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Landscapes in transition: tracking land use change in Australia

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Key points

- Researchers need to track land use change to better understand its consequences for Australia's economy, environment and society. This will help Australians make informed choices about land use alternatives.
- Land use in Australia is changing. There is an overall decline in areas used for agriculture, with increases in more intensive agricultural uses including cropping and horticulture. Areas devoted to conservation, protected and minimal use and intensive land uses (including urban) are also on the increase.
- Nationally, researchers understand where major changes are occurring—but they do not have a clear picture of detailed changes in regions or catchments. Many changes will have long-term effects on sustainable agriculture, food security, forestry, water, climate change mitigation and adaptation, biodiversity protection, and landscape aesthetics.
- Tracking land use change means measuring changes in its area, productivity, intensification and new uses and improvements (for example, improved cultivation practices for agriculture). It involves separating one-off changes from longer-term trends and short-term effects, such as seasonal conditions.
- National reporting of land use should focus on change 'hotspots' for key land uses and develop forecasting methods to better predict future land use patterns.
- This report identifies key needs in tracking land use change in Australia and the steps to address these needs.

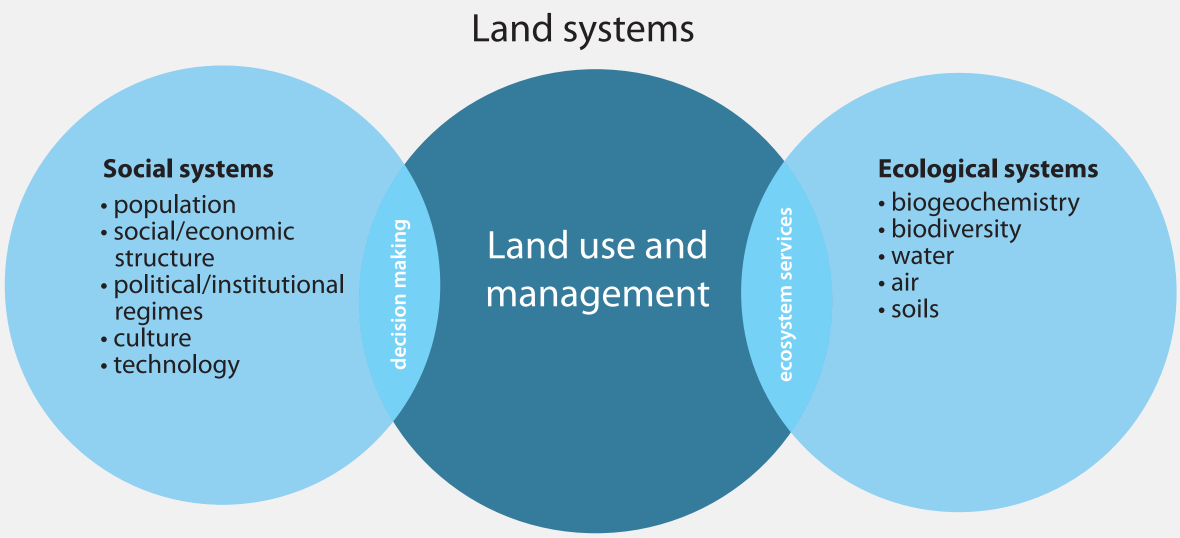
Introduction—why track land use change?

Land use describes the purposes assigned to land. It is fundamental to understanding landscapes, agricultural production and the management of natural resources. Land use choices have a major effect on food production, the natural environment and communities. Land use change is central to much current debate in Australia around agriculture and food security, forestry, water, mining (including coal seam gas extraction), climate change mitigation and adaptation, population, urban expansion, biodiversity protection, and landscape aesthetics.

Researchers and policymakers need accurate and timely information on land use change to help analyse its impacts and manage its consequences. This includes changes in the spatial extent of land use, patterns of intensification, and changes in productivity and innovation.

This report reviews some of the challenges researchers and policymakers face in tracking land use change in Australia, with a particular focus on agriculture and natural resources management. It identifies concepts relevant to tracking change and how land use change can be characterised, and illustrates how these concepts can be applied by using some examples of land use change, mainly in cropping and forestry. It concludes by identifying the information needs to accurately track land use change and the priorities for reporting national land use change.

box 1 Why land use and land management information is important



Adapted from: Global Land Program 2005

Land use and land management links ecological, social and economic systems. Management of natural resources requires better understanding of the dynamics of land systems. Land use decisions can involve trade-offs between the intentional appropriation of ecosystem goods for human consumption, such as food, fibre, and energy and unintended ecosystem responses such as habitat and nutrient loss (DeFries et al. 2004).

Adequate information on land use and land management in Australia will enable researchers and policy makers to respond effectively to challenges such as agricultural sustainability, climate change, water management and biodiversity conservation.

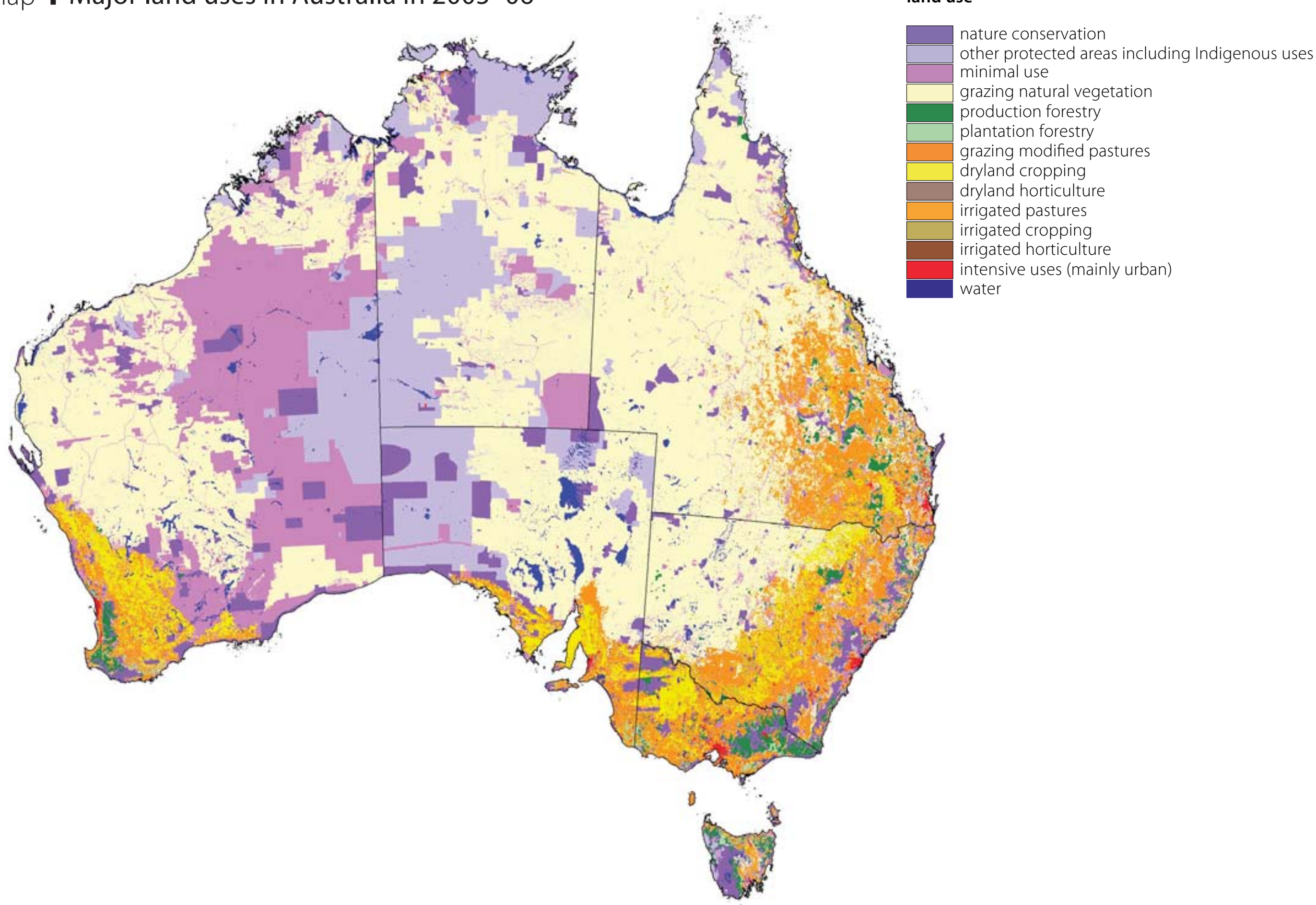
Land use in Australia

The total area of land under agricultural land uses in Australia in 2006 was 4.57 million square kilometres comprising over 59 per cent of the continent (map 1; table 1). The dominant land use overall was livestock grazing on natural vegetation in arid and semi-arid regions (3.56 million square kilometres or 46 per cent). Grazing on modified pastures made up 9.5 per cent (or 730 000 square kilometres) of land use. A much smaller proportion of the land area was taken up by other agricultural uses, including broadacre cropping (270 000 square kilometres or 3.5 per cent) and horticulture (5000 square kilometres or 0.06 per cent).

Intensive land uses, including urban areas, transportation and waste, and some intensive plant and animal production, also occupied a relatively small area (30 000 square kilometres or 0.4 per cent), mainly in eastern and southern coastal locations.

Approximately 37 per cent of Australia (2.83 million square kilometres) was allocated to nature conservation, protected areas including Indigenous uses, and other natural areas subject to minimal use.

map **1** Major land uses in Australia in 2005–06



Note: This 2005–06 land use picture for Australia is the latest in a time series produced since 1992–93. Seven national land use maps are available for the years 1992–93, 1993–94, 1996–97, 1998–99, 2000–01, 2001–02 and 2005–06.
Source: Australian Collaborative Land Use and Management Program 2010

1 Area of major land uses in Australia in 2005–06

Land use	Area (sq. km)	Area (%)
Nature conservation	569 240	7.41
Other protected areas including Indigenous uses	1 015 359	13.21
Minimal use	1 242 715	16.17
Grazing natural vegetation	3 558 785	46.30
Production forestry	114 314	1.49
Plantation forestry	23 929	0.31
Grazing modified pastures	720 182	9.37
Dryland cropping	255 524	3.32
Dryland horticulture	1 092	0.01
Irrigated pastures	10 011	0.13
Irrigated cropping	12 863	0.17
Irrigated horticulture	3 954	0.05
Intensive animal and plant production	3 329	0.04
Intensive uses (mainly urban)	16 822	0.22
Rural residential	9 491	0.12
Waste and mining	1 676	0.02
Water	125 618	1.63
No data	2 243	0.03
Total	7 687 147	100.00

Note: These statistics are drawn from mapping produced by ABARES through the Australian Collaborative Land Use and Management Program (ACLUMP), a partnership of Australian and state government agencies promoting coordinated land use mapping for Australia. The next national land use map will be produced for 2010–11.
Source: Australian Collaborative Land Use and Management Program 2010

The change process

Land use in Australia today is a legacy of patterns of land occupation since European settlement—from early pastoralism, agriculture and prospecting through to today's major agricultural, forest and mining industries, reserve landscapes and urban communities. For most of the past 200 years, land use change has been driven by relatively unrestricted access to land, technological change and growth in productivity and population.

Now land is under increasing pressure, with new demands for multiple objective land use producing combinations of food, fibre, minerals, energy, landscape amenity, water, carbon and biodiversity. Intervention by governments to promote specific objectives can also affect land use. Current examples in Australia include management of carbon, water for irrigation and environmental flows, promotion of sustainable farming, biodiversity protection and feral animal and weed management.

Current issues surrounding land use change include loss of agricultural land to urban expansion and rural residential development, conflicts surrounding mining and coal seam gas extraction, forestry and agricultural production for biofuels. Projected population increase will create further pressure on land for residential, commercial and production purposes. The potential impacts of climate change on agriculture and food production will compound the pressure.

The causes and drivers of land use change (Lambin et al. 2003) are broadly combinations of:

- **pressures on resource availability** including land productivity, resource condition and population
- **changing opportunities** including market development, production costs, new technologies, infrastructure and transport costs
- **policy interventions** including subsidies, taxes, property rights, infrastructure and governance arrangements

- **vulnerability and adaptive capacity** including exposure to natural hazards and the coping capacity of communities and individuals to handle those hazards
- **social changes** including changes in access to resources, income distribution and urban–rural interactions.

Describing land use

Common concepts and approaches to characterising land use change are:

- **Area**—the spatial extent of land use. This is a basic expression of the status of a land use, usually measured in hectares or square kilometres. Change in area provides an indication of whether a land use is increasing or decreasing in significance. One important aspect of area change is the pattern of transition from one land use to another. The spatial configuration of change in area may give insights into processes of change, including points of pressure and conflict.
- **Productivity**—the efficiency with which land use inputs are converted into outputs. It is measured by calculating the ratio of output to input quantities during a specific time period. Productivity change compares changes in this ratio over time. It is most commonly assumed that improvements in productivity reflect technological progress. Climate change, resource depletion and other environmental pressures are acknowledged threats to agricultural productivity growth (Nossal & Gooday 2009).
- **Intensification**—the degree of concentration of land use inputs and outputs. This generally involves greater use of inputs including nutrients, water and energy. Intensification often implies increased environmental and economic risk, but with greater income and financial resources to manage this risk. Intensification measures include production concentration and input concentration (for example, resources [energy, water] input; and cropping frequency).
- **Innovation**—improvement in the approach taken to achieve a land use outcome. Innovation usually occurs through changes in land management practice. These changes are generally adopted in order to improve productivity or address threats to natural resources such as soil and water. An example of changing land management practices for cropping is adoption of cultivation practices such as minimum tillage and direct drilling.

Concepts relevant to tracking aspects of land use change over space and time include:

- **Spatial location**—position in space. Spatial location describes where a land use is physically located using geospatial coordinates such as latitude and longitude. The spatial location of a land use can be expressed as either a point or an area.
- **Trend**—persistence in a condition over time. Trend is often represented as unidirectional change against a baseline period or point in time. Short-term fluctuations or change may mask long-term trends. Trends help quantify variability and risks, and provide trajectories of change.
- **Dynamics**—rates of change and periodicity. The temporal nature of land use change can be explored by analysing whether rates of change are increasing or decreasing, are long-term or short-term trends, or are cyclical (for example, changes as a result of differences in growing seasons, structural adjustments, farming systems or rotation regimes). This may reveal important trends in land use and land management not evident in expressions of simple area change or transformations. Successful analysis of land use dynamics requires consistent, high quality, time-series data.
- **Prediction**—forecasting spatial or temporal patterns of change. Models are used to replicate the past and to predict future land uses based on certain rules, relationships and input data. Prediction may help identify key outcomes of land use change, inform scenario planning and fill gaps in data availability.

Patterns of change—some examples

This section provides some examples of land use change in Australia, describing change in terms of area, partial productivity, intensification and innovation.

Area

Time-series mapping completed between 1992–93 and 2005–06 shows an overall decline in agricultural land uses in Australia of 4 per cent and an increase in conservation and natural environment land uses (including Indigenous lands and natural areas with minimal use) of 8 per cent (table 2).

2 Land use change in Australia, 1992–93 to 2005–06

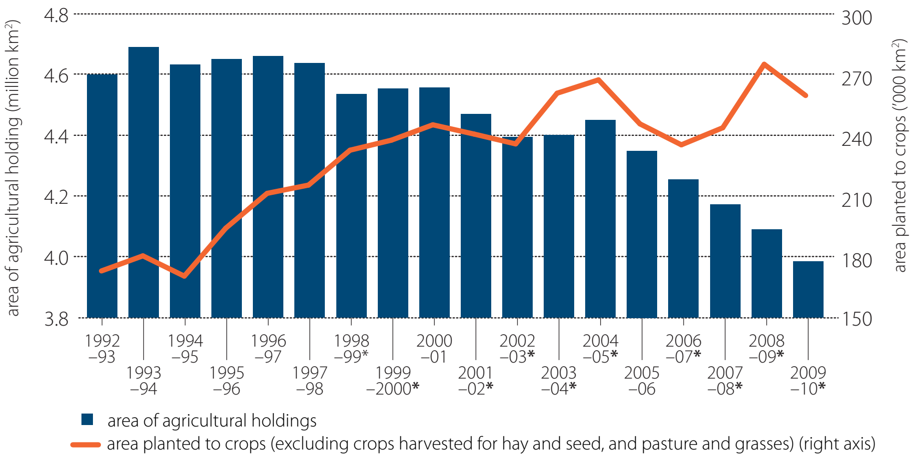
Land use—Australia	Area covered in each year (sq. km)			
	1992–93	1996–97	2000–01	2005–06
Conservation and natural environments	2 609 700	2 619 500	2 674 900	2 821 300
Forestry	161 500	160 500	151 800	138 200
Grazing	4 551 100	4 510 700	4 437 200	4 287 600
Cropping	193 300	225 300	250 300	268 200
Horticulture	4 000	4 100	4 700	5 000
Intensive uses (incl. some agricultural land)	22 900	22 700	24 100	30 800
Water	133 200	133 200	133 200	125 000
No data	2 200	1 900	1 600	1 700
Total area				7 677 800

Notes: Total area was rounded from raw data and benchmarked to 1992–93 mapping. An analysis of land use change derived from the ABARES national land use map series. Minor changes in mapping and statistical collection methods during this period complicate the picture, particularly for land uses with a smaller spatial footprint.

This overall decline in agricultural land uses includes a decrease in grazing (6 per cent) but also significant increases in the area under cropping (39 per cent), horticulture (26 per cent) and intensive uses, which include some intensive plant and animal production (35 per cent).

More recent statistical evidence from the Australian Bureau of Statistics (ABS) confirms this general pattern of change for agricultural land uses has continued beyond 2005–06. Figure 1 shows a decline in the area of agricultural holdings of just over 3 per cent from 1992–93 to 2005–06. Including more recent ABS survey information, the decline in area from 1992–93 to 2009–10 is 8 per cent. Similarly, the area planted to crops (excluding pastures and grasses, and crops

1 Agricultural land use change in Australia, 1992–93 to 2009–10

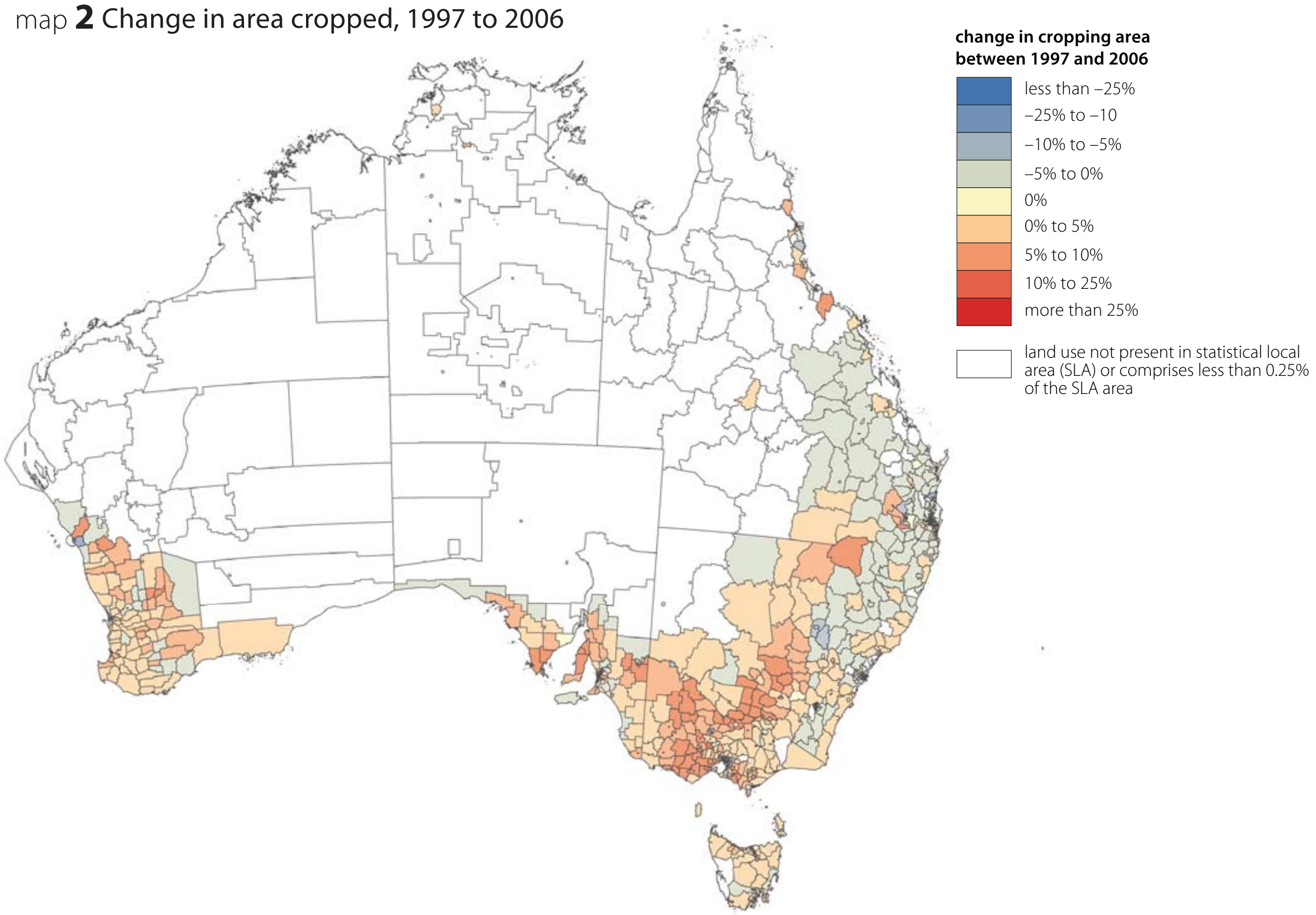


* agricultural survey year rather than agricultural census year and so could be greater sampling errors affecting area calculations for both time series

harvested for hay and seed) increased by 42 per cent between 1992–93 and 2005–06, rising to 50 per cent by 2009–10.

There is, however, considerable variability in the spatial distribution of change across Australia over the period. For example, from 1996–97 to 2005–06 an increase in the area of cropping is evident on the western slopes of New South Wales, western Victoria and generally across the grain growing regions of South Australia and Western Australia (map 2). A small decline in area under cropping is evident across most of northern New South Wales and southern Queensland.

map **2** Change in area cropped, 1997 to 2006

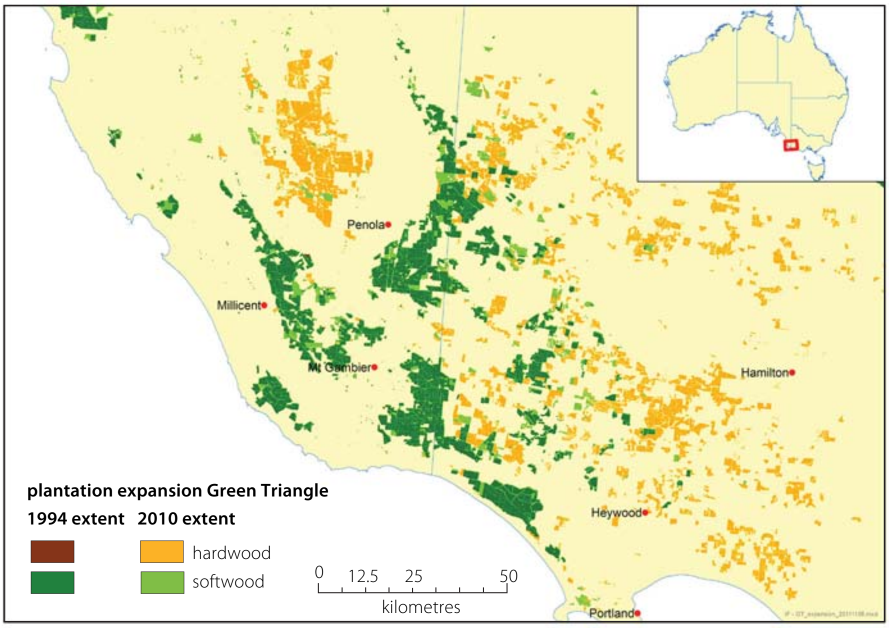


Note: An analysis of land use change derived from the 1996–97 and 2005–06 national land use maps produced by ABARES. Change is represented at the statistical local area (SLA) level by subtracting the percentage of the SLA area cropped in 1996–97 from that in 2005–06, shown as a percentage.

To reveal patterns of area change the scale of land use must match the scale of mapping. This is particularly true for intensive land uses that occupy relatively small areas, such as plantation forestry, where regional or catchment-scale mapping is required.

Plantations established for timber production occupy a relatively small proportion of Australia's total land area, amounting to 2.0 million hectares (0.26 per cent) in 2010—a much smaller area than other major agricultural crops (Garvan & Parsons 2011). Nevertheless, the total area of timber production plantations in Australia has increased substantially over the last 10 years with important economic, social and environmental consequences at the regional level.

map **3** Change in forest plantation area in the Greater Green Triangle region, 1994 to 2010



Note: Plantation expansion into agricultural land in the Greater Green Triangle region has been dominated by hardwoods since 1994.
Source: Garvin & Parsons 2011

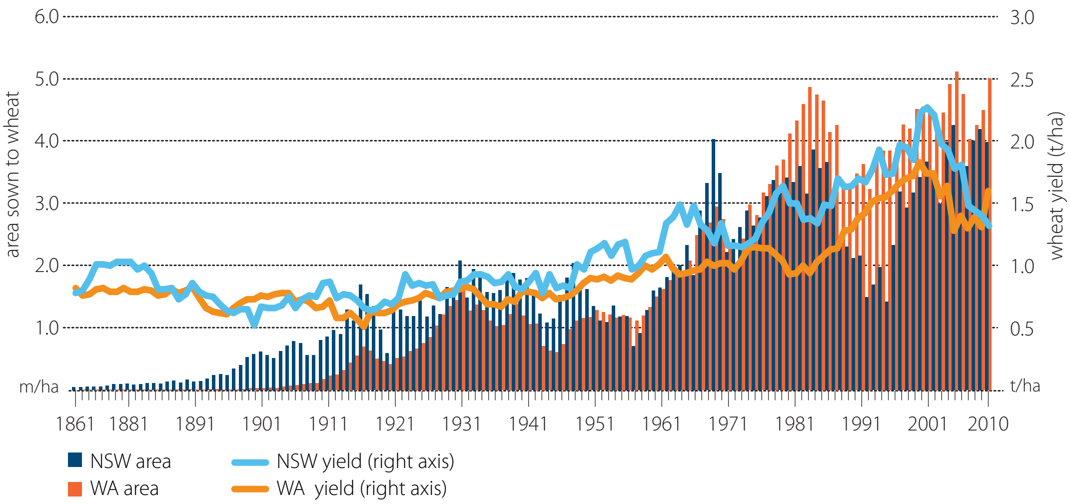
Expansion of forest plantations into agricultural land has, for example, been significant in the Greater Green Triangle region of southern Australia, as shown in catchment-scale mapping (map 3). Since 1994 hardwood plantations have been the main driver of plantation expansion with almost 168 000 hectares planted in the region to 2010. Over the same period the area of softwood plantations increased from 145 000 hectares to 176 000 hectares.

Productivity influences

One of the factors affecting productivity is yields. Wheat cropping in New South Wales and Western Australia since the 1860s provides a good example of long-term change in both land use area and yields (figure 2). Wheat is the dominant dryland agricultural crop in Australia, accounting for 59 per cent of the cropped area in 2009–10.

This time series, drawn from ABS agricultural statistics, illustrates the long-term growth in both the area sown to wheat and yields. Improved technology and innovation has played an important role in driving these trends. Also important are market forces (commodity prices and production costs) which influence the area sown and seasonal conditions which are mainly responsible for yield variations. The impact of events such as the world wars, low prices (1990s) and drought (2000s) is apparent. Also evident is long-term change in the relative size of the Western Australian and New South Wales contribution to wheat production. Post-war agricultural diversification in New South Wales, including a move to beef cattle and adoption of alternative crops such as canola, is part of the explanation for this change.

2 Area and yield trends for wheat cropping in New South Wales and Western Australia, 1861 to 2009–10



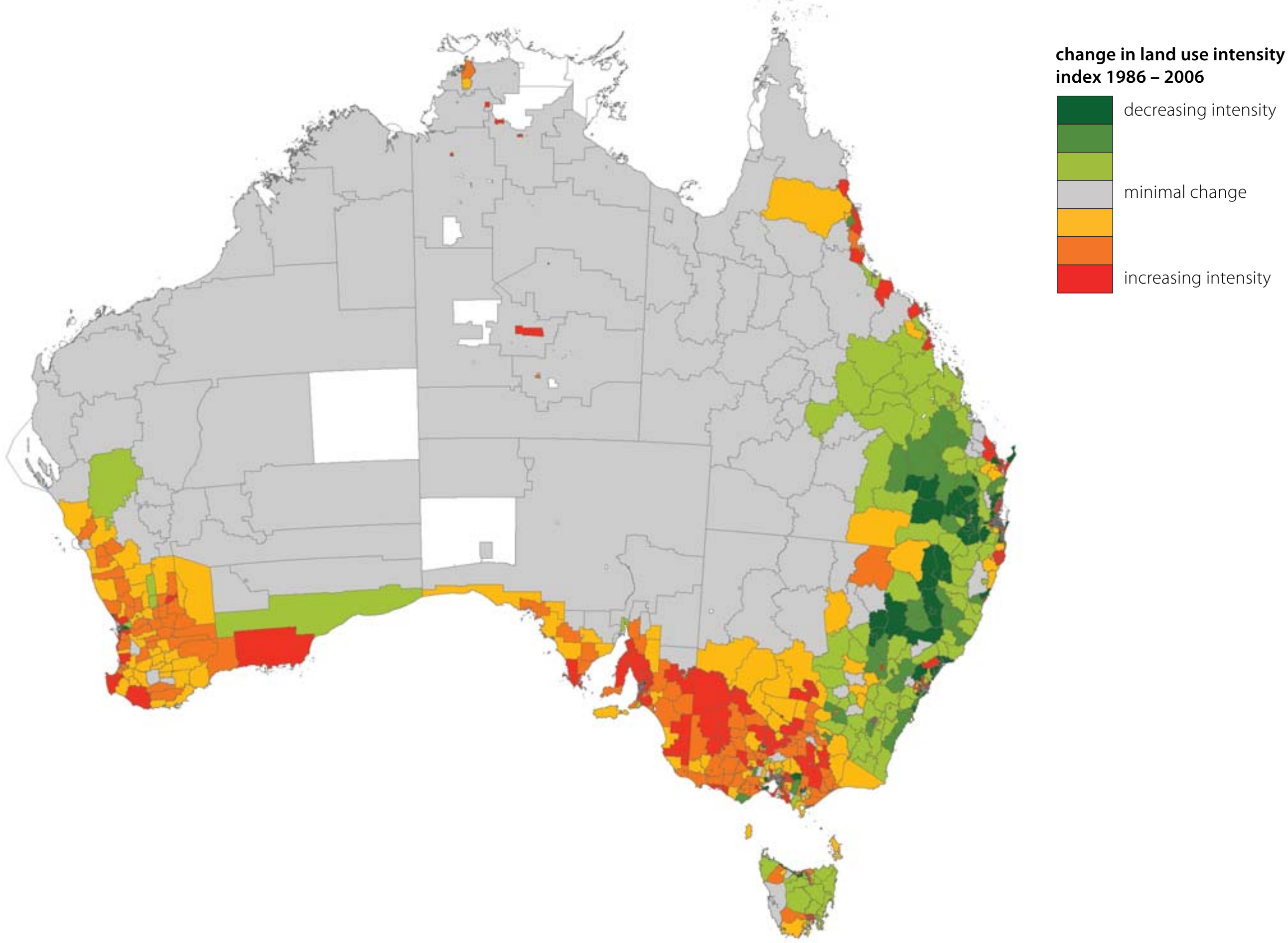
Source: Analysis drawn from ABS agricultural statistics 1861–2010.

Intensification

Some land use changes represent a process of land use intensification. Intensification is one response to the challenges of declining farm terms of trade (changes in input prices relative to output prices) and the increasing demand for land that agricultural producers face. It reflects efforts to maintain or improve economic returns from each hectare through increasing concentrations of inputs, including nutrients, water, energy and management effort. Land use intensification can work both positively and negatively in relation to economic, social and environmental vulnerability, risk and resilience (Zimmerer 2010).

Agricultural land use intensification in Australia is illustrated in map 4, using average input costs per unit area as an indicator of intensity (Walcott et al. 2001). Intensification is generally concentrated in the more agriculturally productive regions that have a greater range of viable land use options, including (in some cases) opportunities for irrigation. Agricultural land use intensification is also concentrated in and around large population centres.

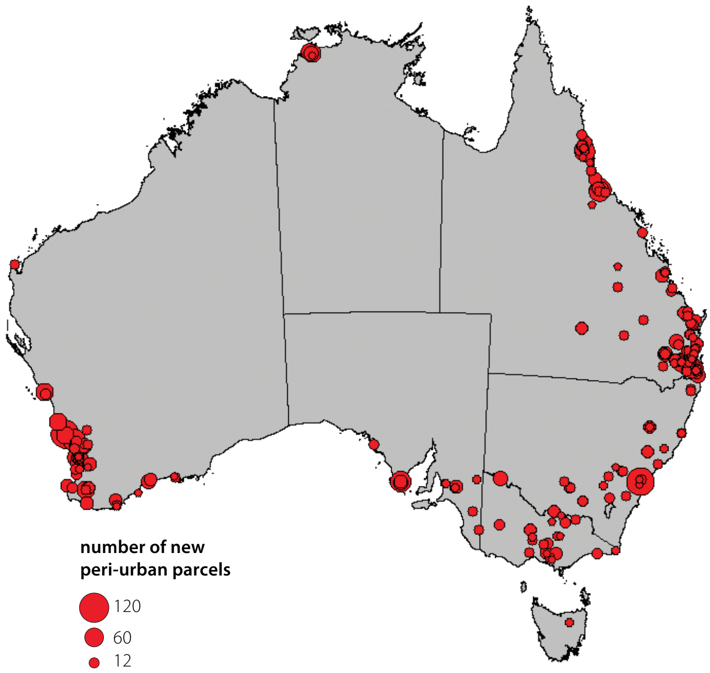
map **4** Change in agricultural land use intensification, 1986 to 2006



Notes: An agricultural land use intensification index based on the average cost of production of specified agricultural land uses. The index is calculated as the sum of $L_i \times F_i$ where L_i is the proportion of different land use categories at the statistical local area (SLA) level, and F_i is corresponding intensity factor based on cost of production taken from the ABS Farm Financial Survey. See table below for weighting factors for land use categories and representative industries used to calculate the land use intensity index.
The analysis reveals an increase in agricultural land use intensity between 1986 and 2006 across southern Australia and around metropolitan centres, along with declines in southern Queensland and northern New South Wales.

Land use category (L)	Representative industry	Weighting factor (F)
Residual or extensive grazing	beef cattle	1
Sown pastures	sheep–beef cattle	2
Grain crops	grains	10
Irrigated pastures	dairy cattle	40
Irrigated crops	cotton, sugar cane, rice	50
Vegetables	vegetables	80
Fruit, nurseries/turf	fruit, horticulture	80

map **5** **Major peri-urban land parcel subdivision, February 2007 to February 2008**



Notes: Major hot spots of peri-urban and rural residential development in Australia based on an analysis of land parcel subdivisions between February 2007 and February 2008. The analysis identifies 2007 land parcels subdivided into 10 or more new land parcels sized between 4000 and 80 000 square metres and excludes any non-residential developments (such as industrial).
Source: Australian Bureau of Statistics, PSMA Australia 2007, 2008

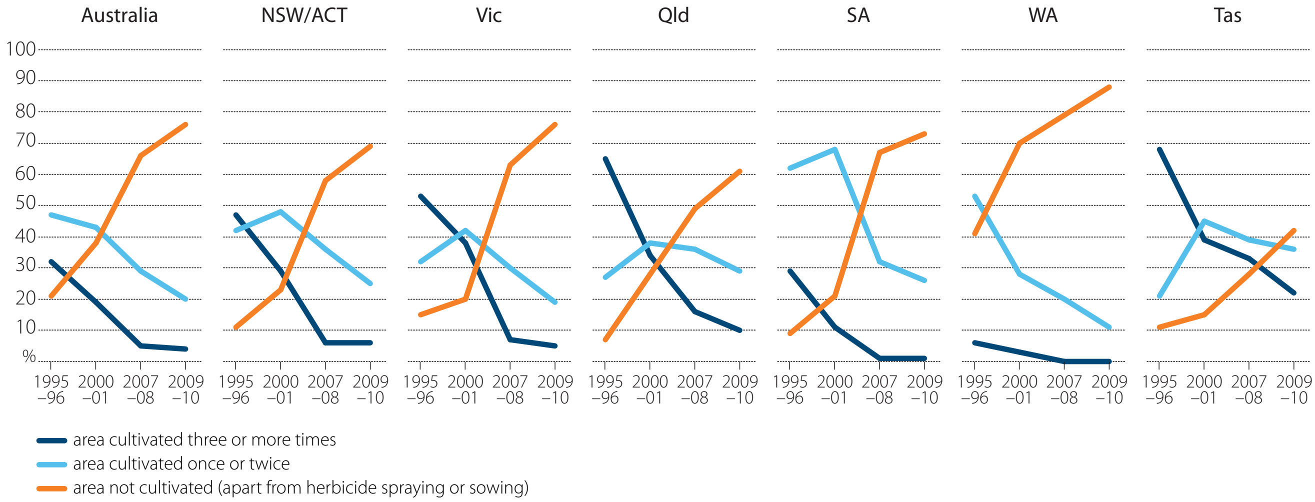
Land use intensification is also evident in urban and rural–residential expansion at the fringe of major cities and other areas of population growth. This generally involves a move out of broadacre agricultural land uses, an increase in population, changes to community composition and to the structure of the local economy (Lambin et al. 2001). Land parcel subdivision is also part of this process. An ABS analysis of land parcel subdivision in Australia between 2007 and 2008 shows peri-urban locations where land parcel subdivision has taken place (map 5). These locations are concentrated around mainland capitals and are widespread across eastern New South Wales, south-western Western Australia, Victoria and coastal Queensland. Other statistical information (such as population growth, land value change) and remote sensing analysis will help refine the change picture in Australia's peri-urban areas.

Innovation

Innovation is a feature of Australian agriculture that has generally driven enough growth in productivity to offset consistently declining agricultural terms of trade (Sheng et al. 2011). Innovation, through improved land management practices, has also increased the agriculture sector's ability to lessen threats to soil, water resources and biodiversity. Adoption of land management practices—the 'how' of land use—are critical to the changes needed for sustainable use of Australian landscapes (Pannell et al. 2006). Land management practice change may be more influential than land use change.

A key outcome sought through the Australian Government's investment program, Caring for our Country, is improving adoption of sustainable farm practices. Statistical collections from ABS Agricultural Census and Agricultural Resource Management Surveys indicate that major change in farm management practices is underway. For example, a striking swing to conservation tillage is evident over the last 15 years in broadacre cropping (figure 3). Conservation tillage helps promote improvements in soil carbon, water accession, reduced soil erosion and nutrient loss as well as cost savings and other production benefits. In 1996 conventional tillage (three or more cultivation passes) was the most common practice, by area, in all states except Western Australia and South Australia. By 2010 it was the least common practice in all states except Tasmania; 'no cultivation' had replaced it as the most common cultivation practice.

3 Cultivation practices for crops and pastures, 1995–96 to 2009–10



Notes: The percentage of area cultivated by farmers using different cultivation intensities between 1995–96 and 2009–10. The 2007–08 numbers include areas prepared for pasture.
Source: Data sourced from ABS 1995–96 and 2000–10 Agricultural Census and the 2007–08 and 2009–10 Agricultural Resource Management Surveys

Information for tracking change—the challenges

Accurately tracking change in land use presents three major challenges; resolving its scale over space and over time and acquiring and analysing data.

Spatial scale

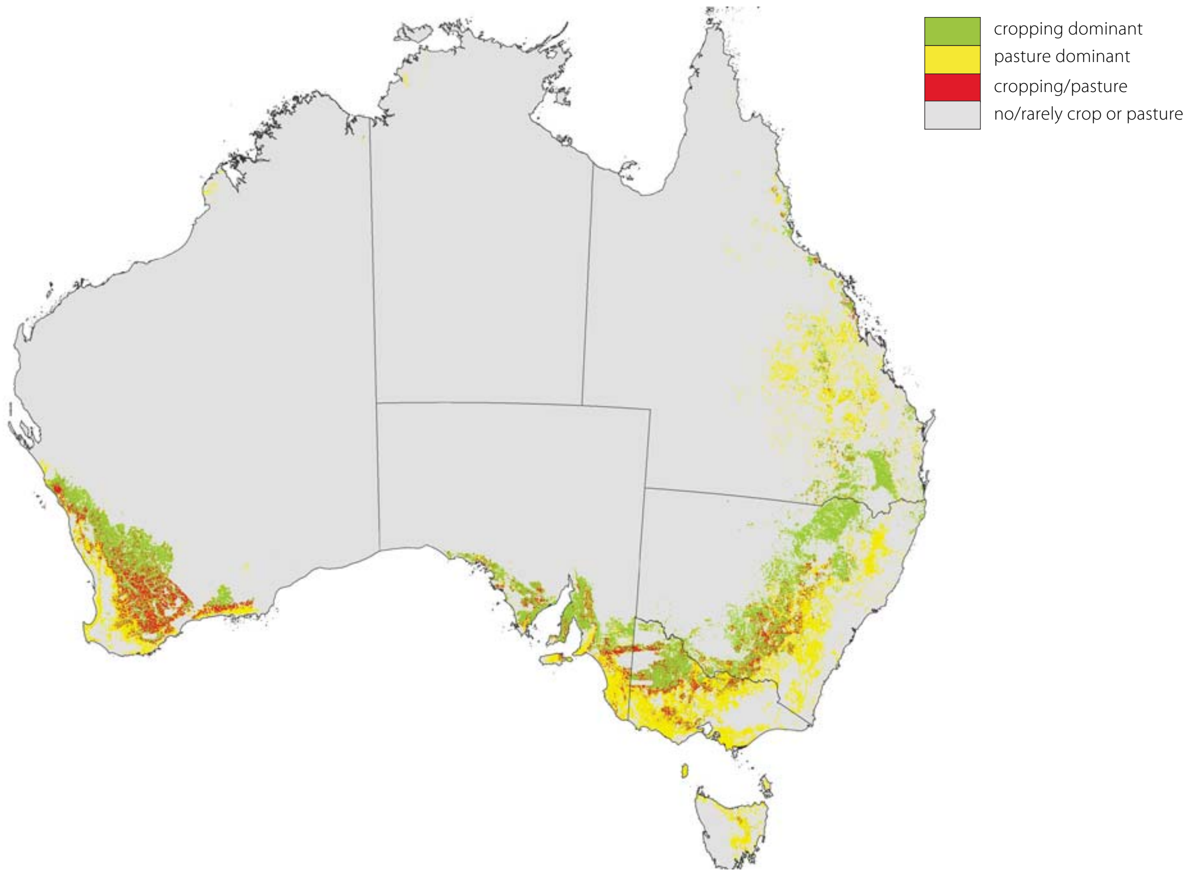
The first challenge is to resolve the spatial scale of change processes. The expansion of urban areas or the conversion of crop land to horticulture, for example, usually takes place at relatively fine spatial scales. This often involves changes in relatively small land parcels. Individually changes may be minor but, in aggregate, can amount to major change. Important changes at fine spatial scale may be difficult to detect using broadscale mapping methods. Other types of change, such as an increase or decrease in the area under cropping, or a change in broadacre crop type, usually involve much larger land units. This may be more readily detected using broadscale mapping methods.

Temporal scale

The second challenge is to resolve the temporal scale of change processes in order to separate trends from cyclical change such as seasonal or market effects or changes that are part of farm systems such as rotations. It may, for example, be difficult to determine whether a shift from cropping to pasture is part of a broad industry transition from grain production to livestock grazing or a short-term response to seasonal or market conditions. The observed change may also be part of a routine rotational cycle; for example, cropping one year and grazing the next. In contrast, a transition from land under pasture to forestry or urban infill is likely to be long-term or permanent.

Temporal change in cropping and pasture at the national level can be identified in the ABARES land use map time series (ABARES 2011) (map 6). The frequency of cropping and pasture land use allocations from 1992–93 to 2005–06 was mapped to identify areas mainly cropped from areas mainly under pasture—and areas where neither dominates (possibly in rotation).

map **6** Cropping and pasture patterns, 1992–93 to 2005–06



Note: Areas in green are those that have been most frequently mapped as cropped (rarely, if ever, sown pasture), areas in yellow most frequently mapped as sown pasture (rarely, if ever, cropping) and those in red mapped as either crop or sown pasture. Areas in light grey were rarely or never allocated to crop or sown pasture.
Source: Temporal change in cropping and pasture derived using the ABARES national land use map series 1992–93 to 2005–06

Acquiring and analysing data

The third challenge in tracking land use change is acquiring and analysing appropriate data. This means time-series data of appropriate frequency and spatial scale. Key information sources available today for tracking land use change in Australia are the regular statistical collections by government and industry, routinely collected government records (such as land parcel information from state valuers general) and remotely sensed imagery. These types of information may be combined to take advantage of their complementary spatial and temporal characteristics as in the ABARES national scale land use mapping.

Statistical collections

The ABS Agricultural Census is the prime source of agricultural commodity statistics in Australia. This was conducted yearly until 1997–98 and then every five years since 2000–01. The census provides statistical information on agricultural land use change at local government scale. The census conducted in 2010–11 was sent to approximately 175 000 farms with an estimated annual value of agricultural operations of greater than $5000.

In non-census years the ABS conducts a survey of around 30 000 farms, stratified by industry, size of operation and region. This survey collects similar data to the census and estimates are produced at national, state and large regional levels. Other ABS surveys collect information relevant to land use and land management, the most recent series being the Agricultural Resource Management Survey conducted in 2007–08 and 2009–10 and planned for 2011–12. The ABS is also planning to survey land management practices to support implementation of the Australian Government's Carbon Farming Initiative.

ABARES carries out a smaller annual survey of around 2000 farms, the Australian Agricultural and Grazing Industry Survey (AAGIS), in the broadacre cropping, grazing and dairy industries (Lubulwa et al. 2010). This survey produces estimates of land area and tenure, labour, farm family characteristics, farm capital, crop type and production, fertiliser use, irrigation, farm receipts, farm costs, farm performance measures, farm debt and farm equity. The relatively small sample numbers (around 2000 farms) limits the capacity for fine-scale spatial analysis.

Remote sensing

Australia's large land area means remote sensing is an attractive option for cost-effective mapping of aspects of land use change. Free access to imagery archives, such as Landsat TM, MODIS and AVHRR, has resulted in their ready uptake in mapping programs. State agencies have also purchased commercial imagery such as SPOT-5 and ALOS imagery of large areas for mapping land use, forestry and updating topographic mapping.

An advantage of remote sensing data for tracking land use change is that it can distinguish land cover patterns, particularly in agricultural areas. A disadvantage is that data from high-frequency sensors like MODIS and AVHRR are at a coarser spatial resolution than many paddocks.

Remotely sensed information products from programs such as, the Australian Collaborative Land Use and Management Program's (ACLUMP) national ground cover monitoring program (Stewart et al. 2011) and the Dynamic Land Cover Mapping for Australia produced by Geoscience Australia in partnership with ABARES (Lymburner et al. 2011), will provide new insights into aspects of land use and land management change.

Where to from here?

Australia is improving its capacity to track land use change, drawing on information sources including satellite remote sensing and statistical collections. ABARES is working with ACLUMP partners to promote collaboration among Australian and state government agencies and others with interests in land use change analysis. The Australian Government's recent move to establish a National Plan for Environmental Information and for the ABS to introduce land and water accounting will further promote capacity to track and report on land use change.

A review by ACLUMP partners in 2011 identified priorities for national land use change reporting. They were:

- tracking 'hotspots' of change, including:
  - land use intensification on the fringes of cities and urban areas
  - loss of prime agricultural land, productive land resources and biodiversity
  - transitions in irrigated agriculture, forestry and carbon farming

- forecasting land use change, including change in response to:
  - increased climate variability
  - disaster risk (including biosecurity, fire, flood and cyclone).

To achieve this will require:

- use of newly available remote sensing and statistical information
- new methods for change analysis (including automated change detection)
- better links between existing data collection and analysis activities, including international engagement
- better methods for identifying and classifying land use transitions, cyclic variability and trends
- improved measurement of error and uncertainty.

The land use and management questions that Australia faces today present a formidable challenge. The ability to monitor land use change is important for managing landscapes and implementing policy settings and program arrangements dealing with agricultural productivity, biosecurity, carbon, natural resources management, biodiversity and food security.

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