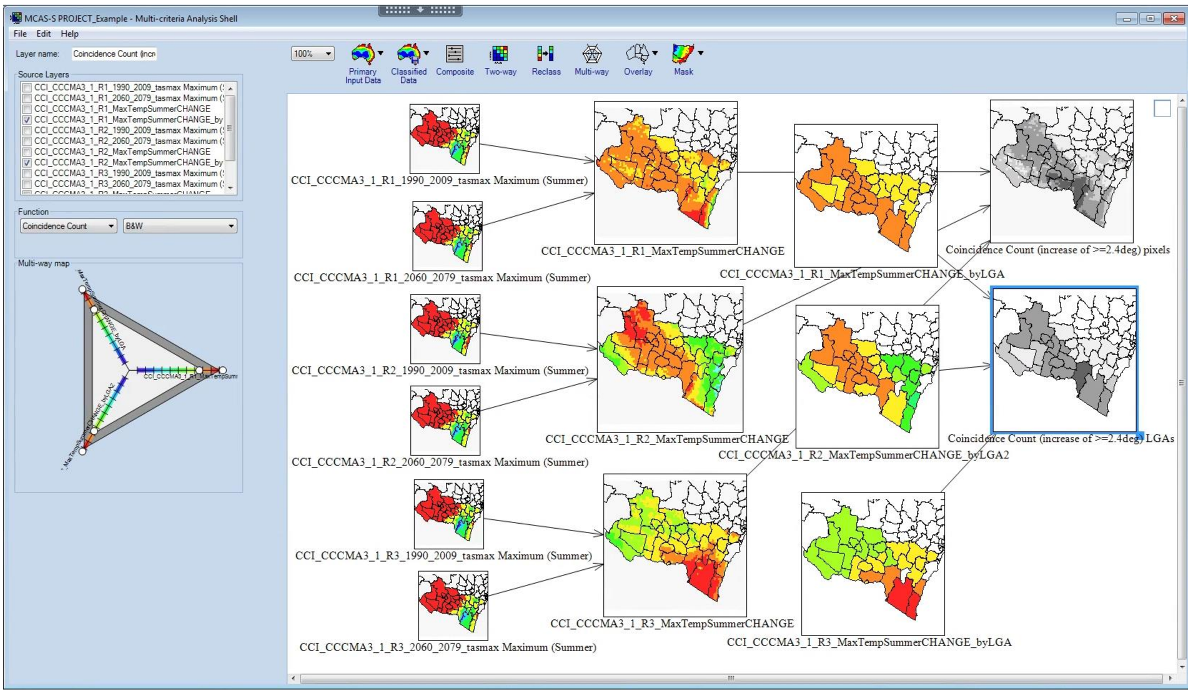


Figure 27 **Final MCAS-S model showing the average predicted increase in maximum summer surface temperature for local government areas and the level of agreement (coincidence count) between the three models for an average increase of ≥2.4°C across all summer months in the time period**

This comparison was undertaken for the average pixel value across the LGA (top right) and for individual pixels (bottom right, and shown in more detail with LGA name labels in Figure 25).

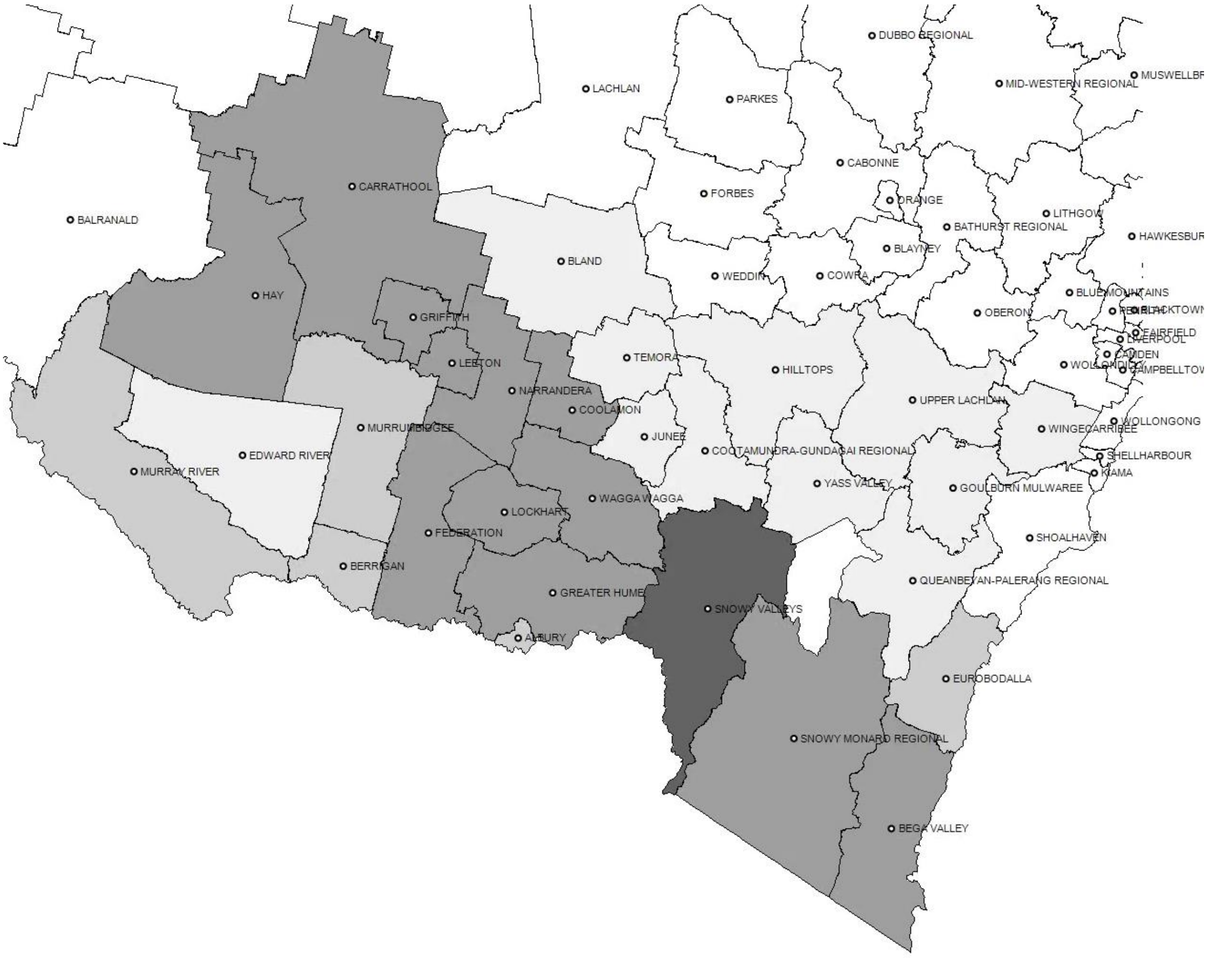


Figure 28 **MCAS-S ‘Multi-way’ function showing the level of agreement (coincidence count) between the three RCMs CCMA3.1 R1, R2 and R3 for an average increase of ≥2.4°C across all summer months in the time period**

Very dark grey=all three models predicted ≥2.4°C, dark grey=two models predicted ≥2.4°C, light grey=one model predicted ≥2.4°C and very light grey=no models predicted ≥2.4°C.

Appendix D – Stakeholder workshop activity: Identifying research needs

Table 7 Water availability research needs

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
What are the research priorities for your work?		
Land management	Integrated assessment	MCAS-S has primarily been used to inform land management and planning decisions.
Planning	Integrated assessment	MCAS-S has primarily been used to inform land management and planning decisions.
Investment	Integrated assessment	MCAS-S has been applied to model spatial priority for investment in land-use and management interventions and investments by the Local Land Services (formerly CMAs).
Education	All	There is potential for the MCAS-S datapacks to form part of an education package.
Where are the gaps?		
Gap between research and on-ground actions	Integrated assessment	The multi-criteria analysis (MCA) process and the interactive nature of MCAS-S means that land managers can participate in the modelling process and this improves the likelihood that outputs address real-world (on-ground) needs.
Research objectives of research organisations are at a different scale to most users	All – general question	This is becoming less of a problem as spatial modelling is being undertaken at finer scales (down to 90 m).
Climate change is happening but what do we do about it?	Integrated assessment	MCAS-S can help here, but first users must develop a specific objective question.
It's not having the data that is the problem, it is knowing what to do with it	Integrated assessment	MCAS-S can facilitate this. But it is just a tool and requires that users understand the data and the natural, cultural, social and economic processes they are modelling.
Low confidence in rainfall projections and models, higher confidence required. Need both variance and variability in rainfall predictions	Impacts on future climate and fire weather	How to deal with variability and confidence of input data is an important question that needs to be addressed when using these datasets in MCAS-S.

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
Need actual data on water infiltration, water movement in soils, and water volume delivered through soils to stream information	Impacts on water availability	These factors have been modelled in the water availability sub-project. They can be reported on for any region, or used in spatial models, in MCAS-S.
Changes of soil parameters due to climate change	Impacts on ecosystem (soil erosion modelling)	
Of the precipitation for a given area need to know what percentage of water infiltrates and moves through the soil and what percentage is runoff	Impacts on water availability	
How previous predictions have measured up on recent data at least for trends (this could really help with credibility)	Impacts on future climate and fire weather All – general question	If the data from previous predictions was imported into the MCAS-S datapack then this comparison could be performed by MCAS-S.
What are the spatial and temporal scale issues?		
Regionally relevant modelling and interpretations There is a need for information at a catchment scale and much finer scale (paddock). Currently using pragmatic averaged which are informed judgement calls	Impacts on future climate and fire weather All – general question	Any outputs from NARCliM or the Climate Change Impact sub-projects can be reported on for any region, or used in spatial models, in MCAS-S.

Table 8 Tourism research needs

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
What are the research priorities for your work?		
Snowfall predictions	Impacts on future climate and fire weather Impacts on tourism	Due to time constraints, snow fall prediction data was not imported into the MCAS-S datapacks. This data could be imported if time and resources become available.
Snowmelt rate	Impacts on future climate and fire weather Impacts on tourism	
Water flow and temperature – important for snowmaking	Impacts on future climate and fire weather Impacts on water availability	
Snowmaking storage requirements	Impacts on tourism	
Replenishment of ground water – groundwater level and temperature to be able to determine which locations to farm snow	Impacts on water availability Impacts on tourism	
Wind projections – direction and intensity to be able to determine appropriate locations of snowmaking fences	Impacts on future climate and fire weather Impacts on tourism	
Direction of systems (i.e increase or decrease in weather systems from the north)	Impacts on future climate and fire weather Impacts on tourism	
Air temperature – number of cold nights	Impacts on future climate and fire weather Impacts on tourism	
Extreme weather events – will there be an increase in extreme snow dumps (positive), increase in extreme rainfall and wind events (negative), colder or warmer extreme events or a combination?	Impacts on future climate and fire weather Impacts on tourism	

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
Need to be able to guarantee a reliable quality product (snow) in the future	Impacts on future climate and fire weather Impacts on tourism	
Where are the gaps?		
Research scope should cover the climate change impacts over the full year, rather than just snow, including impact of climate change on green season activities such as fishing, canoeing, trail bike riding, Snowy Hydro (as a tourist attraction)	Impacts on future climate and fire weather Impacts on tourism	
How will fire risk impact tourism?	Impacts on future climate and fire weather Impacts on tourism	If fire risk maps are available they could be used in an MCAS-S model of impact on tourism and infrastructure.
Biodiversity – vulnerability to climate change (e.g. warmer nights) could add more layers of compliance to resort businesses which might impact on viability	Impacts on biodiversity Impacts on tourism	MCAS-S may be used to map 'where' these impacts might occur.
Current averages and models do not assist decisions about snowmaking infrastructure investment	Impacts on future climate and fire weather Impacts on tourism Integrated assessment	Potential MCAS-S question: ***Where** to invest in snowmaking infrastructure?*
Capacity of local government to distil the information into the right format for grants can be limited	Impacts on tourism Integrated assessment	MCAS-S has the potential to generate new or derived spatial products that address a specific spatial question.
What are the spatial and temporal scale issues?		
Fine-scale resolution, as there is climatic variability between resorts that are within 10 km of each other and they can create their own microclimates when using snowmaking machines.	Impacts on future climate and fire weather	The finer-scale environmental data included in the MCAS-S datapack may be able to address this question.
For the long-term projections, 250 m scale would be beneficial	Impacts on future climate and fire weather	The next generation of NARCliM modelling will be at a finer scale.

Table 9 Biodiversity and ecosystem services research needs

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
What are the research priorities for your work?		
Biodiversity risk assessment processes to incorporate climate change	Impacts on biodiversity	
Adaptation options (e.g. buffering sensitive environmental values including evolutionary processes from future impacts, such as fire regimes for Mountain Ash forests and alpine bogs)	Impacts on biodiversity Impacts on future climate and fire weather Integrated assessment	Potential MCAS-S question: ***Where** should adaptation option (X) be applied to minimise climate change impacts on biodiversity?*
Biodiversity benefits mapping (mapping of where investment (e.g. planting, buffering, weeding, other habitat management) is most beneficial). How to avoid maladaptation?	Impacts on biodiversity Integrated assessment	Potential MCAS-S question: ***Where** would investment in land management actions maximise biodiversity benefits and minimise climate change impacts on biodiversity?*
Developing MCAS-S as a useful tool for NRM policy and conservation research teams, as well as specialists within park management	Impacts on biodiversity Integrated assessment	The Kosciuszko National Park datapack could be used to inform park management. A pilot project that used MCAS-S to model potential impact of fire history on biodiversity in Kosciuszko NP (Barrett & Allen in prep.) has demonstrated the utility of MCAS-S.
Biodiversity corridors, should we steer development way from climate refugia areas?	Impacts on biodiversity Integrated assessment	Potential MCAS-S question: ***Where** would avoiding development maximise biodiversity benefits and minimise climate change impacts on biodiversity?*
Erosion impacts in relation to sustainable trails. Maintenance costs are an important consideration for local government which has high exposure to this.	Impacts on ecosystem (soil erosion modelling)	Potential MCAS-S question: ***Where** are the highest erosion risks for trails in LGAs?*
Where are the gaps?		
Traditional ecological knowledge with regards to burning. What was the purpose of traditional burning? Previously the purpose across the landscape was for hunting which suggests it is less likely that fire was a big influence on the biodiversity of alpine areas in the past	Impacts on future climate and fire weather Impacts on biodiversity	A pilot project that used MCAS-S to model potential impact of fire history on biodiversity in Kosciuszko NP (Barrett & Allen in prep.) has demonstrated the utility of MCAS-S.

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
Pathways, process and tools to help buffer ecological and evolutionary processes (e.g. weeds and vegetation) and protect against the effects of climate change?	Impacts on biodiversity Integrated assessment	Potential MCAS-S question: *Need to define is the objective, or **where** question?*
Build staff capacity to undertake some modelling themselves and better understand research results	Impacts on biodiversity Integrated assessment	Comment on use of MCAS-S
Avoiding maladaptation, e.g. effect of climate change on feedback loops like slashing roadsides for fire control, which encourages African lovegrass. Lovegrass is a fire promoter, thus alpine ecosystems are now perpetually in early succession states because of fire. We need to allow the vegetation to go through a higher fire risk successional stage in order to reach a lower fire risk stage. How does this sit with traditional burning?	Impacts on biodiversity Impacts on future climate and fire weather Integrated assessment	Potential MCAS-S question: *Need to define is the objective, or **where** question?*
Understanding the integrated 'story of change' for adaptation of biodiversity and ecosystems. Key variables are heat extremes (amplitude) and their duration; fragmentation; snow retreat; fire extremes; pest and weed encroachments; change in precipitation	Impacts on future climate and fire weather Impacts on biodiversity	Potential MCAS-S question: *Need to define is the objective, or **where** question?*
What will future vegetation communities look like? For both biodiversity and cropping. Will they burn in a different way? How will this affect planning for development?	Impacts on biodiversity Impacts on agriculture (cropping) Impacts on future climate and fire weather Integrated assessment	Potential MCAS-S question: ***Where** would planning (avoided development) decisions maximise benefits and minimise climate change impacts on biodiversity?*
What are the spatial and temporal scale issues?		
Resort scale		The Kosciuszko NP datapack is 30 m resolution. Is this scale fine enough? Note that many of the input datasets will be at a coarser scale.
Information appropriate to both operational plans (10 year life span) and also annual plans of management and might incorporate community programs		A pilot project that used MCAS-S to model potential impact of fire history on biodiversity in Kosciuszko NP (Barrett & Allen in prep.) has demonstrated the utility of MCAS-S.

Table 10 Future climate and fire weather projections research needs

Workshop questions and answers	Relevant project(s)	Potential for use of MCAS-S
What are the research priorities for your work?		
Impacts of climate on cropping and grazing in the high country?	Impacts on agriculture (cropping) Integrated assessment	Potential MCAS-S question: ***Where** (and how much) will climate change impact on cropping and grazing in the high country?*
How previous predictions have measured up on recent data at least for trends (this could really help with credibility)	Impacts on future climate and fire weather Integrated assessment	MCAS-S could be used to analyse spatial correlation between current and previous predictions (if they were sourced and imported into the datapacks).
MCAS-S mapping tools look very useful	Integrated assessment	Comment on use of MCAS-S
Need for options analysis – what levers can you pull, what are the trends?	Integrated assessment	Potential MCAS-S question: *Need to define the objective, or **where** question for the different options?*
Site specific information for adaptive planning for infrastructure. What innovative approaches are being used by others internationally?	All – general question	MCAS-S can report on any region or area. Need to decide what data to report on and how to interpret it.
Where are the gaps?		
Extreme rainfall at finer spatial and temporal scale	Comment on use of MCAS-S	The next generation of NARCliM modelling will be at a finer scale.
Long-term drought projected by NARCliM simulations	Impacts on future climate and fire weather Integrated assessment	Potential MCAS-S question: *Need to define the objective, or **where** question?*
Uncertainty in future projections (snow and rainfall)	Impacts on future climate and fire weather Impacts on tourism	MCAS-S could be used build a spatially explicit model of uncertainty.
What are the spatial and temporal scale issues?		
250 m resolution climate data	Impacts on future climate and fire weather	The next generation of NARCliM modelling will be at a finer scale.
Projections for 12-member instead of ensemble mean	Impacts on future climate and fire weather	As a trial, in this project we imported 3 out of the 12 members of the ensemble into MCAS-S for the monthly mean across the whole epoch for one variable. This constituted 108 data sets for the three epochs.