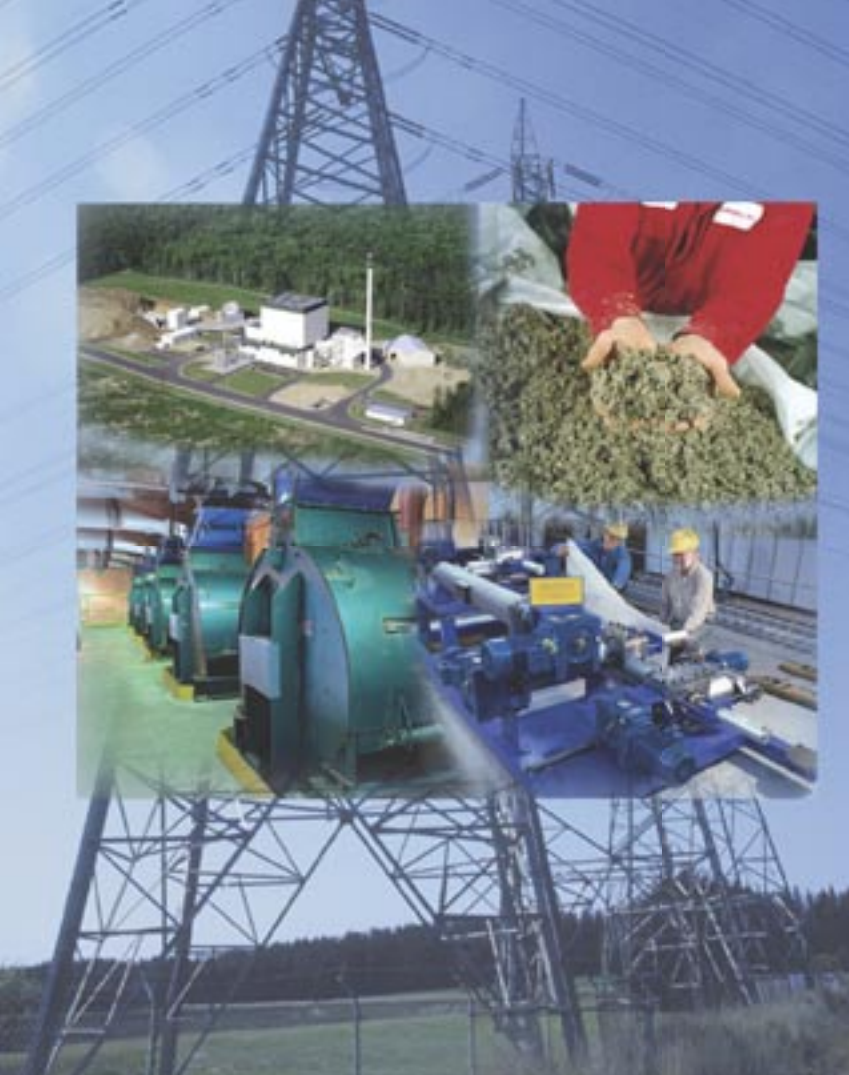




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BIOENERGY ATLAS of Australia





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Bioenergy Atlas of Australia

An online Geographic Information System and Decision Support System

A report for the Joint Venture Agroforestry Program and The Australian Greenhouse Office

by Adrian L. Bugg, Ian Nuberg, Rod Keenan and Lyndon Zimmermann

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Bioenergy Atlas of Australia

Executive summary

The online Bioenergy Atlas of Australia (http://www.brs.gov.au/bioenergy_atlas/) is a new and exciting tool to assist in planning an emerging bioenergy industry. It brings together the best available data and information at the time of the study – on existing and potential resources, industry and infrastructure – and presents this using state of the art online GIS technology. The Atlas will provide greater availability and accessibility of information on existing and potential bioenergy resources in Australia. The project was undertaken collaboratively by the University of Adelaide and Bureau of Rural Sciences in conjunction with the Australian Greenhouse Office and the Joint Venture Agroforestry Program.

The Atlas has two main components: a Geographic Information System (GIS) that provides on-line mapping and query capabilities; and a Decision Support System (DSS) that is used to perform pre-determined analyses. A user can identify the location and extent of bioenergy resources that meet specified criteria using the DSS, for example processing residues within 50 kilometres of major roads and population centres. In addition to the national GIS and DSS, more detailed information (where available) is provided for the Lachlan and Goulburn-Broken catchments of south-eastern Australia. Further development and update of the Atlas in consultation with users is envisaged to include other relevant bioenergy industry data and information for various regions across Australia.

The emerging bioenergy industry in Australia

The federal Government's Mandatory Renewable Energy Target (MRET) commenced on 1st April 2001, as part of Australia's response to global warming. It requires the generation of 9,500 gigawatt (GW) hours of extra renewable electricity per year by 2010. This is enough power to meet the residential energy needs of 4 million people.

Concern over global warming has provided a strong incentive to consider alternative energy sources. Global warming is attributed to the release of greenhouse gases through human actions. This includes increased carbon dioxide levels in the atmosphere caused by combustion of coal, oil and natural gas.

As with other forms of renewable energy, use of biomass for electricity production – bioenergy – does not increase the overall levels of carbon dioxide in the atmosphere. Carbon dioxide is emitted when biomass is burned or energy is extracted in other ways, but regrowth of the biomass takes an equivalent amount of carbon dioxide from the atmosphere. Bioenergy does not contribute to global warming because there is no increase in carbon dioxide levels.

Power plants fuelled by biomass could conceivably contribute 1,000 megawatts (MW) of Australia's electricity generating capacity to replace an equivalent electricity production capacity from coal-fired power plants. This level of displacement, if achieved, would lead to a fall of about 7.4 million tonnes a year in net carbon dioxide emissions.

Biofuels such as ethanol can also be used to replace petrol or diesel powered vehicles, similarly reducing net carbon dioxide emissions. A current government-initiated study is investigating market barriers to increased use of biofuels in transport to develop a broad strategy that will increase production of biofuels to 350 million litres/year by the year 2010. Government initiatives of this type will provide further market incentives for bioenergy in Australia.

Atlas URLs

Home Page:	http://www.brs.gov.au/bioenergy_atlas/
National GIS:	http://www.brs.gov.au/mapserv/biomass/
National DSS:	http://www.brs.gov.au/mapserv/biomass/national_dss.html
Lachlan regional GIS:	http://www.brs.gov.au/mapserv/lachlan/
Lachlan regional DSS:	http://www.brs.gov.au/mapserv/lachlan/lachlan_dss.html
Goulburn-Broken regional GIS:	http://www.brs.gov.au/mapserv/goulburn/
Goulburn-Broken regional DSS:	http://www.brs.gov.au/mapserv/goulburn/goulburn_dss.htm

Background to the Atlas

Concern over greenhouse gases and the need for sustainable environmental management have prompted interest in bioenergy resources in Australia and overseas. A bioenergy industry could be based on existing resources (established crops and residues, plantation slash, etc) and/or new resources (eg tree planting). The bioenergy industry has the potential to provide a source of renewable energy and provides an additional incentive for addressing land degradation problems in rural and regional Australia through tree planting and other activities. The Bioenergy Atlas of Australia was developed to help meet the information needs for this emerging industry.

The Atlas provides maps and information on existing and potential bioenergy resources in Australia. Bioenergy uses biomass in the production of energy (electricity; liquid, solid, and gaseous fuels; and heat) (<http://www.bioproducts-bioenergy.gov/>). Bioenergy resources include residues from agricultural production, such as rice husks and cotton trash, material from tree plantations and forest harvesting residues. Bioenergy material may occur in the field as left over material from harvesting operations (in-field resources) or at industry sites as waste material from processing (post-processing resources). In addition to information on the location and amount of existing and potential resources, the Atlas includes data on infrastructure (eg transport), demand (population), industry capacity and electricity distribution networks to assist in determining the feasibility of bioenergy projects.

Project Collaborators

The University of Adelaide is one of Australia's oldest and most prestigious universities (<http://www.adelaide.edu.au>).

The Bureau of Rural Sciences (BRS) is a scientific agency within the Commonwealth Department of Agriculture, Fisheries and Forestry – Australia (<http://www.affa.gov.au/brs>).

The Australian Greenhouse Office (AGO) is the Commonwealth's lead agency on Greenhouse issues (<http://www.greenhouse.gov.au>).

The Joint Venture Agroforestry program (JVAP) is a collaborative effort between the Rural Industries Research and Development Corporation (RIRDC), Land and Water Australia, Forest and Wood Products Research and Development Corporation (FWPRDC), the Murray Darling Basin Commission (MDBC) and other contributing organisations. The JVAP is hosted on the RIRDC website:

<http://www.rirdc.gov.au>

Atlas functions

The main functions performed by the Atlas are to:

- display bioenergy data nationally and for two case study regions (GIS);
- perform simple data queries that provide tabular summaries of existing and potential resources (GIS);
- perform more complex queries that identify resources that meet specified criteria (DSS); and
- provide data descriptions and other information including limitations and acknowledgements.



Bioenergy in Australia

Interest in bioenergy in Australia is driven by changes in three sectors:

Disaggregation of the Australian electricity industry:

In 1998 a National Electricity Market was established. This market, which is managed by an independent body, promotes competition at each stage of the electricity production and supply chain (<http://www.nemmco.com.au/>). It has created opportunities for renewable electricity producers (e.g. from bioenergy) to enter the electricity market.

Greenhouse gas abatement policy:

Bioenergy is a greenhouse abatement technology with enormous potential. It has been estimated that up to 40% of the green energy mix in Australia could viably be achieved from bioenergy. A Mandatory Renewable Energy Target (MRET) enforces electricity retailers and wholesale electricity buyers to purchase an additional 9,500 giga watt (GW) hours per annum of renewable energy by 2010 (http://www.greenhouse.gov.au/markets/2percent_ren/).

Landuse change:

There is a pressing need to develop economically viable tree-based landuse systems, especially in low-rainfall regions, to intercept groundwater recharge that is responsible for dryland salinity. Bioenergy electricity generation from Short Rotation Coppice (SRC) systems is a possibility, but returns from bioenergy or biofuel production need to be considered on a case-by-case basis. Markets for co-products, other than electricity, that can be extracted from woody biomass (e.g. eucalyptus oil, activated carbon, fuel bioethanol and industrial heat) are therefore needed.

Atlas design

At the start of this project, there was no system that provided access to information on existing and potential bioenergy resources in Australia, although various online mapping and web GIS systems had been developed for other purposes and regions. The Atlas needed to achieve a balance between providing sufficient relevant data at an appropriate level of detail/complexity while also ensuring adequate response times for users. It also needed to support relatively complex queries to identify resources that met criteria defined by the user. In addition, the Atlas needed to be easy to learn and use for both novice and advanced users, provide information in a manner that was appealing and interesting, and return maps, queries and other information within a reasonable time.

Software availability

Name of the software:	The online Bioenergy Atlas of Australia
Software requirements:	Internet connection and web browser. Internet Explorer 5.0 or Netscape 4.08 or higher required for java enabled version. Non-java version is provided for earlier versions of Netscape and Internet Explorer, other browsers, and UNIX and Macintosh PC users. Both the Java and non-java enabled version require Javascript. Preferred screen resolution is 1024 x 768 (still functional at 640 x 480).
Program Language:	MapServer (server side), Java and Javascript (client side).
Availability:	The Atlas home page – http://www.brs.gov.au/bioenergy_atlas/ - can be accessed from the AGO and RIRDC websites using a web browser. The application used to develop the Atlas, Mapserver, can be downloaded from http://mapserver.gis.umn.edu/ for those wishing to develop their own web mapping applications.

Atlas description

The online Bioenergy Atlas of Australia provides a national GIS and DSS and regional GIS and DSS for two case study regions – the Lachlan and Goulburn–Broken catchments in southeastern Australia. The main components of the Atlas and their organisation are shown in Figure 1.



Figure 1 Main components of the Atlas

The GIS is used to create maps and retrieve information about existing and potential bioenergy resources. The DSS is used to perform a set of predefined analyses to answer questions such as what are the bioenergy resources of a particular type (eg Agricultural production) within a specified distance of major population centres, major roads and electricity distribution networks.

The Atlas also provides a brief description of the data, more detailed data descriptions for specific attributes (known as metadata) and help for users. Scenarios are used to demonstrate application of the Atlas to identify opportunities for bioenergy projects. One of these scenarios - identification of potential areas for growing woody vegetation for bioenergy and salinity abatement - is described briefly in this report. A more detailed case study is described as part of the Atlas.

Development of the Atlas

The first product developed was a National Atlas that presented summaries of the existing and potential Bioenergy resources within Statistical Local Areas (SLAs). This was originally intended to be a series of static maps, but ultimately was implemented using online mapping technology. The National Atlas included industry processing sites, infrastructure and other relevant data. As opposed to later products, it did not show the actual location and extent of existing and potential resources.

The next components developed were case studies for the Lachlan and Goulburn-Broken regions that established how data for the location and extent of resources were to be incorporated in the GIS, as well

as determining the DSS functionality. Once these components were completed, the National GIS/DSS was developed to present available national data in less detail than the case studies.

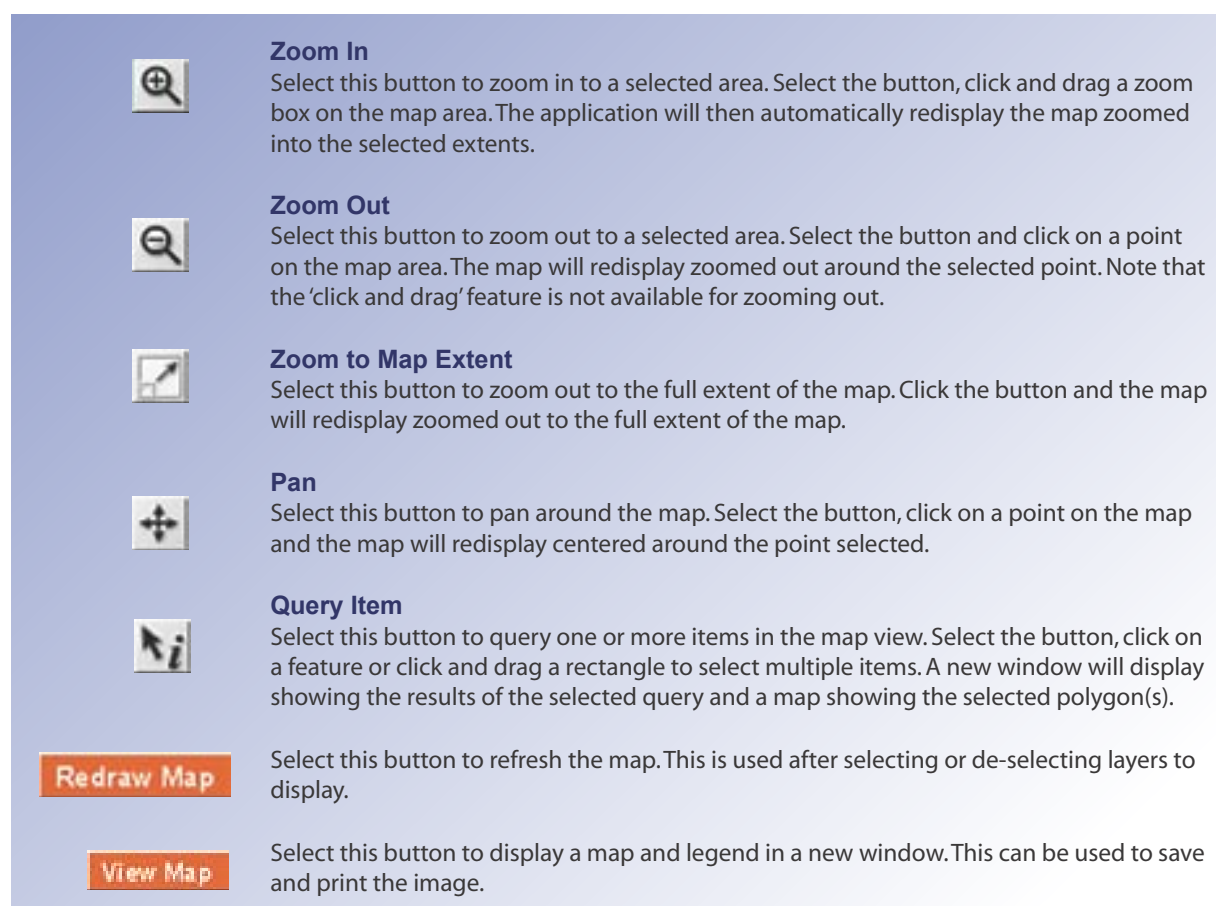
The National GIS/DSS replaced the National Atlas developed previously. It shows the actual extent and location of existing and potential resources and includes other information, such as available electricity distribution data. Much of the data for the National Atlas, for example industry processing sites, was reused in the National GIS/DSS. Although no longer used for mapping, the SLA based estimates developed previously are still used to provide tabular summaries for regions.

Atlas users

It is expected that there will be many different users of the system including government employees, researchers, members of industry, community groups and the general public with an interest in bioenergy. The majority of users are not expected to have extensive experience with the Atlas and there will only be a small proportion of frequent users. While many users will be proficient with the Internet and have modern computers with adequate bandwidth, some users from home, industry and community groups may have less capable systems and limited Internet experience. Most users will not be familiar with the underlying Map Server Technology or on-line GIS/DSS. For these reasons the Atlas needs to be user friendly and appealing to users with a wide range of skills and experience.

User Interface

The Atlas is available to a wide range of users with access to a web browser and Internet connection. Web browsers are familiar to many potential users and the Atlas makes use of hyperlinks and standard tools that are commonly employed in web browsers and other applications. A consistent layout and page design is employed through all the components of the GIS and DSS. The GIS and DSS have links to all of the main Atlas components so that the user can switch between these components. Help for users of the system is also provided online (Figure 2).



The screenshot displays a list of map interaction tools with their corresponding icons and descriptions:

- Zoom In**: Select this button to zoom in to a selected area. Select the button, click and drag a zoom box on the map area. The application will then automatically redisplay the map zoomed into the selected extents.
- Zoom Out**: Select this button to zoom out to a selected area. Select the button and click on a point on the map area. The map will redisplay zoomed out around the selected point. Note that the 'click and drag' feature is not available for zooming out.
- Zoom to Map Extent**: Select this button to zoom out to the full extent of the map. Click the button and the map will redisplay zoomed out to the full extent of the map.
- Pan**: Select this button to pan around the map. Select the button, click on a point on the map and the map will redisplay centered around the point selected.
- Query Item**: Select this button to query one or more items in the map view. Select the button, click on a feature or click and drag a rectangle to select multiple items. A new window will display showing the results of the selected query and a map showing the selected polygon(s).
- Redraw Map**: Select this button to refresh the map. This is used after selecting or de-selecting layers to display.
- View Map**: Select this button to display a map and legend in a new window. This can be used to save and print the image.

Figure 2 Online help for users of the Atlas.

Atlas components

This section describes each component of the Atlas – the national GIS/DSS, Lachlan GIS/DSS and Goulburn-Broken GIS/DSS. It illustrates how the GIS can be used to make maps showing specific data and the results of particular queries performed using the DSS. The *Scenarios and worked examples* section describes a specific application in more detail.

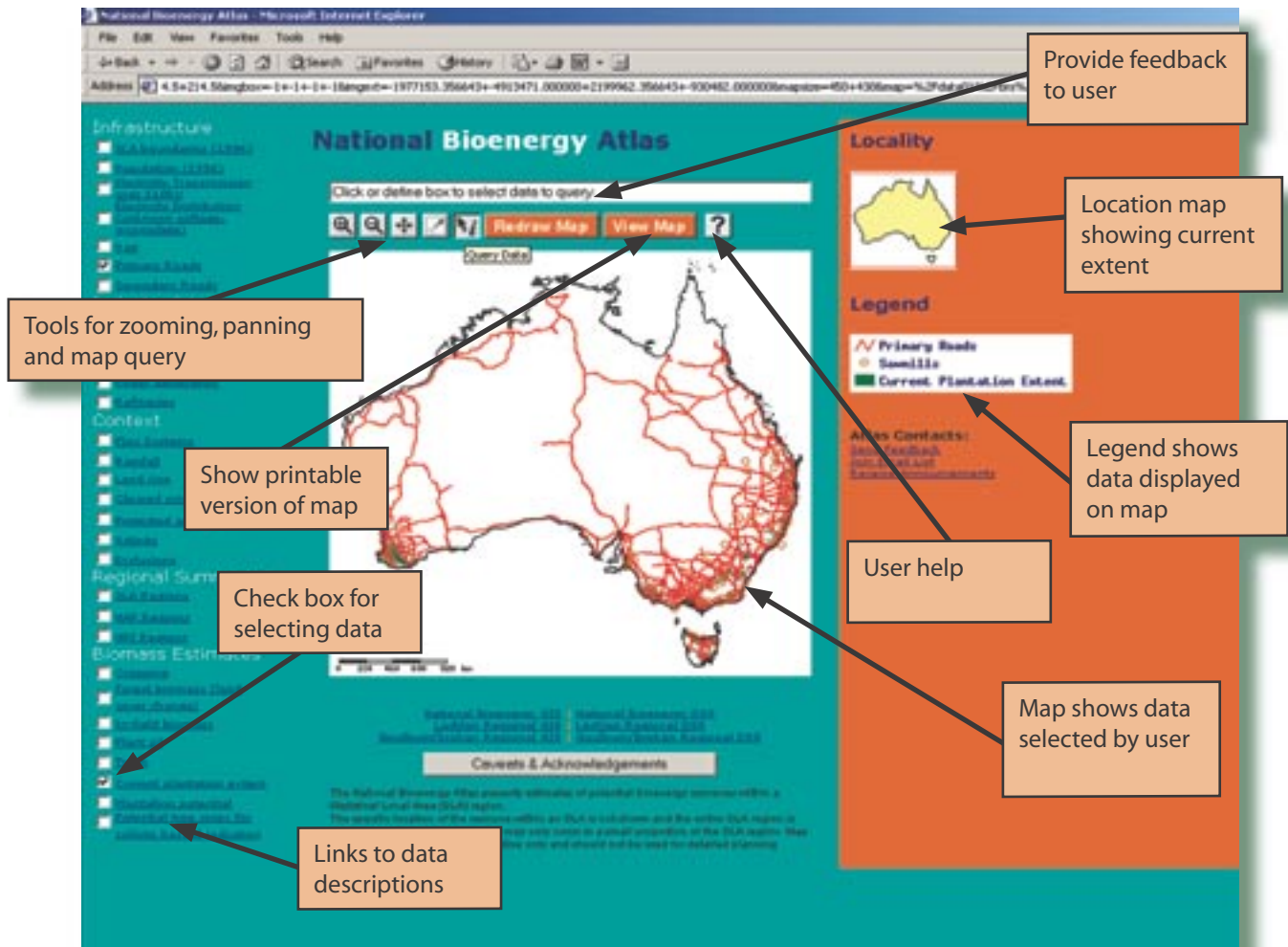


Figure 3 Interface for the National GIS component of the Atlas that is used to display and query existing and potential bioenergy resources.



The DSS (Figure 4) presents an intuitive query interface for the user to specify search criteria by selecting from pull down lists on a form. Users can construct queries to show the extent of biomass resources of a particular type that are within a specified distance of certain infrastructure. The query, once submitted, produces a map displaying data that meets the specified criteria. The user can then add other layers to the map view. Queries are predefined in the sense that data have been pre-processed to facilitate rapid system response.

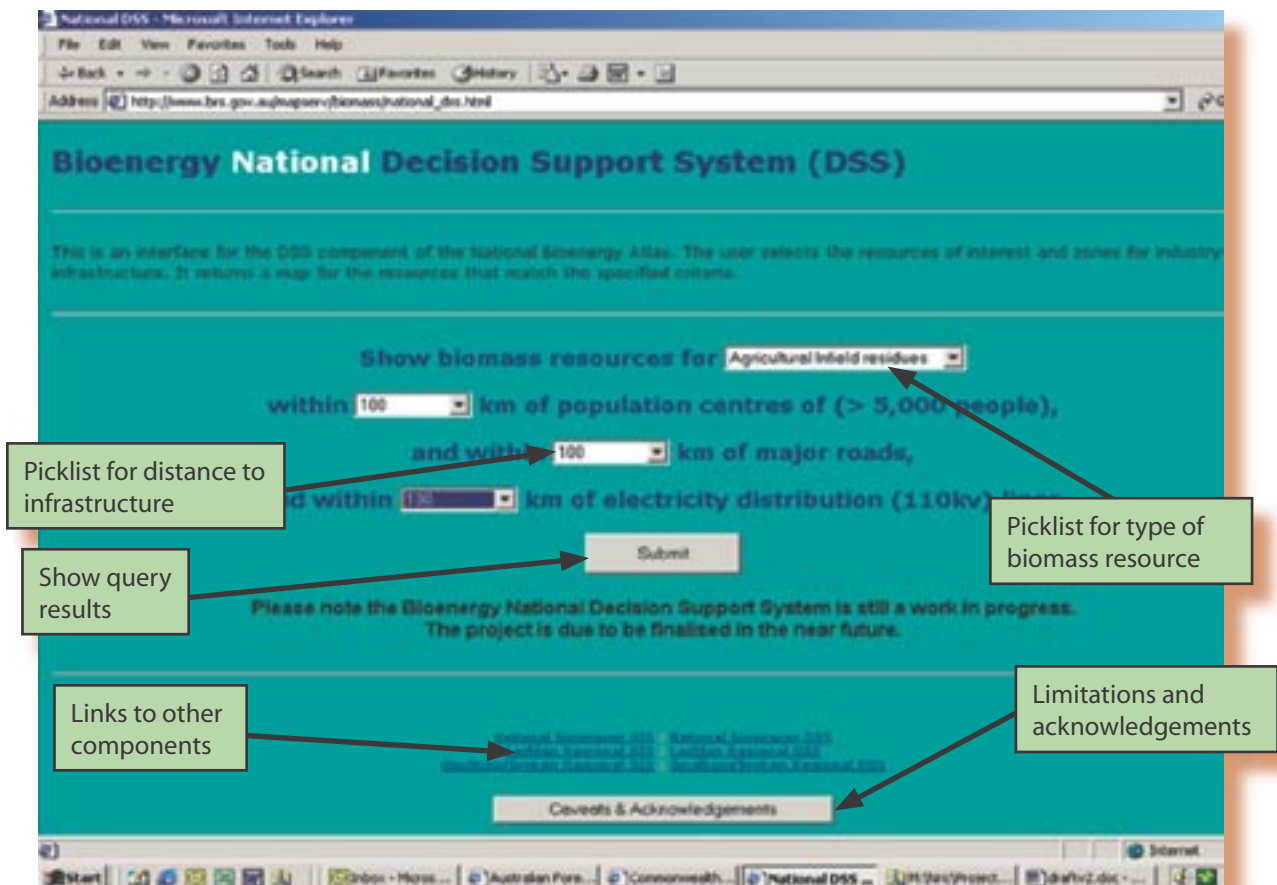


Figure 4 Interface for National DSS that is used to construct queries to identify the extent of biomass resources of a particular type within specified distances of infrastructure.



National GIS and DSS

This application uses the National GIS and DSS to show agricultural resources nationally in conjunction with infrastructure that could be used for initial identification of regions with potential for bioenergy projects. Agricultural In-field resources are displayed using the GIS (Figure 5). The DSS is then used to show Agricultural Infield resources within 100 kilometres of population centres, major roads and electricity transmission networks (Figure 6).

Lachlan regional GIS and DSS

This application uses the regional GIS/DSS to show existing forest biomass, only a proportion of which may actually be available for bioenergy production, and infrastructure within the Lachlan catchment in south-central NSW. The GIS is used to show existing forest biomass with roads and railways overlain (Figure 7). The DSS is then used to identify Forest Biomass within 25 kilometres of population centres, 50 kilometres of major roads and 25 kilometres of electricity transmission networks (Figure 8).

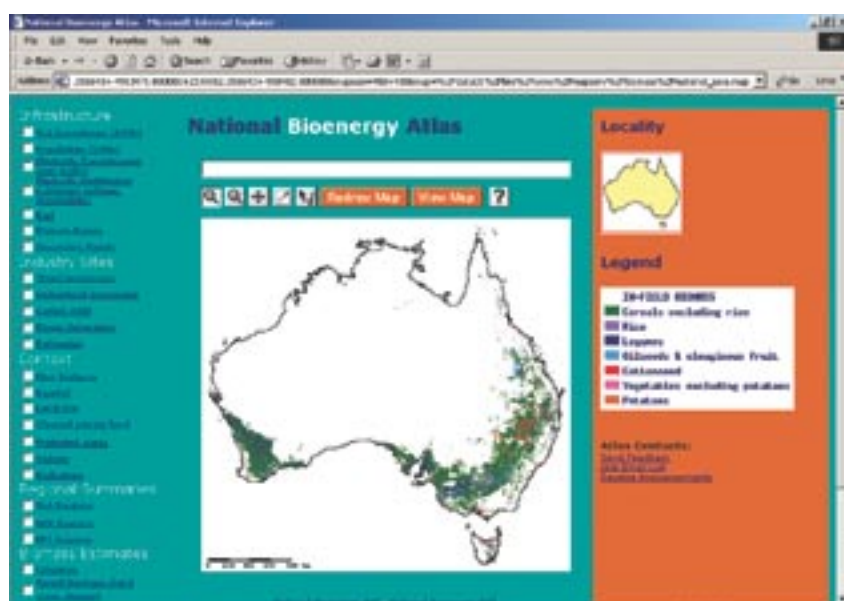
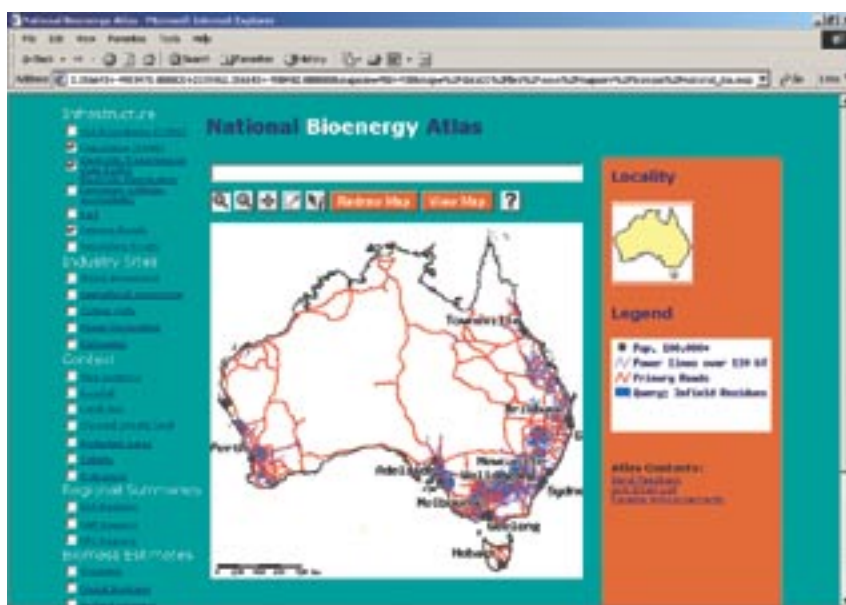


Figure 5 National GIS/DSS showing residues from Agricultural harvesting - infield biomass resources - for Australia.

Figure 6 National GIS/DSS query results showing infield biomass resources within 100 kilometres of population centres, major roads and electricity transmission networks.



Goulburn-Broken regional GIS and DSS

This application identifies areas of salinity hazard and areas of cleared private land that may be suitable for revegetation using the regional GIS and DSS for the Goulburn-Broken catchment in Northern Victoria. The GIS shows cleared private land and land with high salinity hazard (Figure 9). The DSS is then used to identify areas of the Goulburn Broken catchment with high salinity hazard (derived from national data) within 25 kilometres of population centres (Figure 10).

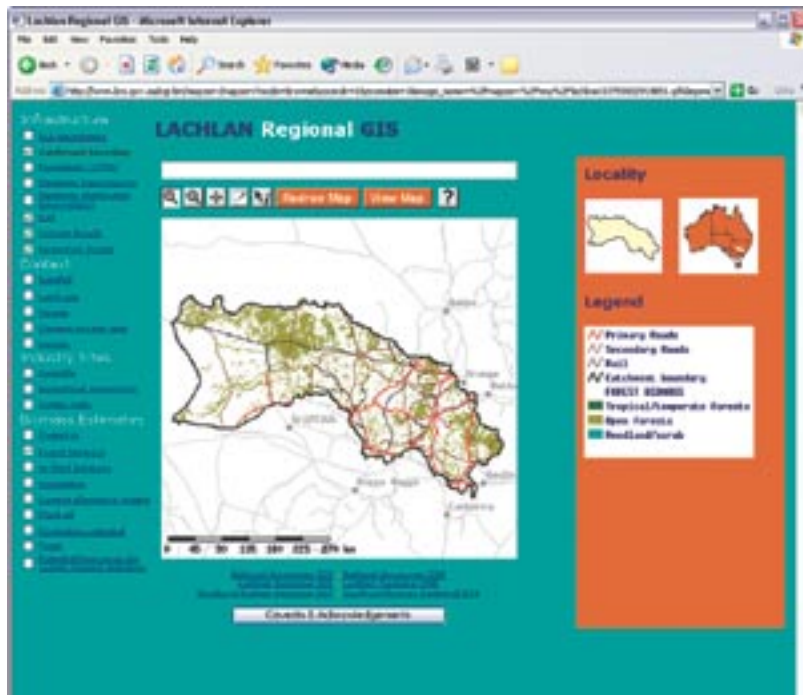
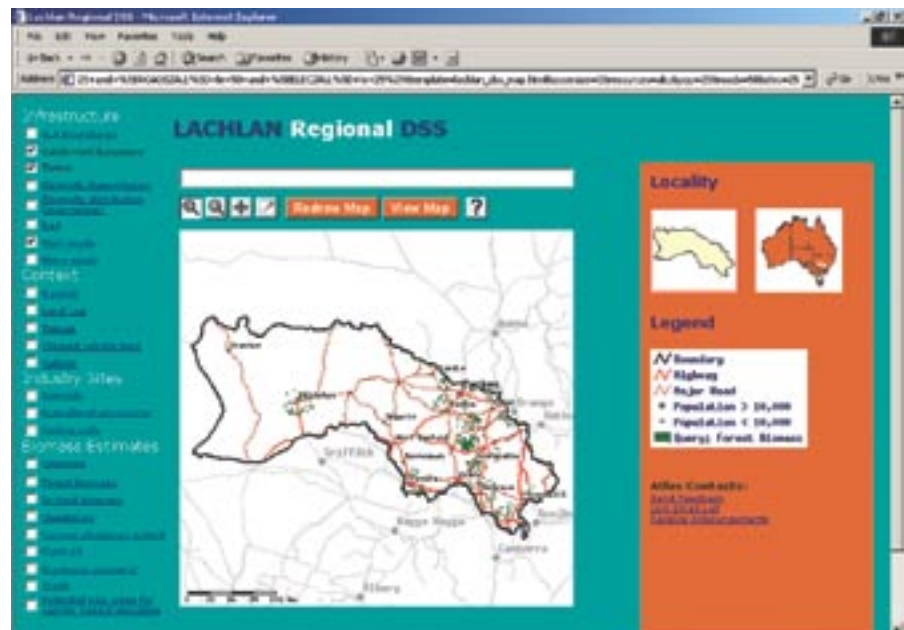


Figure 7 Regional GIS/ DSS for the Lachlan catchment showing existing forest and woodland biomass with roads and railways overlain.

Figure 8 Regional GIS/ DSS for the Lachlan catchment showing forest and woodland biomass within 25 kilometres of population centres, 50 kilometres of major roads and 25 kilometres of electricity transmission networks.



Data

The Atlas provides production estimates for areas that produce agricultural and forest commodities as well as the location and production/residue capacity of the actual processing sites. Existing and potential bioenergy resources include in-field resources left over from harvesting and post-processing resources at processing sites. Standing biomass estimates are shown for existing woody vegetation. The Atlas includes other data on infrastructure (eg transport), demand (population), industry, electricity networks and other context information.

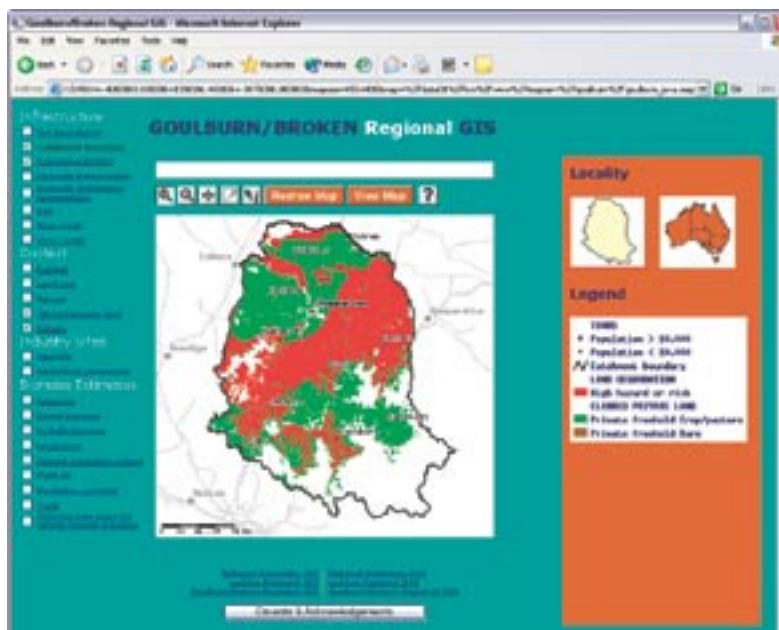
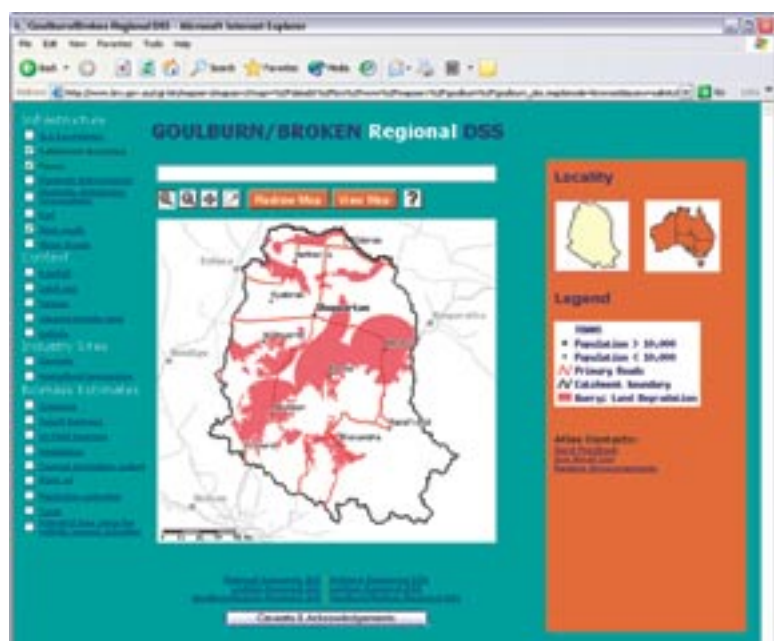


Figure 9 Regional GIS/DSS for Goulburn-Broken catchment showing cleared private land and land with high salinity hazard.

Figure 10 Regional GIS/DSS showing areas of the Goulburn Broken catchment with high salinity hazard (derived from national data) within 25 kilometres of population centres



Data presented in the Atlas are listed and briefly described in Appendix 1. Methods for derivation of biomass estimates are described in Appendix 2.

More advanced users may wish to access the data and analyse this using their own systems. Data presented in the Atlas are in ESRI shapefile format that is compatible with ArcView and other GIS software. However, the Atlas does not currently allow download of the data by users. Links are provided to the custodian's web site and the metadata provides information on access to the data. Some data may be available online from the custodian (see Appendix 3) or by arrangement with the authors.



Biomass estimation

A brief description of the methods used in deriving the SLA-based biomass estimates is provided in Appendix 2. Biomass estimation methods applied to data for the location and extent of resources are also described where appropriate. Estimates for the case study regions may have been obtained using different source data and methods from those described in this report. Further information is provided in the metadata and other documentation available on the website.

Biomass estimates

Biomass estimates for Australia are summarised below to provide an indication of potential biomass nationally. These estimates are aggregated from SLA-based estimates used in the Atlas (see methods in Appendix 2) and variation in these biomass resources is expected over time and across the continent. Development of national estimates for Australia was not the purpose of this study, and consequently users should refer to the section on *assumptions and limitations*.

Table 1 Estimated biomass for Australia

Notes: Agricultural resource estimates are based on ABS 1996 Agricultural Statistics (AgStats) data; Plantation resource estimates are from Connell et al. (1999); and Forest harvesting residue estimates are based on Ryan et al. (2001).

Biomass type	Estimated biomass (t)
Plant Oil (1996 incl. Cottonseed oil)	410,000
In-field Agricultural resources	55,000,000
Post-processing Agricultural resources	425,000
Forest harvesting residues	2,986,856
Uncommitted plantation resource	1,220,000
Uncommitted softwood plantation residue	260,000
Uncommitted Native Forest residue	224,000
Total estimated Sawmill residue	1,796,794

Only a proportion of the total resource estimated for Australia may actually be available for bioenergy applications. While some resources are a waste product, there will be competing uses of other resources. Some resources, such as plant oils, are almost fully allocated and their availability for the bioenergy industry depends on the extent to which production can be increased. In addition, the Atlas focuses on estimates of the existing resource and it does not provide projections for planning future uses.

Assumptions and limitations

While the information was the best available at the time of the study, some of the data are incomplete and inconsistent. For example, electricity distribution data vary in terms of detail and coverage and the national electricity transmission data are currently being updated. The methods used in compilation of data may also differ and lead to inconsistencies. Production information provided for industry processing sites is often incomplete and derived from a range of different sources. Wherever possible, only uncommitted residues were identified, but this information was not available in many cases. The case study regions provide more detailed data where this is available, but many of the data are derived from national layers and may not provide sufficient detail for regional planning. Other initiatives, such as the National Carbon Accounting System (NCAS) and the JVAP funded project for Seed and Information Support for Commercial Farm Forestry (Booth et al. in press), provide more complete and up to date data than was available for this study.

The information presented in the Atlas provides a snap-shot for a particular point in time and there may be inconsistencies in the date when data was compiled. For example, productivity estimates (in term of tonnes per hectare) and multipliers used to estimate agricultural biomass were applied nationally. Although native forest harvesting and plantation production figures were available for RFA and NPI regions, these regions did not coincide with the SLA regions used in the Atlas. Productivity, particularly agricultural productivity, varies

through time and across the landscape in response to climate, soil fertility, management and other factors. For these reasons the biomass estimates provide an indicative estimate and more detailed studies would be required to estimate the existing and potential resources within specific regions.

The resource estimates provided in the Atlas are an indication of the existing and potential resource that does not consider practical restrictions on the use of biomass, such as the need for retention of organic material to maintain soil fertility and structure. Legislative requirements may also prevent use of existing biomass for bioenergy projects. For example, clearing restrictions in most Australia states would limit the availability of biomass from non-production native forests. For this reason, the Atlas only shows plantation potential on areas of private land without significant woody vegetation. Proponents of bioenergy projects would need to make their own assessment of the availability of bioenergy resources identified in the Atlas.



National Carbon Accounting System (NCAS)

(<http://www.greenhouse.gov.au/ncas/index.html>)

The NCAS provides a complete accounting and forecasting capability for human-induced sources and sinks of greenhouse gas emissions from Australian land-based systems. It was developed to support an optimum greenhouse policy response to requirements of the United Nations Framework Convention on Climate Change and its instruments.

Through fine resolution (25-meter grid) satellite monitoring of vegetation disturbance history (which can provide age of forest) and the application of forest growth modeling, the National Carbon Accounting System (NCAS) is able to determine, as a dynamic inventory, standing biomass nationally at a sub-hectare resolution.

NCAS provides vegetation change data and forest productivity (growth modeling) since the early 1970s. Linkage with the National Vegetation Information System developed by the National Land and Water Resources Audit also allows for determination of forest floristics and structure. This capability will be maintained on a biannual basis.

Through analysis of merchantable components of commercial forests and the forest management practices applied, the NCAS is also able to determine the amount of harvest residue accumulated, and to subsequently model its decomposition.

Scenarios and worked examples

This section presents a scenario for short rotation coppice cropping¹ and provides an example of how the Atlas can be used to identify areas with potential to grow tree crops for salinity abatement. A more detailed worked example is also available on the Atlas web site.

Growing trees for bioenergy and salinity abatement

Another function of the Atlas is to indicate areas where a tree-based bioenergy industry may have positive impacts on dryland salinity by reducing recharge into local and intermediate groundwater flow systems. This scenario identifies areas with potential for growing trees for bioenergy and salinity abatement where there may be complementary drivers for bioenergy projects in the future, such as salinity credits. More detailed data and analyses are required at regional scales, such as for catchment management planning.

Firstly, data for potential tree growth in areas of salinity hazard² are displayed (Figure 11). Secondly, infrastructure (roads, rail and electricity transmission) and population data are displayed (Figure 12). Finally, groundwater flow systems provide a broad indication of local and intermediate flow systems where tree planting may affect recharge/discharge within reasonable time horizons for catchment management (Figure 13). Lastly, the Atlas is zoomed to an area of interest, for example South-central NSW and other data is displayed, including electricity transmission lines (Figure 14).

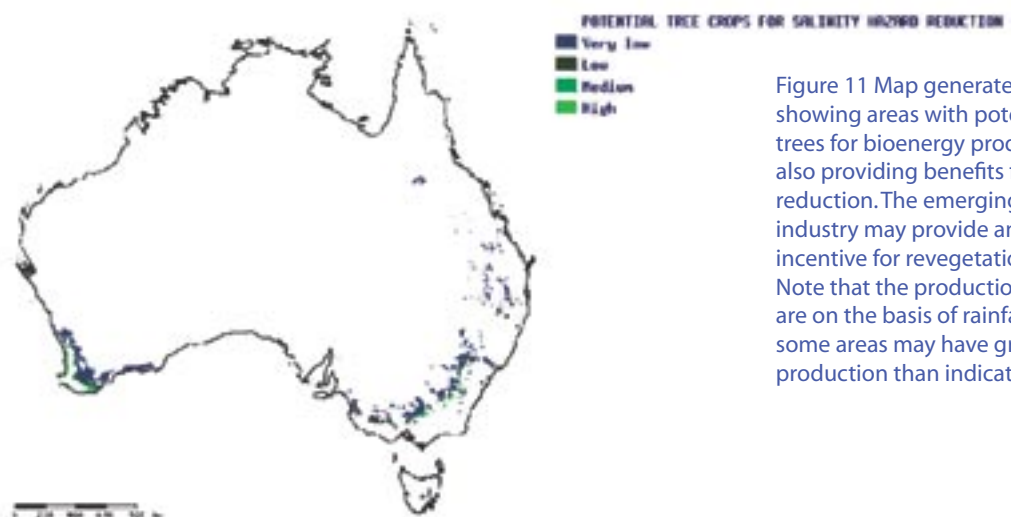


Figure 11 Map generated using the Atlas showing areas with potential to grow trees for bioenergy production while also providing benefits for salinity hazard reduction. The emerging bioenergy industry may provide an additional incentive for revegetation in these areas. Note that the production estimates shown are on the basis of rainfall alone and some areas may have greater or lesser production than indicated in this example.



Figure 12 Map showing areas with potential for tree crops for salinity hazard reduction with infrastructure (roads, rail and electricity transmission networks) and population centres overlain. Consideration of infrastructure in conjunction with resource availability is important in planning bioenergy projects.

¹ See page 18

² As discussed in the data and methods sections, the method and criteria used for salinity hazard mapping is not consistent between states and more appropriate tree growth estimates may be available for specific regions.

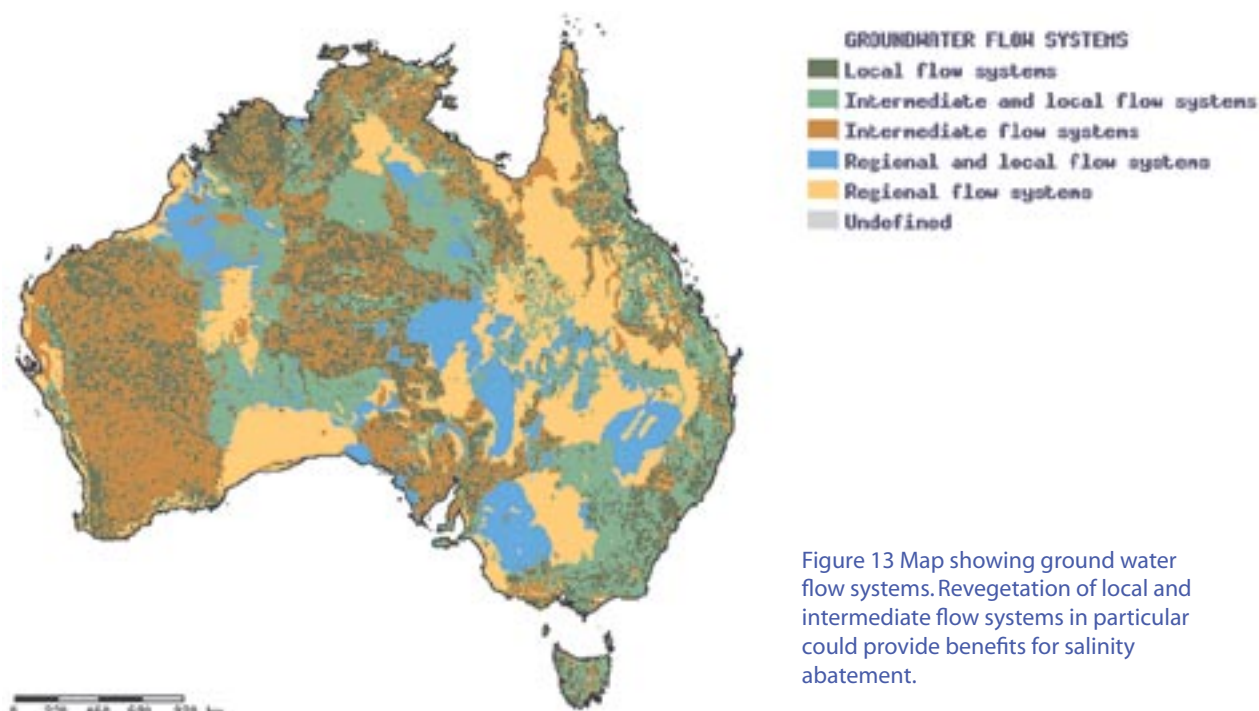


Figure 13 Map showing ground water flow systems. Revegetation of local and intermediate flow systems in particular could provide benefits for salinity abatement.

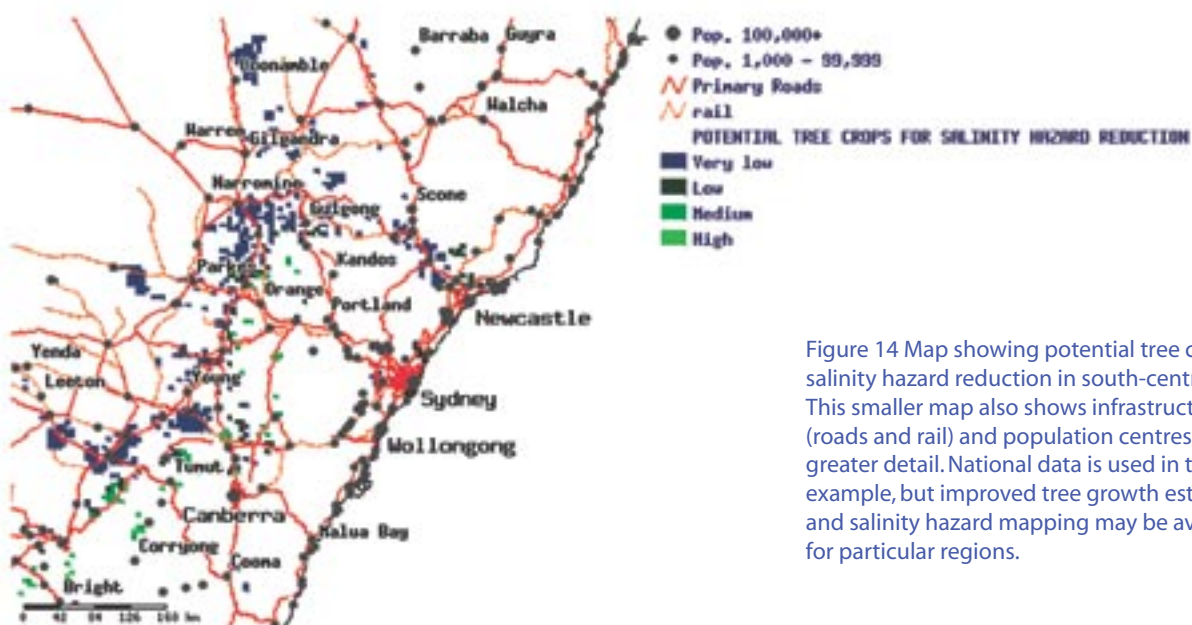


Figure 14 Map showing potential tree crops for salinity hazard reduction in south-central NSW. This smaller map also shows infrastructure (roads and rail) and population centres in greater detail. National data is used in this example, but improved tree growth estimates and salinity hazard mapping may be available for particular regions.

Short rotation coppice (SRC)

Agroforestry systems are a promising means for addressing land degradation and enterprise diversification issues in lower rainfall areas. Redefining the range of possible farming and agroforestry systems in these lower rainfall areas (400-650 mm) requires new and innovative approaches to agroforestry. Starting new industries requires integration of activities and products in the system - from biophysical systems through to the manufacture of novel products, the definition of new markets and industry or regional capacity.

Two new systems of tree cropping show great potential for agroforestry in low rainfall areas:

- Short rotation tree crops which are grown in rows or blocks within existing farming systems. The trees use available soil water - effectively lowering or maintaining the water table - while they grow and can be harvested in short cycles (ranging from 5-10 years) and regrown from coppice (eg mallee systems).
- 'Phase farming' that involves growing deep rooted perennials (such as lucerne) in rotation with other crops that use less water. This system also shows potential with trees that are planted in blocks and harvested after 5-10 years. The tree crop phase is followed by a conventional crop phase of a similar or longer period. During the cropping phase, the water tables rise again prior to the tree growth phase.

A JVAP feasibility study entitled 'Integrated Tree Processing (ITP) of Mallee Eucalypts' showed that it was not economically viable to rely on individual product streams from mallees. An integrated processing system which can produce three commercial products - activated carbon, electricity and cineole - from a single tree feedstock is, however, a much more viable option. A pilot plant is currently being constructed in Narrogin, WA, on the basis of this feasibility study.



Usability evaluation

A limited evaluation of the useability of the system was conducted prior to completion of the Atlas. Firstly, heuristics, or approximate rules of thumb, were used for initial assessment of the system design by the evaluator (Dix et al. 1998). Secondly, observation was employed in conjunction with a questionnaire and interview to evaluate the system implementation. Cooperative evaluation (Dix et al. 1998) was used to observe and provide limited assistance while the user performed a series of tasks. Data on the time taken to complete the tasks and number of errors made was recorded. Only a limited number of users (6) were involved in usability testing. Most users performed testing in their workplace using their standard desktop computer with one user performing testing at home using a laptop computer and dial up connection.

Overall, the time taken to perform tasks and the number of errors made were within specified usability goals. Both the time taken to perform tasks and number of errors made also decreased during testing. All users were able to perform tasks within the specified goals (5 minutes on average for novice users and 2 minutes on average for advanced users) with the average time for all users to perform a task being 1.9 minutes. All users were also able to perform all tasks successfully with the average error rate for all users and tasks approximately 1 error in every 5 minutes or 36 percent of tasks performed. The system also exhibited flexibility, as users were found to use the system in novel ways during testing.

Notwithstanding the limitations of the study, this evaluation indicated that the Atlas is easy to use and learn. Questionnaire responses indicated strong agreement that the system has good usability characteristics, although there were some specific concerns with the clarity and accessibility of information and help. Adoption of World Wide Web (WWW) browser technology is likely to have been a factor in the positive usability results because it was well understood and accepted by the users. The software also utilises interface paradigms that are already well established, such as graphical icons. The usability study provides information that will be useful for future system developments through incorporating usability into system design. Many of the specific usability problems identified in the study have since been rectified. These improvements include increasing the level of feedback, improving the prominence of this feedback and providing more informative error messages.



Discussion and Conclusion

The Bioenergy Atlas is a valuable tool for a wide range of stakeholders in the newly emerging bioenergy industry. It assembles and presents previously unavailable data for preliminary scoping studies at national and regional levels. It also provides a framework for presenting relevant bioenergy data that may yet come to hand. The value of this Atlas lies not only in the data it contains, but also in the common sense application by the user. The case studies and other online documentation provide information on its potential and limitations.

The Atlas utilises state of the art online GIS technology to make information on bioenergy resources available. Because of the expansion of the Internet it should be accessible to a range of industry, policy, research and other users. An initial evaluation indicates that the system is user friendly, flexible and responsive. It should therefore appeal to a range of users.

The Atlas provides access to existing national and regional data that is relevant to bioenergy projects. Since this study was completed, other studies have produced more complete, accurate and up to date data. Data that have recently become available includes an assessment of tree growth in the Murray Darling Basin. Future activities should expand the Atlas to provide more detailed information for other regions and incorporate new data available through NCAS and other initiatives.

Expansion of the Bioenergy Atlas to include other forms of energy, in particular solar energy, and other industries/regions has been proposed. This expansion may include the capacity to display and query information for different time periods, instead of the single snapshot currently provided. In addition to these activities, future upgrades are likely to focus on increasing the information content and providing additional context and guidance to assist interpretation by users of the Atlas. The Atlas increases the availability of bioenergy data as part of the online resources available for rural industries.



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Appendix 1

Data presented in the Atlas

Table 2 Bioenergy Atlas data summary

Type	Name	Description	Source and derivation
SLA-based estimates	Existing cropping resources	SLA-based estimates of seed oil, trash and in-field residues. Includes cereals, oilseeds and pulses, cotton, bagasse, rice, lucerne (stems) and other crops.	ABS production data obtained from Agstats 1996 for SLAs – the last full census of agricultural production.
	Native forest harvesting residues	SLA-based estimates of in-field residues from timber production harvesting of native forests in regions covered by a Regional Forest Agreement (RFA).	Estimates of biomass were based on state-based volume estimates published in Ryan et al. (2002). These were assigned to SLAs proportionately based on the area of production forest.
	Plantation material	SLA-based estimates of uncommitted material from softwood and hardwood plantations.	State-based estimates of the uncommitted and the expected resource in 2010 were obtained from Connell et al. (1999). The extent of existing plantations for each SLA was determined using national land cover data from Agricultural Land Cover Change (ALCC) (Barson et al. 2000) with a 250 metre cell size.
	Plantation potential	SLA-based estimates of potential production from plantations on capable and suitable land.	Estimates of potential plantation production were determined using national plantation capability layers developed for the Wood and Paper Industry Strategy (Burns et al. 1999). These layers were developed by analysis of climate data with a 250 metre cell size using criteria for potential growth of species in plantations from Booth & Jovanovic (1991).
	Population	The locations and population size classification for major towns and cities.	ABS 1996 Census data.
	Electricity transmission	Includes powerlines over 110 kiloVolts. Australia wide coverage is under construction from Geoscience Australia and this is the most recent version.	AUSLIG national data at a scale of 1:250,000 (under development).

Type	Name	Description	Source and derivation
SLA-based estimates	Electricity distribution	Includes electricity distribution data compiled from several network operators. Coverage is incomplete due to inconsistent data availability.	Data was obtained from various sources including private utilities and therefore varies in its content and resolution.
	Roads and Rail	Primary and secondary roads and railways. Primary roads are main thoroughfares between major towns. They may be any number of lanes and may or may not be sealed. Secondary Roads are thoroughfares between populated places. They can be any number of lanes and may or may not be sealed.	Roads and railways from AUSLIG Global Map Data Australia 1M.
Industry sites	Wood processing	Location and production/capacity (depending on data availability), including estimated biomass residue, from wood processing mills.	Volume data for larger sawmill and pulpmills were sourced from Ausnewz 2000. Data for smaller mills were obtained from various industry organisations (including NAFI, VAFI, FIAT, Victorian Timber Production Council) and from unpublished data being collected by SFNSW and Forestry SA. Utilisation for many smaller mills in NSW was sourced from SFNSW.
	Agricultural processing	Agricultural processing facilities including wineries, breweries, canneries and rice mills.	National Pollutant Inventory (NPI) database and other sources. Geocoding using AUSLIG gazetteer.
	Cotton mills	Cotton mills with estimated cotton production for 2000-2001. Points are usually at the town nearest the cotton mill.	Geocoding using AUSLIG gazetteer.
	Power generation	Known operating renewable energy power stations.	Various sources with geocoding approximate.
	Refineries	Location and name of petroleum and non-petroleum refineries.	National Pollutants Inventory database and other sources. Database was geocoded using ANZLIG Gazetteer.

Type	Name	Description	Source and derivation
Context	Flow systems	The data shows the distribution of groundwater flow systems at a national scale.	These flow systems were based on hydrogeological characteristics using a combination of geology, geomorphology and topographical (Digital Elevation Model) information for the National Land and Water Resources Audit (NLWRA).
	Rainfall	Average annual rainfall classified to show semi-arid (250-400 mm) and low rainfall (400-650) regions.	Bureau of Meteorology.
	Landuse	Land use includes conservation and natural environments, intensive uses, dryland farming systems, irrigated farming, native vegetation and water features.	1996/97 Land Use of Australia developed for the NLWRA (Stewart et al. 2001) with a cell size of approximately 1 kilometre.
	Cleared private land	Private freehold or private leasehold land that is either crop, pasture or bare.	This excludes land where there is an existing woody vegetation cover, as defined by the ALCC data (Barson et al. 2000), public land and other unsuitable land (i.e. protected areas) identified by the NLWRA LandUse 1996/97 data (Stewart et al. 2001).
	Protected areas	The protected areas shown meet the guidelines of the International Union for the Conservation of Natural Resources (IUCN, 1994).	Protected areas have been taken from NLWRA LandUse 1996/97 (Stewart et al. 2001), which was derived from the Collaborative Australian Protected Areas Dataset (CAPAD).
	Salinity hazard	Areas of high or moderate salinity hazard.	National salinity hazard mapping for the NLWRA that shows areas of salinity hazard for Australia compiled using different methods and criteria.
	Exclusions	Land that is not suitable for tree planting and hence excluded from the plantation potential and the potential tree crops for salinity hazard reduction data. This includes protected areas, public land and land with existing woody vegetation cover.	Protected areas according to the Land use dataset, and the woody vegetation according to the Australian Land Cover Change (ALCC) dataset.

Type	Name	Description	Source and derivation
Biomass estimates	Cropping	This layer shows agricultural commodities including cereals, hay and silage, legumes, oilseeds and oleaginous fruit, sugar, cotton and other cropping. Non-agricultural land and protected areas are not shown.	The data was derived from 1996/97 Land Use of Australia (Stewart et al. 2001).
	Forest biomass	This layer displays broad forest types and contains Carnahan code values and a biomass estimate in tonnes/hectare taken from the National Greenhouse Gas Inventory.	Woody vegetation from Australian Land Cover Change dataset, removing the protected areas (as above) and attaching biomass estimates given by the National Greenhouse Gas Committee, 1997,1998 (Barson et al. 2000). Some areas of existing forest and woodland are not shown due to gaps in the mapping extent.
	In-field residues, Trash and Plant Oil	In-field residues are material that is not removed during harvesting of crops. Trash is material left over at the facility after the processing of sown pastures, rice, cottonseed, etc. An example is rice husks. Plant oil is the organic material left over from processing of canola, sunflower, linseed, oil poppies, safflower and sesame seeds into various products.	This data was derived using biomass estimates for AgStats 1996 attached to the agricultural layer of the 1996/97 NLWRA land use data.
	Plantation extent	Current plantation extent.	Plantation extent obtained from ALCC (Barson et al. 2000) with a cell size of 250 metres.
	Plantation potential	Plantation potential provides an indication of potential tree growth in plantations, referred to as land capability. Several areas have been excluded from this data (see the exclusions data).	The 'Low', 'Medium', and 'High' classes were taken from a national assessment of commercial plantation potential (as above). The 'Very low' class was derived from BOM rainfall data for between 400 - 800mm of rainfall. The productivity figure in tonnes/hectare was based on values given in ABARE and BRS 2001.

Type	Name	Description	Source and derivation
Biomass estimates	Potential tree crops for salinity hazard reduction	This dataset shows potential tree growth on cleared private land where a salinity hazard exists. It is designed to show where revegetation may provide benefits for salinity hazard reduction.	This layer was created by combining the plantation potential layer and salinity hazard mapping (as above) and excluding woody vegetation and publicly owned land (refer to exclusions).

Notes:

Data for case study regions may differ slightly. For example the Lachlan case study used land degradation and plantation potential described in ABARE and BRS 2001.

SLA based estimates of agricultural and forest biomass were developed for the National Atlas and are presented in the summary tables for the SLA regions.

Estimates of plantation potential are based on annual rainfall alone, which is highly variable in low rainfall zones. Other factors, such as access to groundwater and soil properties, may result in higher or lower growth in some regions, particularly in low rainfall regions.

Appendix 2

Biomass estimation methods

Agricultural production and harvesting residues

Estimates of agricultural biomass were developed using ABS production data for statistical local areas obtained from Agstats 1996 – the last full census of agricultural production. Annual production figures for different crop types (tonnes) were converted to biomass estimates using multipliers (Table 3) adapted from Mendelsohn and Sweeney (1994) based on the material left over from harvesting/processing that commodity. The biomass estimates obtained for the different commodities were classified into In-field resources, post-processing resources and post-processing plant oil residues.

In-field resources include material that is left in the field after harvesting. Post processing production estimates are shown for areas growing commodities for which residues are produced during processing. Post-processing resources are material left over from processing of sown pastures, rice, cottonseed, etc. Post-processing plant oil is the organic material left over from processing of canola, sunflower, linseed, oil poppies, safflower, and sesame seeds into various products. Even though the Atlas shows estimates of the post-processing residues for areas growing different commodities, these post-processing resources occur at processing facilities (also shown) and not the areas where the commodity is grown.

Table 3 Indicative biomass estimates for agricultural resources (adapted from Mendelsohn and Sweeney 1994)

<i>Atlas data</i>	<i>Commodity (tonnes)</i>	<i>Yield estimate</i>
Infield resources – harvesting residues	Oilseed production	1.78 times total grain production.
	Rice production	1.22
	Grain legume production	1.78 times total grain production.
	Summer cereal production	1.78
	Vegetable production	0.1
	Winter cereal production	1.78
Post processing resources	Cotton trash	0.25 of total seed
	Lucerne trash	Assumes 50% stem trash from an integrated premium feedstuffs/ bioenergy facility. Note - no such operation yet exists in Australia.
	Rice processing trash (hulls)	0.2
	Bagasse	0.36
Post processing resources - Plant oil	Seed oil processing residues	0.18 – 0.4

These multipliers, the inverse of an indicative harvest index, indicate the material produced from harvesting crops for which data was available. However, there is considerable variation for particular crops within these categories. The multipliers were also used to provide estimates of potential biomass for commodities mapped using the 1996 national landuse mapping data for the NLWRA (Stewart et al 2001) by applying the multipliers to a reclassification of the landuse spread attributes.

Agricultural processing

The location and capacity (where available) of agricultural processing sites was obtained from various sources, but the production units are not readily convertible to biomass estimates. This meant that estimation of potential biomass from many agricultural processing sites was not possible. For this reason, various units of production (eg volume in litres) are shown and not estimates of biomass.

Timber plantations

Estimates of the extent and production of timber plantations were not available for SLAs. Therefore estimates of the current plantation resource that is not committed and the expected resource in 2010 for different states were obtained from Connell et al. (1999). This study provided the most complete and up to date information for most states except Western Australia, the Australian Capital Territory and Northern Territory. To apply these estimates, the extent of existing plantations for each SLA was determined using land cover data from ALCC (Barson et al. 2000). The volume of production for each state (from Connell et al. 1999) was then allocated proportionately to an SLA based on the extent of existing plantations within that SLA. The volume estimates were then converted to biomass using a wood density of 0.5 t/m³ as being typical for softwood plantations.

Plantation potential

Estimates of potential plantation production were determined using national plantation capability layers developed for the Wood and Paper Industry Strategy (Burns et al. 1999). These layers were developed by analysis of climate data using criteria for potential growth of species in plantations from Booth & Jovanovic (1991). The potential annual production estimates are estimates of biomass production for all cleared private land under the different capability classes. These classes are based on a typical Mean Annual Increment at 20 years of age of 12, 18 and 22 for the low, medium and high capability classes respectively (ABARE and BRS 2001).

Because these data are only for moderate to high rainfall zones usually considered for commercial timber production (generally greater than 800mm annual rainfall), a 'Very low' growth class was added for the 400 - 800mm annual rainfall zone. The actual growth will depend on other factors and users should be aware that production at sites will differ from the estimates presented, depending on management and local conditions, especially soils. More accurate growth estimates for low rainfall plantations have been developed for specific regions, such as the Murray Darling Basin (Booth et al. in press), but these data were not available at the time of this study.

Forest harvesting

Estimates of biomass residues from timber production harvesting of native forests in regions covered by a Regional Forest Agreement (RFA) were based on volume estimates published in Ryan et al. (2002). Biomass estimates were obtained by multiplying the annual volume of production by wood density of 0.7 tonnes per cubic metre (t/m³) with modifiers developed for this study that estimate the proportion of slash (logging residue) depending on the harvest regime and the type of forest (wet or dry) present in the area. The area of production forest for different forest types was determined using available National Forest Inventory (NFI) and Regional Forest Agreement (RFA) data.

Wood processing sites

Volume data for wood utilisation, outputs and/or capacity of wood processing sites was obtained from various government and industry sources (see Appendix 3). The volume utilised was classified as follows:

0-5,000 m³pa;

5,000 – 10,000 m³pa;

10,000 – 20,000 m³pa;

20,000 - 40,000 m³pa; and

greater than 40,000 m³pa.

The midpoints of these ranges were used to estimate the volume of residues in cubic metres per annum (m³pa) for those sites without published information on utilisation. The volume of biomass residues was estimated using information obtained from Jaako Pöyry (1999) on mill utilisation/recovery rates (i.e. percent wood utilisation) or the volume of residue produced (i.e. sawdust and other leftover material). Volume estimates were converted to biomass by multiplying by an indicative wood density of 0.5 t/m³ for softwood or 0.7 t/m³ for hardwood. Actual wood density for plantation timber commonly varies between 0.4 and 0.8 depending on the species, site conditions and management.

Appendix 3

Sources of data for the Atlas

Australian Surveying and Land Information Group (AUSLIG)	http://www.auslig.gov.au/
Australian Spatial Data Database (ASDD)	http://www.auslig.gov.au/asdd/
Geoscience Australia (Australian geological Survey Organisation)	http://www.agso.gov.au/map/
Renewable Energy Website (developed for AGO and hosted by AGSO)	http://www.agso.gov.au/renewable/
Australian Bureau of Meteorology	http://www.bom.gov.au/climate/
Country Energy (formerly Northpower, Advance and Great Southern Energy)	http://www.countryenergy.com.au/
Australian Inland Energy and Water	http://www.aienergy.com.au/
Powercor Australia	http://www.powercor.com.au/
Energex	http://www.energex.com.au/
Ergon	http://www.ergon.com.au/
Aurora Energy	http://www.auroraenergy.com.au/
Agriculture Fisheries and Forestry Australia (AFFA)	http://www.affa.gov.au/content/data.cfm
Australian Natural Resources Data Library	http://adl.brs.gov.au/ADLsearch/
National Pollutant Inventory	http://www.environment.gov.au/epg/npi/
NSW EPA Public Register	http://www2.epa.nsw.gov.au/prpoeo/
Qld Environmental Protection Agency	http://www.env.qld.gov.au/
Energy Developments Limited	http://www.energydevelopments.com.au
Victorian Office of the Regulator General	http://www.reggen.vic.gov.au/elec_5.htm
Office of the Renewable Energy Regulator	http://www.orer.gov.au

Appendix 4

Glossary and Abbreviations

ABARE	Australian Bureau of Agricultural and Resource Economics
AGO	Australian Greenhouse Office
ALCC	Agricultural Land Cover Change
Bioenergy	Bioenergy uses biomass in the production of energy (electricity; liquid, solid, and gaseous fuels; and heat) (http://www.bioproducts-bioenergy.gov/). Bioenergy resources include residues from agricultural production, such as rice husks and cotton trash, material from tree plantations and forest harvesting residues.
Bioenergy Atlas of Australia	- an online Atlas of Australia that provides data and information on existing and potential bioenergy resources in Australia.
BOM	Bureau of Meteorology
BRS	Bureau of Rural Sciences
case study regions	The Lachlan and Goulburn-Broken catchments in south-eastern Australia.
DSS	Decision Support System – a system that provides information to assist users in decision making.
GIS	Geographic Information system – a system for display, query and management of spatial data.
infield resources	Residual material that is left in the field after harvesting operations.
JVAP	Joint Venture Agroforestry Program
MapServer	Open Source software for development of on-line mapping applications used in the Bioenergy Atlas of Australia.
MRET	Mandatory Renewable Energy Target
National GIS/DSS	A component of the Bioenergy Atlas of Australia that includes an online GIS and DSS for Australia.
NAFI	National Association of Forest Industries
NCAS	National Carbon Accounting System
NLWRA	National Land and Water Resources Audit
post-processing re-sources	Residual material left over from processing agricultural and forest/plantations material.
Regional GIS/DSS	A component of the Bioenergy Atlas of Australia that includes an online GIS and DSS for two case study regions.
RFA	Regional Forest Agreement
SLA	Statistical Local Area used for reporting ABS production data.
slash	Residue material from trees left over from forest/plantations harvesting.
SRC	Short Rotation Coppice – Tree crops grown and harvested after about 5-10 years and that may have regenerated from coppicing.
trash	Residue material left over from agricultural harvesting, eg stubble.
VAFI	Victorian Association of Forest Industries
WWW	World Wide Web



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