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Value of Returns to Land and Water and Costs of Degradation

Project 6.1 Final Report to the
National Land & Water Resources Audit

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Volume I



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on behalf of consortium members



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A consultancy report to the National Land and Water Resources Audit by the Policy and Economic Research Unit of CSIRO Land and Water

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Executive Summary

This report presents new datasets developed through the National Land and Water Resources Audit¹ that relate to economic aspects of natural resource management in Australia. There is a focus on resources used to support agriculture and resources impacted by agriculture. The report provides:

1. An overview of the economic returns from the Nation's land and water resources used in agriculture;
2. An agricultural or within paddock perspective on economic aspects of salinity, sodicity and acidity;
3. A "beyond the farm gate" perspective on impacts of agriculture on local infrastructure and downstream water users;
4. Information on willingness to pay to slow rural population decline and improve environmental attributes that are not part of the market for agricultural products;
5. An overview of how the databases developed for this project are organised and observations about ways they can be developed further to assist decision makers.

Consistent with protocols used by the Australian Bureau of Statistics and the Australian Bureau of Agriculture and Resource Economics, the database provides a new capacity to integrate natural resource information in Australia. The datasets are primarily built for the 1996/97 financial year, the year of an agricultural census. *Except where stated otherwise, all dollar values given are in 1996/97 dollars.*

Most of the data is represented on a 1km by 1km grid covering agricultural land. Whilst modelled at this level of spatial detail interpretation should generally occur at coarser levels. Data on downstream infrastructure costs of deteriorating water quality has been assembled by river basin.

The Storyline

An understanding of economic issues surrounding natural resource management in Australia is progressively developed here in a manner analogous to 'story-telling'.

¹ Referred to henceforth as the Audit.

The study commences with a nation-wide assessment of economic returns, obtained through agriculture, to the natural resource base. Profit at full equity is used to measure returns to natural resources and managerial skill. The assessment maps returns to the natural resource base for the nation. It covers both the rangelands, which are vast low-rainfall areas used mostly for sheep and beef grazing, and areas of intensive agricultural production.

The profit function, used to determine profit at full equity, contains a yield term that can be used to link biophysical landscape condition to agricultural profit. This is used in the next phase of the study to assess the current economic opportunities associated with managing saline, acidic and sodic soils. In addition, the economic implications of increasing severity and extent of dryland salinity from 2000 to 2020 are also assessed. The economic merits of soil treatment are assessed through a benefit cost analysis of lime and gypsum application, to ameliorate acidic and sodic soils.

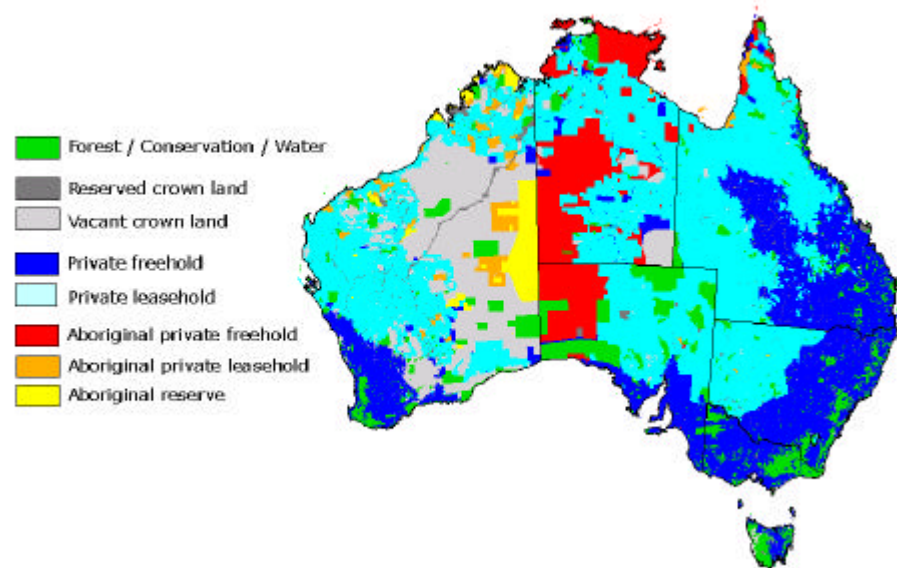
From here the assessment looks towards tangible economic impacts that occur beyond the farm gate. This involves an analysis of infrastructure damage costs resulting from land and water degradation. Infrastructure damage is broken up into two main classes: local and downstream. The local infrastructure impacts occur in the same location as the degradation agent, e.g. salt damage to buildings. The downstream infrastructure impacts are felt some distance from the degradation agent, e.g. maintenance of reservoirs due to sedimentation.

Also beyond the farm gate, but of a more intangible nature, are the non-market impacts of resource management. These are assessed through choice modelling, a valuation technique that determines monetary values for environmental and social assets from information collected in surveys. The attributes valued include the impact of people leaving rural areas, bushland, species and waterways.

Drawing this information together, a comparison is made between the different sources of salinity impact cost (agriculture, local infrastructure and downstream) over the next twenty years. This illustrates the integrative capacity of the datasets developed through this project. These datasets will provide foundation information for economic and policy analyses relating to Australian natural resource management.

An Overview of the Nation's Land and Water Resources

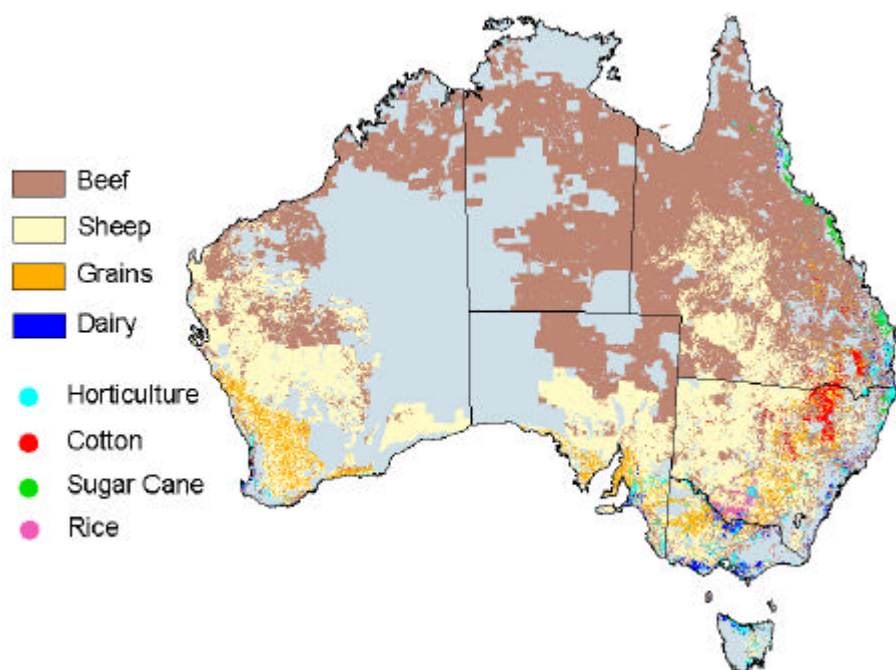
Large areas of Australia are under private freehold or leasehold ownership. This has important implications for the way natural resources are managed. Changes of land use and solutions to land degradation will arise only through cooperation between government, landholders and the community.



In area terms, most of the Nation's land resources allocated to agricultural production are grazed by either sheep or beef cattle. Only a very small portion the nation's agricultural land is used for intensive production. The table below shows areas of agricultural land use based on a 1996/97 Land Use Map of Australia developed for this project.

Areas of agricultural land use in Australia

Landuse	Area ('000 ha)
Beef	287,913
Sheep	157,795
Grain	21,191
Dairy	3,505
Sugar Cane	491
Cotton	405
Horticulture	405
Rice	157
Other	155
Total	472,016



The land use map shown above covers the intensively used agricultural lands, mostly in coastal areas, and the vast sparsely used low rainfall regions commonly referred to as the rangelands. As analysis latter in the report shows, the rangelands represent a large portion of Australia's agricultural area but have extremely low productivity per hectare.

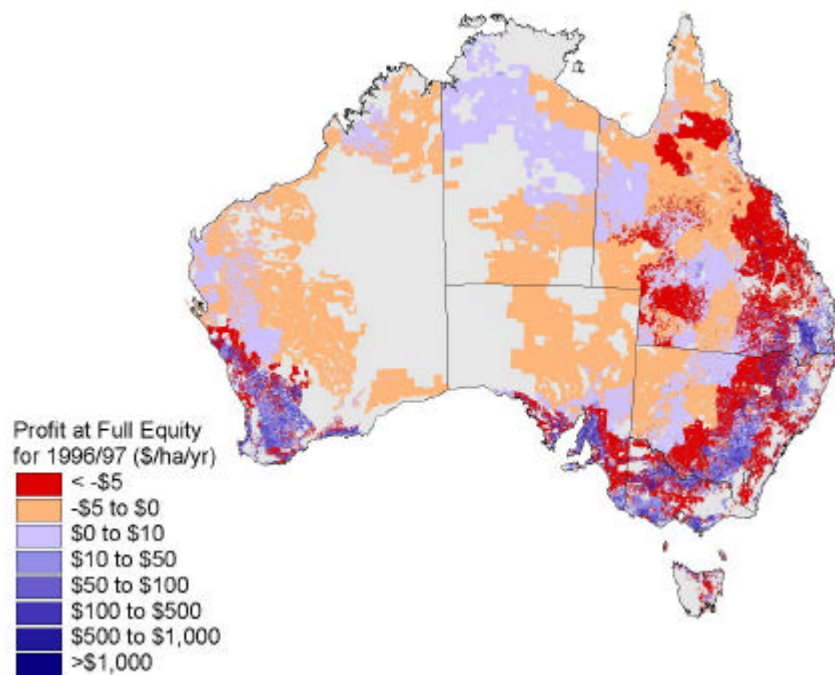
Economic Returns to the Natural Resource Base

Economic returns to natural resource base from agriculture are measured using profit at full equity. This is the economic return to land, capital and management after the value of labour provided by managers has been deducted. It does not include any debt payments to financial institutions. Estimates of profit at full equity differ from gross margins, a commonly used measure of agricultural financial performance, by including fixed costs of production (e.g. depreciation of capital assets, labour).

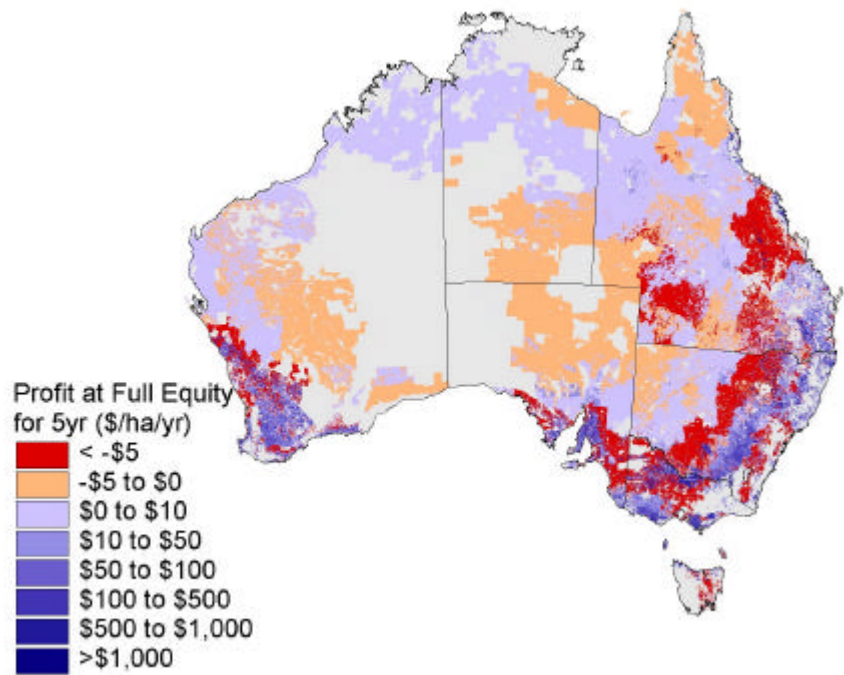
Profit at full equity measures presented in this report are derived from survey data, satellite data, government reports, gross margin handbooks and other sources. Profit has been mapped on a 1km by 1km grid covering the nation, although underlying source data is accurate at coarser levels of spatial detail. The twelve variables relating to prices, yields and costs used to derive profit at full equity are also mapped to a 1km grid. A shortened version of the profit equation reads:

$$\text{Profit At Full Equity} = \text{Price} \times \text{Quantity} - \text{Variable Costs} - \text{Fixed Costs}$$

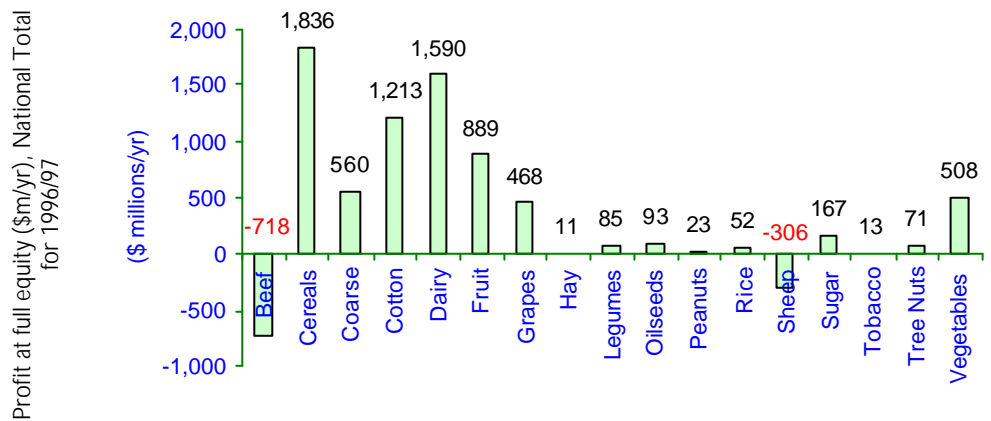
To gain an appreciation for how economic returns to agriculture varied across Australia, profit at full equity was computed based both on 1996/97 prices and at average prices over the period 1992/93 to 1996/97. Using 1996/97 prices and yields, the estimated total profit at full equity was roughly \$6,555 million for the Nation. An area of 311.5 million hectares, 66% of agricultural land, made a loss and 159.9 million hectares, 34% of agricultural land, made a profit. The bulk of the loss-making areas were the low-rainfall sheep/beef grazing lands. The following map shows profit at full equity for 1996/97.



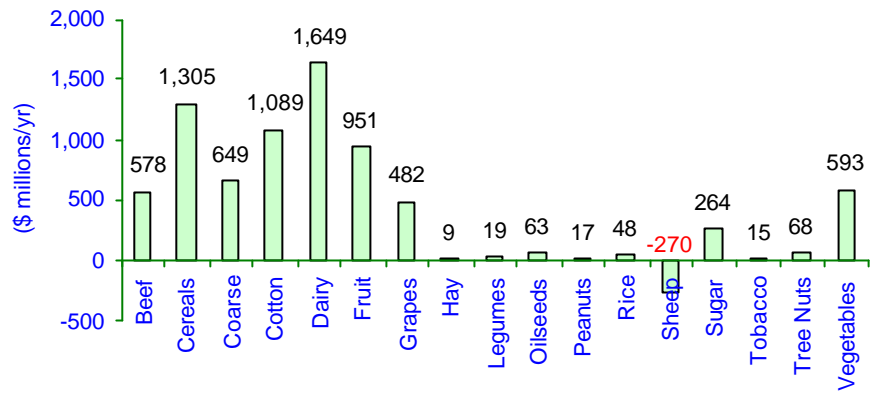
Mean prices and yields were used to estimate average profit at full equity over the five year period 1992/93 to 1996/97. This provides a total profit at full equity of \$7,530 million per year. Using these values sheep grazing was the only land use that made a loss, at \$270 million per annum. Nationally, an area of 220.7 million hectares, 47% of agricultural land, made a loss and 250.6 million hectares, 53% of agricultural land, made a profit. Following is a map of profit at full equity for the 1992/93 to 1996/97 five-year period.



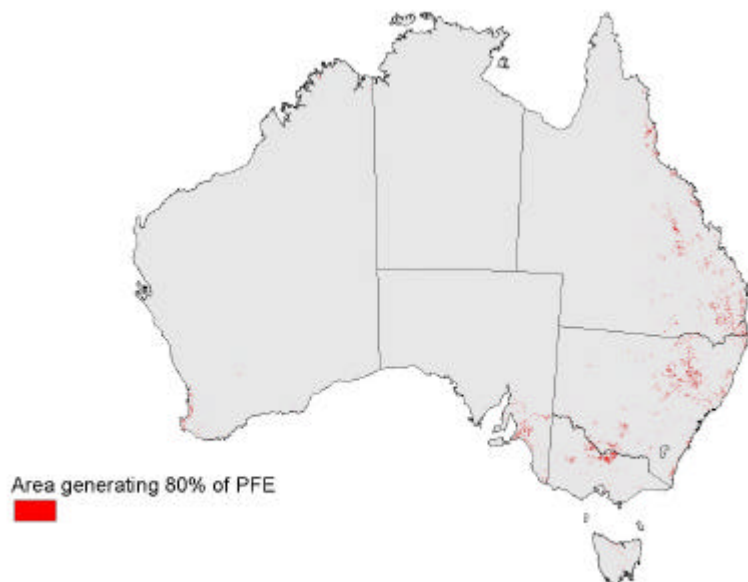
In climate terms, 1996/97 was an “average” year. Incomes in this year were lower for beef and sheep primarily due to low commodity prices. Prices for beef have since risen markedly, as can be seen in the following two charts.



Profit at full equity (\$m/yr), National Total, 5yr Average for 1992/93 to 1996/97



Only relatively small areas of Australia have high returns per hectare. In 1996/97 the returns made were not sufficient to cover production costs and pay land managers a wage in most areas. In fact, 80% of Profit at full equity—the return to land, water, capital and managerial skill—comes from 4 million hectares, less than 1% of the area used for agriculture. The minimum area of Australia’s agricultural lands needed to produce 80% of the Profit at full equity is shown below. Excluding the rangelands, using a definition of the area based on river basins, around 3% of agricultural land produces 80% of profit at full equity.



The Audit identifies over 200 river basins in Australia. Over the five-year period (1992/93 to 1996/97) fourteen (14) of these basins produced over half of the total profits from Australian agriculture, as shown below.

Contribution of catchments to total agricultural income based on five-year mean profit at full equity (1992/93 to 1996/97)

Basin	Profit at Full Equity (\$000)	Cumulative %
Condamine-Culgoa Rivers	424,572	5.6
Murrumbidgee River	418,392	11.2
Namoi River	380,857	16.3
Avon River	303,668	20.3
Lower Murray River	302,864	24.3
Mallee	283,720	28.1
Border Rivers	266,110	31.6
Gwydir River	225,494	34.6
Broken River	197,455	37.2
Fitzroy River (Qld)	196,296	39.8
Goulburn River	193,330	42.4
Brisbane River	191,824	44.9
Broughton River	168,094	47.2
Macquarie-Bogan Rivers	159,375	49.3
Rest of Australia	3,817,938	50.7
Total	7,529,989	100.0

Assistance to Agriculture

Profit at full equity is a measure of returns to private landholders. From an economic perspective, it is necessary to recognise the costs of assistance to agricultural production via government subsidies, tariff protection, extension support and other means. Subtracting the value of these support payments from profit at full equity results in an estimate of Net Economic Return. For the 1996/97 financial year the average annual cost of assistance to agriculture, obtained by spreading estimates of nominal rates of assistance by industry across the land use map, was \$2,239 million.² The value of this subsidy was equivalent to 34% of Profit at full equity in 1996/97. The net economic return in the same year, profit at full equity less assistance, was equal to \$4,316 million.

These estimates do not include the cost of government contributions to environmental and natural resource programs like Landcare and the Natural Heritage Trust. More recently, the extent of support to the dairy industry — the industry that has produced the greatest return to our land, water and capital resources — has been reduced. Thus, 34% is now an overestimate.

² The nominal rate of assistance measures the extent to which consumers pay higher prices and tax payers pay subsidies to support local output, compared against a hypothetical situation where no assistance or support is given.

Irrigated Agriculture

In proportional terms, most of the profit at full equity has come from irrigated land uses. Less than 1% of land used for agriculture is irrigated, but it contributes roughly half of total agricultural profits. However, it should also be noted that profit at full equity can vary substantially from year to year and dryland agriculture can be a very efficient user of rainfall. A comparison of profit at full equity derived from dryland and irrigated land uses is as follows.

	Area		Profit at full equity (\$m)			
	(000 ha)	%	1996/97	%	5yr	%
Dryland cropping & grazing	469,659	99.5%	2,888	44%	3,691	49%
Irrigation agriculture	2,357	0.5%	3,667	56%	3,839	51%
All agricultural land	472,016	100%	6,555	100%	7,530	100%

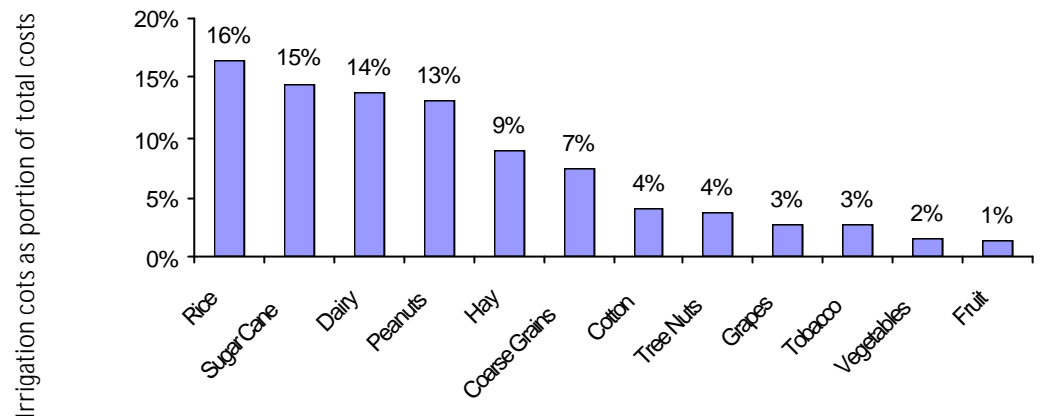
The efficiency of irrigation water use varies from land use to land use. In the past, it has been common to report water use efficiency in terms of the dollar gross return per megalitre used. In this report, an estimate of profit at full equity per megalitre used is provided. Intensive land uses, like vegetable and fruit production, have high returns per unit of water used. Dairying, the largest user of irrigation water in Australia, accounts for 40% of the water applied to crops and pastures in Australia.

Returns to water and intensity of water use by land use (profit at full equity 1996-97) ¹

Land Use	Water Returns (\$/ML)	Water Use (ML/ha)	Percent of total water use
Vegetables	1295	3	2.6%
Fruit	1276	7	4.4%
Tobacco	985	4	0.1%
Grapes	600	8	5.2%
Tree Nuts	507	6	0.9%
Cotton	452	7	15.5%
Coarse Grains	116	3	3.5%
Dairy	94	7	39.5%
Peanuts	90	3	0.2%
Hay	54	4	0.1%
Rice	31	11	11.3%
Legumes	24	3	0.2%
Sheep	23	4	0.1%
Sugar Cane	21	7	8.0%
Beef	14	4	7.2%
Oilseeds	10	3	0.6%
Cereals	-9	3	0.6%
All irrigated land uses	245	6	100.0%

1. Does not include unmetered transmission and storage losses.

Industries for which water charges and fees represent a high portion of the total costs, above 15%, include legumes, dairy, cereals, rice, sugar cane and oilseeds. The profitability of these land uses is likely to be sensitive to changes in water charges and fees.³ The industries of cotton, tobacco, vegetables and fruit all have low water costs, below 5%, as a portion of total costs. The profitability of these industries will be less sensitive to a change in water use charges.



Estimates are based on the assumption that all water used is charged at the price set by the local authority. This means that in cases where irrigators supply their own water there is an overestimate of water cost.

Soil Resources: Economic Opportunities

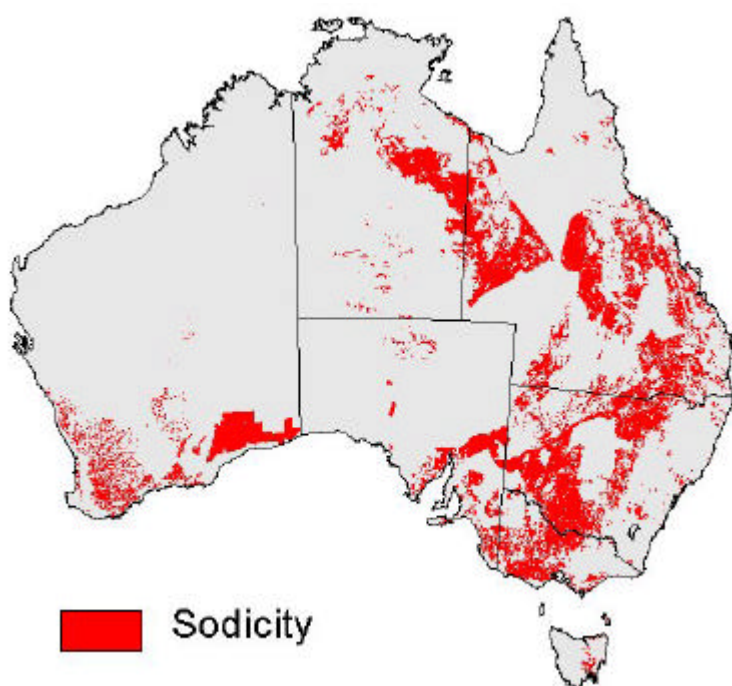
An assessment was made of the economic opportunities associated with managing saline, sodic and acidic soils. This assessment did not contrast current soil conditions with pristine soil conditions. Rather, it focused on the economic opportunities arising from future changes to soil condition.

In the assessment measures of gross benefit and impact cost are provided. The gross benefit is the additional profit at full equity attainable in a given year if the soil constraint were removed without cost. It can be considered an approximate investment ceiling for soil treatment. Impact cost measures the decline in profits due to worsening salinity extent and severity over the next 20 years (2000 to 2020). In addition to these measures, a benefit cost analysis of lime and gypsum application to ameliorate acidic and sodic soils was undertaken.

³ No allowance is made for the cost of water purchased by buying water and trading it into the area where the production occurs. In all cases, it is assumed that all water rights are owned by the managing entity.

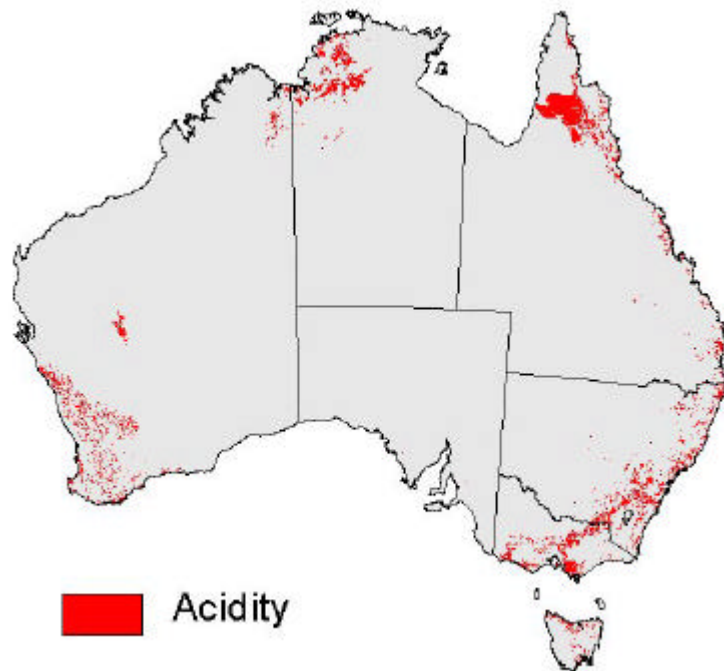
Soil Sodicty

From a purely agricultural production perspective and without regard to broader natural resource management and environment issues, the most common soil attribute limiting potential yield is soil sodicity. Much of this sodicity is natural—an inherent characteristic of many Australian soils. Nevertheless, it is possible to increase yields on sodic soils by applying gypsum. The map shows areas where soil sodicity reduces the potential productivity of crops/pastures by over 5%.



Soil Acidity

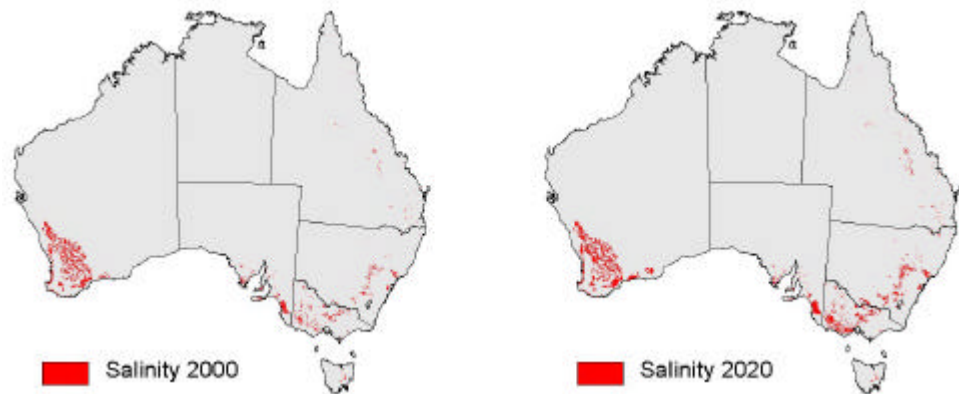
Soil acidity, both induced and natural, constrains production opportunities in Northern Australia, South Eastern Australia, Western Australia and the Queensland Coast. The following map shows areas where soil acidity reduces crop/pasture potential productivity by over 5%.



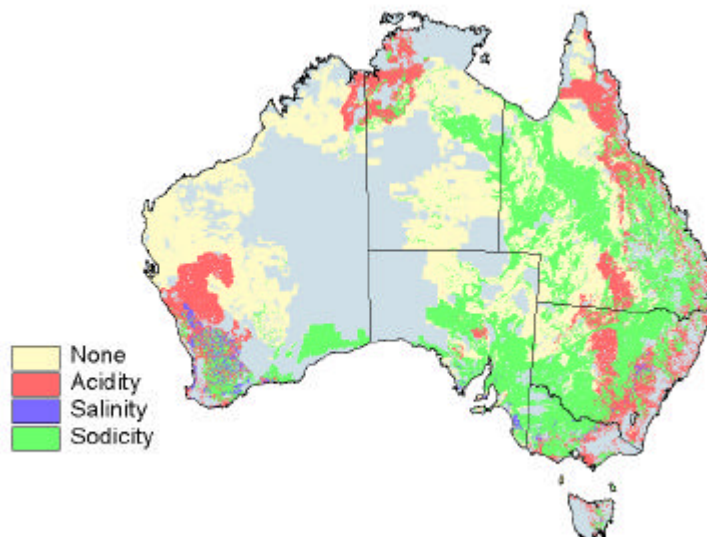
Soil Salinity

Across the nation there has been much discussion about the extent that the area of saline soils is expected to increase. In the *Audit's Dryland Salinity Assessment* salinity hazard, rather than salinity extent, was mapped using different definitions of hazard in each State and Territory. As economic analysis requires consistent information on extent, all hazard maps were standardised and converted into estimates of extent. A 2000 salinity map was generated for Queensland using point data from a survey of extent in the early 1990s and information imbedded in the 2050 map supplied by that State.

From a current agricultural production perspective the area affected by salinity is very small. Saline soils cover small areas on the map below. In 2000, the total area is estimated to cover 0.7% agricultural land. But where soils are affected by salinity the reductions in yield are generally much greater than for sodicity or acidity. The following two maps show salinity related crop/pasture yield loss for 2000 and 2020.



The area dominated by sodicity is over 5 times the area dominated by acidity, which in turn is over 6 times that dominated by salinity. The map below shows that location of the most limiting soil productivity constraint at each location. These data provide a starting point to assessing where strategic intervention might be profitable.



Summary of current soil attribute constraints on agricultural yield by State and Territory ^{a, b}

	Saline Soils				Acidic Soils		Sodic Soils	
	2000		2020		Area in ha '000	Portion of Ag. Land (%)	Area in ha '000	Portion of Ag. Land (%)
	Area in ha '000	Portion of Ag. Land (%)	Area in ha '000	Portion of Ag. Land (%)				
New South Wales	89	0.1	286	0.4	4,095	6.3	24,731	38.0
Victoria	287	2.0	689	4.9	2,754	19.5	8,008	56.6
Queensland	62	0.0	145	0.1	6,192	4.2	42,191	28.7
South Australia	472	0.8	670	1.2	20	0.0	7,635	13.6
Western Australia	2,169	1.8	2,602	2.2	4,602	3.9	14,615	12.5
Tasmania	26	1.4	35	1.9	677	36.9	504	27.5
Northern Territory	0	0.0	0	0.0	2,973	4.2	11,533	16.2
Australian Capital Territory	0	0.0	0	0.2	4	13.3	1	3.7
Australia	3,106	0.7	4,426	0.9	21,317	4.5	109,219	23.1

^a Table shows the area and proportion of total agricultural land affected by salinity, sodicity or acidity in each state. Affected areas are where yields are judged to be 95 per cent or less of potential yield.

^b The Northern Territory and Australian Capital Territory were considered to have very minor salinity problems and were not included in the Audit salinity hazard areas (NLWRA 2001).

Soil Productivity Constraints By Land Use

An issue of interest to many agricultural scientists is the distribution of soil productivity constraints by land use. The table summarises the most significant constraint to productivity for each land use. Economic analysis on the profitability of amelioration strategies is a necessary precondition to the use of these data to justify more research or changes in management practice.

Areas of land where soil attributes currently constrain agricultural yield by land use grouping ^a

	Salinity 2000		Acidity		Sodicity	
	Area in ha '000	Portion of Ag. Land (%)	Area in ha '000	Portion of Ag. Land (%)	Area in ha '000	Portion of Ag. Land (%)
Agroforestry	1	4.5	7	32.8	1	6.6
Beef	570	0.2	13,796	4.8	53,327	18.5
Cereals	703	4.1	2,980	17.6	1,898	11.2
Coarse Grains	21	1.5	13	1.0	222	16.4
Cotton	1	0.3	0	0.0	89	22.0
Dairy	65	1.9	1,309	37.3	1,442	41.2
Fruit	1	0.6	51	44.4	37	32.1
Grapes	3	3.0	21	21.5	43	43.3
Hay	4	3.5	11	10.8	19	19.0
Legumes	134	6.0	490	22.0	148	6.6
Oilseeds	23	3.7	230	36.8	73	11.8
Other	0	1.0	5	16.3	4	13.5
Peanuts	1	3.5	3	9.1	9	24.7
Rice	1	0.5	0	0.0	10	6.5
Sheep	1,574	1.0	2,123	1.3	51,793	32.8
Sugar Cane	3	0.6	162	33.1	46	9.4
Tobacco	0	0.0	3	83.7	0	12.9
Tree Nuts	0	0.4	13	55.7	3	13.4
Vegetables	3	1.6	99	59.3	53	32.0
All land uses	3,106	0.7	21,317	4.5	109,219	23.1

^a Table shows the area and proportion of total agricultural land affected by salinity, sodicity or acidity for each land use. Affected areas are where yields are judged to be 95 per cent or less of potential yield.

The Benefits and Costs of Soil Treatment

A benefit cost analysis was undertaken to assess treatment of sodic and acidic soils with gypsum and lime. Using a 10% discount rate, to reflect private decision-making, this analysis found that lime and gypsum applications beyond current levels are profitable in only 4% of sodic or acid soils on agricultural land. On the remaining 96% of these soils additional lime and gypsum application results in financial loss. However, within the 4% of land where the soil treatments are profitable there are considerable financial gains, with net present values of soil treatments run in perpetuity ranging from \$10.8 to \$16.5 billion.

Areas where soil treatment options are profitable, determined with a private landholder discount rate of 10%, with treatments run in perpetuity

Optimal soil treatment ¹	Area	
	('000 ha)	% of Total
Do nothing	218,524	95.9%
Apply lime and gypsum	782	0.3%
Apply lime only	5,377	2.4%
Apply gypsum only	3,174	1.4%
TOTALS	227,857²	100%

¹ The optimal soil treatment is the one that provides the highest net present value. At any given location where yield loss is occurring, four soil treatment options are available. These include doing nothing, applying lime, applying gypsum, applying lime and gypsum together.

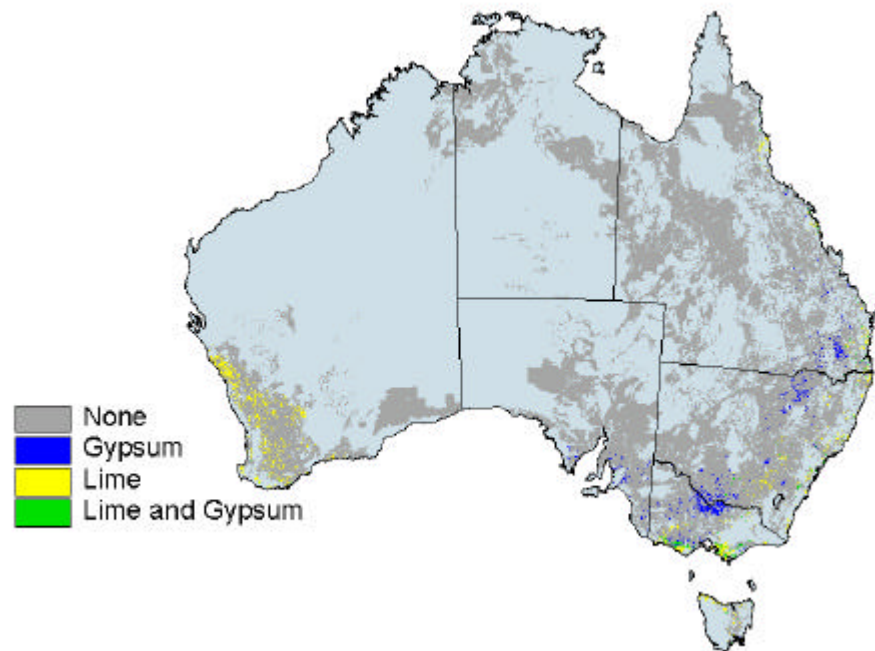
² This represents the total area with a potential yield opportunity associated with lime and/or gypsum application. In other words, it is the area where sodic and acid soils are causing at least some yield loss (less than 100% relative yield).

Lime and gypsum application are generally private land management practices that can be judged as either financially worthwhile, or not worthwhile, by individual farmers. If the market is failing to apply optimal rates of lime and gypsum the data presented here show that it affects a relatively small area of sodic/acidic soils (4%). Opportunities for further soil treatment in these areas could be investigated.

It is also worth noting that the net present values resulting from this analysis are attainable only with optimal soil treatment, i.e. applying precisely the soil ameliorants where they will have the optimum affect. In reality we would expect much lower net present values because there would be considerable sub-optimal application.

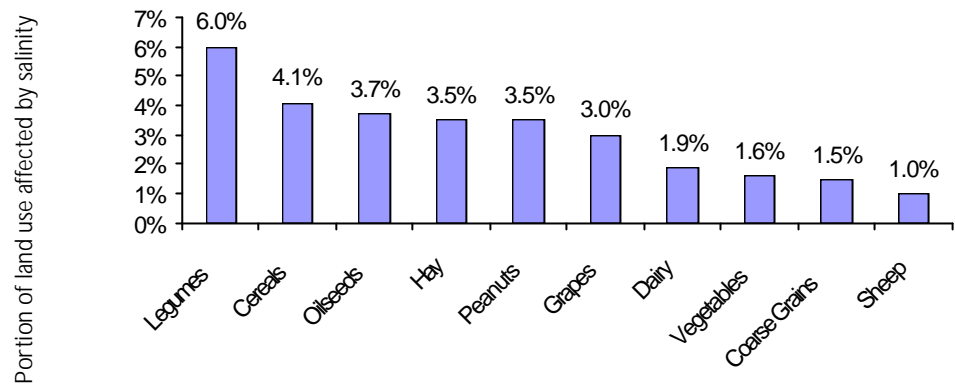
The net present value of the four soil treatment options was mapped over areas with a valid agricultural land use and a soil constraint. The soil treatment options included: (1) doing nothing; (2) applying gypsum; (3) applying lime and (4) applying lime and gypsum. Treatment is not

worthwhile for very large areas of sodic and acidic soils throughout large parts of the continent, particularly the low rainfall interior. Unsurprisingly, the areas most likely to hold net benefits are the high value crop and intensive production regions along the coast and within the Murray Darling Basin. The map below shows which of the four treatment options provides the highest return on investment per 1km² grid cell.



Managing Soil Resources for Profit

Salinity has a much greater capacity to cause off-site effects or externalities (than acidity and sodicity) and, is expected to increase in severity and extent over the next century. It has, therefore, been a major concern of governments. However, salinity appears to be an insignificant problem for many high value land uses such as cotton, horticulture, sugar and, to a lesser extent, dairy production. The proportion of specific land uses currently affected by dryland salinity is shown below.



The gross benefit is the additional profit at full equity attainable from agriculture if a soil constraint were costlessly removed. The gross benefit for dryland salinity is estimated at about \$187 million per year, around 3% of total profits from agriculture. This can be compared to about \$1,585 million per year for acidity and \$1,035 million per year for sodicity. These amounts could be viewed as investment ceilings on projects aimed solely at improving agricultural yields currently limited by dryland salinity, acidity and salinity.

Potential increase in profit at full equity (1996/97) if salinity, sodicity and acidity problems were costlessly corrected by land use grouping.

Land Use	Salinity		Sodicity		Acidity		Combined Impact	
	Gross Benefit (\$m/yr)	% of Total profit at full equity	Gross Benefit (\$m/yr)	% of Total profit at full equity	Gross Benefit (\$m/yr)	% of Total profit at full equity	Gross Benefit (\$m/yr)	% of Total profit at full equity
Beef	16	2%	138	19%	95	13%	220	31%
Cereals	71	4%	168	9%	157	9%	338	18%
Coarse Grains	3	1%	29	5%	5	1%	34	6%
Cotton	2	0%	76	6%	2	0%	78	6%
Dairy	24	2%	224	14%	255	16%	451	28%
Fruit	3	0%	93	10%	516	58%	595	67%
Grapes	6	1%	54	11%	118	25%	167	36%
Hay	2	17%	2	18%	2	20%	5	51%
Legumes	10	11%	13	15%	13	15%	28	33%
Oilseeds	2	3%	8	9%	23	24%	29	31%
Peanuts	1	4%	2	7%	1	4%	3	13%
Rice	0	0%	2	4%	0	0%	2	4%
Sheep	39	13%	169	55%	50	17%	223	73%
Sugar Cane	1	0%	8	5%	28	17%	32	19%
Tobacco	0	0%	0	1%	18	139%	18	139%
Tree Nuts	0	0%	4	6%	12	17%	16	22%
Vegetables	8	2%	45	9%	290	57%	319	63%
TOTAL	187	3%	1,035	16%	1,585	24%	2,560	39%

Salinity Impacts on Crops Yields

The extent and severity of dryland salinity is expected to increase over the next 20 years. Assuming that the decline in productivity to 2020 caused by salinity is linear and, also assuming no changes in prices, costs and technology, the impact cost of dryland salinity on agricultural production is estimated to have a net present value of roughly \$558 million.⁴ That is, by 2020 agricultural profits will be around \$101million per annum lower than they currently are. Following is a brief summary of the economic impacts of dryland salinity on agriculture:

- An additional \$187 million per annum would have been obtained in 1996/97 if dryland salinity did not limit crop/pasture yields;

⁴ Estimated using a 5% discount rate. Downstream impacts on irrigation are not included.

- Profit at full equity is predicted to decline throughout Australia by 1.5% (\$101 m/yr) over the next 20 years given projections on the growth of salinity areas; and

Based on the 1996/97 baseline data, the present value of costs to agriculture from increasing dryland salinity severity and extent is \$558 million (at a discount rate of 5%).

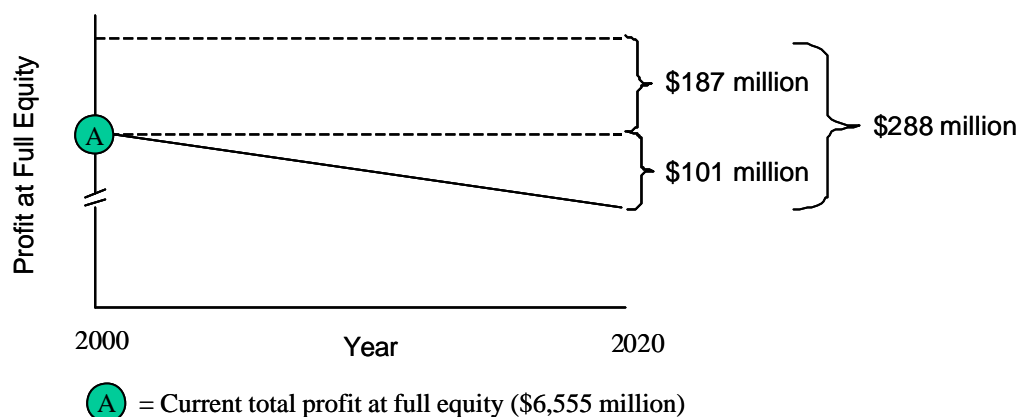
In practice, however, we would expect farmers to adopt a suite of strategies to avoid some of these costs and, hence, this is probably an over-estimate of the cost. In relative terms, the maximum expected decline in agricultural profits represents around 1.5% of the nation's total agricultural profits. Consequently, direct impacts on agricultural exports and agricultural profits are not likely to be noticed in National or State accounts. The losses in profits and present value of impact costs are shown below.

Present value of salinity cost increases to agricultural production from 2000 to 2020 (\$m)¹

Discount rate	Present Values (\$m)			% Loss in PFE
	3%	5%	6%	
New South Wales	157	123	109	1.1%
Victoria	266	208	185	3.3%
Queensland	54	42	37	0.6%
South Australia	117	91	81	1.7%
Western Australia	115	90	80	1.7%
Tasmania	4	3	3	0.4%
Australia	712	558	496	1.5%

1. Data is unavailable for the Northern Territory and Australian Capital Territory

The diagram below shows the decline in profits under a business-as-usual scenario and the additional potential profits if salinity did not constrain crop/pasture yield.



Issues other than salinity, sodicity and acidity were not included in this analysis primarily due to lack of national datasets and models relating soil condition to crop/pasture yield. It is worth noting that there exist many other land conditions that constrain crop/pasture yields, e.g. soil compaction, soil erosion, weed infestation etc. Current knowledge of the economic opportunities associated with managing these problems, at a national scale, is limited.

Costs Beyond the Farm Gate

In addition to the agricultural productivity impacts described above, increasing concerns are being voiced about the effects of land and soil degradation on water quality, landscape amenity values, biodiversity, the environment and other attributes. The direct market impacts of agriculture that occur beyond the farm gate fall into two categories:

- Local impacts on infrastructure; and
- Downstream impacts on urban and industrial water users.

Local Infrastructure Costs of Salinity and Watertable Rise

In order to estimate local infrastructure impacts, unit cost functions for salinity and water table rise were developed for three levels of impact: slight, moderate and severe for the following infrastructure categories:

- General urban and minor infrastructure in non-metropolitan towns and rural areas including minor roads, bridges, underground drainage, aerodromes, public buildings, parks and gardens, and sporting fields;
- Private non-agricultural assets in non-metropolitan towns: domestic buildings, commercial/retail buildings, industrial buildings, septic systems and service stations;

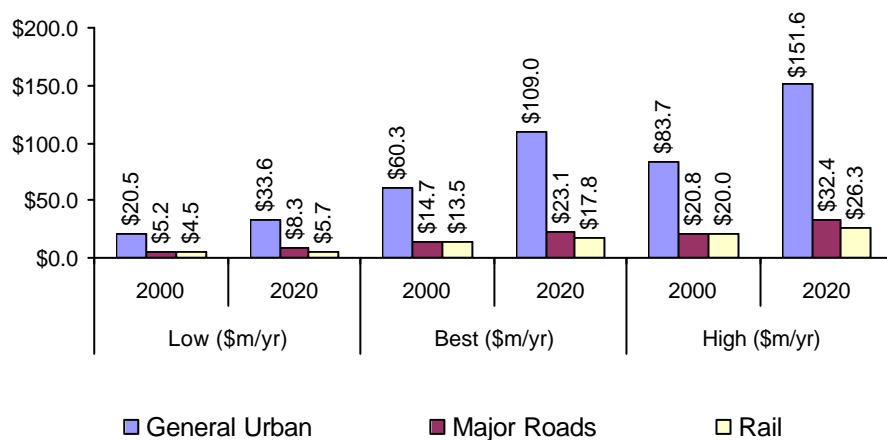
- Major roads, including national highways, rural arterials and urban arterials and bridges associated with these;
- Railways; and
- Power and communication infrastructure: power transmission, pipelines etc.

The current impact of water table rise and dryland salinity in non-metropolitan Australia is estimated to range between \$30 million/yr and \$125 million/yr with a best-bet estimate of \$89 million/yr as shown in the following table.

Estimated current impacts on local infrastructure of watertable rise and salinity in non-metropolitan areas (millions/yr)

	Low estimate	Best-bet estimate	High estimate
New South Wales	4.4	14.0	19.7
Victoria	3.9	12.2	17.3
Queensland	0.7	2.2	3.1
South Australia	4.5	6.7	8.3
Western Australia	16.3	51.8	73.8
Tasmania	0.6	1.9	2.7
Australian Capital Territory	0.0	0.0	0.0
Total	30.3	88.8	124.9

The greatest cost increases over the next 20 years can be expected to occur in New South Wales and Victoria. By type of infrastructure the greatest impacts can be expected to occur in general urban areas and on minor infrastructure as shown below.

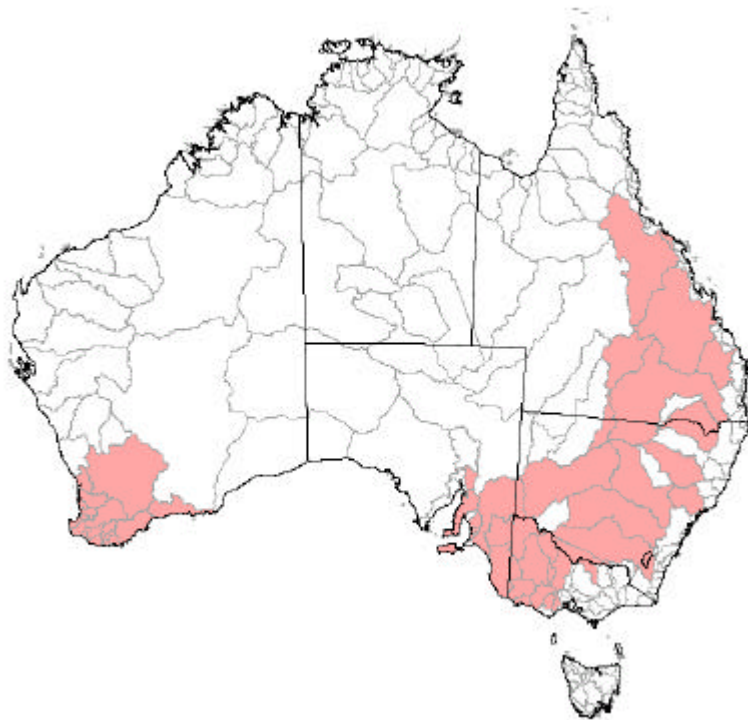


Downstream Costs

Data on expected trends in water quality in Australia is extremely poor. Furthermore, where it does exist, it is rarely organised in a form suited to economic or policy analysis. Consequently, economic assessments were based on scenarios for water quality deterioration over the next twenty years. The results are presented as a series of 'what-if' scenarios.

Aggregate Downstream Impacts

Net present values of downstream (or ex-situ) costs of degradation were determined for increased severity of salinity, erosion, sedimentation and turbidity over the next 20 years (2000 to 2020) using data available from the Audit. Increases in salinity were only modelled for the basins shown in the figure below. Each of these basins contains significant areas of dryland salinity that are expected to increase in extent and severity, with worsening downstream impacts, over the next 20 years.



The present values of infrastructure damage costs associated with declining water quality are presented in the following tables for two scenarios: a 5% increase in the water quality parameter and a 10% increase in the water quality parameter. A 5% social discount rate has been used.

Present value of downstream infrastructure damage costs arising from worsening salinity levels over 20 years, from 2000 to 2020^{1, 2, 3}

	Increase in water salinity	
	5%	10%
	\$ millions	
Queensland	13	26
New South Wales	68	137
Victoria	20	39
South Australia	292	584
Western Australia	118	235
TOTAL	511	1,021

1. Present values were determined using a social discount rate of 5%.
2. Data for Tasmania, Australian Capital Territory and Northern Territory are unavailable.
3. Only for river basins considered having a risk of future river/stream salinisation. None of the river basins in the Australian Capital Territory were identified as at risk of future river/stream salinisation.

Some insights into what might be a likely increase in national river salinity can be drawn from data collected for the Murray Darling Basin's Salinity Audit. Under this Audit, estimates are provided of River Salinity at 1998 and 2020 for 33 river valleys in the Murray Darling Basin. Of these river valleys 15 show an increase over 20% and 21 river valleys show an increase over 10%. The median percentage increase in river salinity for all the river valleys is 19%. If these estimates are considered to be representative of national trends, then some of the larger percentage estimates should apply.

For scenarios assuming slower rates of water quality decline (i.e. less than 5%, for increases) turbidity has higher costs than salinity. Estimates of the costs of turbidity, erosion and sedimentation are as follows.

Present value of increases in water treatment costs due to rising levels of turbidity over 20 years from 2000 to 2020^{1, 2}

	Increase in turbidity	
	5%	10%
	\$ millions	
Australian Capital Territory	8	9
Queensland	278	307
New South Wales	161	193
Victoria	122	137
South Australia	119	137
Western Australia	27	31
TOTAL	715	814

1. Present values were determined using a social discount rate of 5%.
2. Data for Tasmania and Northern Territory are unavailable.

Present value of downstream costs due to an increase in erosion and sedimentation over 20 years from 2000 to 2020^{a, b, c}

	Increase in sedimentation	
	5%	10%
	\$ millions	
Australian Capital Territory	0	1
Queensland	52	84
New South Wales	22	34
Victoria	3	4
South Australia	1	1
Western Australia	0	0
TOTAL	78	123

1. Present values were determined using a social discount rate of 5%.

2. Data for Tasmania and Northern Territory are unavailable.

Present value of national costs resulting from a 1%, 5% and 10% deterioration in water quality over the period 2000 to 2020.

Water Parameter Increase	1%	5%	10%
	\$ millions		
Water Cost			
Salinity	102	511	1,021
Turbidity			
Upgrades to existing water treatment plants	614	614	614
Upgrades for specified increase in turbidity	8	41	81
Operating Cost impacts	12	60	119
Total Turbidity	634	715	814
Erosion and Sedimentation			
Reservoirs	6	28	55
Local Government, Road and Rail	33	33	33
Channels	4	18	35
Total Erosion & Sedimentation	42	78	123
Totals	778	1,304	1,959

1. Present values were determined using a social discount rate of 5%.

Incremental Costs of Salinity on Infrastructure

Incremental cost estimates were derived using a methodology developed by *Gutteridge, Haskins and Davey* and used for two previous studies of costs for the Murray Darling Basin. Review of previous work and the collection of additional data revealed that:

- the economic assessments made had used straight line discounting methods rather than standard amortisation techniques used for cost estimation by economists;⁵ and
- some assumptions that no longer appear to hold were used.

Amortisation alone doubles the impact cost of many items. Amortisation requires recognition of the opportunity cost of capital. When a real discount rate of 4% is used for an item with an expected life of 40 years, amortisation roughly doubles the “cost”.

The most critical assumptions relate to assumptions about the way water is used in cooling towers and other industrial facilities. Our estimate of the impact cost of these items is approximately 6 times that previously estimated.

Incremental salinity cost estimates for the Murray Darling Basin

Previous estimates of downstream costs of salinity for the Murray Darling Basin by GHD separate the estimated annual impact cost per EC for lower reaches of the Murray River into two components. In 1999 dollars:

- The estimated impact cost per EC for non-agricultural impacts is \$53,000 to \$55,000 per year;
- The estimated impact cost per EC for agricultural impacts is \$87,000 to \$124,000 per year; and
- The total estimated impact per EC is \$142,000 to \$177,000 per year.

The Resource Economics Unit’s (REU) and PPK’s revised estimates of the impact costs are 352% higher than those made previously. Summarised below, this much larger estimate is due to:

- Amortisation of costs rather than use of straight-line depreciation;
- Recognition of higher impacts on household plumbing than previously assumed;
- Changes in assumptions about industrial water treatment practice leading to much higher unit cost estimates than previously assumed; and

⁵ An amortised cost estimate is the amount of money that would need to be paid if the entire cost of an asset was borrowed from a bank. Another way of thinking about amortisation is the amount of money that would have to be put aside each year in a sinking fund to pay for the purchase of a new asset when the current one ceases to function.

- Use of the higher water use estimates provided by the Audit.

Comparison of marginal damage costs per EC unit for water supplied for urban and industrial purposes from Morgan

Demand Sector	Estimated water use (kl/yr)	Marginal cost of salinity and associate hardness (\$)		Percentage increase (REU&PPK /GHD*100)
		REU & PPK	GHD	
Households	118*10 ⁶	111,270	27,513	404%
Industrial	16*10 ⁶	54,780	21,800	251%
Commercial	5*10 ⁶	7,400	0	Na
Total		173,450	49,313	352%

Use of Audit water quality and water use data results in a much higher estimate of impact cost for water users who draw water from the Lower Murray in South Australia. The revised estimate is \$345,000 per EC per year for all non-agricultural impacts. Changes of this magnitude, if accepted, have major implications for assessments of the cost and benefits of salinity interception and salinity trading proposals and programs. As the differences between these estimates are so large and because some of the information used is not underpinned by experimental data, we are of the opinion that there is a need for systematic review of both:

- the methodological options; and
- the quality of the data used to make these estimates.

Specifically, it is recommended that:

- the sensitivity of government policies and investment decisions to the absolute value of these estimates be identified;
- the methodologies used to derive these estimates be reviewed
- the reliability of the assumptions underpinning each part of the estimate be carefully reviewed; and
- if appropriate, a research program be implemented to collect the necessary data to enable these estimates be refined.

An Assessment of Social and Non-market Environmental Values

As well as direct market impacts, Australians are also concerned about environmental and social considerations that are not reflected in prices and costs. Focus group work identified four factors of particular concern:

- Species protection;
- Landscape aesthetics;
- The condition of waterways for fishing or swimming; and
- The net loss of people from country towns each year.

Choice modelling—the state of the art in collecting information on the willingness of people to pay for environmental improvements—was used to assign values for these attributes in a manner that enables them to be transferred, with care, from one location to another. The resultant implicit price estimates are:

- 68 cents per household each year for every additional species protected;
- 7 cents per household each year for every additional 10,000 hectares of bushland protected or farmland restored;
- 8 cents per household each year for every additional 10 kilometres of waterway restored for fishing or swimming;
- Minus 9 cents per household each year for every 10 persons leaving country communities.

The choice model also allows the estimation of aggregate values for an array of potential policy options. For instance, a large 20-year National program involving:

- The protection of an additional 50 species;
- Improvement of the aesthetics of 2 million hectares of bushland and farmland;
- The restoration of 1500 kilometres of waterway for swimming and fishing; and
- The loss of an additional 5,000 people per year from rural areas.

In aggregate a program producing these benefits would result in a welfare benefit of \$3.1 to 6.3 billion in present value terms at 3% discount rate, or a best-bet value of \$4.6 billion. If the same environmental improvements

could be achieved while reversing the decline in rural communities by 10,000 people per year, the best-bet estimate increases to \$6.7 billion.

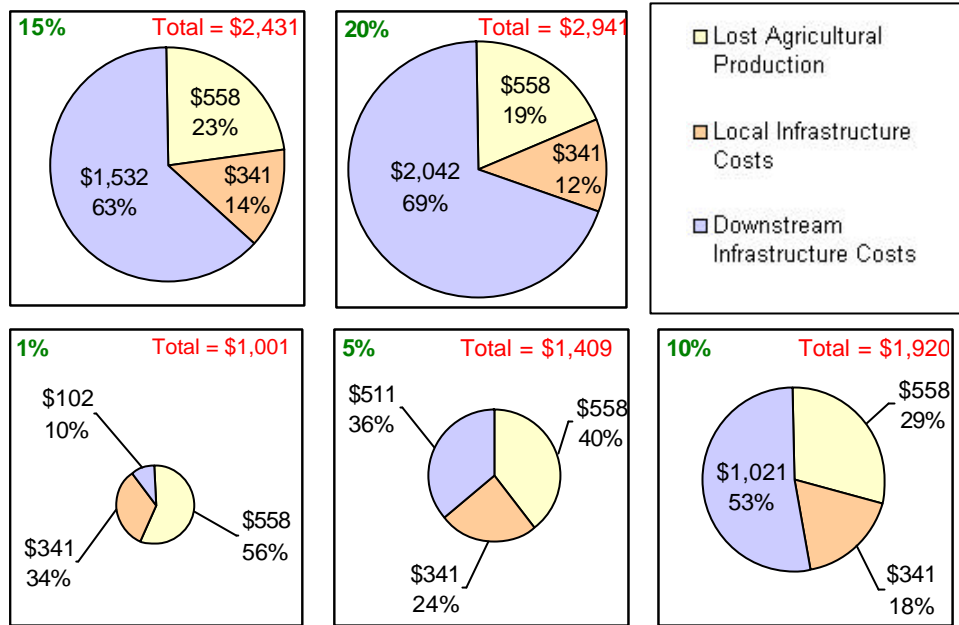
It is stressed that the program described above is very large. For example, “50 species” is 13% of the 381 plants and animals listed as endangered; “2 million hectares” is roughly equivalent to all the irrigated land or one third of the current area of land identified as High salinity hazard; “1,500 kilometres of river” is 40% of the length of the River Murray; and, depending upon the assumptions made, around 15,000 people per year are leaving rural areas.

The survey data suggests that people are willing to contribute financially to both environmental and social benefits, such as might be achieved with an environmental levy. The numbers, however, are not as large as might have been expected. Commonwealth and State Governments, for example, has recently committed Australia to a \$1.4 billion program to improve salinity and water quality in 20 catchments over 7 years.

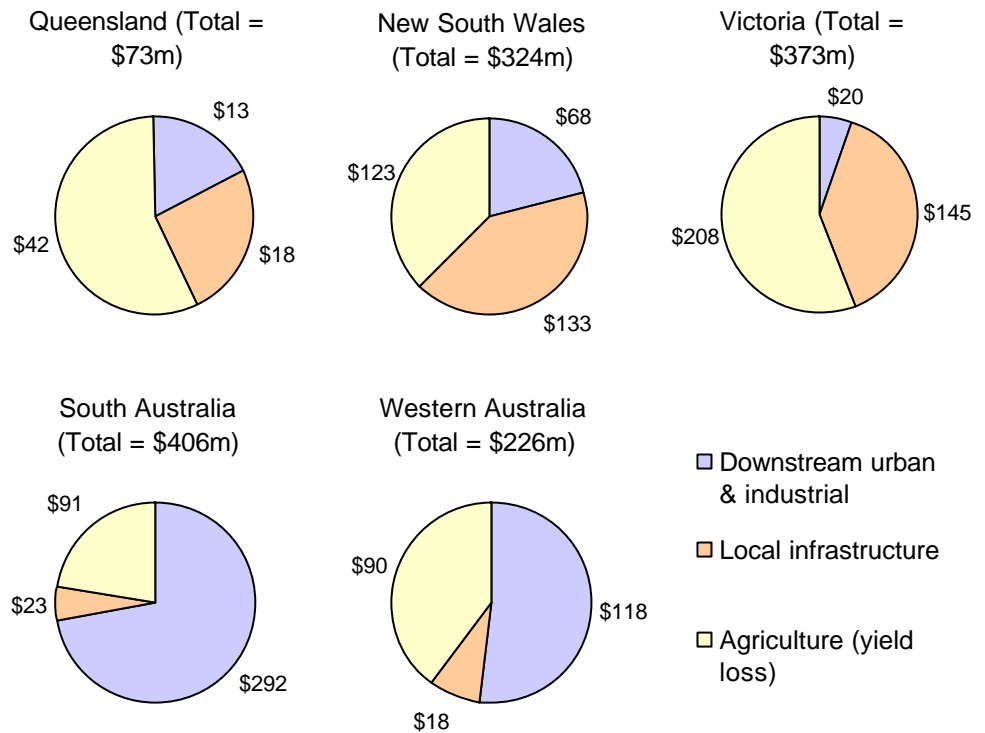
Comparison of River and Dryland Salinity Cost Increases

A comparison of national salinity cost increases, above and beyond current levels, over the next 20 years (2000 – 2020), provides insights regarding where defensive expenditure may be most needed. The division of cost increases is heavily influenced by the extent to which water and stream salinity is likely to worsen. There is much uncertainty relating to river and stream salinity trends. Consequently, in the comparisons river salinity increases have been varied, whereas dryland salinity impacts on agriculture and local infrastructure have been held constant.

Below the marginal salinity costs are shown for five scenarios, with water salinity increases of 1%, 5%, 10%, 15% and 20% in catchments classified as having salinity risk. Dollar values are given as net present values at a discount rate of 5% in \$millions. It should be noted that none of these estimates cover the cost of applying saline irrigation water to agricultural land, and they do not include non-market values.



In the pie graphs below a comparison of salinity cost is made between the States and Territories. This is based on a 5% increase in river/stream salinity levels within catchments classified as having salinity risk, and uses a 5% discount rate. Based on these assumptions, the two States with the highest downstream costs include South Australia and Western Australia.



An Integrated Overview or Accounting Perspective

This is the first attempt at a National scale to build a spatially explicit set of natural resource accounts. Through this process agricultural statistics collected at regional scales by Commonwealth, State and Territory agencies have been meshed with satellite data, gross margin handbooks, and land use maps. Additional data has been assembled on soil attributes, yield constraints, infrastructure damage and non-market costs.

Through this project an economic database of Australia's natural resources has been developed. With few exceptions the maps in this database have national coverage and represent data using a 1km² grid. The database contains:

- Mapped surfaces of all variables required to determine profit at full equity. The variables mapped include price, yield, variable costs and fixed costs. Also mapped is a surface of government support to agriculture.
- Mapped surfaces of yield limitations caused by salinity, sodicity and acidity (expressed as percentages).

- c. A set of functions that relate relative yield in different crop/pasture types to soil attributes for salinity, sodicity and acidity.
- d. Mapped surfaces of exchangeable sodium percentage (sodicity) and soil pH (acidity). Also maps estimating where salinity is likely to be causing yield loss in 2000 and 2020.
- e. Mapped surfaces of costs, benefits and net present value, derived from benefit cost analysis, of lime and gypsum application to ameliorate acidic and sodic soils.
- f. A land use map showing over 60 categories of commodity production, classified into irrigated and dryland categories.
- g. A set of functions to determine the downstream cost impacts arising from salinity, turbidity, erosion and sedimentation. These have been used to determine estimates of costs over the next 20 years by river basin.
- h. A set of functions and tables to determine the local infrastructure cost impacts of rising water tables and salinity.
- i. A set of maps and tables showing the local infrastructure costs associated with salinity and rising water tables. These have been derived by combining salinity/watertable maps with detailed infrastructure maps.
- j. A methodology and framework for valuing the non-market costs associated with natural resource degradation and estimates of the non-market values attached to natural resources by Australians.

If the estimates of the return to the Nation's land and water resources are adjusted for subsidies and taxes, the result could be an estimate of the net economic value per square kilometre of agricultural production in Australia. If costs of land and water degradation could be adjusted so that impact costs could be reassigned to the year when they occurred then deducted a final set of accounts could be produced. Ideally, these data would be presented spatially so it would be possible to determine where returns to the natural resource base are greatest.

To prepare such a set of spatially explicit regional or national accounts, for alternative land-use scenarios it would be necessary to:

- Understand the relative size of each type of cost;
- Understand and model time lags involved;
- Differentiate impacts due to historical actions from those caused by current practices;
- Separate impacts from causes.

Having assembled these accounts, further work would be required to analyse the welfare and equity impacts of policy changes. The accounts will be an important information input to models and analyses of this nature.

While the data currently available does not allow us to develop a fully integrated accounts along such lines, we can present an comparative assessment of the relative size of impact costs for expected changes in soil salinity, local infrastructure costs and downstream impacts on urban and industrial water users.

Acknowledgements

This report is possible only because of the efforts of a large number of people. Moreover, as its production has involved a number of consulting firms, many of the people are not even known to us. We are aware, however, that many people have put much time into its production. At the outset, we all knew that what we were trying to do had never been done before and was very ambitious. We are pleased to report that in the final analysis, it was possible. Many people are due considerable thanks.

A very special thanks is due to Warwick McDonald and George Reeves who gave us all untiring support and guidance throughout the project.

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Production of the report itself has benefited immensely from the support and assistance of Steve Marvanek and Graham Watmuff from the Spatial Technology Unit in Adelaide. Steve and Graham's patience and willingness to do what ever was asked in record time is an asset to be valued.

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