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Introduction

Range-ASSESS is a computer program for exploration of potential impacts of changes in livestock and other grazing regimes, changes in fire frequency and changes in woody plant management or establishment on carbon stocks in Australian rangelands during 5-year Kyoto reporting periods under the influence of any of the possible 5-year historical climates experienced in Australian between 1889 and 1999.

Range-ASSESS has been substantially documented and tested, and applied to a comprehensive analysis of risks to soil carbon associated with climate and livestock grazing (Hill et al., 2002; 2003; 2005).

Range-ASSESS is designed for exploration of general responses and system behaviours in a framework that transforms complex spatial, temporal and process interactions into rule sets with indexes and thresholds. As such it represents an attempt to simplify the system down to a few main effects with straightforward interactions. No temporal dependency is considered and events and effects occur only once in a 5-year reporting period. The overall philosophy follows that of the 'state-and-transition' approach (Westoby et al. 1989), where rangeland states with pre-defined carbon stocking rates transit in response to changes in the main drivers of the system.

Range-ASSESS is made available to the scientific and management community to enable individuals to explore the responses of the rangeland system to major forcing factors. It is also made available for educational purposes to allow tertiary students to explore, in a simple way, the effect of disturbance on vegetation and carbon stocks. The software is used for practical exercises in the Masters of Contemporary Science course available on-line from the Australian National University.

Limitations

1. Input data

Range-ASSESS was constructed at a continental scale using available data layers and data layers synthesised from variable sources both in terms of spatial explicitness and qualitative/quantitative nature. The user needs to be aware of the limitations imposed by the input data used in Range-ASSESS and the assumptions, approximations, simplifications and averaging used to create a reporting framework and the output estimates of system response in terms of carbon. The table below documents some of these issues for the major input data sources.

<table>
<thead>
<tr>
<th>Data layers</th>
<th>Limitations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rangeland zones</td>
<td>These are an approximate mapping of the rangeland zone types from Harrington et al. (1984) onto the Carnahan 1788 pre-settlement vegetation map of Australia. Since understoery descriptions are limited in Carnahan, they do not exactly match with descriptions in Harrington et al. (1984). In addition, the zones in Harrington et al. (1984) are principally based upon understoery grassland type, and not on variation in woody vegetation component other than for major species distinctions (e.g. poplar-box vs. rosewood-belah woodland). Therefore, these rangeland zones are a better representation of zonation in understoery grazing resource and therefore soil carbon, than they are of zonation in vegetation biomass, and therefore biomass carbon. These generalised zones result in some biomass anomalies in output maps where state and transition model effects result in uniform application of carbon index adjustments across biomass gradients and sub-zone boundaries.</td>
</tr>
<tr>
<td><strong>Sheep and cattle density freehold-leasehold</strong></td>
<td>These sheep and cattle density layers are based on mapping of 1997 agricultural census data at Statistical Local Area level onto the freehold-leasehold tenured land with adjustment of density values accordingly. This is used as the “normal” stocking rate for initial set-up of Range-ASSESS.</td>
</tr>
<tr>
<td><strong>Sheep and cattle density – water points</strong></td>
<td>These alternative sheep and cattle density layers are based on mapping of 2001 agricultural census data at Statistical local Area level onto water points with an assumed piosphere radius of 8 km from the National Wilderness Assessment (Lesslie and Maslen, 1993). These may be used as the “normal” stocking rate for initial set-up of Range-ASSESS.</td>
</tr>
<tr>
<td><strong>Feral grazing animal density (horse, donkey, camel and goat)</strong>&lt;br&gt;<strong>Rabbit density</strong>&lt;br&gt;<strong>Kangaroo density</strong></td>
<td>The feral grazing animal data are based upon a combination of qualitative relative density maps produced by Wilson et al. (1992) and quantitative estimates of animal numbers recorded in a number of species specific publications (Parkes et al., 1996; Dobbie et al., 1993; Johnson, 1997). Because there was a major donkey cull in the Kimberley region in the late 1990s, we downgraded estimates of donkey densities used. The rabbit density was also based on maps in Wilson et al. (1992) and quantitative estimates in Williams et al. (1995), but these were adjusted using calici virus impact reporting (Neave, 1999). Kangaroo density was based on mapping in Pople and Grigg (1999) and adjusted using information in Caughley (1987) and Short (1985). Therefore, all these density layers should be regarded as indicative only. We have therefore set a starting level for feral grazing animal density of 50% of the data value for the combined camel, horse, donkey and goat layer.</td>
</tr>
<tr>
<td><strong>Density of fire-susceptible and fire-resistant woody weeds</strong></td>
<td>These qualitative data layers from Thorp and Lynch (2000) are used to make an index and have no underlying quantitative density value.</td>
</tr>
<tr>
<td><strong>Climate (SOI/IPO) year type growth deviation layers</strong></td>
<td>The year type growth deviations represent the association of spatial variations in dryness and wetness across Australia with cycles in the Interdecadal Pacific Oscillation and the Southern Oscillation Index. They map patterns of variation in growth potential associated with these indexes. They have most sensitivity in the arid and less seasonal areas of Australia between the southern and northern highly seasonal climates. However, they are not a representation of general climate variability based on some overall continental classification. Therefore the variability in the extreme south and north of the continent (winter rainfall and monsoonal rainfall areas) is not well represented. This means that model sensitivity and responsiveness to climate is reduced in these areas for zones such as mallee (south) and northern tallgrass (north).</td>
</tr>
<tr>
<td><strong>Continental 1 km data for biomass, litter, and soil carbon stocks modified by scenario changes</strong></td>
<td>This represents a steady state, pre-settlement assessment of soil and biomass carbon stocks based on a limited set of undisturbed field data sites (Barrett 2001; 2002). These data are adjusted to a current condition by applying the initial area proportions and relative soil and biomass carbon indexes for each zone uniformly across the zone without considering internal variation in biomass or soil carbon within a zone. When combined with zone approximations, this means that zone outcomes represent the product of substantial averaging across fine scale errors and approximations. This should be kept in mind when viewing output maps on the screen and examining output zone summaries and cumulative probability graphs.</td>
</tr>
<tr>
<td><strong>Frequency of fires (annual) and timing of fires (seasonal)</strong></td>
<td>The fire frequency and timing data layers are constructed from monthly fire scar data from the WA Department of Land Administration archive for 1997-2000. The aggregate layers were then smoothed with a kernel filter to create a pseudo fire frequency layer for development of the fire index. Data were also aggregated into seasonal periods to define the occurrence of late season fires with potential to damage woody biomass growth and stocks. These data only approximate a fire frequency map and are unrepresentative of fire frequencies outside the wildfire areas of the northern savannas since the length of data record is insufficient to capture fire frequencies of less that about 1 in 3 years.</td>
</tr>
</tbody>
</table>
2. System representation

Range-ASSESS seeks to map a series of complex spatial, temporal and decision-making interactions into a simple system framework that captures the major responses and impacts of management change. Essentially, it attempts to map a highly multi-dimensional interactive system response space into a much simpler response space where the temporal and spatial dimensions are reduced to simple scalar values at the level of a carbon outcome for a zone for a given assumed response period. This simplification of the system depends upon:

1. Adequate capture of the main spatial variability in a simple zonal structure.
2. Adequate capture of the main changes that can occur in the zones and quantisation of these into a few classes with clear and different carbon stock levels.
3. Summary of temporal responses through restriction of operation to a reporting period over which multiple changes are unlikely to occur.
4. Capture of relativities between periods required for full expression of a change, and the effective reporting period for single changes.

In Range-ASSESS, the principal source of error arises from the relationship between the rangeland reporting zones and the base soil and biomass carbon layers. The zones define the response of vegetation types to changes in climate and management. The responses are either uniformly applied across the zone on a pixel by pixel basis, or partially applied for each separate sub-model within each pixel across the zone. Hence there is:

a) No spatially explicit application of state and transition models within zones; and
b) No accounting for regional variation in carbon stock or system response within zones other than the variation supplied by spatially explicit driver layers for stocking rate, fire and climate-based growth deviation.

If a finer scale zonal map could be constructed with accompanying state and transition models, then a better representation of system response would be obtained. Better vegetation mapping does exist for the northern parts of the rangelands through Tothill and Gillies (1992) and Fox et al., (2001). The latter is available in digital form, but covers only the area of interest for the Cooperative Research Centre for Tropical Savanna Management.

Therefore, given the issues surrounding the match between the rangeland zones and the base carbon stock layers, users should view with caution the detail of the maps of carbon change produced from analysis with Range-ASSESS. The system is designed to produce aggregate estimates of change at the rangeland zone reporting level. The released version has therefore been configured to provide users with outputs at this level in the form of tables of zone stock and changes, graphs of zone stocks and changes, and frequency histograms and cumulative probability curves for stocks and change by zone and overall.

Installation

Range-ASSESS is distributed as a self-extracting zip file, containing the Range-ASSESS executable file, the input spatial data layers, an example user-defined zone, the end-user agreement, and the user guide (this document). Range-ASSESS requires Windows 95 or greater; 512Mb RAM or greater. A screen resolution of 1024 x 768 pixels or greater is recommended.
Creating a simulation using default settings

Running the program

Running Range-ASSESS. Double click on Range-ASSESS.exe

The viewer will appear with the Range-ASSESS rangelands zone map and information about the concept, design and programming attribution.
Users must read the end-user licence and be aware of the licence provisions regarding use of this software.

The command widget also opens.

This provides preliminary options for data input, index thresholds and zone models and a series of steps to follow in order to develop a scenario and run Range-ASSESS.

None of the options may be accessed until zones are selected for use in the analysis.

All data layers used in Range-ASSESS may now be viewed by clicking the “View input grids” button on the command widget. The View input grids widget allows users to examine the input data under a range of headings.
Step 1: Pressing the ‘Select rangeland zones’ button on the command widget opens the following form.

Users may select any number of zones or all zones.

Zones may then be limited to State boundaries, tenure classes, the ABARE Rangeland zone, grazed areas only, or a user-defined region.

In order to use the area limitation, the activation box must be ticked first, then one or a number of the options must be ticked.

The corresponding study region will appear in the map window.

For user-defined zones, the user must have created a layer as described under Advanced options: user-defined zones. If the activation box is ticked, the user is prompted to provide a filename.
At this stage a series of preliminary options should be examined.

**Step 2:** Set rangeland recovery rates

This option allows users to define periods (years) over which rangelands will degrade or recover. You may accept the default values or provide your own estimates. For example, Mitchell grasslands are quite resilient so you might decide that conditions for degradation of perennial grassland (i.e. the grazing index and drought index must exceed 4) must prevail for 3 years, but that good conditions (i.e. grazing index and drought index < 3) must occur for only 2 years to enable recovery. By contrast, for fragile saltbush lands, these periods might be only 2 years for degradation, but 20 years for recovery.

<table>
<thead>
<tr>
<th>Rangeland</th>
<th>Recovery</th>
<th>Degradation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi-arid woodlands</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Chenopod shrublands</td>
<td>30</td>
<td>5</td>
</tr>
<tr>
<td>Mallee</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Mitchell Dicentium grasslands</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Northern tallgrass</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Hummock grasslands</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Hummock woodlands</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Central arid woodlands</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Arid mulege</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Eastern tallgrass</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Midgrass</td>
<td>20</td>
<td>5</td>
</tr>
<tr>
<td>Cracking clay</td>
<td>20</td>
<td>5</td>
</tr>
</tbody>
</table>
**Step 3:**

On this form you can:

- change the stocking density for cattle, sheep, feral grazers, rabbits and kangaroos.
- adjust the occurrence of woody weeds.
- introduce browse shrubs within the suitable areas.
- implement prescribed burns on a range of land types within the Northern tallgrass zone.

![Management options](image)

**Step 4:**

At this stage, you can select an historical period over which to make a scenario run. This provides a period of 5 climate years which can have any historical sequence of year types associated with dry, wet or average conditions.

The period may be selected by typing in a start year, or by dragging the bar inside the year type graph to the appropriate year. The average effect of the year type combination chosen is shown as a percentage of the period and a relative change in rainfall and growth. The spatial distribution of effects can be viewed by clicking on the “View input grids” button and selecting the year type maps for display in turn.
The economic and social risks can be adjusted using the slider bars. These index levels are used to scale back the modelled carbon effect based on the index value as an indicator of the proportion of the area over which management change actually occurred.
Step 5: Pressing the ‘Model carbon’ button opens the run options dialog box.

![Image of Carbon modelling dialog box]

When you click the run button, another dialog appears asking you for a name (optional) for the scenario run.

![Image of Provide a brief description of this ASSESS run dialog box]

Once you click ‘Ok’ the run commences.

Step 6: Examining the output

At the conclusion of the run, a dialog box appears asking if you want to view the results. If yes is selected, a results spreadsheet appears in a scrollable window.

The results sheet provides:
   a) a complete listing of parameters used in the run;
   b) a complete list of natural, present and modelled carbon stocks, and changes in carbon stocks by zone; and
   c) a list of zone average values for derived variables such as dryness and grazing index.

At the bottom of this window, there are buttons for deleting the results, closing the window, and viewing graphs.

The results may be saved as a named text file using the File menu. These text files can be imported into Microsoft Excel for further manipulation and analysis.
The complete listing of parameters occupies the topmost part of the sheet. There are two types of parameters listed; ‘Global parameters’ and ‘Zone-specific parameters’. The values are taken from the various user forms of the Range-ASSESS interface, e.g. the ‘Management options’ and ‘Risk factors’ forms shown above.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nyears</td>
<td>The period over which the analysis takes places (held constant at 5 years)</td>
</tr>
<tr>
<td>LState</td>
<td>Whether the analysis is limited spatially by state, and if so, what states are to be included (WA, SA, NT, QLD, NSW, VIC).</td>
</tr>
<tr>
<td>LTenure</td>
<td>Whether the analysis is limited by tenure, and if so, what tenure classes are included (Multiple-use forests, Conservation areas, Private freehold, Private leasehold, Reserved crown land, Other Crown land, Aboriginal freehold, Aboriginal leasehold).</td>
</tr>
<tr>
<td>LGrazingLand</td>
<td>Whether the analysis is limited only to areas with domestic livestock grazing.</td>
</tr>
<tr>
<td>LABZone</td>
<td>Whether the analysis is limited by ABARE rangeland zone, and if so, what zones are included (zones1, 2 and/or 3).</td>
</tr>
<tr>
<td>CarryingCapacityLayer</td>
<td>Which of the three carrying capacity layer options are currently selected (Rainfall-based, General-fertility based or Regional-rainfall based)</td>
</tr>
<tr>
<td>StockingRateLayer</td>
<td>Which of the two stocking rate layers are currently selected (freehold/leasehold or waterpoint).</td>
</tr>
</tbody>
</table>
The zone-specific parameters offer the potential of having different parameter values for each of the 12 rangeland zones. The parameters are:

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Column headings (with explanation, where required, in parentheses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stocking densities, as a % of current</td>
<td>Cattle%, Sheep%, Grazer%, Rabbit%, K/roo% (kangaroo).</td>
</tr>
<tr>
<td>Woody weed susceptibility and resistance to fire (%)</td>
<td>W/sus, W/res.</td>
</tr>
<tr>
<td>Introduction of browse shrubs</td>
<td>bs1, bs2, bs3 (Tagasaste, Leucaena, Saltbush).</td>
</tr>
<tr>
<td>Prescribed burns to Northern tallgrass tenure zones.</td>
<td>pb1, pb2, pb3, pb4, pb5, pb6, pb7, pb8, pb9 (Multiple-use forests, Conservation areas, Private freehold, Private leasehold, Reserved crown land, Other Crown land, Aboriginal freehold, Aboriginal leasehold).</td>
</tr>
<tr>
<td>Climate start year</td>
<td>The year at which to start the 5-year record of climate.</td>
</tr>
<tr>
<td>Climate year types</td>
<td>y1, y2, y3, y4, y5, y6 (the percentage of each of the 6 possible climate year-types that are present within the selected 5-year period).</td>
</tr>
<tr>
<td>Economic and cultural risk multipliers (0-1)</td>
<td>EconRisk, CultRisk</td>
</tr>
<tr>
<td>Grazing index thresholds</td>
<td>gi1, gi2, gi3, gi4 (the threshold values for grazing pressure used in the calculation of the indices in the state-transition models)</td>
</tr>
<tr>
<td>Dryness index thresholds</td>
<td>di1, di2, di3, di4 (the threshold values for dryness (drought) used in the calculation of the indices in the state-transition models)</td>
</tr>
<tr>
<td>Fire index thresholds</td>
<td>fi1, fi2, fi3 (the threshold values for fire frequency used in the calculation of the indices in the state-transition models. Effects of fire timing are hard-wired into the state-transition models; see Hill et al. 2005).</td>
</tr>
<tr>
<td>The number of state-transition sub-models for each zone</td>
<td>NModels</td>
</tr>
<tr>
<td>The proportional coverage of each sub-model within each zone (i)</td>
<td>M[i]Prop</td>
</tr>
<tr>
<td>The number of possible states within each sub-model i.</td>
<td>M[i]NStates</td>
</tr>
<tr>
<td>The proportional coverage of each state j within each model i.</td>
<td>M[i],Sj,P</td>
</tr>
<tr>
<td>The relative soil carbon index of each state j within each model i.</td>
<td>M[i],Sj,SoilC</td>
</tr>
<tr>
<td>The relative biomass carbon index of each state j within each model i.</td>
<td>M[i],Sj,BiomassC</td>
</tr>
<tr>
<td>Rangeland degradation and recovery rates</td>
<td>YearsToFullyDegrade, YearsToFullyRecover.</td>
</tr>
</tbody>
</table>
Further down the sheet can be found the summary of the simulation results:

### RESULTS:

<table>
<thead>
<tr>
<th>Region</th>
<th>S-A Wood</th>
<th>Chemwood</th>
<th>Mahall</th>
<th>Mitchell</th>
<th>NT/A Wood</th>
<th>Hurstgrass</th>
<th>Hurst/Wood</th>
<th>CA/A Wood</th>
<th>And/Pilgas</th>
<th>El/Tahans</th>
<th>Midgrass</th>
<th>Dac/Quo</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Areas (ha</td>
<td>1100)</td>
<td>37600</td>
<td>507600</td>
<td>62125</td>
<td>43170</td>
<td>553325</td>
<td>1161000</td>
<td>732700</td>
<td>414250</td>
<td>552550</td>
<td>216725</td>
<td>275400</td>
<td>316500</td>
</tr>
</tbody>
</table>

#### NATURAL

- Soil C density (tC/ha): 47.46, 31.64, 42.08, 38.65, 57.78, 23.91, 55.74, 31.14, 25.22, 100.89, 62.82, 118.72, 42.82
- Biomass C density (tC/ha): 18.52, 9.20, 8.96, 18.79, 30.69, 4.54, 22.93, 9.84, 4.45, 54.26, 23.16, 17.05, 16.80
- Total C density (tC/ha): 57.30, 40.84, 50.67, 54.54, 97.47, 28.36, 75.67, 39.68, 28.67, 153.18, 100.31, 88.27, 61.19

#### PRESENT

- Soil C density (tC/ha): 44.20, 24.97, 41.63, 30.65, 45.90, 23.01, 55.46, 31.14, 22.70, 53.03, 57.92, 116.76, 39.96
- Biomass C density (tC/ha): 21.30, 7.00, 8.43, 18.65, 46.32, 4.26, 24.07, 8.82, 3.47, 32.29, 28.44, 10.36, 14.46
- Total C density (tC/ha): 65.50, 31.37, 52.66, 55.19, 96.40, 27.07, 79.71, 42.47, 26.17, 128.23, 71.35, 126.60, 56.44

#### MODELLED

- Soil C density (tC/ha): 43.69, 24.57, 41.63, 30.17, 45.40, 23.01, 55.47, 31.14, 22.91, 50.05, 59.29, 110.75, 39.98
- Biomass C density (tC/ha): 21.41, 7.07, 8.43, 18.65, 46.36, 4.26, 25.95, 8.18, 3.55, 49.02, 28.47, 10.32, 17.84
- Total C density (tC/ha): 65.00, 31.94, 52.66, 55.63, 96.94, 25.17, 71.11, 43.26, 26.46, 138.17, 83.56, 126.67, 57.94

#### CHANGE FROM THE PRE

- Soil C change %: -1.19, 0.22, 0.06, 0.26, -1.00, 0.00, 0.00, -0.91, 0.06, -0.17, 0.00, -0.17, 0.00, 0.00, 0.01, 0.01
- Biomass C change %: 0.02, 0.06, 0.00, 1.36, 0.76, 0.99, 1.36, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69
- Total C change %: 0.76, 0.69, 0.00, 1.36, 0.76, 0.99, 1.36, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69, 0.69

#### CLIMATE GROWTH/YEAR

- Average growth index (Yt): 0.0100, 0.0220, 0.0289, 0.0210, 0.0204, 0.0000, 0.0289, 0.0000, 0.0289, 0.0000, 0.0289, 0.0000, 0.0289, 0.0000, 0.0289
- Average drought index (Yt): 0.0300, 0.0310, 0.0315, 0.0318, 0.0318, 0.0318, 0.0318, 0.0318, 0.0318, 0.0318

#### DROUGHT INDEX

- Average drought index (Yt): 0.0300, 0.0310, 0.0315, 0.0318, 0.0318, 0.0318, 0.0318, 0.0318, 0.0318, 0.0318

#### GRASSING PRESSURE

- Average grassing pressure: 0.3916, 0.1375, 0.0443, 0.0045, 0.1329, 0.0443, 0.1074, 0.0124, 0.0045, 0.1329, 0.0443, 0.1074, 0.0124, 0.0045, 0.1329, 0.0443

### NATURAL

These values correspond to ‘natural’ or ‘pre-European’ carbon stocks (MtC, summed over the entire zone) and densities (tC/ha, expressed on a per unit area basis).

### PRESENT

These are the natural values, modified by the Range-ASSESS state-and-transition models to include the default present-day grazing regimes.

### MODELLED

These are the present values, modified by the Range-ASSESS state-and-transition models to include the user-defined changes to grazing, etc.

Also included are the % change between modeled and present, and for each zone, the spatially averaged growth index, drought (dryness) index, and grazing pressure.
If you click on View graphs, another dialog panel appears with a summary histogram of present and modelled carbon density, carbon stock and percentage change in stocks with a selection dialog for soils, biomass and total.

If you have run a number of scenarios in succession, named them and appended the results to the results file, then a dialog window at the top of the panel allows you to select previous results for viewing and comparison.
If you return to the Carbon modelling dialog panel, maps of results can be viewed. If you click the button to view change in soil carbon, a change map appears in the viewer window.

This map shows changes in soil carbon resulting from running cattle and sheep at 136% stocking density and using 1.5 as the biomass index for state 1 of the Semi-Arid Woodlands Poplar Box model. It can be seen that the Queensland woodlands have some soil carbon accumulation associated with woodland regrowth hard-wired in the zone models. It can also be seen that there is variation in soil carbon in northern Australia associated with the influence of fire and the higher grazing pressure. In particular we can see that soil carbon declines somewhat in the semi-arid woodlands of western NSW and southwestern Queensland. This run used the default climate start year of 1889 and the five-year period was one of reasonably good conditions.
A zoom window is available from the Viewer menu, and can be used to examine map detail at a range of magnifications. The maps can be saved as bitmap pictures.

**Changing the default settings**

Select “Alternate input data options” from the Command widget.

There are a number of alternative layers that may be used in Range-ASSESS.

1. **Safe carrying capacity options**

   Three versions of safe carrying capacity may be selected; one based on relationship between stocking rate and rainfall; one based on a continental relationship between winter-spring rainfall and stocking rate adjusted for soil fertility; and one based upon separate relationships between winter-spring rainfall and stocking rate for each State.

2. **Stocking rate options**

   Two versions of sheep and cattle stocking rates may be selected: one based on 1997 agricultural census data allocated onto freehold and leasehold land only; and one based on 2001 agricultural census data allocated to 8km buffer zones around stock watering points.
3. Index thresholds

Select “Adjust index thresholds” from the Command widget.

Transitions from one carbon state to another are controlled by three key indexes. The grazing index, the dryness index and the fire index. The thresholds for calculation of these from the corresponding base data for grazing pressure (total stocking rate/carrying capacity), % deviation from median long term growth, and fire frequency may be adjusted by the user. Changes to the thresholds for index levels 2 and 4 will change the way the system performs as these index values are used in the state and transition rules. For example, if the Dryness index threshold values are reduced relative to the median, more climate periods will have dryness index values of > or = 4, and < or = 2. Similarly, if the threshold for grazing index of 4 is increased, less areas will have an index of 4 or more and be potentially involved in state changes.
4. Rangeland zone model options

Select “Define rangeland zone models” from the Command widget.

The results from any run with Range-ASSESS depend directly upon the area proportions and soil and biomass carbon index values in the State and Transition Models. The user may change these from the default values for all models in all zones. This is particularly useful if recent data collection or literature has provided measurement that enable more accurate definition of the changes in soil or biomass carbon resulting from grassland degradation or ingress of woody plants.
Advanced options

1. Factorial analysis

With factorial analysis you can set up experiments with the system to look at response patterns.

You need to establish the settings for the parameters that you want to remain fixed by going through the procedure described above in 1 to 4. However, don’t make any changes to the parameter(s) that you intend to factorialise.

Then once you bring up the “Model carbon” panel, select the factorial button. Then, click the run button and a new dialog panel will appear.

This dialog panel provides three groups of model parameters for carrying out factorial analysis: management options; risk and uncertainty; and rangeland zone models.
Let us examine the risk/uncertainty options as a first example.

If you click on the button opposite climate start year, a new dialog panel appears. The user can vary the climate start year from 1889 – 1999 in equal steps of any number.

Or if the user-defined check box is clicked, another dialog panel appears. Here the user can insert starting year values manually.

Once completed, select “OK”. You will be returned to the main factorial dialog panel. The number of runs involved with your factorial combination appears in a box at the bottom right of the pane.

If factorial combinations are also selected for the “Management options” and “Rangeland zone model options” it is very easy to set up thousands of runs, and very complicated multi-factorials, which will be time consuming and difficult to interpret.

As a rule, it is better to set up single factor factorials to establish simple response functions. For example, a natural analysis might involve a series of single factor factorials with climate start date, varying the stocking rate in an increment between 0 and 200% for each separate factorial run. This would result in a series of output data sets with all possible climate outcomes for a series of changes in stocking rate. See Hill et al. (2005) for an example of the kind of analysis that is possible.
An example of simple factorial analysis is provided by the following scenario:

The default climate start year 1889 is used – this provides a relatively favourable climatic period.

Cattle and sheep stocking densities are increased to 136% each. You do this at step 2 when you adjust Management Options.

A factorial analysis is carried out to look at the effect of varying the soil carbon index for state 1 of the poplar/Box woodland model in the Semi-arid Woodland zone between 0.5 and 1.5 in 11 steps i.e. 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.1, 1.2, 1.3, 1.4, and 1.5.

You set this up by selecting the “Rangeland zone model options” pane from the “Factorial experiment options” dialog panel that appears once you click on “Model Carbon”.

![Factorial experiment options](image)
Enter 0.500, 1.500 and 11 in the fields for “Vary from”, “to” and “equal steps” respectively. Click on OK. Then click OK to close the main panel.

The dialog asking you to name the scenario run will appear. Enter a name and click “OK”.

Your scenarios will now run – the model will run iteratively 11 times and tell you when it completes offering the opportunity to view the results file.

The results file will contain the usual summary of initial conditions and parameters. It will also contain a table showing the results of each of the 11 factorial runs listed against the parameter that was varied.
Click on the button to “View graphs”.

The graphical summary result panel appears, but this time it has an additional tab for factorial output.

If you select the factorial output tab, a new graphical panel appears displaying an xy scatterplot of selectable carbon stock attributes plotted against the factorised parameter.

This panel has a number of selectable lists:

1) Chart type
2) Region to plot – allows selection of total area or other zones. In this case we are interested only in the SA woodlands.
3) Variables to plot on the y-axis (9 options): modelled soil, biomass and total C density; modelled soil, biomass and total C stock; and % change in soil, biomass and total C stock.
4) Variables to plot on the x-axis – the parameter or parameters used for the factorial.
5) Variables to plot on the z-axis - the parameters used for the factorial if more than one. This allows 3-dimensional response surfaces to be displayed and rotated, allowing the effect of the joint variation in two parameters on the model outputs to be visually assessed.

If the Chart type list is changed to “Frequency distributions”, a new graph appears showing a frequency histogram of carbon stock outcomes for the range of parameter values used.

The display shows number of occurrences of different levels of change in soil carbon arising from the factorial variation in the soil carbon index for State 1 of the poplar box model in the Semi-arid Woodland zone.
The display can be changed to show Cumulative frequency by selecting the appropriate checkbox.
2. Chart editing

A number of functions are available with the graphs:

- These buttons control the display characteristics for 3D plots
- This button enables plot rotation
- This button enables movement of plot vertically and horizontally
- This button enables the plot to be zoomed in and out.
- This button enables the axes aspect ratio to be changed.
- This button switches the graphics to a 3D xyz plot suitable for use with 2-way factorials
- This button allows the graph to be printed
- This button allows the graph to be saved to a file
- This button accesses the facility for chart editing and data export

The data, axes, titles, legend, and 3d characteristics can be changed. Help should be accessed for details.
If the “Export” tab is selected, a dialog panel appears allowing the data from the chart to be output as text or Microsoft Excel files.

These data files can then be imported into any other plotting package for production of publication quality graphs.

3. User-defined zones

When selecting the rangeland zones on which to operate, there is the option of loading a user-defined mask. This is either an ArcInfo 32-bit floating point file (*.flt) or a 32-bit floating point Idrisi raster file (*.rst). The projection of the file must be Lambert Conformal Conic with the following projection parameters:

- ref.system : Lambert Conformal Conic for Australia
- projection : Lambert Conformal Conic
- datum : Australian Geodetic 1984
- delta WGS84 : -134 -48 149
- ellipsoid : Australian National
- major s-ax : 6378160
- minor s-ax : 6356774.719
- origin long : 135
- origin lat : 0
- origin X : 0
- origin Y : 0
- scale fac : na
- units : m
- parameters : 2
- stand ln1 : -18
- stand ln2 : -36
Range-ASSESS assumes values less than or equal to zero are background, with values greater than zero defining the areas to be included. The dimensions of the layer must be:

- Number of columns: 901
- Number of rows: 701
- ref. units: m
- min. X: -2811008.2500000
- max. X: 2254512.2500000
- min. Y: -5274380.0000000
- max. Y: -1172097.8750000

An example user-defined layer is included with the software (TestUserDefinedLayer.flt, with and associated TestUserDefinedLayer.hdr ascii header file).
References


Johnson, A. (1997). Feral donkey eradication: reducing grazing pressure on Kimberley rangelands. Agriculture Western Australia, Derby,


