NCCARF Adapted Future Landscapes Project

Landscape futures analysis and NRM planning tool description

1 Introduction

The assessment of a range of possible landscape futures can aid natural resource management (NRM) planning and support investment decision-making. Informed planning and decision-making is required soon if Australia's regions are to adapt to global challenges such as climate change.

Spatially-explicit and quantitative datasets which make up landscape futures analysis are a key information product for supporting regional planning for adapted futures. Engagement with potential users of this tool—regional planners and natural resource managers—has revealed that whilst this information is of great benefit to them, standard forms of communication and delivery are inflexible and form a barrier to its use in decision-making and planning processes.

This document outlines a software tool which puts landscape futures information into the hands of natural resource managers and decision-makers for closer investigation and analysis. The tool will be developed for **two NRM regions**:

1. Eyre Peninsula (EP)
2. South Australian Murray-Darling Basin (SAMDB)

Both of these regions are dominated by agricultural land use—both are subject to ongoing environmental degradation—and both will be affected by external drivers such as climate change, policy (e.g. carbon price), and commodity prices.

The tool will use landscape futures analysis techniques to support regional natural resource management planning and investment decision-making under a range of climatic, policy, and economic scenarios. In this initial version, the tool will include demonstration applications focussing on **three key NRM planning issues**. It will enable natural resource managers and planners to explore potential options for managing these three issues given future climate, policy, and economic uncertainties. The three key NRM planning issues are:

1. Conserving biodiversity—managing remnants and restoring corridors
2. Managing weeds—targeted monitoring of future invasion risk hotspots
3. Storing carbon—finding the best places for carbon plantations

These three demonstration issues also illustrate different approaches to the application of landscape futures analysis. Conserving biodiversity uses an economic cost-benefit type approach to inform policy such as targeted incentive schemes under climate change. Managing weeds uses a risk analysis framework to identify areas at high risk of both agricultural and ecological weed invasion under climate change for targeting monitoring and management efforts. Storing carbon uses a landscape planning type approach to identify areas that are suitable (and unsuitable) for carbon plantations subject to satisfying several specific criteria. Each of the three issues is **implemented as a separate interface** in the Landscape Futures Analysis and NRM planning tool. The tool is extensible, as interfaces can be added to address other specific NRM planning issues as necessary.

Regional NRM agencies typically have limited access to Geographic Information Systems and limited capacity for their effective use. Therefore, we propose a web-based solution to communicate information on landscape futures which is described in detail below.

2 Scenarios

Four climate scenarios are considered:

1. S0 Baseline: Historical climate
2. S1 Mild warming/drying: +1 degree, 5% reduction in rainfall and 480ppm CO2
3. S2 Moderate warming/drying: +2 degrees, 15% reduction in rainfall and 550ppm CO2
4. S3 Severe warming/drying: +4 degrees, 25% reduction in rainfall and 750ppm CO2

Four agricultural commodity price scenarios are considered: 0.5x, 1.0x, 1.5x, and 2.0x 2012 prices for wheat, wool, and sheep meat.

Four carbon price scenarios are considered: 15, 30, 45, 60 $/t CO2-e.

3 NRM planning issues and interfaces

3.1 Conserving biodiversity—managing remnants and restoring corridors

This interface will support spatial planning for remnant vegetation management and the establishment of corridors, considering the benefits for biodiversity and economic trade-offs. This interface will enable the user to integrate landscape futures information with their own knowledge and experience to evaluate options for managing remnants and establishing corridors. A typical goal would be to identify areas for management and restoration that minimise the loss to agricultural production, or are achievable within a given budget. The user can also make investment and allocation decisions that are most robust to future climate change.

The user needs to be able to **visualise the data and orient themselves**:

- Display underpinning data layers include satellite imagery or aerial photography, remnant vegetation patches, land use (agriculture, protected areas, etc.), plus some ancillary data (main roads, towns etc.), water bodies (rivers etc.), floodplain, irrigated agriculture, dryland agriculture (cleared land), land tenure (public/private)
- Overlay the current extent of native vegetation
- Overlay individual species habitat suitability layers. There are a few hundred species in each region and for each species there are four layers—one for each climate change scenario. The user should be able to select individual species of interest for mapping
- Overlay biodiversity benefit layers. These show important remnant areas for management and important cleared agricultural areas for restoration—these are outputs from Zonation analysis of species niche modelling and are a key information layer. There will be 4 of these, one for each climate scenario
- Overlay cost layers. These layers are the economic returns to agriculture. One layer for each combination of agricultural commodity price and climate change scenario

- Overlay agricultural production layers. These are layers describing typical production levels for dryland agriculture in tonnes of wheat per ha, head of sheep per ha etc. One layer for each climate change scenario

- Overlay cost-benefit layers. These are the net present value of the economic returns to environmental plantings (inc. opportunity cost) divided by the biodiversity benefit score. Lower values are better. There will be 64 of these layers—one for each combination of carbon price, commodity price, and climate scenario

- Overlay incentive payment cost layers. Incentive payment cost is the likely net cost to government of an incentive payment required for landholders to switch from agriculture to environmental plantings. It is calculated as the net present value of environmental plantings minus the NPV of returns to agriculture.

- Overlay cost-benefit and incentive payment cost layers for privately-owned remnant vegetation. The costs of managing this land are calculated as the opportunity cost associated with sheep grazing.

- Layers for managing remnants and for restoring cleared lands should be able to be overlayed separately

- In all cases, the user should be able to select layers using a dialogue box displaying relevant scenario combinations

Based on information from the above layers, the user needs to be able to **identify, map, analyse, and compare areas** for both managing remnants, and for restoration of cleared agricultural land to create corridors which link remnants. To do this, the user will need to:

- Identify areas of vegetation polygons for management agreements using heads-up digitising on the screen i.e. private land of high biodiversity benefit and low opportunity cost.

- Identify areas of cleared agricultural land for environmental plantings and ecological restoration using heads-up digitising on the screen i.e. private land of high biodiversity benefit and low opportunity cost

- Dashboard should present aggregate statistics of areas selected, vegetation types, land tenure, benefit score, opportunity costs of foregone agricultural production, total foregone agricultural production (i.e. tonnes of wheat, head of sheep), cost-benefit score, total incentive payment required, and names and potentially the names and contact details of the landowners.

- The user should be able to compare several candidate areas for either remnant vegetation management and/or environmental plantings

Some **possible extensions** to the conservation corridors interface include:

1. Calculate and display the level of representation of remnant vegetation communities (% of pre-European extent remaining)

2. Calculate and display selected landscape ecology metrics for remnant vegetation polygons such as patch size, degree of fragmentation etc.

3.2 Managing weeds—targeted monitoring of future invasion risk hotspots

This interface will support the targeting of pest plant activities and weed management—including weeds that affect high-value agricultural enterprises and native ecosystems. A particular focus of this interface will be the identification of areas that become potential hotspots for weed invasion risk under climate change. Individual weed species can be analysed or hotspots involving multiple species. We will take a **risk mitigation approach** where we combine spatial layers of the likelihood with the consequence of weed invasion. Likelihood is derived from modelled weed species habitat suitability and dispersal layers such that the greater the suitability of weed habitat under climate change nearer to known locations—the greater the likelihood of invasion (Crossman et al. 2011). Consequence is derived from the potential value-at-risk from weed invasion. For agricultural weeds, the highest consequence are the high-economic-return agricultural areas. For ecological weeds, the highest consequence are those areas of high-value remnant patches or those cleared areas that are of high priority for environmental plantings and ecological restoration (see section 3.1). The risk layer is multiplicative such that high-risk areas are those that have both a high likelihood and a high consequence.

This interface can enable regional natural resource managers to target investment and effort in specific areas to address the threat of invasive species to both agricultural and native ecosystems under future climate change. This will enable the user to target monitoring, management, extension, and the provision of specific and targeted information to local landholders, farmer groups, community groups, and conservation agencies.

The user needs to be able to **visualise the data and orient themselves**:

- As for the *Conserving Biodiversity* interface, this interface must display underpinning data layers include satellite imagery or aerial photography, remnant vegetation patches, land use (agriculture, protected areas, etc.), plus some ancillary data (main roads, towns etc.), water bodies (rivers etc.), floodplain, irrigated agriculture, dryland agriculture (cleared land), land tenure (public/private)
- Overlay weed species habitat suitability layers. The user needs to be able to select one or more of these and overlay them, adjust transparency etc. For each species there will be 4 layers, one for each climate scenario. Ideally, we would allow the user to select species and then create hotspot maps for the selected species set and climate scenario (layers may need to be pre-calculated). There will need to be a distinction between agricultural weeds and ecological weeds, some weeds may pose a risk to both
- Overlay layers of economic returns to agriculture. These layers provide a metric of the agricultural value-at-risk from weeds (consequence). One layer for each climate change scenario and agricultural commodity price scenario
- Overlay conservation value layers. These layers provide a metric of the ecological value-at-risk from weeds (consequence). As for the *Conserving Biodiversity* interface, these are outputs from Zonation analysis of species niche modelling. This includes both remnant vegetation and cleared agricultural areas. One layer for each climate change scenario

Based on information from the above layers, the user needs to be able to **identify, map, analyse, and compare areas** at risk of weed invasion. To do this, the user will need to:

- Calculate risk layers for selected combinations of invasive species
- Specify risk thresholds to identify and map areas at high, moderate, or low risk

- Analyse areas at various levels of risk
- Dashboard should present aggregate statistics of areas at risk including average risk score, areas of native ecosystems and agricultural land, land tenure, biodiversity benefit score, economic returns from agricultural production, total agricultural production (i.e. tonnes of wheat, head of sheep), and potentially the names and contact details of the landowners in areas of high risk
- The user should be able to compare several candidate risk areas for management

3.3 Storing carbon—finding the best places for carbon plantations

This interface will support spatial planning for the reforestation of carbon plantations—monocultures of fast-growing *Eucalyptus* species for the sequestration of carbon in biomass. This interface will take a planning approach akin to the *traffic light* approach developed for planning the reconfiguration of irrigation districts (Crossman et al. 2011). It which will consider a number of criteria including:

- carbon sequestration potential
- land use and land tenure
- benefits for mitigating soil erosion
- water-sensitive areas
- prime agricultural land
- fire risk
- sensitive biodiversity conservation areas
- dryland and river salinity
- economic potential and trade-offs
- impacts of climate change

This interface will enable the user to integrate landscape futures information with their own knowledge and experience to evaluate options for locating carbon plantations. A typical goal would be to restrict carbon plantations to acceptable areas to support planning processes. For example, natural resource managers may want to identify areas that satisfy some combination of being privately-owned, with higher carbon sequestration potential, are at risk of wind erosion, do not affect water resources, are not prime agricultural land, do not preclude future restoration in high biodiversity priority areas, have significant economic potential, and do all this under a range of possible climate futures.

The user needs to be able to **visualise the data and orient themselves**:

- As for the *Conserving Biodiversity* interface, display underpinning data layers include satellite imagery or aerial photography, remnant vegetation patches, land use (agriculture, protected areas, etc.), plus some ancillary data (main roads, towns etc.), water bodies (rivers etc.), floodplain, irrigated agriculture, dryland agriculture (cleared land), land tenure (public/private)
- Overlay criteria layers. Criteria layers describe the spatial distribution of a selected indicator for each criteria. As a first cut, these indicator layers could be:

- carbon sequestration potential*—tonnes of CO2-e sequestered in standing forest biomass as estimated by 3-PG2
- land use—land use is the extent of cleared areas under dryland agriculture
- land tenure—public/private land tenure as per national database held by CSIRO
- benefits for mitigating soil erosion*—remotely sensed layers from UA or layers developed under Lower Murray Landscape Futures
- water-sensitive areas*—water supply catchments or areas of prescribed water resources, areas of groundwater recharge(?), increased evaportranspiration by reforestation
- prime agricultural land*—based on modelled wheat yields from APSIM
- fire risk—proxy of distance from built-up area
- sensitive biodiversity conservation areas*—high priority areas as modelled using species climatic niche modelling
- dryland and river salinity—salinity layers for SAMDB from Lower Murray Landscape Futures, not sure about EP
- economic potential and trade-offs[+]—net economic returns to carbon plantations (net of agricultural opportunity costs
- impacts of climate change—inherently considered through variation in various criteria with climate

* - there are 4 of these, one for each climate scenario

[+] - there are 64 of these, one for each climate scenario, carbon price, commodity price combination

The interface will enable the user to **explore a range of thresholds for identifying critical areas** for each criteria, such as:

- Prime agricultural areas—user can choose the cut-off of 2, 2.5, 3 tonnes of wheat per ha and assess the impact on the areas identified
- Water-sensitive areas—user can explore choosing cut-offs of 1, 2, or 3 ML/ha of increased evapotranspiration from reforestation in water supply or groundwater recharge areas

Using the thresholded criteria layers, the user needs to **overlay and intersect criteria layers, and compare areas** suitable for carbon plantations. To do this, the user will need to:

- Use suitable areas to select land parcels
- Dashboard needs to present aggregate statistics of suitable areas for each of the criteria. These metrics include areas under various land tenures, opportunity costs of foregone agricultural production, total foregone agricultural production (i.e. tonnes of wheat, head of sheep), biodiversity benefit score, impact on water resources, wind erosion, salinity etc. In addition, potentially the names and contact details of the landowners could be presented to support extension and engagement needs.

- The user should be able to compare several candidate areas for carbon plantations across multiple indicators, possibly using graphs

4 Interface features and functionality

The objective of this tool is to provide a platform that allows the team to deliver derived geographical data to be accessed by employees in the Eyre Peninsula and South Australian Murray Darling Basin Natural Resources Management agencies. The software development will incorporate four components:

1. The GIS server platform and application development software
2. Basic GIS functionality
3. Performance measures and comparison
4. User training

4.1 The GIS platform and application development software

The software may be built on an ESRI ArcGIS 10 SP2 web server which is already functioning at the National Centre for Social Applications of Geographic Information Systems (GSICA). The server enables the creation and distribution of geospatial web services in order to visualise, manage and undertake spatial analysis of geographic data.

A costs sharing and licensing arrangement will need to be negotiated before the application is developed.

Microsoft Silverlight may provide a potential development platform. It provides a cross-browser, cross-platform development environment for building and delivering internet applications for the web. The ArcGIS API for Silverlight enables the integration of ArcGIS server services and capabilities in a Silverlight application. The software may be created as an ArcGIS API for Microsoft Silverlight based on the ArcGIS web server. The ArcGIS API for Silverlight allows for:

- simple map display and interaction
- geospatial functionality beyond simple map display and interaction
- creation and display of dynamic (user –inputted) display graphics
- execution of geo-processing models for geographic analysis of data

4.2 Basic GIS functionality

The interface will need to include basic GIS functionality including:

- Loading of spatial datasets
- Simple identification tool
- User selection tool
- Visualisation tools
- Panning and zooming
- Exporting of high resolution maps, graphs, and tabular datasets

- Additional information that can be extracted from the spatial datasets that will further help in NRM decision making and communication strategies
- Layer lists identify the number of layers which can be toggled on and off through a check box and a slider can be adjusted to adjust layer opacity or ability to swipe layers
- Scale bar
- Show mouse coordinates
- A defined map projection
- Navigation actions and navigation bar – similar to Google Earth, zoom and movement around map extent
- Attribute query zoom to specific sub region

General GIS tools are also required by the user to interrogate the datasets. These include the ability to:

- Identify data values at specific points (Identify tool)
- Draw freehand areas – (Graphics Action – redline – Simplify polygon)
- Measure distances between two points (measure tool)
- Undertake interactive spatial queries to retrieve spatial features or underlying information by using point, polygon (regional representation), and areas of interest either through shape based or freehand representations
- Undertake queries with distance buffers around points of interest (dynamic buffer distance)
- Query spatial datasets without maps
- Exporting of maps to a graphical format

4.3 Performance measures and comparison

Non-spatial information describing individual properties of spatial units, through to aggregate statistics and performance metrics need to be displayed in an effective, clear, uncluttered way. A range of tables and graphs and maps may be combined for best effect.

4.4 User training

There is a need to facilitate an introduction to the use of spatial information in NRM planning for natural resource managers. There are two audiences that we need to consider, those that use the interface (NRM planners) and those that the higher level who need to understand the broader principles involved.

Therefore we have broken the software roll out into two stages.

The first is an interactive introduction to the GIS concepts which will be undertaken with the potential users (NRM planners) in the initial phases of the software development. These include the use of:

- Loading of spatial datasets
- Simple identification tool

- User selection tool
- Visualisation tools
- Panning and zooming
- Exporting of high resolution maps and table datasets
- Additional information that can be extracted from the spatial datasets that will further help in NRM decision making and communication strategies

This introduction is required so that the user has an intimate knowledge of the underlying basic processes used. Changes will be noted at this meeting and refinements made.

At meeting 2 we will take the overarching group through a process where we use the datasets in an NRM planning context.

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