# **APPENDIX 1** METHODS OF ANALYSES

## CALCULATION OF GLOBAL LANDSCAPE INTEGRITY INDEX

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### Introduction

Our approach to calculating a global landscape integrity index for Tropical Savanna Woodland builds upon the method applied by Miles *et al.* (2006). All spatial analyses were undertaken using ARCMap Version 9.0 GIS (ESRI 2004). The index developed here combined three global data sets:

- A land cover classification generated from satellite imagery by the International Geosphere-Biosphere Programme (IGBP). This layer was used to identify landscapes containing savanna vegetation, and savanna that has been cleared for cropping;
- Estimates of livestock densities for cattle, sheep and goats produced by the Food and Agricultural Organisation of the United Nations (FAO); and
- Human population numbers produced by the Center for International Earth Science Information Network (CIESIN).

Analyses were restricted to data falling within the tropical zone, defined by the Tropic of Cancer and the Tropic of Capricorn. The three indices values for each grid cell were summed to give a relative index of Landscape Integrity. Details of the data sets and analytical techniques follow.

### Global Land Cover data

Documentation about the IGBP Global Land Cover classification can be found at this URL: http://edcsns17.cr.usgs.gov/glcc/globdoc2_0.html. Our analyses used the Version 2.0 release of the global land cover characteristics database. This land cover classification was developed by the US Geological Survey's (USGS) National Center for Earth Resources Observation and Science (EROS), the University of Nebraska–Lincoln (UNL), and the Joint Research Centre of the European Commission (Loveland *et al.* 2000). The data set is derived from 1 km Advanced Very High Resolution Radiometer (AVHRR) data spanning a 12-month period (April 1992 – March 1993). The base data used are the International Geosphere Biosphere Programme (IGBP) 1 km AVHRR 10-day composites for April 1992 through March 1993 (Eidenshink and Faundeen 1994). Multitemporal AVHRR

1 Tropical Savanna with termite mound, Mungkan Kandju National Park, Cape York Peninsula. *Photo by Bruce G Thomson*

NDVI data are used to divide the landscape into land cover regions, based on seasonality. A data quality evaluation was conducted and is reported by Zhu and Yang (1996).

For these analyses we followed the definition of Savanna as proposed by Scholes and Hall (1996) who argued that the importance of the tropical tree-grass systems has been obscured in the past by the vagueness of vegetation type definitions. They noted that the woodier savanna variations are often grouped with tropical forests, while the grassier forms are lumped with temperate grasslands. In reality, related vegetation types form a seamless continuum which can only be divided into distinct structural types by applying arbitrary limits. They recommended the following definitions, which we drew upon in defining savanna for the purposes or this study:

- *Forests* have complete tree canopy cover and three or more overlapping vegetation strata;
- *Woodlands* have 50–100% tree canopy cover by trees, and a sometimes sparse, but always significant gramineous layer;
- *Savannas* have 10–50% cover by woody plants, and in the unexploited state, a well-developed grass layer; and
- *Grasslands* have less than 10% tree cover.

Based on the Scholes and Hall definition, we mapped the global distribution of Savanna using the two relevant classes of the IGBP Land Cover classification data set, namely, class (8) Woody Savannas and class (9) Savannas. In addition, class (12) was used to map Savanna that had been converted to cropland, and class (14) to map land that is a mosaic of cropland/natural vegetation.

### Global Livestock Data

The global livestock data were produced by FAO (2005). The data value units are densities (animals per square kilometre). They are corrected for the year 2000, and comprise a combination of observed and predicted estimates. Density data were available for eight species (cattle, buffalo, sheep, goats, pigs, chickens, bovines, small ruminants). We selected three indicative species, namely, cattle, sheep and goats. Note that the data did not include density estimates of feral livestock species.

### Global Human Population Data

The gridded data for the world's population were in units of *persons per* $km^2$ and were georeferenced at a 2.5 arc-minutes resolution. These data were produced by the Center for International Earth Science Information Network (CIESIN), Columbia University; United Nations Food and Agriculture Programme (FAO); and Centro Internacional de Agricultura Tropical (CIAT). The data set were published in 2005 as 'Gridded Population of the World: Future Estimates (GPWFE). Palisades, NY and the Socioeconomic Data and Applications Center (SEDAC), Columbia University. The data are available at http://sedac.ciesin.columbia.edu/gpw.

### Spatial Data Analysis

In preparation for analysis, the three data sets were converted to the same geographic projection and spatial resolution. The projection used to calculate the index was World Geodetic System spheroid of 1984 (WGS84), and the resolution was 1 km. Analyses were restricted to data falling within the tropical zone, defined by the Tropic of Cancer and the Tropic of Capricorn which lie at 23.5 degrees latitude north and south of the Equator. This tropical region was extended to 25 degrees north and south to provide an appropriate geographic buffer for the spatial analyses.

The gridded values of the Global Livestock Densities and Global Human Population Data were first normalised by their data range, resulting in relative indices scaled 0.0–1.0:

$$Xn = (X - X\,min) / (Xmax - Xmin)$$

where $X$ is the data value in each grid cell for the GIS layer, $Xmin$ is the minimum cell value in the GIS layer, and $Xmax$ is the maximum cell value in the GIS layer.

This step produced a relative Livestock Index and a Human Population Index, where '1' corresponds with high levels and '0' low levels of livestock and humans.

The Savanna data layer produced from the IGBP Land Cover Classification was assigned relative index values as follows: 0.0 = Savannas; 0.5 = Cropland/Natural Vegetation Mosaic; 1.0 = Cropland

The three relative indices values for each grid cell (i.e., Livestock Index, Human Population Index, Savanna Index) were then summed to generate a new GIS layer with values ranging from 0.0–3.0. A final Landscape Integrity Index (*LI*) was then calculated:

$$LI = 1 - ((X - Xmin) / (Xmax - Xmin))$$

where $X$ is the summed index value (Livestock,

Human Population, Savanna) for each grid cell in the GIS layer, *Xmin* is the minimum summed index value in the GIS layer, and *Xmax* is the maximum summed index value. Landscape Integrity Index values of 1.0 indicated locations that have not been exposed to high levels of the three threatening processes. The natural log was then taken of the Landscape Integrity Index layer as the distribution of the values was highly skewed with orders of magnitude difference in the value range.

### References


Eidenshink, JC & Faundeen, JL 1994, 'The 1 km AVHRR Global Land Data Set: First Stages in Implementation', *International Journal of Remote Sensing* 15, pp. 17:3, 443–3,462.

ESRI 2004, ESRI® ArcMap™ 9.0, ESRI Inc.

FAO 2005, *Global Livestock Distributions*, data archive produced by Environmental Research Group Oxford Ltd for the Food and Agriculture Organisation of the United Nations, Rome, http://ergodd.zoo.ox.ac.uk and http://ergoonline.co.uk. (FAO were the funding organisation.)

Loveland, TR, Reed, BC, Brown, JF, Ohlen, DO, Zhu, J, Yang, L & Merchant, JW 2000, 'Development of a Global Land Cover Characteristics Database and IGBP DISCover from 1km AVHRR Data', *International Journal of Remote Sensing*, vol. 21, no. 6/7, pp. 1:303–1,330.

Miles, L, Newton, AC, Defries, RS, Ravilious, C, May, I, Blyth, S, Kapos, V & Gordon, JE 2006, 'A global overview of the conservation status of tropical dry forests', *Journal of Biogeography*, pp. 33:491–505.

Scholes, RJ & Hall, DO 1996, 'The carbon budget of tropical savannas, woodlands and grasslands', *Global Change: effects on coniferous forests and grasslands*, eds. A Breymeyer *et al.*, SCOPE 56, John Wiley, Chichester, pp. 66–100.

Zhu, L & Yang, L 1996, Characteristics of the 1 km AVHRR data set for North America. *International Journal of Remote Sensing*, www.informaworld.com/smpp/title~content=t713722504~db=all~tab=issueslist~branches=17#v17, 17 (10), pp. 1915–1924.


## DATA AND METHODS FOR CONTINENTAL COMPARISON OF AUSTRALIAN WOODLANDS

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### Data

There were three geographic data sets used in the continental comparison of the condition of Australia's woodland vegetation: (1) Carnahan's map of pre-1788 Australian vegetation (Commonwealth of Australia 2003), recently modified with supplementary data (Nicholas Gellie, *pers. comm.*); hereafter the Carnahan map; (2) the Integrated Vegetation Cover V1 of the Bureau of Rural Sciences (BRS 2003); hereafter IVC1; and (3) An unpublished continental assessment of vegetation condition that used the VAST approach (Thackway and Lesslie 2006); hereafter, the VAST data.

The pre-1788 distribution of Australian Low and Medium Woodland was obtained from the Carnahan map at a map scale of 1:5 million scale map. The map broadly shows the probable state of Australia's vegetation around 1788 when European settlement began, depicting 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. The mapped data are available as a GIS layer, geo-coded with geographical coordinates (latitude and longitude) in decimal degrees using the Australian Geodetic Datum 1966 (AGD 1966).

The pre-1788 distribution of Australian Woodland vegetation was mapped by selecting the following formations from the Carnahan map:

1. Eucalypt Low Open Woodland
2. Eucalypt Low Woodland
3. Eucalypt Melaleuca Low Woodland
4. Eucalypt Open Woodland
5. Eucalypt Woodlands
6. Low Open Woodland
7. Low Woodland
8. Melaleuca Low Open Woodland
9. Melaleuca Low Woodland
10. Melaleuca Woodland
11. Terminalia/Lysiphyllum Low Open Woodland

Based on the these formation classes, we were able to distinguish between Low and Medium Woodlands where Low Woodland

has a tree canopy <10 metres, and Medium Woodland has a tree canopy 10–30 metres.

Geographic data about land cleared for cropping and other forms of intensive land use activity were obtained from the IVC1 which was compiled from a number of recent vegetation-related datasets. Data are stored as a raster of 100 m resolution and are projected in Albers conic equal-area coordinates. Version 1 incorporates a selection of the latest available vegetation data as at July 2003. Vegetation cover in the IVC1 dataset is described using a 12-class attribute schema that was developed to meet vegetation-related information needs of the Commonwealth Government natural resource management arena.

The VAST data were generated following the approach documented by Thackway and Lesslie (2006) using available continental scaled data. This new continental VAST analysis was made available curtsey of the authors. VAST is an approach to classifying vegetation condition along a set of ranked (ordinal) classes as detailed in Thackway and Lesslie (2006).

### Calculations

The spatial data were stored in the D_WGS_1984 (Degrees) map projection. However, for the GIS calculation, the data were re-projected to Lambert Conformal Conic (Meters). The cell resolution used for the analysis was 0.01º, which is the resolution of the VAST data grid. ArcMap was used to generate the maps and calculate the geographic statistics. The pre-1788 Woodland coverage was the overlaid with (1) land cleared for intensive land use (including cropping) from IVC1 and (2) the continental VAST data. The percentage of each VAST class (and land cleared for cropping) was calculated for the pre-1788 distribution of Low and Medium Woodland. These percentages were then calculated for Northern Australia.

### References

Australian Survey and Land Information Group (AUSLIG) 1990, *Atlas of Australian Resources, Vegetation*, third series, vol. 6, Canberra, viewed 20 July 2006, Australian Government Geoscience Australia, 2004, http://www.ga.gov.au/nmd/products/thematic/veg.htm.

BRS, The Bureau of Rural Sciences 2003, *Integrated Vegetation Cover V1*, Australian Government Department of Agriculture, Fisheries and Forestry, viewed 20 July 2006, ivc03_md.doc (D:\Data\wc_Data\vegetation\BRS\Integrated_veg\vcov_exp).

Thackway, R & Lesslie, R 2006, 'Reporting vegetation condition using the Vegetation Assets, States and Transitions (VAST) framework', *Ecological Management & Restoration* 7, pp. 1: 53–62.

## AUSTRALIAN RIVER DISTURBANCE INDEX

The River Disturbance Index (RDI) shown in Figure 4.6 is an update of the continental Wild Rivers analysis undertaken by Janet Stein and colleagues and reported in Stein *et al.* (2002). The analysis shown in Map 1 was kindly provided for this report by Janet Stein. The RDI is designed to assess anthropogenic river disturbance. The GIS-based method calculates indices of disturbance for individual stream segments. The method considers both point and diffuse impacts on water quality, and includes both catchment and in-stream factors that alter flow regimes. Specifically, the method used data about the intensity and extent of human activities within the catchment, along with in-stream structures that alter the flow regime.

### References

Stein, JL, Stein, JA & Nix, HA 2002, 'Spatial analysis of anthropogenic river disturbance at regional and continental scales: identifying the wild rivers of Australia', *Landscape and Urban Planning*, pp. 60:1–25.