

Information, indicators, agricultural productivity and sustainable practices – Australian case studies

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Executive Summary

This paper investigates the information dependence of the policy response to three major emerging issues in Australian agriculture – the challenge of natural resource management, the need to maintain and lift productivity over coming decades and the challenge of climate change and its mitigation.

There has been an increased focus on natural resource management in Australia since the late 1980s and a significant increase in expenditure by the national government. Caring for our Country, the current national initiative has increased the focus on clear targets for investment and expected changes in soil condition and landscape biodiversity. To address the complex need to measure improvement in agricultural ecosystem health as a result of investment in natural resource management, the new Caring for our Country Program recognises interdependence between program design and information support and uses three specific approaches:

- the application of spatial and process information to identify areas for investment;
- tracking the adoption of farm management practices that reduce soil loss through wind and water erosion, enhance soil carbon storage and ameliorate soil acidification processes, and increase the protection of biodiversity on-farm; and
- the development of monitoring capacity nationally to measure and predict trends in natural resource condition.

At this point, the wind erosion program is the most developed; rates of change in land management practices are being monitored, methods for monitoring resource condition have been agreed and projects funded to collect and integrate the ground-based, remotely sensed and modelled information needed to detect trends in wind erosion.

Understanding the dimensions and direction of agricultural productivity, including the interdependence with soil-landscape health, is similarly challenging. Current indicators suggest that Australian productivity is slowing in key industries, perhaps due to climate conditions, land quality degradation and a decline in research investment. It is possible and necessary to go beyond statistical indicators of production and productivity change to measure the factors which underpin productivity and the progress made by industries and regions or R&D providers in providing productivity improvement. The paper illustrates relevant work with crop system models integrated into farm systems, the application of the Signposts approach to productivity issues, and spatially explicit systems which measure the important changes in productivity as spatial shifts occur.

Climate change – its management and mitigation, and its direct effects – is already having a broad and significant impact on Australian agriculture. These impacts are well described by formal national indicators. In addition, Australia's National Carbon Accounting System integrates remote sensing, climate, soil type / soil carbon, vegetation and land use data and ecosystem modeling to measure net emissions from the land. These data underpin and inform the policy debate and are central to it. Beyond these approaches, spatial decision support models and systems which track the extent to which carbon sequestration is being achieved are now essential.

In most cases the current information sets and the indicators which arise from them are only the start of the information need; the OECD indicators, for example, address only some of the important agri-environmental issues for Australia. The need for repeated spatial data with time-series remote sensing, process and statistical models, monitoring schemes designed to match environmental gradients and integrations between these is now clear. In Australia, this is supported by a national infrastructure program known as the Terrestrial Environmental Research Network and potentially by

the proposed National Environmental Information System (NEIS). Both are part of the solution to the need for scientifically robust, spatially explicit, continuous or periodic measurements and reports. In Australia, a model solution is being developed for water information. A similar broadening of agricultural and ecological information collection, collation and supply is needed.

Introduction

Australian agriculture faces a range of interacting forces. While many of these mirror similar issues elsewhere in the world, there are local drivers which have led to specific Australian challenges or which have changed the relative importance of these challenges. Many Australian agricultural soils are endemically water and nutrient limited and are 'old' soils in the sense that many of the components of soil resilience have been weathered away over time. They are thus highly vulnerable to land degradation especially through wind and water erosion. Australia's domestic market is small, with most agricultural land devoted to producing product for export. Consequently there is a strong reliance on global markets and sensitivity to exchange rates for both inputs and outputs. In many cases, Australian agricultural enterprises are relatively small and Australian production does not itself influence price. The resultant 'cost-price squeeze' has been an almost ubiquitous feature of Australian agriculture, although the rate of decline in the terms of trade has slowed since the 1990s (Mullen 2007). The success of agricultural enterprises has therefore been predicated on productivity gains. The latest complication in this already challenging mix is climate change. Parts of Australia appear highly vulnerable to climate change but, in addition to these direct effects, the sector will be strongly affected in the short term by the actions needed to mitigate climate change. Against this background and the need to maintain profitability and sustainability through constant improvements in productivity, the role of effective indicators of the status and trend of agriculture and its interaction with the environment is clear.

Indicators and the current situation

This paper will make the case that OECD or similar global indicators provide necessary but insufficient support for the policy response to major emerging issues. It works through three examples of these issues to explore the information support needed to define the issue, to develop effective policy and to iterate policy settings over time. Global indicators, Australian natural resources audits and productivity analyses suggest both that the challenge to sustain profitable, ecologically sound agriculture is tightening, and that the information available to observe the dimensions of the struggle and to design potential solutions is currently limited.

Measuring the impact of agriculture, its health and the success of interventions to achieve better outcomes is a recurring issue in agriculture and environmental policy in Australia. Amongst key stages in this debate and in the pursuit of better information support have been two versions of an audit of the state of land and water resources in Australia. The first audit ran from 1997-2002 and the second from 2002 to 2008. An extremely simplified summary of their activities in terms of information support for agri-environmental policy was that the first established a series of benchmark statements of the state of the natural resource base and the second developed and delivered a collaborative institutional model for indicators in the areas of land salinity; soil condition; native vegetation; estuarine, coastal and marine habitat; water quality; significant native species and communities; invasive weeds and vertebrate pests; and the social and economic dimensions of natural resource management (NLWRA 2008). It is simplified in the sense that both audits covered broader areas than this would suggest; nonetheless, with the data collected by the national statistical agencies – Australian Bureau of Statistics and ABARE, intensive information collection for the national carbon accounts and the OECD agri-environmental indicators, these represent the key information sources and the key steps in the development of information to support agri-environmental policy in Australia.

Here we consider different dimensions of these information sources (indicators in the broadest terms) and the interaction with policy designed to equip agriculture for a sustainable future in Australia. We consider the policy development and information issues in three areas: natural resource management, agricultural productivity and industry performance, and the agricultural response to climate change – in terms of the role of existing and emerging indicators. We also note that the information support available is less than required. We describe the kind of information required,

which in some cases is in development and, in the conclusions section, discuss important initiatives which are a response to this need.

Natural resource management

Natural resource management in Australia is a shared responsibility between state and territory governments and the Australian Government. While the states and territories have formal responsibility for land management, increasingly, the Australian Government has provided resources and leadership. Since the later 1980s there has been a significant increase in expenditure by the Australian government on natural resource management. Beginning in 1985, the National Soil Conservation Program was an extension of national – state / territory arrangements, but during the term of this program and as the succeeding National Landcare Program developed, the emphasis increased on fostering community participation in improved natural resource management through the national Landcare movement (Campbell 1994, Carey and Webb 2000). The focus on community participation developed further over time and was accompanied by a stronger focus on regional natural resource management planning and the development and support of regional institutions to manage and deliver natural resource management (Hajkowicz 2009). Hajkowicz summarized this evolution from the start of the National Landcare Program in Figure 1.

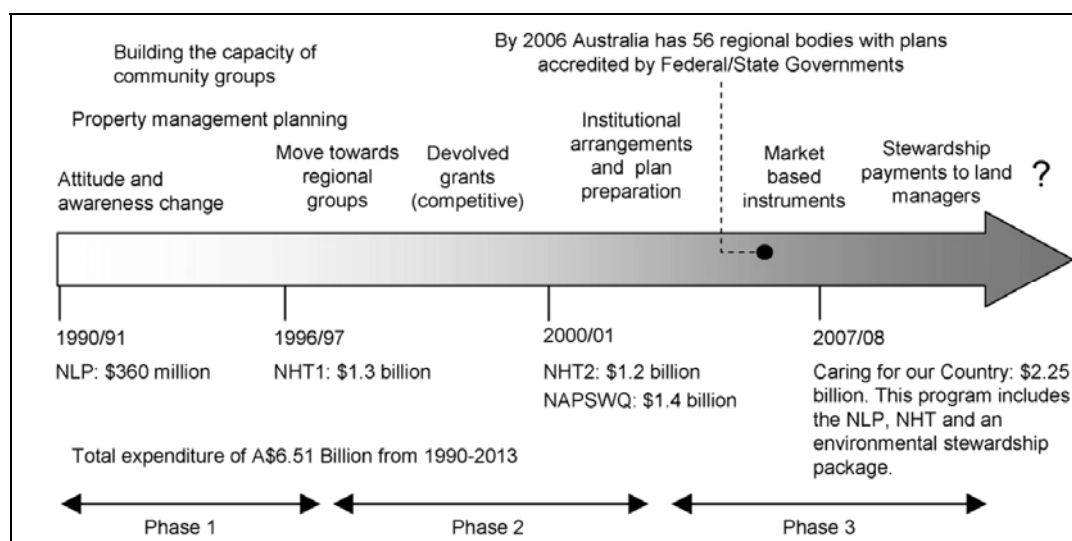


Figure 1 Evolution of Australian national NRM policies (from Hajkowicz 2009) (NLP – National Landcare Program; NHT1 and 2 – Natural Heritage Trust 1 and 2; NAPSWQ – National Action Plan for Salinity and Water Quality).

Caring for our Country began in 2008 and is the current national initiative for natural resource management. It has just released its second Business Plan (Commonwealth of Australia 2010) which has increased the focus on clear targets for investment and expected changes in soil condition and landscape biodiversity. This is clearly dependent on quality information in setting the targets and evaluating performance, but it is also a response to an accumulating set of information and indicators that suggest that agricultural health has not measurably improved over the years of investment in natural resource management. There may have been an unmeasured improvement, but the programs and Australia's information base has not been able to report on investment returns nor the extent to which investment might have improved resource condition.

What has been the role of information and indicators in the development and implementation of this policy? The most notable information input came from the first National Land and Water Resources Audit. For the first time in systematic studies, the Audit estimated the extent and effect of land degradation issues such as erosion, salinity and acidification (NLWRA 2001). The Audit brought together existing data, identifying high and unacceptable levels of salinity, acidification and soil erosion. An immediate policy response to this and several other analyses, and to the observed costs due to salinity in the Murray-Darling Basin (Wilson 2004) and elsewhere, was the

establishment of the National Action Plan for Salinity and Water Quality. This program, together with the second version of the Natural Heritage Trust Program initiated a strongly increased focus on regional institutions. A significant proportion of national expenditure was managed by various forms of natural resource management regional bodies. Some 56 regional bodies cover the country, although they vary in status across the states and territories. In some states / territories, the bodies are statutory and are an integral part of the delivery of natural resource management programs. Elsewhere, they complement state / territory programs.

Outcomes, outputs and the information which document the alignment of plans, the state and trend of the underlying issue and the extent to which the plans have been met have been a long term underlying issue for natural resource management. The Australian National Audit Office in reviewing the National Action Plan and the Natural Heritage Trust 2 concluded:

The quality and measurability of the targets in the regional plans is an issue for attention and is being addressed in some States. This should be considered nationally—especially as the absence of sufficient scientific data has limited the ability of regional bodies to link the targets in their plans to program outcomes.

and

There is little evidence as yet that the programs are adequately achieving the anticipated national outcomes or giving sufficient attention to the ‘radically altered and degraded Australian landscape’ highlighted in the 1996 Australia: State of the Environment Report. Performance measurement has been an ongoing issue covered by three previous ANAO audits since 1996–97 and should be a priority for attention in the lead up to NHT 3¹.

Nevertheless, the programs provided sustained and significant investment. Hajkovicz (2009) estimate Australian expenditure at about A\$11.60 per hectare per year for cropland – commensurate with other OECD countries although across the broader landscape a lower investment of A\$0.63 per hectare per year applies.

Achieving and reporting better outcomes are in many respects complex information and indicator issues. Regional bodies and state governments have found it necessary to establish sophisticated project management tools which track expenditure against targets (eg. <http://www.enquire.net.au>). These vary substantially between states and regional organizations – and track project rather than environmental performance. Indeed the ability to invest in natural resource management and track the change in natural resource outcomes is challenging – and requires innovation in both program design and in information support.

The latest iteration in natural resource management policy (Caring for our Country – <http://www.nrm.gov.au/>) recognises this interdependence between program design and information support. Roughly (2009) describes the development of the Program Logic. For the Sustainable Practice target there is a clear connection with the information collected for the National Land and Water Resources Audit, through later development of indicators of soil condition (soil carbon, soil acidification, wind and water erosion) to the establishment of the Sustainable Practice targets which are informed by a national assessment of need and priority. There remains an important reliance on community level action, management and reporting, but the program now adds three specific areas of information support:

1. the application of spatial and process information to identify areas for investment;
2. tracking the adoption of land management practices by farmers that will reduce soil loss through wind and water erosion, enhance soil carbon storage and ameliorate soil acidification processes, and
3. the development of a monitoring capacity nationally to measure and predict trends in natural resource condition.

¹ Australian National Audit Office 2008 p.16

Wilson et al. (2009), Baldock et al. (2009), Smith and Leys (2009) and Hairsine et al. (2009) describe the processes followed to identify areas where investment in land management practices to address soil acidification, soil carbon, wind erosion and water erosion respectively will provide the biggest benefits. Each involved the collation and integration of spatial soil and land use information and model and process data. Importantly, Natural Heritage funds had been used to enhance this information and improve the process. Soil pH priority areas are illustrated in Figure 2.

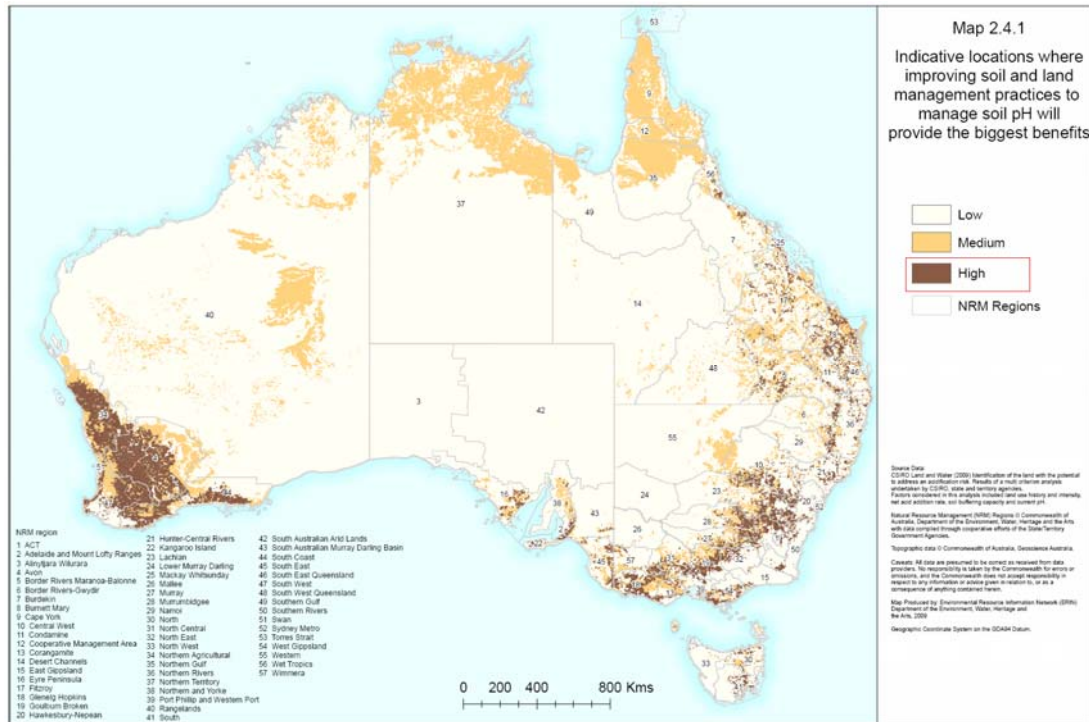


Figure 2 Areas for investment in natural resource management - the acidification example

Monitoring of resource condition outcomes has not been possible in Australia to this point; existing indicators lack the spatial breadth and precision to measure progress against the aims of Caring for our Country. Consequently, a priority for the Sustainable Practice target has been the scoping, design and development of monitoring programs in soil carbon, soil pH, water and wind erosion. At this point, the wind erosion program is the most developed; the information content and approach needed to monitor progress in mitigating wind erosion has been agreed (Leys et al, 2008) and the recommended projects funded.

The simplest indicator of susceptibility to wind erosion is the level and quality of groundcover – in a soil, vegetation and climate context. The monitoring also concentrates on on-site loss and off-site dust loads and uses remote sensing, rapid roadside observations and calibration / validation sites. The wind erosion model (CEMSYS) allows scaling and integration. A significant challenge remains to disentangle the extent to which this set of indicators is climate or management driven.

Agricultural productivity and industry performance

Understanding the dimensions and direction of agricultural productivity, including the interdependence with soil-landscape health, is similarly complex and complementary to policies fostering improved natural resource management. Australian agriculture has depended on productivity gains to maintain profitability – and has consistently outstripped the general economy – 2.8% versus 1.4% over the past two decades (Nossal and Gooday 2009). Mullin (2007) illustrates that much of the value of farm output and therefore farm viability has come from productivity improvement over the last 50 years. These gains have tended to come in phases with periods of slow

growth (Donald 1965; Angus 2001), have been achieved with a combination of technological change and adoption and through changing economies of scale (Angus 2001; Kingwell and Pannell 2005). Current indicators suggest that Australian productivity is slowing in key industries, perhaps due to climate conditions and a decline in research investment (Nossal and Gooday 2009). There are also indications in some industries eg. sugar cane, that decline in the crop–land management–land quality systems may be significant (Garside et al. 2005).

The productivity performance in Australian agriculture is tracked across all products by the Australian Bureau of Statistics using multi-factor productivity concepts (ABS 2007); the ABARE uses comprehensive farm survey data to create indices for specific industries. Figure 3 shows OECD production indices and ABARE productivity data for broadacre cropping for Australia. Both are strongly influenced by recent severe droughts but are suggestive of a decline in productivity.

It is possible and necessary to go beyond these indicators to measure the factors which underpin productivity and the progress made by industries and regions or R&D providers in providing the

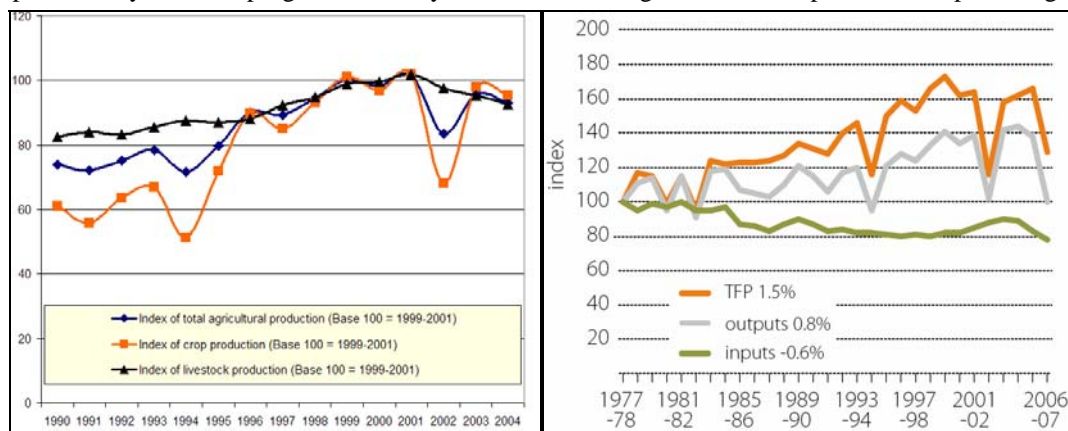


Figure 3 OECD production index and ABARE productivity index for broadacre cropping in Australia

productivity improvement. Historically, much of the gain has been obtained by research identifying specific efficiency opportunities; however, Carberry et al. (2009) have observed that the exploitable gap between farm and experimental yields has narrowed substantially in recent years. The Carberry et al. (2009) paper revisits work which applied crop system models to commercial farming systems. Over time, this program developed coupled information on farm performance and decision-making with modelling on actual and potential outcomes. It suggests that powerful indicators of progress can be achieved with the integration of crop systems models with monitored farm management.

At broader scales, the “Signposts for Australian Agriculture” (Signposts) project has demonstrated the capacity for industry-specific reporting and the integration of biophysical performance, social and economic performance (<http://nlwra.gov.au/national-land-and-water-resources-audit/signposts-australian-agriculture>). An important aspect underpinning past productivity performance has been the level of adoption (and invention) of more efficient approaches. Signposts has been seen as a useful indicator of management change by some of Australia’s Rural R&D Corporations; a focus on the match with productivity outcomes may be the next stage of this project.

An important aspect of productivity change which is hidden in national or site based approaches are spatial shifts in agriculture and therefore a change in the connection between land use and the land resource. This has always been a feature of Australian agriculture – a reflection of adaptive learning as crop and pasture systems are tested and refined in new landscapes. In some cases, limits have been crossed and agriculture could not be sustained, as in the Goyder Line in South Australia (Nidumolu et al. 2009). With an apparent increase in climate variability (perhaps an expression of climate change), substantial spatial shifts are contemplated in Australia, for example:

- Nidumolu et al. (2009) suggest that the limit of dryland cropping may be contracting in South Australia.

- The Murray-Darling Basin has experienced an unprecedented sustained decline in runoff and is projected to have 30% less water available for irrigation in the future (CSIRO 2008).
- Higher than normal rainfall has been experienced in northern Australia.

As a reflection of concern with the long term sustainability of the existing distribution of agriculture in Australia, the Office of Northern Australia has recently published an extensive review of the potential for agricultural intensification in northern Australia (http://www.nalwt.gov.au/science_review.aspx). As a more general response, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and its partners are now developing new programs which integrate crop system modelling with time-series remote sensing to develop finescale indices of the dimensions underpinning productivity. These are likely to be needed as supplements to existing indicators as the productivity issue intensifies and the policy settings become more complex.

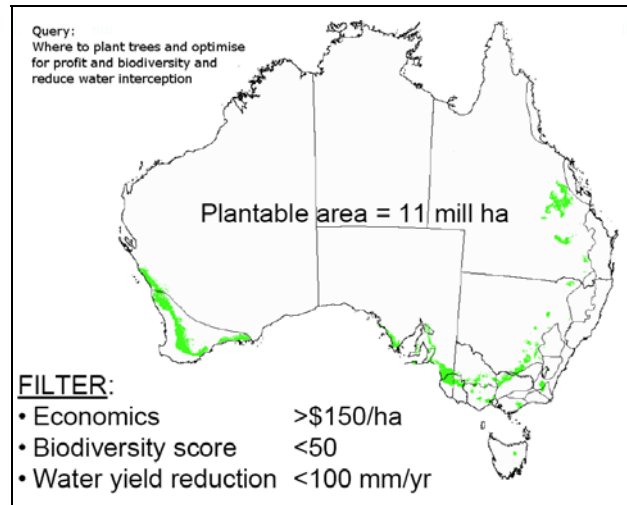


Figure 4 An illustration of the spatial output from the spatial model of forestry options of Polglase et al. (2008)

Agricultural response to climate change

Climate change – its management and mitigation, and its direct effects – is already having a broad and significant impact. This is an area where Australian indicators are well developed and focused and influence the policy debate. Australian agriculture is close to the climate change issue. In 2007, of the total national emissions of 597 Mt CO₂-e of greenhouse gases (Department of Climate Change 2008), the agriculture sector contributed 88 Mt CO₂-e (with methane emissions from livestock prominent) and a further 77 Mt CO₂-e was emitted from deforestation, including land cleared for agriculture. This is a relatively high level of contribution by agriculture compared with other OECD nations, and a substantial policy debate continues on the role of the sector in the efforts to reduce national emissions. The debate is far from settled, but the information needed for the debate and the emerging policy options have grown in importance. The role of forestry in carbon sequestration and potential for soil carbon capture on agricultural land to be credited are potent current examples.

Australia's National Carbon Accounting System integrates remote sensing, climate, soil type / soil carbon, vegetation and land use data and ecosystem modeling to measure net emissions from the land. These data underpin and inform the policy debate and are central to it. Building on that, CSIRO researchers are creating tools which explore the options for land management responses to climate change or biosequestration. Polglase et al. (2008) have built a spatial model of agroforestry potential to allow exploration of the options available to include “carbon forestry” in agricultural and forestry enterprises. An economic model allows sensitivity testing of carbon prices on likely outcomes (Figure 4). Despite acknowledged limitations in assumptions and the non-inclusion of key environmental factors such as salinity, the model has supplemented the indicator data from the Department of Climate Change in the policy debate.

Soil carbon declines from the moment land is cleared for agriculture. Sanderman et al. (2010) estimate from a review of published studies that from 40-60% is lost as land becomes pasture or cropland respectively. This represents a significant potential for sequestration, if the carbon can be reintroduced and retained in the soil. However, decline and build-up of soil carbon do not follow the same path (Chan 2001). More resistant carbon pools are lost more gradually and replaced slowly over time, so that vulnerability to loss is highest in the early stages of carbon buildup. Indicators of

soil carbon levels in Australia are based around crop / vegetation mapping, soil type and a soil carbon model (a version of Roth C built into the Department of Climate Change's FULLCAM model).

If on farm soil carbon sequestration becomes part of the voluntary carbon market (bringing a range of side-benefits from higher levels of soil organic matter), the demand for information will substantially increase. At farm level, some aspects of this information will be integral to the farm business. This may include an array of proximal sensing systems, standardized or adaptive sampling schemes and rapid soil analysis services. At this fine scale, this information is unlikely to be freely available. Broader indicators which still track the extent to which sequestration is being achieved will be essential. This will probably integrate some form of farm survey with a national monitoring scheme, remote sensing (using model – data fusion approaches eg. Barrett et al. 2005) and rapid soil measurement using proximal sensing of carbon pools.

Relationship to OECD's agri-environmental indicators

The Signposts framework provides a convenient basis for comparing indicators described in this paper with those of the 37 indicators used by OECD to measure the environmental performance of agriculture (OECD 2008). The Signposts framework measures agriculture's performance in terms of assets for which the industry has management responsibility (for example, agricultural land) and assets that are managed by others (for example, atmosphere) (Chesson et al 2009, Chesson et al 2007). This distinction determines how performance is measured. For assets managed by agriculture, performance is measured by the change in condition of the asset. For assets managed by others, performance is measured by the impact of agriculture on the asset. The Signposts framework includes economic, social and bio-physical assets, but only bio-physical assets are shown in Figure 5 as these are the ones relevant to environmental performance. Figure 5 shows coincidence between the components emphasised in this paper (shaded) and OECD agri-environmental indicators (numbers in bold) for soil erosion and greenhouse gas emissions. Other components of current significance in Australia (soil salinity, soil acidity, soil carbon and carbon sequestration) are not specifically addressed by the OECD indicators.

Indicators of management practices are also relevant to the Australian needs, especially for the Caring for our Country initiative (OECD indicators 25-32). While not shown in Figure 5, data on the area of certain farms under nutrient management, farms using nutrient testing, ground and other vegetative cover on farms and biodiversity management practices on farm are collected for policy setting, monitoring and review. Caring for our Country and Signposts for Australian Agriculture require a more extensive range of management practices than those included in the OECD indicator set. Additionally, some OECD practices are not necessarily those that are regarded as most important in Australia; e.g. having nutrient management plans is less important for Australia's mostly low input farming systems.

Even where there are components in common, the OECD indicator does not necessarily suit Australia's needs. For example, Australia has an interest in indicators that relate to specific soil condition outcomes such as pH and soil carbon. While these might broadly fit under indicator 28 which covers the area of arable land under soil conservation practices, the need is for indicators better matching the policy drivers and targets. Agricultural water use in total national water utilisation (OECD indicator 3) while available and easily reported is not particularly informative in terms of environmental performance. What is more informative is agricultural water use relative to the sustainable yield from surface and groundwater systems – an indicator that should be available from the Bureau of Meteorology in the future.

These observations reinforce the conclusion that a single, simple set of indicators is not sufficient to characterise the performance of agriculture across OECD countries. The OECD can provide important support for the development of concepts and frameworks, but policy development and decision making require that applications be tailored to the situations of individual countries.

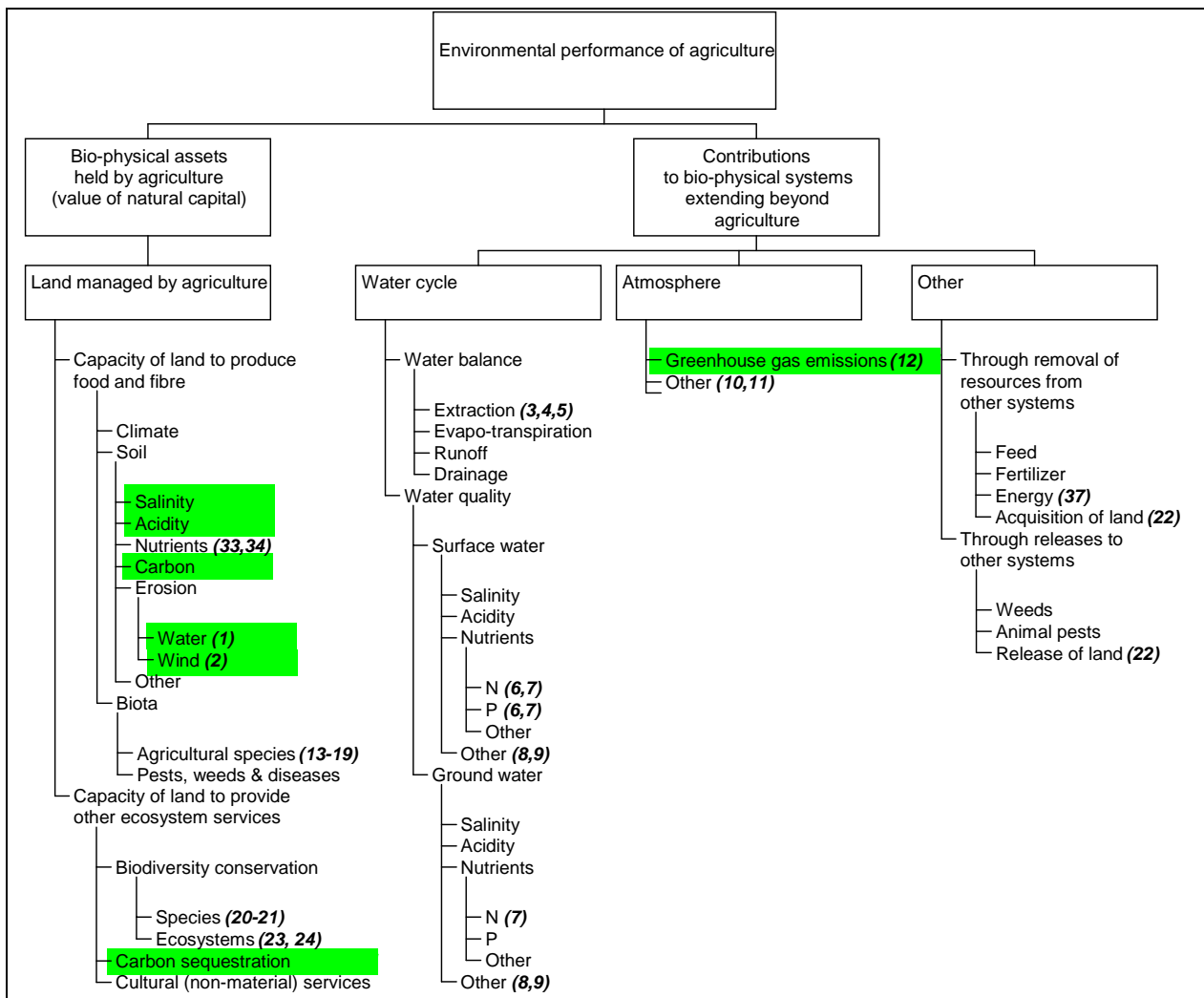


Figure 5 Relationship between components of environmental performance emphasised in this paper (shaded) and OECD agri-environmental indicators (numbers in bold) using a simplified version of the Signposts for Australian Agriculture framework.

Conclusions and some policy / structural responses to information needs

In three of the key policy areas for Australian agriculture, there is a need for improved information resources to inform policy development and implementation, the options available and the need to adapt as outcomes change. For each of these areas, there is a clear interaction between the design of the policy or program and the information resource which supports it. These information needs are challenging. Australia has been well served by the national statistical agencies and the integrity of their data systems and approaches. In most cases, however, these information sets and the indicators which arise from them are only the start of the information need. This includes the need to interrogate these data to disentangle cause and effect, but it also suggests that we need to go beyond these data sets. Crucially, for the examples listed here, that includes repeated spatial data (ie. time-series remote sensing), process and statistical models, monitoring schemes designed to match environmental gradients and integrations between these. There is a sense that these information sources are still in the research arena – although this is changing as policymakers increasingly ask questions that can only be resolved, for example, by spatial modelling. The

Australian Government has instigated a national infrastructure program known as the Terrestrial Environmental Research Network² (TERN). This is developing a concerted national program to coordinate and make available time-series remote sensing data. The challenge is to incorporate the products of this investment and the design of these products into the policy process so that they inform each other.

A more direct policy response to the need for richer information is being investigated currently. A National Environmental Information System (NEIS) has been proposed and is being scoped by national and state / territory jurisdictions through a policy and program planning process. This solution arises from the kind of policy and implementation experiences outlined in this paper and from direct and influential calls. This includes influential groups such as the Wentworth Group of Concerned Scientists (2008), the Australian National Audit Office statements cited earlier and the most recent State of Environment Report (Beeton et al. 2006). The State of Environment report included in its introduction the caveat:

*Since 1996, three Australian state of the environment (SoE) reports have been prepared. Yet because of the lack of accurate, nationwide environmental data, the Committee is still not in a position to give a clear national picture of the state of Australia's environment.*³

The shape of the NEIS, the nature of the information contained within it and whether it will be established in the near future are still uncertain. But the need remains for scientifically robust, spatially explicit, continuous or periodic measurements and reports. These go beyond current indicators and match the policy and management imperatives which are emerging for agriculture and land management. In Australia, a model solution is being developed for water information. The Bureau of Meteorology has a new mandate for water information services (<http://www.bom.gov.au/water/>). It aims to accurately monitor, assess and forecast the availability, condition and use of water. A similar broadening of agricultural and ecological information collection, collation and supply is needed.

Acknowledgement

The authors acknowledge the input of Dr Jean Chesson of the Bureau of Rural Sciences for her contribution on the Signposts project and Agri-environmental indicators – and for her comments on the overall paper

² TERN url: <http://ncris.innovation.gov.au/Capabilities/Pages/TERN.aspx>

³ Beeton et al. (2006) p. 1

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