www.csiro.au

Predicting the functional properties of Australian soils

Prospects and priorities for terrestrial carbon-cycle research

Neil McKenzie
CSIRO Land and Water
August 2007

CSIRO

Outline

- Australian soils and landscapes
- Key functional properties
- Status of spatial data – Australian Soil Resource Information System (ASRIS)
- Limits to prediction
- Transition to digital soil mapping
- Monitoring and forecasting soil condition

Australian soils and landscapes

- Australian soils and landscapes have coevolved with vegetation and fauna
- Ancient landscapes are widespread and have multiple environmental imprints
- Affinities with other Gondwanan landscapes
- While generally weathered and impoverished, there are young soils and landscapes with good nutrient supplies

Mapping key functional soil properties

Plant available water capacity (tractable)

- Function of available water capacity, constraints to root growth and species
- Difficult to measure precisely
- Local hydrology (e.g. land surface, landform) is critical

Nutrient supply capacity (tractable)

- Cation Exchange Capacity
- pH

Carbon fractions (tractable with new methods)

- Total organic carbon, particulate organic carbon, humus, charcoal

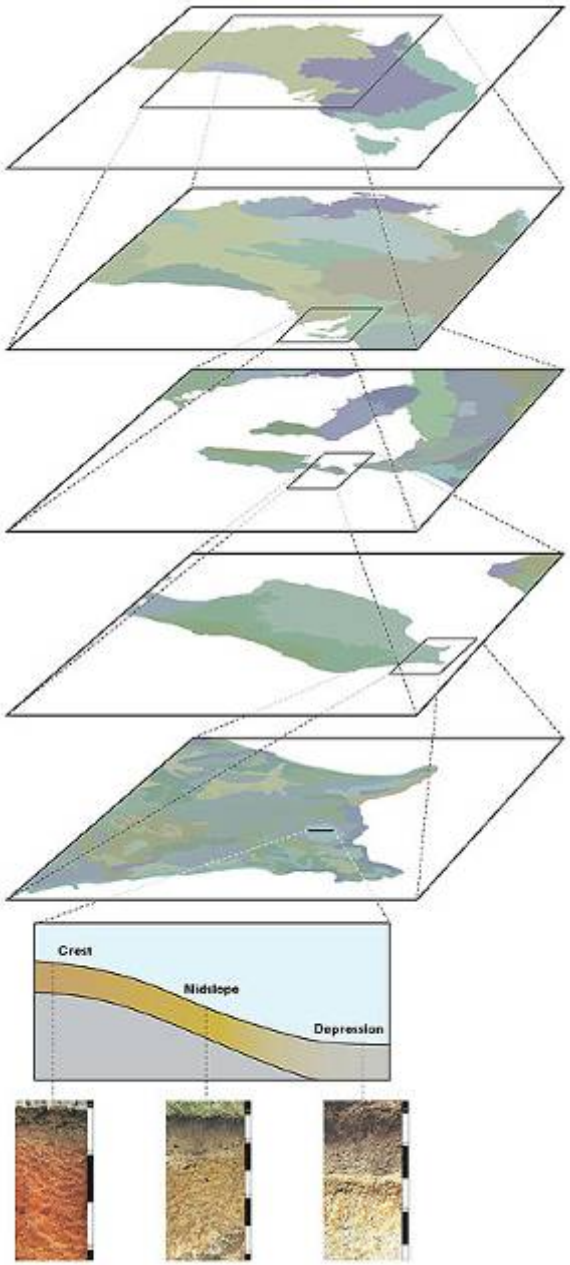
Individual concentrations of nutrients (difficult)

- N, P, K
- Nutrient availability is more difficult than total concentration

Status of spatial data
The Australian Soil Resource Information System (ASRIS)

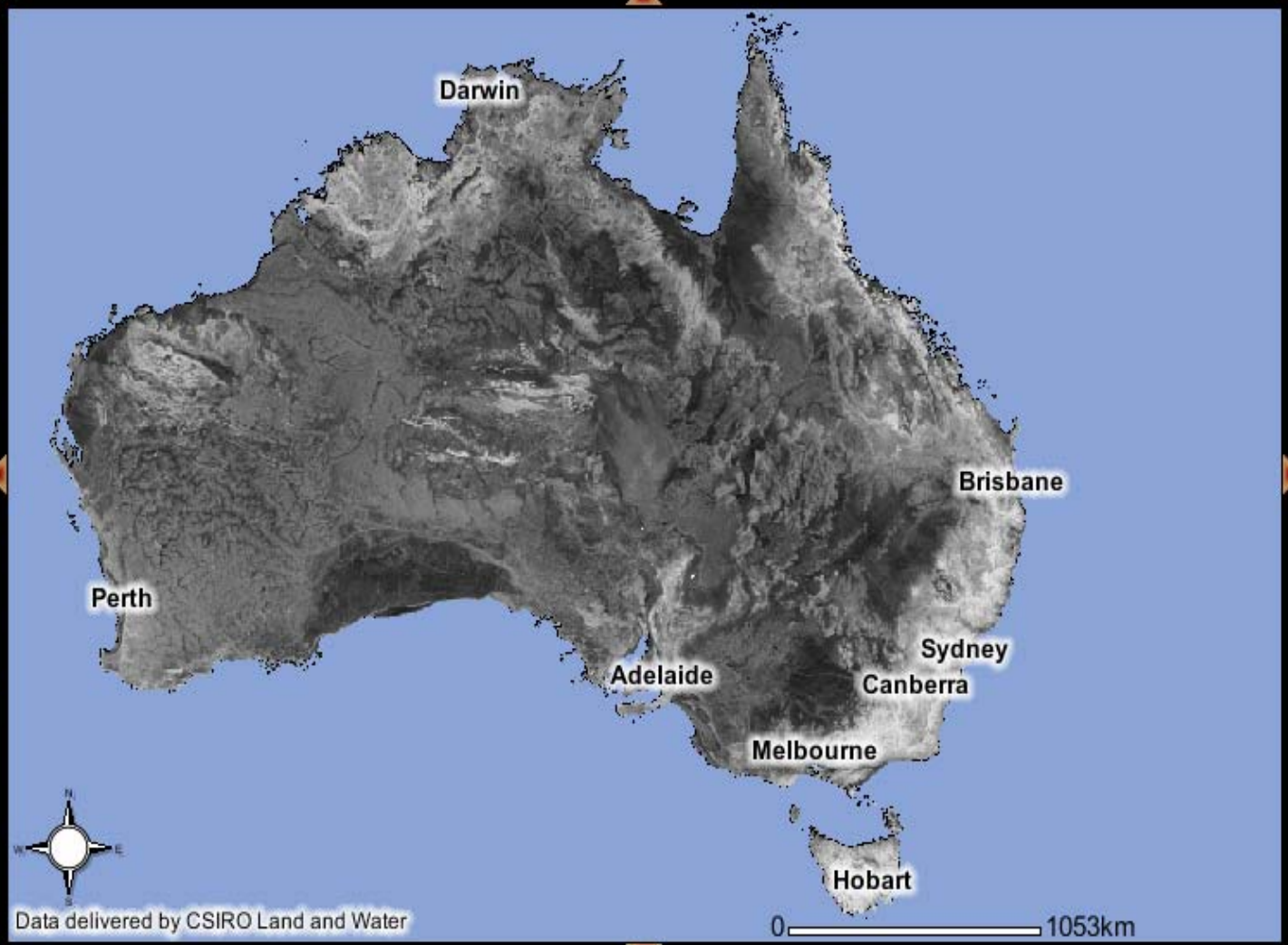
ASRIS is an online geographic information system and it:

- provides access to the best available soil and land resource information across Australia
- combines the best of qualitative mapping with new quantitative information
- integrates soil and land information from many sources
- opens many new possibilities for monitoring and forecasting the condition of Australia's soils and landscapes.



Level and tract name	Mapping window	Main attributes used for mapping	Typical uses for the information
Level 1 Division	30 km	Broad physiography (slope and relief)	Broad geographic context
Level 2 Province	10 km	Water balance, physiography	National natural resource policy
Level 3 Zone	3 km	Substrate lithology, water balance, physiography	Regional natural resource policy
Level 4 District	1 km	Groupings of geomorphically related systems	Catchment planning, location of new industries
Level 5 System	300 m	Local climate, relief, slope, lithology, drainage network, soil profile class	Catchment management, hydrological modelling, land conservation, infrastructure planning
Level 6 Facet	30 m	Slope, aspect, land curvature, soil profile class	Farm management, land-use planning, on-ground works
Level 7 Site	10 m	Soil properties, surface condition, microrelief	Precision agriculture, site development

Maps - Pan



Layers

- Geographic Context
- Level 7 (Point Data)
- Level 5 (Intensive)
- Level 4
- Level 3
- Level 2
- Level 1 (Broadscale)
- Australian Frameworks
- Coastal Acid Sulfate Soils
- APSRU
- Landscape and Climate
  - Pre-European Vegetation
  - Relief
  - Hill Slope length
  - Runoff and Drainage
  - MrVBF
  - Land Use Catchment Scale
  - Land Use 96-97
  - Landsat Mosaic 2002
  - Topo Map
  - Hill Shade 90m
  - Hill Shade 250m
- ASRIS 2001
- Base Map

Legend

Help

Messages

Australia (all attributes), south west Western Australia (limited attribution) and parts of Queensland (Level 5 pH only).

REFRESH MAP

Auto Refresh

GDA94 Longitude: 163.5512 Latitude: -16.4936 Bookmark: -select- Approx Scale: 1 : 27,075,602

ASRIS

Australian Soil Resource Information System

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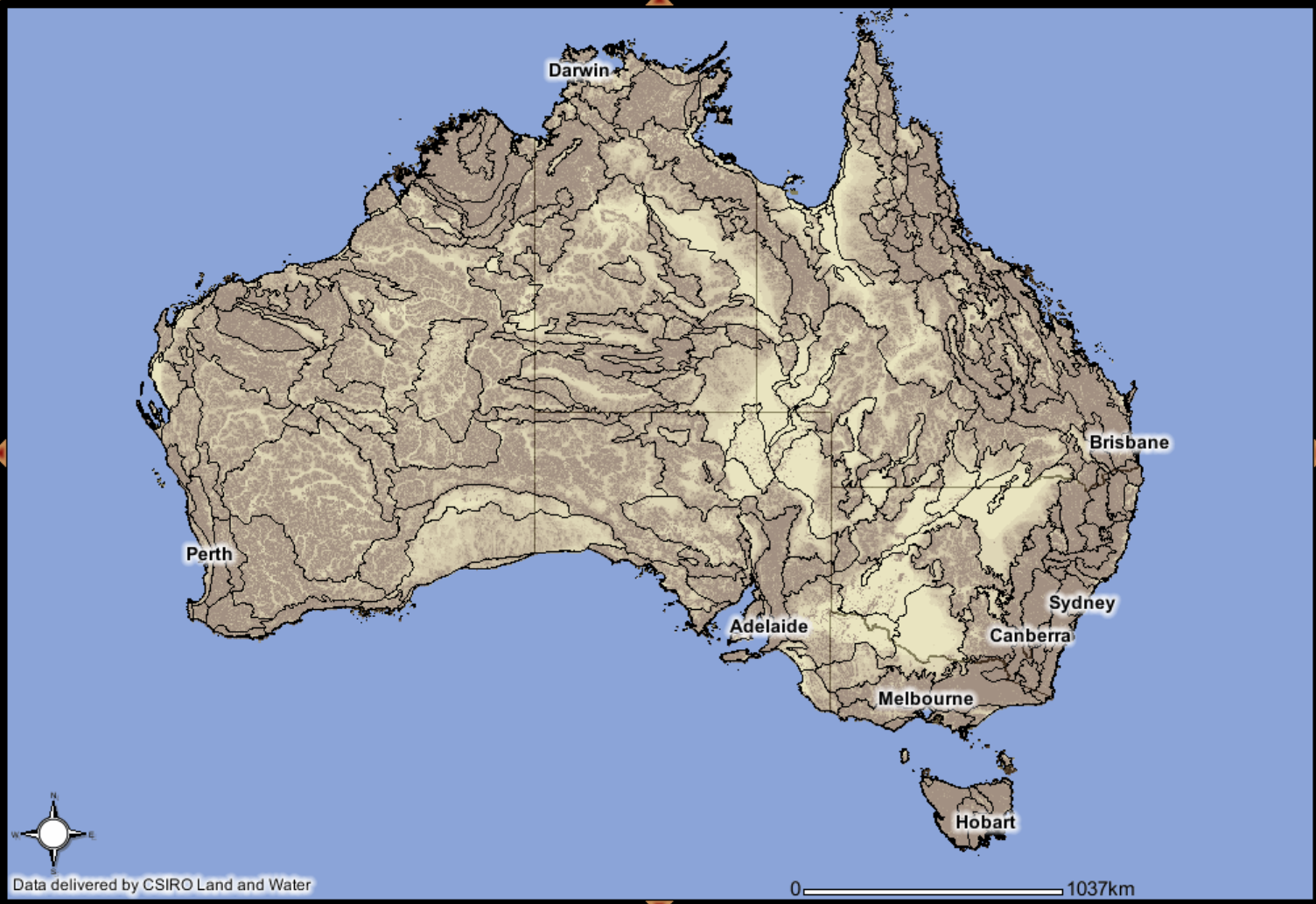
Maps - Zoom In



L2 Provinces is now the Active Layer

Layers

- L3 Extent
- L3 Tracts
- L3 Drainage
- L3 Rock Outcrop
- L3 Surface Fragments
- Texture/Clay Content
- Bulk Density
- Available Water Capacity
- Hydraulic Conductivity
- Aggregate Stability
- Organic Carbon
- pH
- Electrical Conductivity
- Exchangeable Bases
- Cation Exchange Capacity
- Ex. Sodium Percentage
- L3 ASC Soil Order
- L3 Substrate Permeability
- Atlas Tracts
- Atlas ASC Soil Order
- Atlas PAWC
- L3 NT TRACTS
- L3 Regions
- Level 2
- Level 1 (Broadscale)
- Australian Frameworks
- Coastal Acid Sulfate Soils
- APSRU
- Landscape and Climate
  - Pre-European Vegetation
  - Relief
  - Hill Slope length
  - Runoff and Drainage
  - MrVBF
  - Land Use Catchment Scale
  - Land Use 96-97
  - Landsat Mosaic 2002

Legend

Help

Messages

Currently, level 3, 4 and 5 soil attribute maps are only available for southern South Australia, north west Tasmania, south

REFRESH MAP

Auto Refresh

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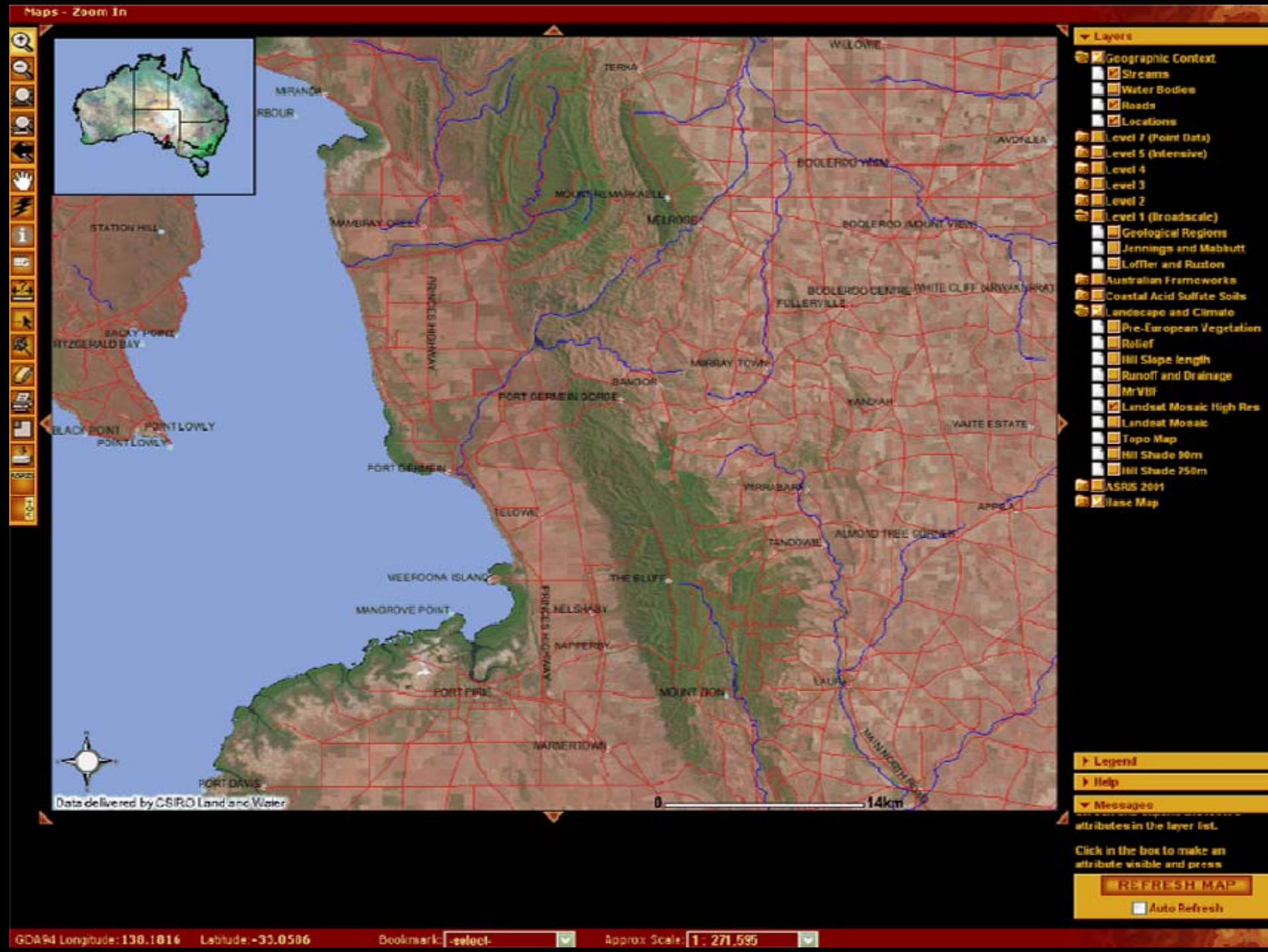
Maps - Zoom In
Layers
Geographic Context
Streams
Water Bodies
Roads
Locations
Level 7 (Point Data)
Level 5 (Intensive)
Level 4
Level 3
Level 2
Level 1 (Broadscale)
Geological Regions
Jennings and Mabbutt
Loffler and Ruxton
Australian Frameworks
Coastal Acid Sulfate Soils
Landscape and Climate
Pre-European Vegetation
Relief
Hill Slope length
Runoff and Drainage
MrVBI
Landsat Mosaic High Res
Landsat Mosaic
Topo Map
Hill Shade 90m
Hill Shade 250m
ASRIS 2001
Base Map
Legend
Help
Messages
attributes in the layer list.
Click in the box to make an attribute visible and press
REFRESH MAP
Auto Refresh
STATION HILL
BACKY POINT
FITZGERALD BAY
BLACK POINT
POINT LOWLY
PORT GERMEIN
TELOWIE
WEEROONA ISLAND
MANGROVE POINT
PORT PIRIE
PORT DAVIS
WARNERTOWN
MOUNT ROSA
NELSHABY
NAPPERBY
THE BLUFF
TANDOWIE
ALMOND TREE CORNER
YIRRABARA
APPILA
LAURA
MOUNT HOPE
MAINNORTH ROAD
PRINCES HIGHWAY
MURRAY TOWN
BANDON
PORT GERMEIN GORGE
YANDYAH
WAITE ESTATE
FULLERVILLE
BOOLEROO CENTRE
WHITE CLIFF (WARWAKIRNA)
BOOLEROO (MOUNT VIEW)
MELROSE
MOUNT REMARKABLE
MAMBRAY CREEK
TERKA
WILLOWIE
AVONLEA
BOOLEROO VIEW
MIRANDA
RBOUR
Data delivered by CSIRO Land and Water
0
14km
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Latitude: -33.0506
Bookmark: -select-
Approx Scale: 1 : 271,595

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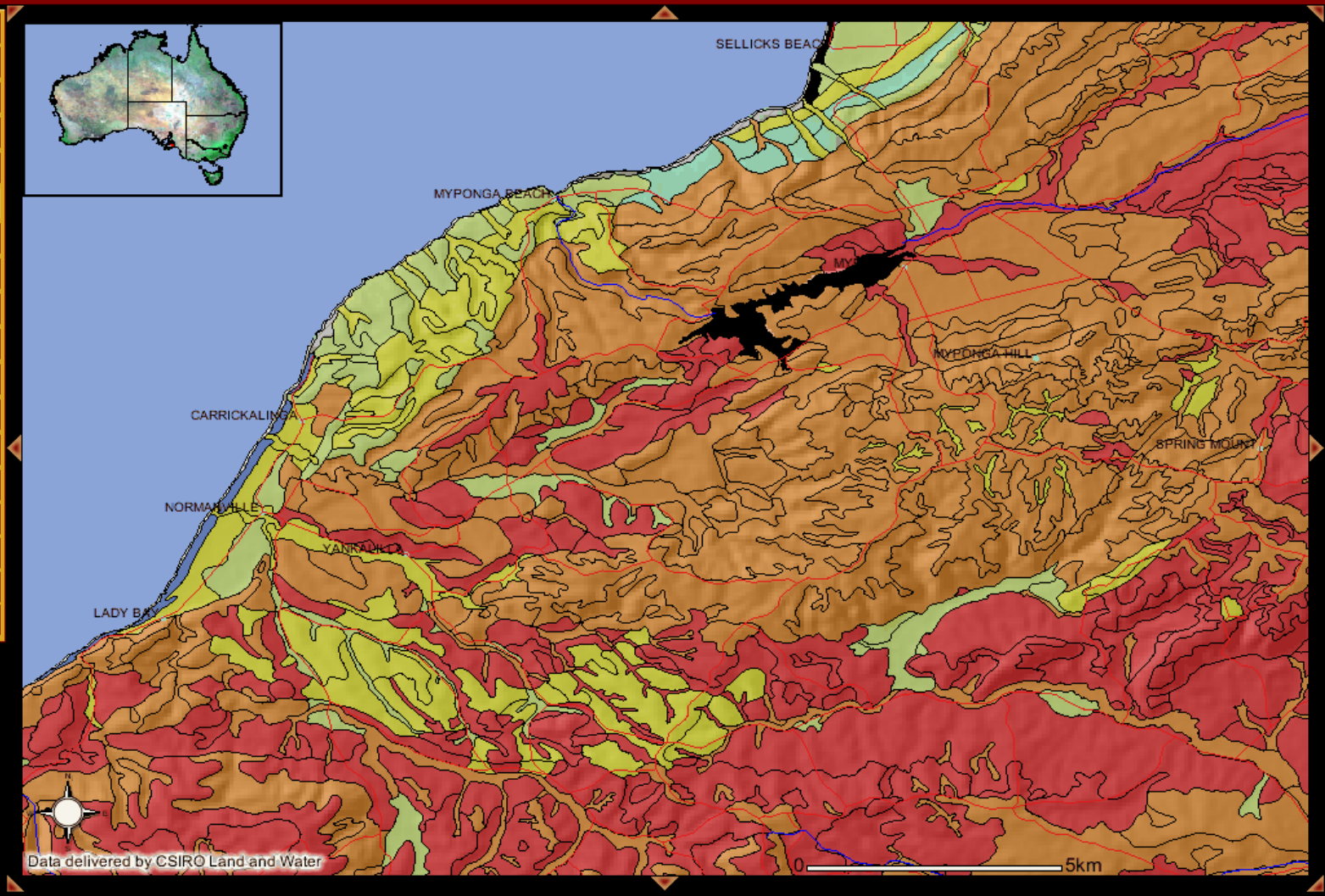
Maps - Pan



Layers

- Geographic Context
- Level 7 (Point Data)
- Level 5 (Intensive)
  - L5 Extent
  - L5 Tracts
  - L5 Drainage
  - L5 Rock Outcrop
  - L5 Surface Fragments
  - Texture/Clay Content
  - Bulk Density
  - Available Water Content
  - Hydraulic Conductivity
  - Aggregate Stability
  - Organic Carbon
  - pH
    - L5 pH Layer 1
    - L5 pH Layer 2
    - L5 pH Layer 3
    - L5 pH Layer 4
    - L5 pH Layer 5
  - Electrical Conductivity
  - Exchangeable Bases
  - Cation Exchange Capacity
  - Ex. Sodium Percentage
  - L5 ASC Soil Order
  - L5 Substrate Permeability
- Level 4
- Level 3
- Level 2
- Level 1 (Broadscale)
- Australian Frameworks
- Coastal Acid Sulfate Soils
- APSRU
- Landscape and Climate
  - Pre-European Vegetation
  - Relief

Legend

Help

Messages

ASRIS will provide the best available land resource data for Australia by the end of 2006.

REFRESH MAP

Auto Refresh

GDA94 Longitude: 138.3636 Latitude: -35.5074 Bookmark: -select- Approx Scale: 1 : 100,889

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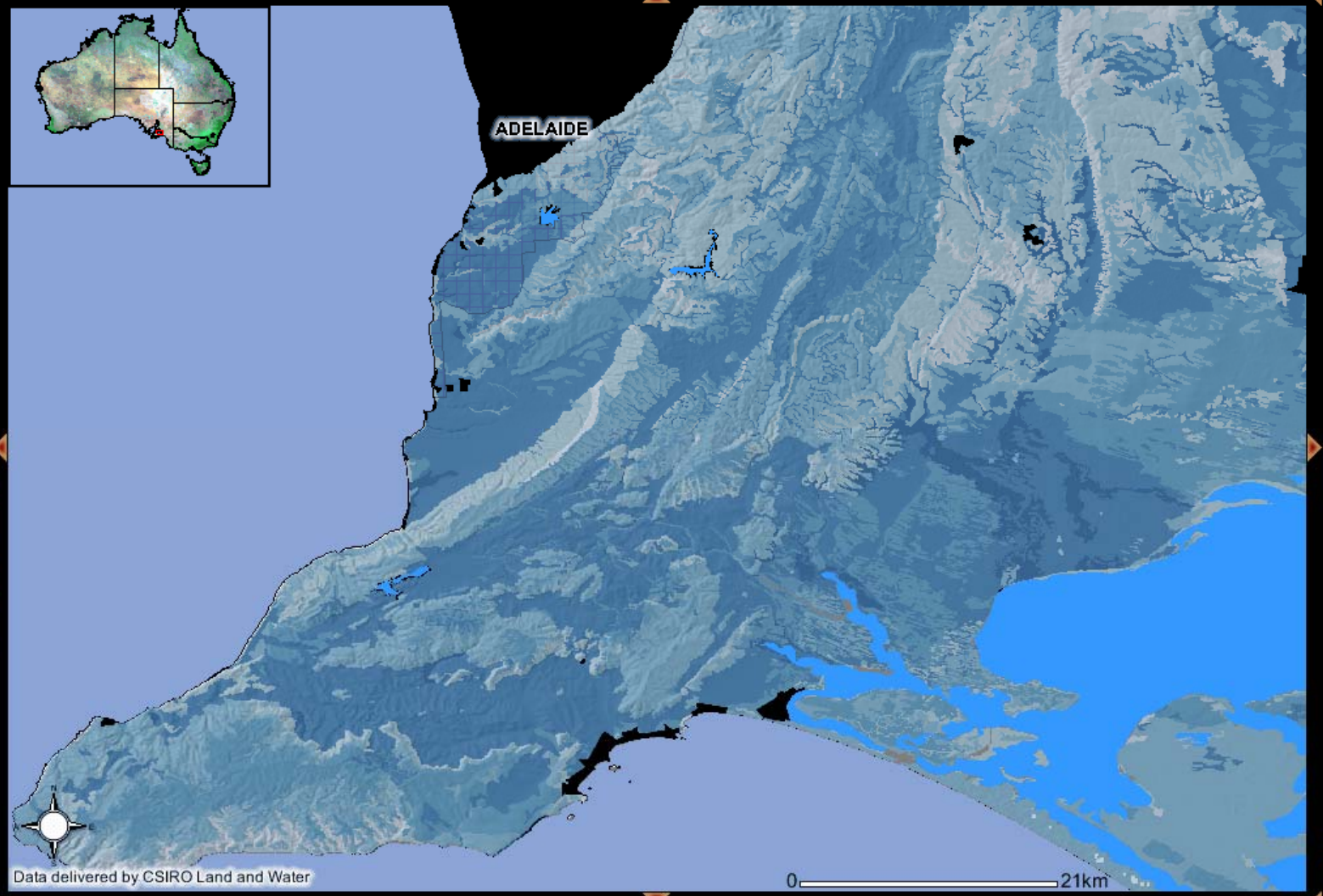
Maps - Pan



Layers

Legend

- Inland Water Bodies
- L5 PAWC Perenial Native Vegetation
- 0 - 25 mm
- 25 - 50 mm
- 50 - 100 mm
- 100 - 150 mm
- 150 - 200 mm
- 200 - 250 mm
- 250 - 400 mm
- > 400 mm
- Not Applicable
- Not Recorded
- Builtup Areas
- Hill Shade 90m
- Base-Map

Help

Messages

The maps presented on this website only provide a graphical representation of the data. Analysis and queries must be

REFRESH MAP

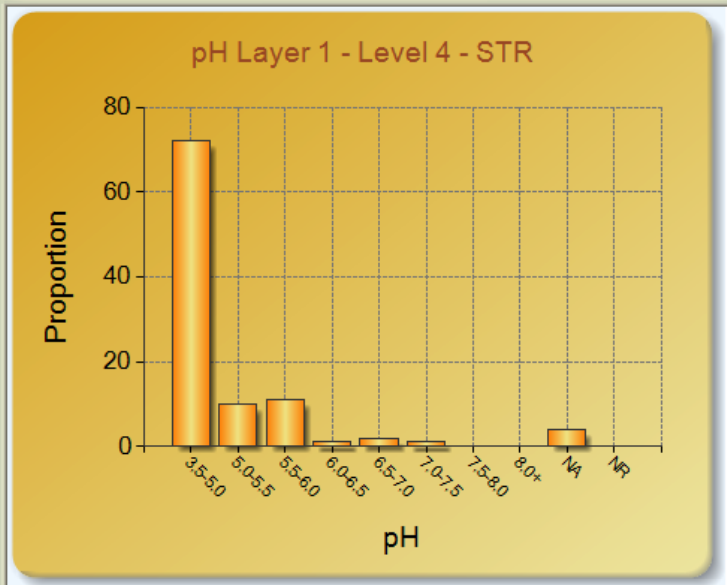
Auto Refresh

ASRIS

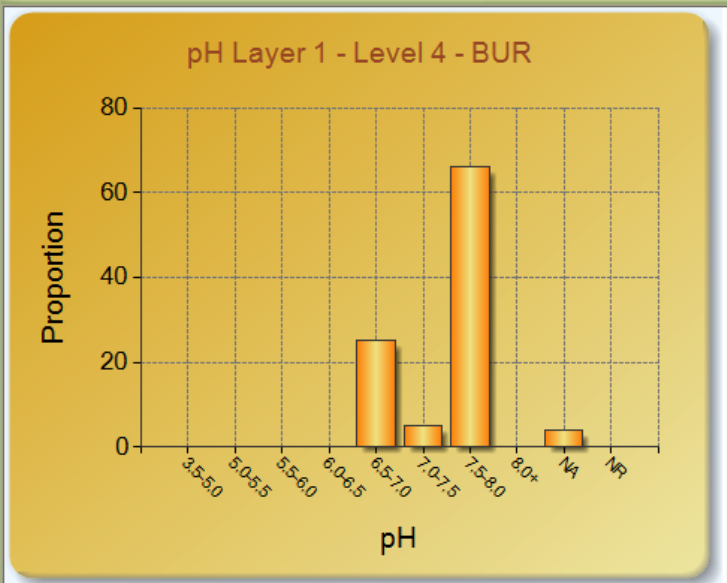
Australian Soil Resource Information System

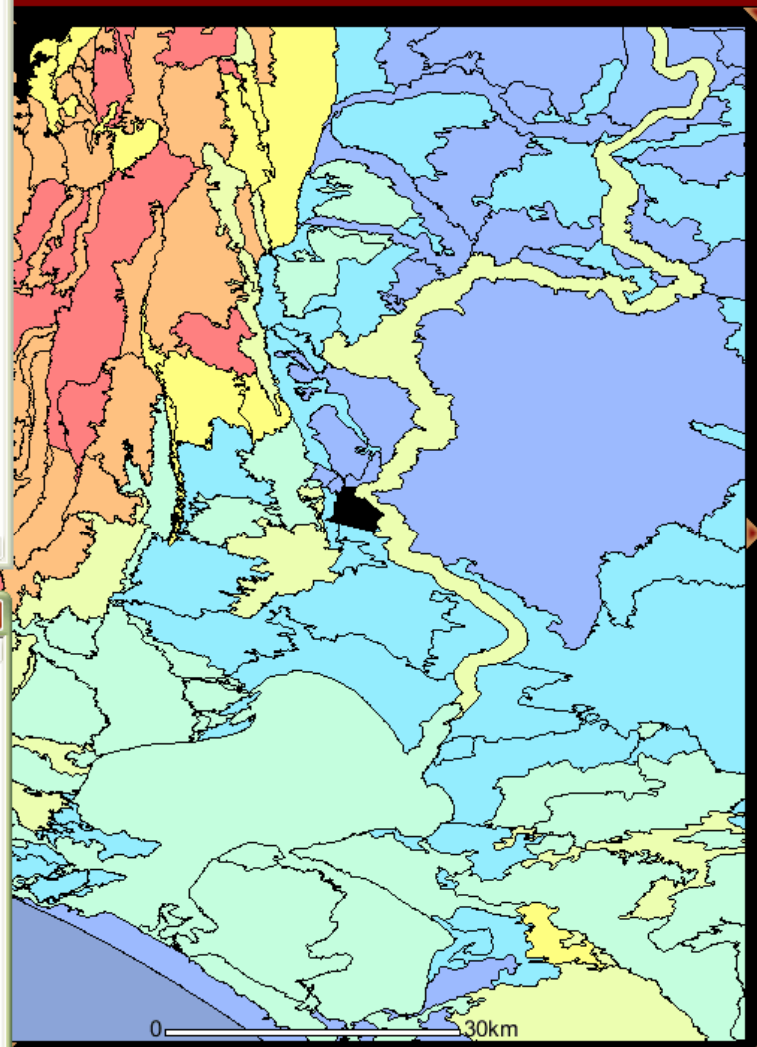
Contacts

Asris Graph - Microsoft Internet Explorer



Asris Graph - Microsoft Internet Explorer





Layers

- L4 Tracts
- NSW Landsystems Tracts
- TAS Landsystems Tracts
- VIC Geomorphic Units
- NT Landsystems Tracts
- L4 Drainage
- L4 Rock Outcrop
- L4 Surface Fragments
- Texture/Clay Content
- Bulk Density
- Available Water Content
- Hydraulic Conductivity
- Aggregate Stability
- Organic Carbon
- pH
  - L4 pH Layer 1
  - L4 pH Layer 2
  - L4 pH Layer 3
  - L4 pH Layer 4
  - L4 pH Layer 5
- Electrical Conductivity
- Exchangeable Bases
- Cation Exchange Capacity
- Ex. Sodium Percentage
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- L4 Substrate Permeability
- Level 3
- Level 2
- Level 1 (Broadscale)
- Australian Frameworks
- Coastal Acid Sulfate Soils
- APSRU
- Landscape and Climate
- ASRIS 2001
- Base Map

Legend

Help

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for the south eastern agricultural region of South Australia.

REFRESH MAP

Auto Refresh

LBC_poly^BUR&T=pH%20Layer%201%20-%20Level%204%20-%20&YT=Proportion&XT=pH

Approx Scale: 1 : 574,484

ASRIS

Australian Soil Resource Information System

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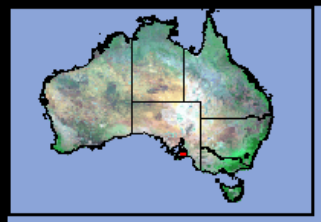
Maps - Hyperlink



MYPONGA BEACH

CARRICKALINGA

NORMANVILLE

LADY BAY

CH003

CH0

RAPID BAY SECOND VALLEY

CH100

CH105

CH020

CH102

DELAMERE

CH103

CH104

CH058

Data delivered by CSIRO Land and Water

Reference profiles

Hyperlink to http://www.asris.csiro.au/mapping/hyperdocs/SA/CH100.pdf

http://www.asris.csiro.au/mapping/hyperdocs/SA/CH100.pdf -...

Bookmarks | Signatures | Layers | Pages | Comments

BLACK CRACKING CLAY

General Description: *Black cracking clay with a well structured surface, becoming coarsely structured, greyer and calcareous with depth*

Landform: Gentle to moderate slopes.

Substrate: Grey heavy clay with coarse structure and slickensides.

Vegetation: Grassland

Type Site:

Site No.:	CH100	1:50,000 sheet:	6526-4 (Cape Jervis)
Hundred:	Yankalilla	Easting:	248150
Section:	1556	Northing:	6065100
Sampling date:	17/10/96	Annual rainfall:	600 mm

Fan adjacent rolling low hills. Hard setting, cracking surface, 8% slope. Water table at 130 cm.

Soil Description:

Depth (cm)	*Description*
0-10	Black firm medium clay with strong polyhedral structure. Clear to:
10-30	Black calcareous heavy clay with strong coarse blocky breaking to strong polyhedral structure. Abrupt to:
30-45	Orange and dark brown calcareous heavy clay with weak coarse blocky breaking to strong polyhedral structure. Abrupt to:
45-70	Olive brown and orange calcareous heavy clay with weak coarse blocky structure and 20-50% soft carbonate. Gradual to:
70-120	Greyish brown very highly calcareous heavy clay with weak blocky structure and 20-50% soft carbonate. Clear to:
120-140	Olive heavy clay with strong lenticular structure, slickensides and 2-10% soft carbonate segregations.

Classification: Epicalcareous, Epipedal, Black Vertosol

8.26 x 11.69 in

1 of 2

Layers

- Geographic Context
- Level 7 (Point Data)
  - Reference Profiles
- Level 5 (Intensive)
  - L5 Extent
  - L5 Tracts
  - L5 Drainage
  - L5 Rock Outcrop
  - L5 Surface Fragments
  - Texture/Clay Content
  - Bulk Density
  - Available Water Content
  - Hydraulic Conductivity
  - Aggregate Stability
  - Organic Carbon
    - L5 OC Layer 1
    - L5 OC Layer 2
    - L5 OC Layer 3
    - L5 OC Layer 4
    - L5 OC Layer 5
  - pH
  - Electrical Conductivity
  - Exchangeable Bases
  - Cation Exchange Capacity
  - Ex. Sodium Percentage
  - L5 ASC Soil Order
  - L5 Substrate Permeability
- Level 4
- Level 3
- Level 2
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- Australian Frameworks
- Coastal Acid Sulfate Soils
- APSRU
- Landscape and Climate
- ASRIS 2001

Legend

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the layer list.

Click in the box to make an attribute visible and press

REFRESH MAP

Auto Refresh

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ASRIS

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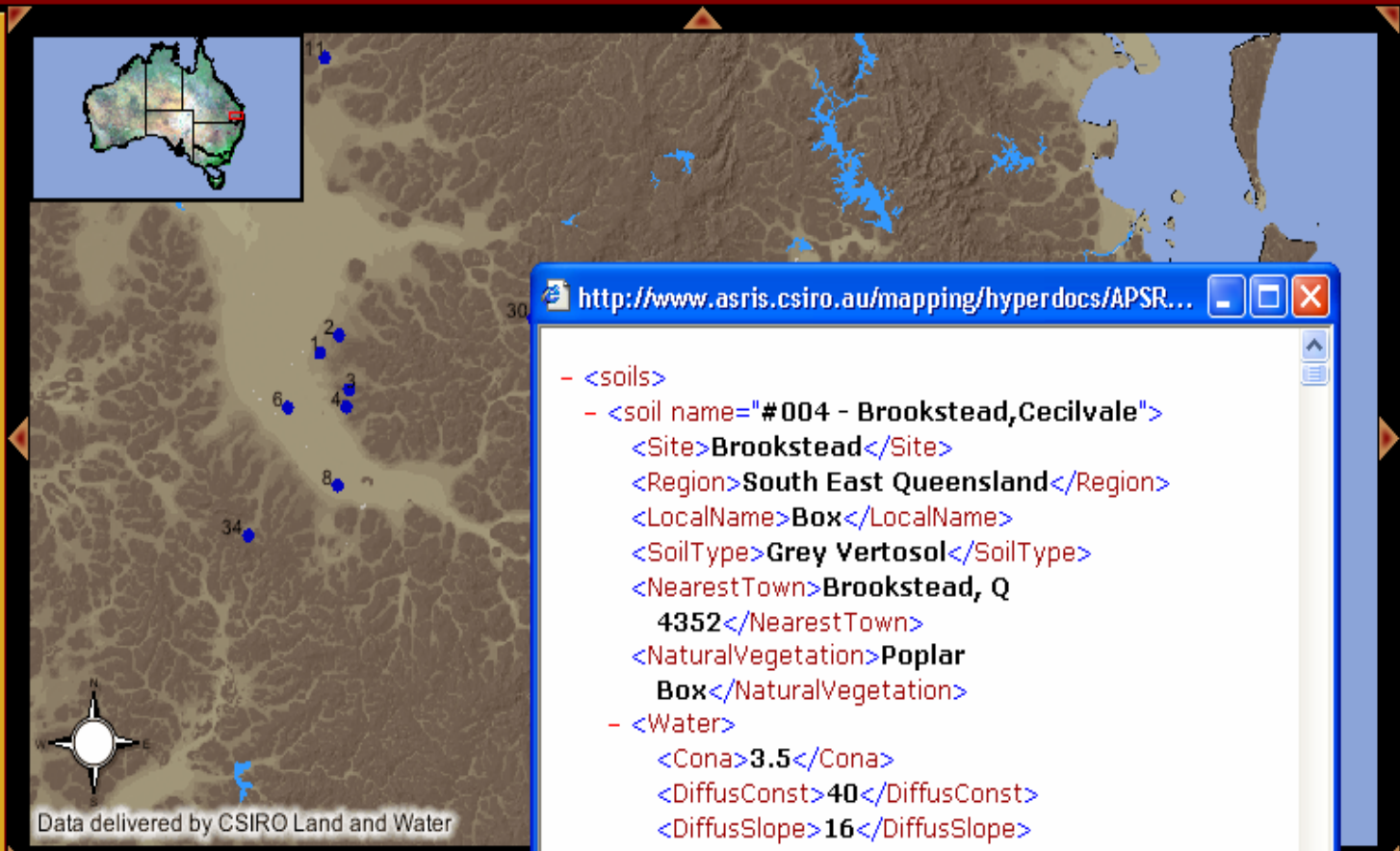
Maps - Hyperlink



APSRU Reference Sites

Hyperlink to http://www.asris.csiro.au/mapping/hyperdocs/APS

http://www.asris.csiro.au/mapping/hyperdocs/APSR...

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        <CnRed>20</CnRed>
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Done | Internet

Layers

- APSRU
  - APSRU Reference Sites
- Landscape and Climate
  - Pre-European Vegetation
  - Relief
  - Hill Slope length
  - Runoff and Drainage
  - MrVBF
  - Land Use Catchment Scal
  - Land Use 96-97
  - Landsat Mosaic 2002
  - Topo Map
  - Hill Shade 90m
  - Hill Shade 250m
- ASRIS 2001
- Base Map
  - Capitals
  - Builtup Areas
  - Lat/Long Grid

Legend

Help

Messages

Site designed and developed by CSIRO Land and Water and ESRI Australia.

REFRESH MAP

Auto Refresh

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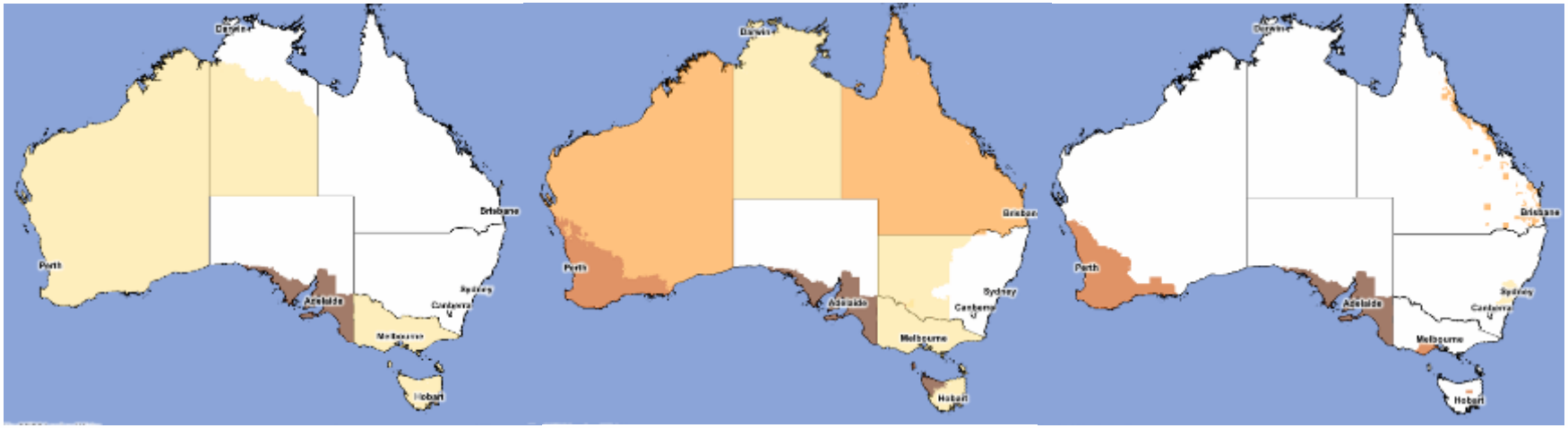
August 2007



Level 3: land zone

Level 4: land district

Level 5: land system

Why is ASRIS significant in Australia?

- Framework for accumulating and communicating knowledge about Australia's soils and landscapes
- Provides the point of access on soil for scientists analysing the major natural resource issues of our time
- Industry groups can assess opportunities for expansion and new crops
- Land holders learn about the characteristics of their soils

Why is ASRIS significant more generally?

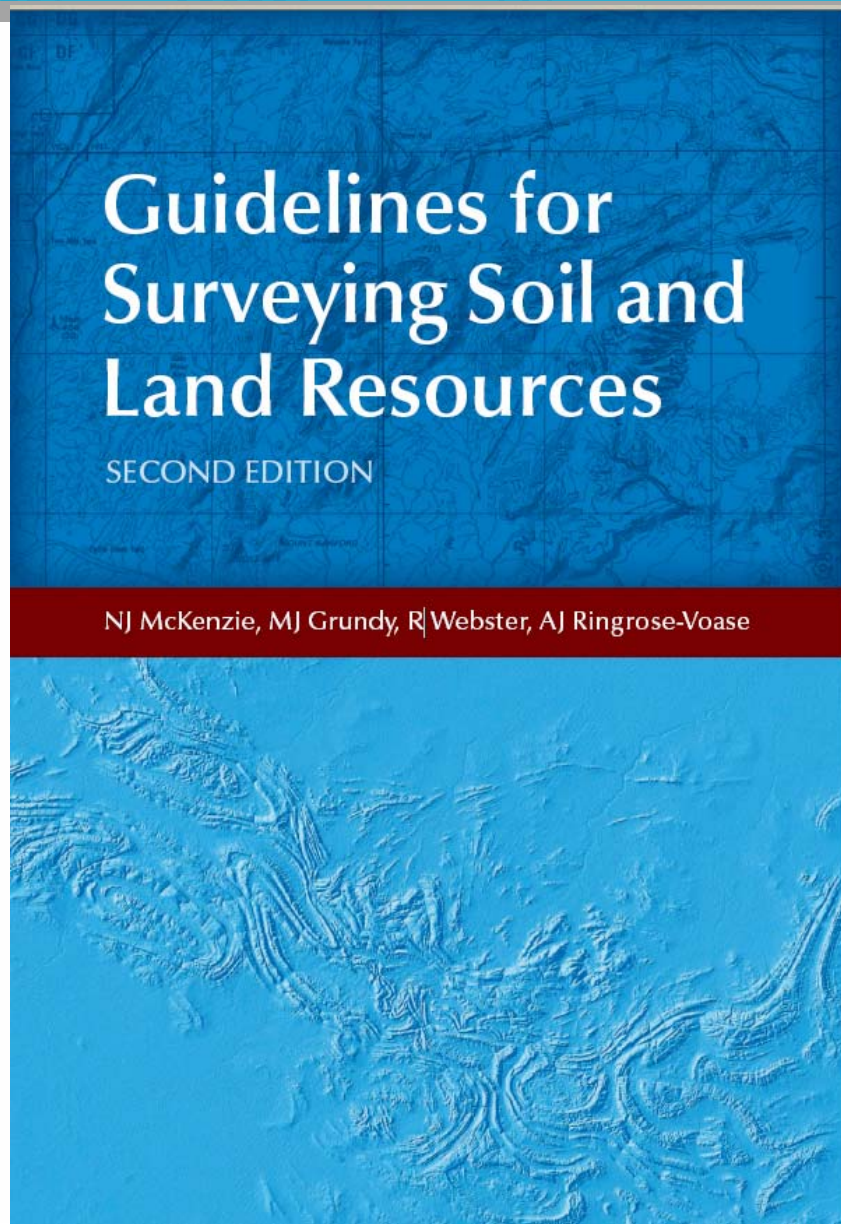
- Next step is presentation of custom interfaces on soil function (e.g. water storage, carbon storage) and threats (e.g. acidification and erosion)
- Interoperable
- Database and system design are generic and available on request
- One node in the developing global digital soil information system (www.globalsoilmap.net) – the 90 m grid of functional soil properties for the world

Limits to prediction

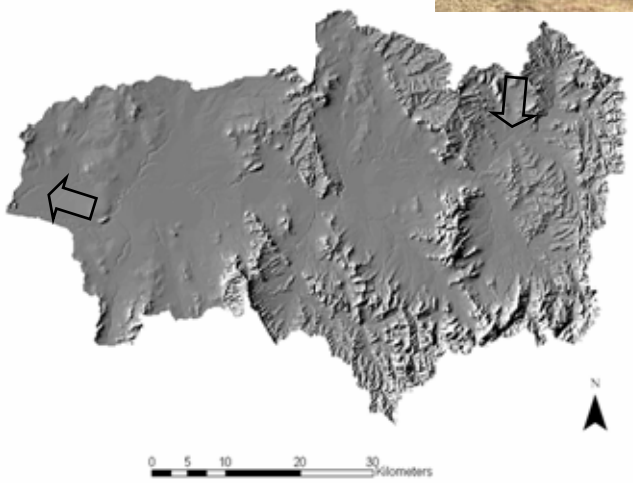
- Short range variation for most soil properties is large – up to 50% of variance present in a few hectares is commonly present in a few m^2
- Most spatial data have been gathered using a polygon model that assumes high covariance
- Direct measurements of functional properties are sparse and restricted

The transition to digital soil mapping

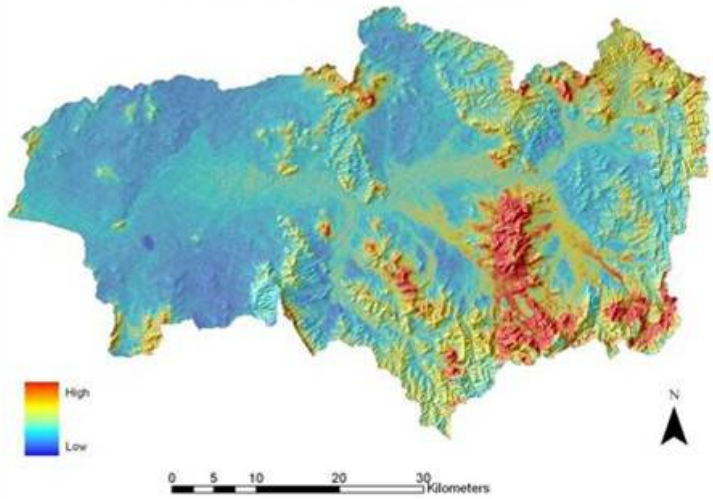
- Feasible because of the revolution in sensors and computing power
- Must be adapted to Australian conditions
- New survey programs are essential
- Emerging agreement on methods: new edition of the *Guidelines for surveying soil and land resources*



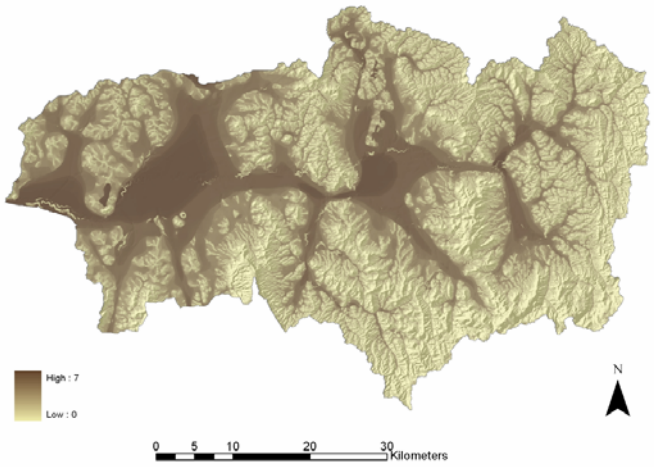
Environmental predictors



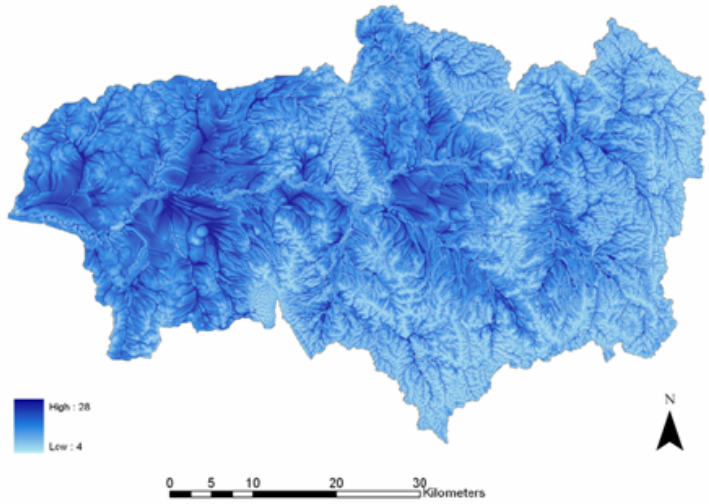
Gamma radiometric potassium



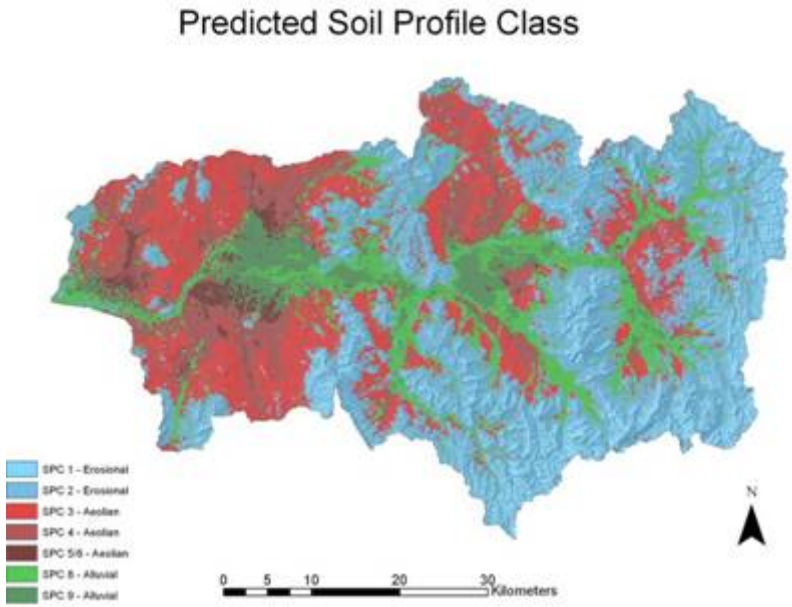
Multi-resolution Valley Bottom Flatness (MrVBF)

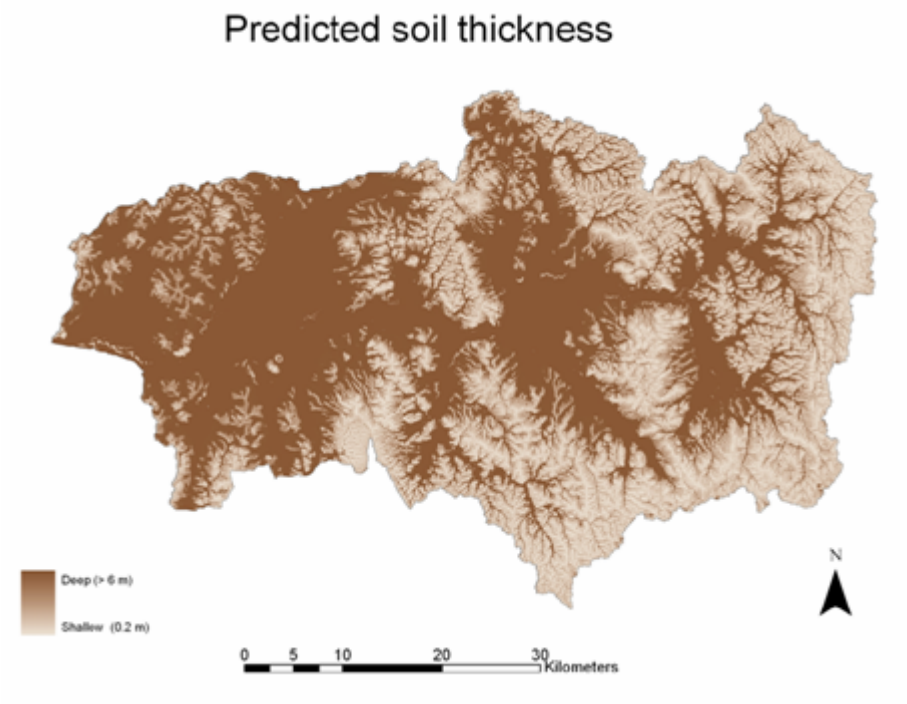


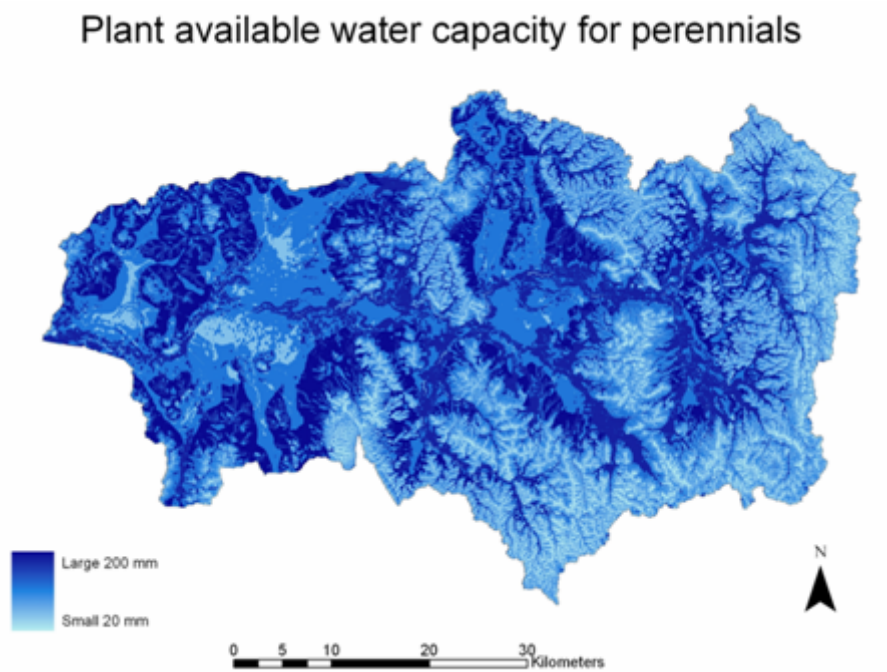
Topographic wetness index



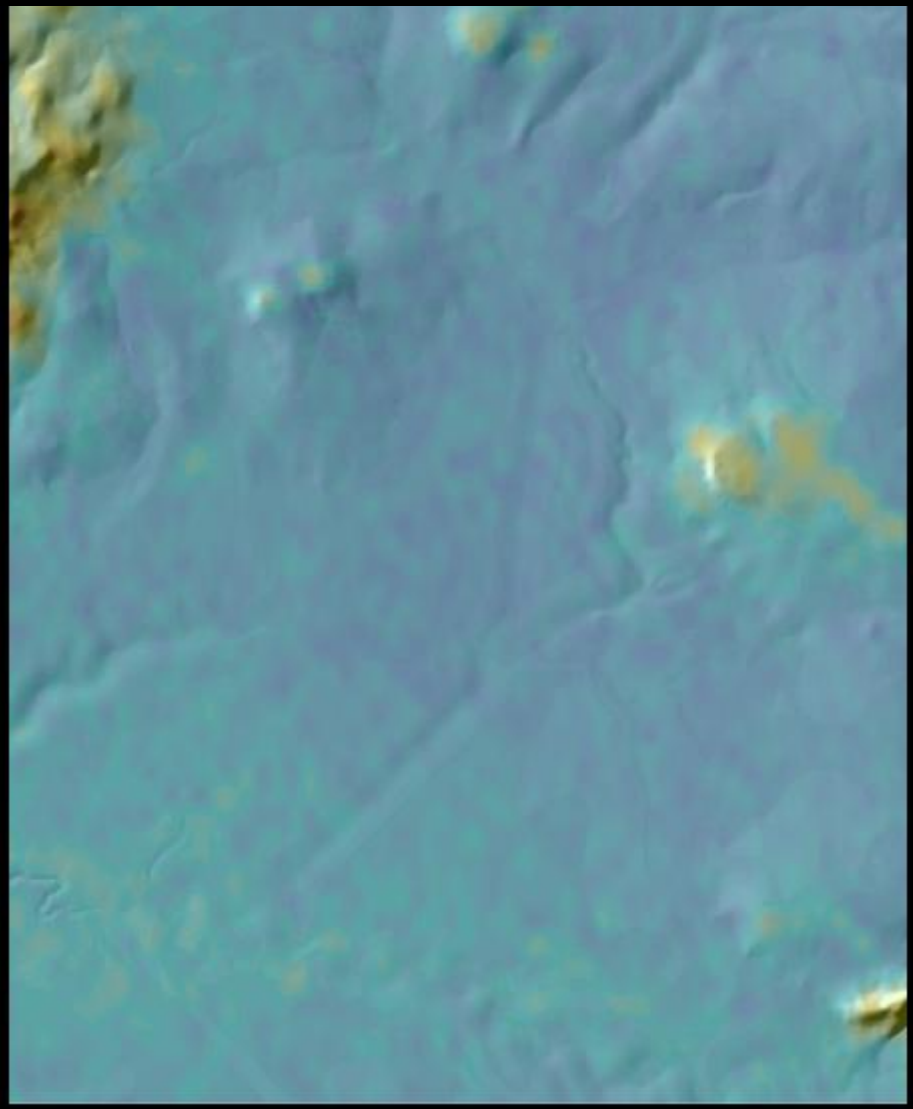
Geomorphic unit	Definition	Variation within the geomorphic unit
Erosional uplands	*K* > 111 cps AND *MrVBF* < 2.7 OR *K* < 111 cps AND *slope* > 6%	SPC 1: *TWI* < 5.5 SPC 2: *TWI* > 5.5
Aeolian slopes and plains	*K* < 111 cps AND *slope* < 6%	SPC 3: *slope* > 2% SPC 4: *slope* 0.5% – 2% SPC 5: *slope* 0.1% – 0.5 % SPC 6: *slope* < 0.1%



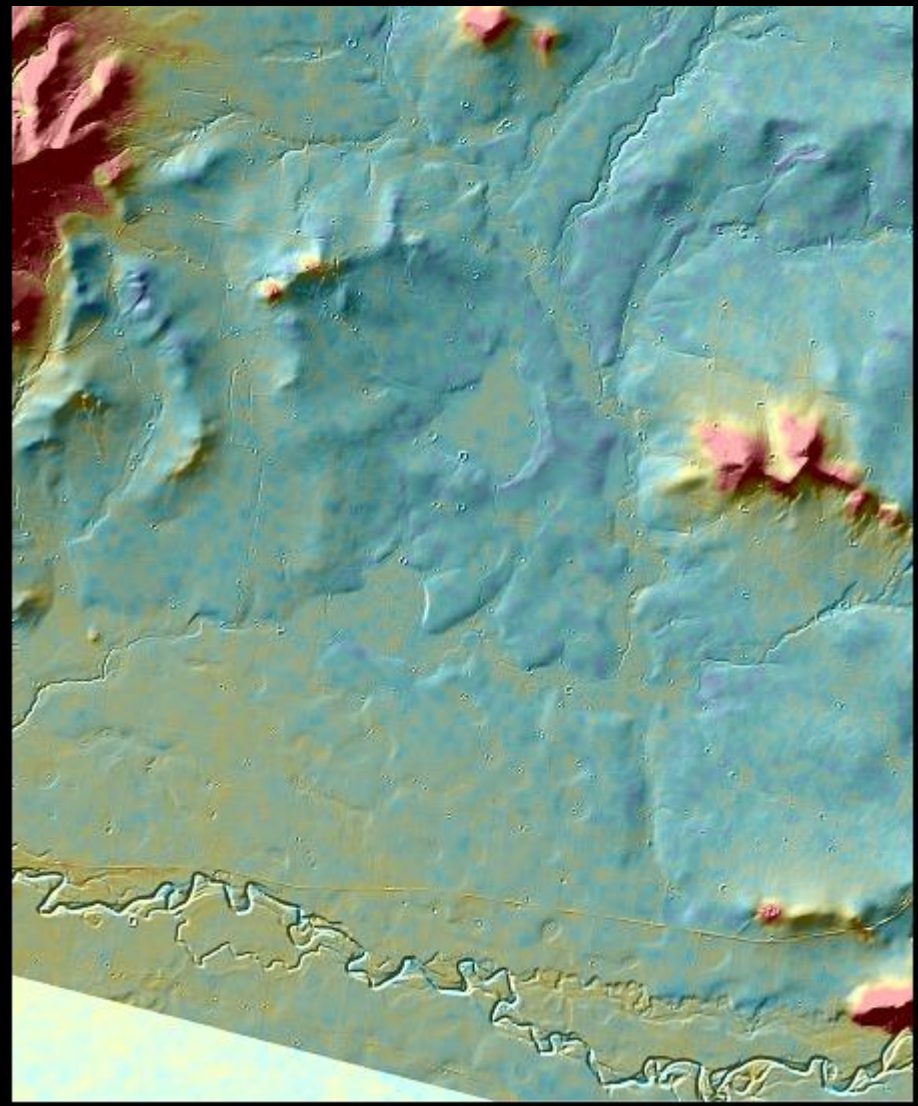




Large improvements are possible with higher resolution environmental predictors and better stratigraphy



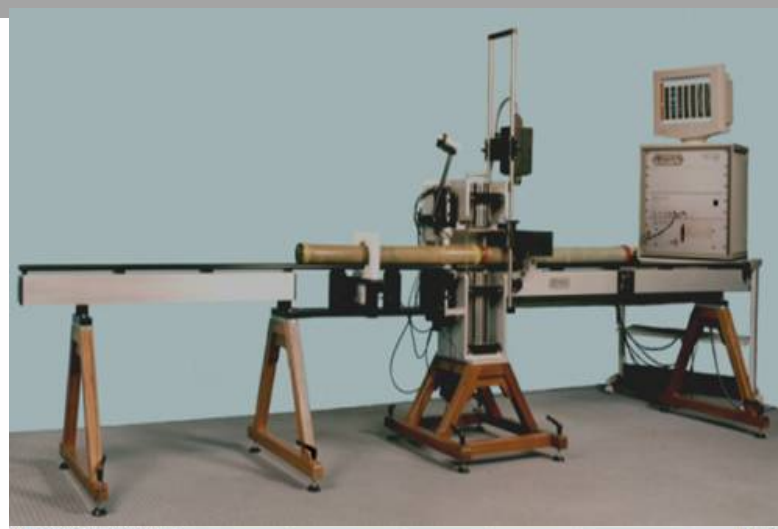
DEM source: 1:50 000 contours
Radiometrics: 200 m line spacing

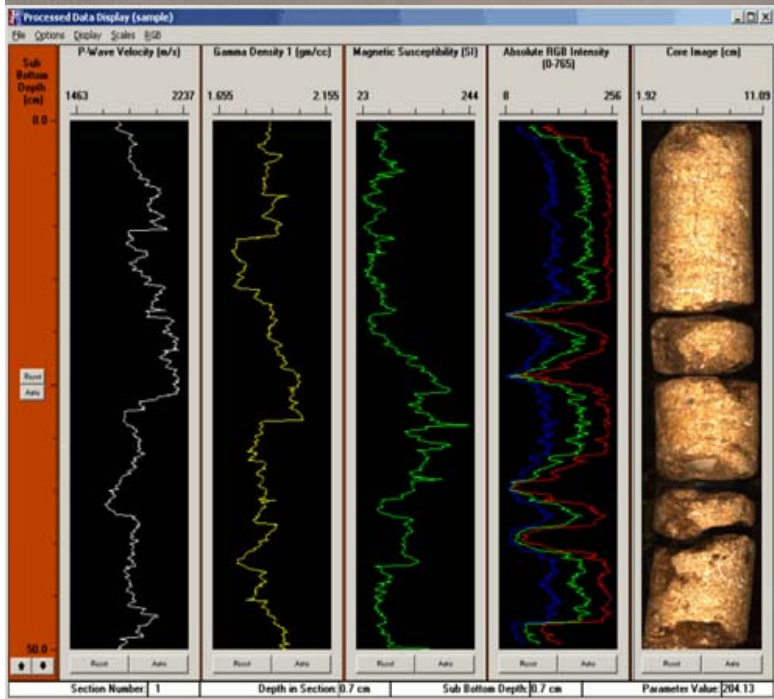


DEM source: LASER Altimetry
Radiometrics: 50 m line spacing

Rapid soil measurement

- There is a widely recognized ‘crisis of soil data’
- Excellent prospects for rapid soil measurement
- Soil spectroscopy (especially mid and near infrared), active gamma, electromagnetic induction are promising





Monitoring and forecasting soil condition

The demand

- Enable rational investment in natural resource management
- Enable adaptive management at the farm and regional scale
- Basic information for understanding soil processes, landscape function and earth systems

Some nodes of activity

- National Land and Water Resources Audit
- Catchment Management Agencies
- Work of the Expert Panels on Soil Condition
- Formulation of NHT3
- CSIRO strategic investment process

Priorities for the Expert Panels

- Soil and landscape acidification
- Soil carbon
- Soil erosion by wind
- Soil erosion by water

Key challenges

- Build the capacity for rapid soil measurement
- Create and maintain several active survey teams with full capacity in digital soil mapping
- Improve the spatial data infrastructure
- Aim for 3D grid (~25m horizontal resolution) of agreed soil function properties by 2015
- Establish network for monitoring soil condition as recommended by the National Committee on Soil and Terrain

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Thank you

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