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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 1

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Volume I

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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 Audit[1] 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 organized 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'.

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[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.

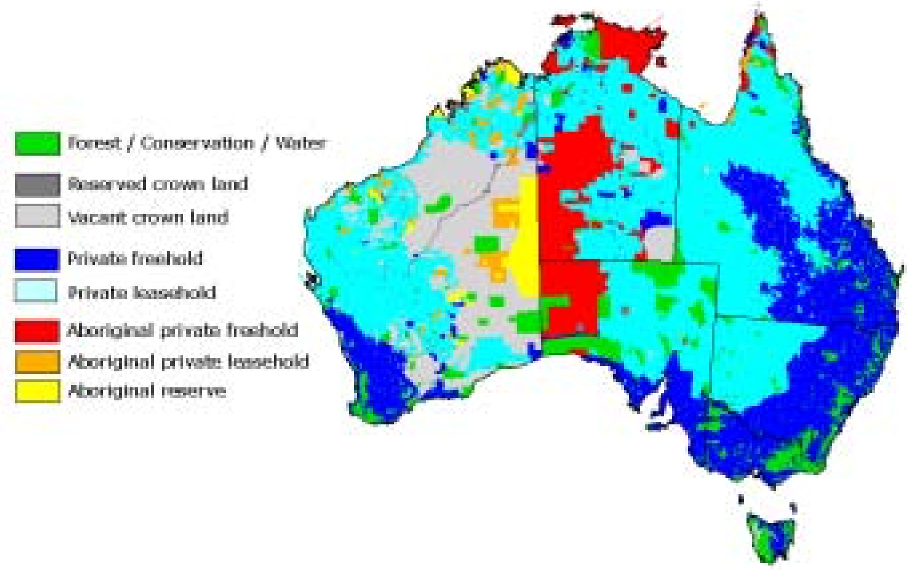
From here the assessment looks towards tangible economic impacts that occur beyond the farm gate. This involves an analysis of infrastructure damage costs resulting from land and water degradation. Infrastructure damage is broken up into two main classes: local and downstream. The local infrastructure 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

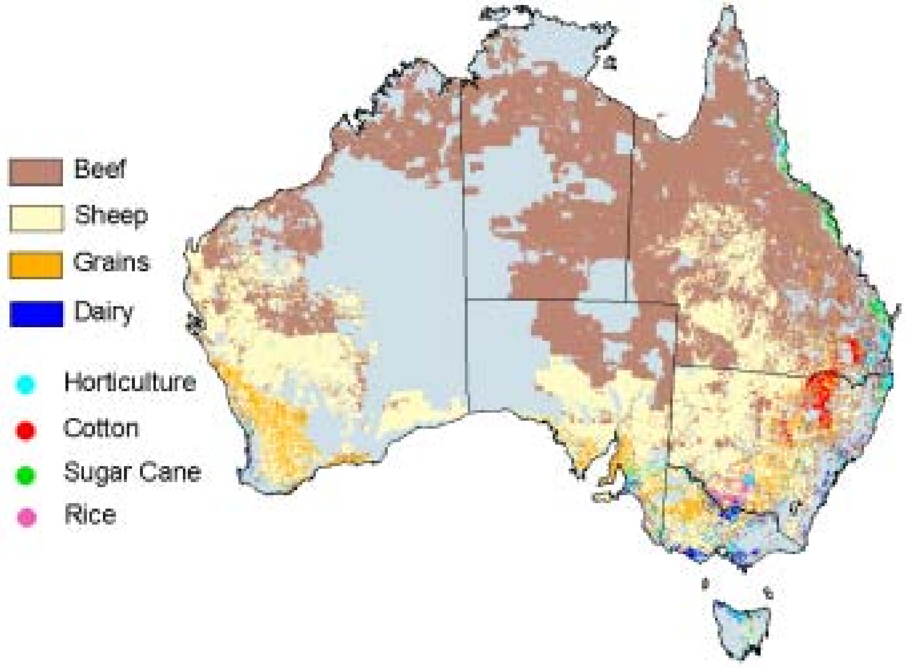
Large areas of Australia are under private freehold or leasehold ownership. This has important implications for the way natural resources are managed. Changes of land use and solutions to land degradation will arise only through cooperation between government, landholders and the community.



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.

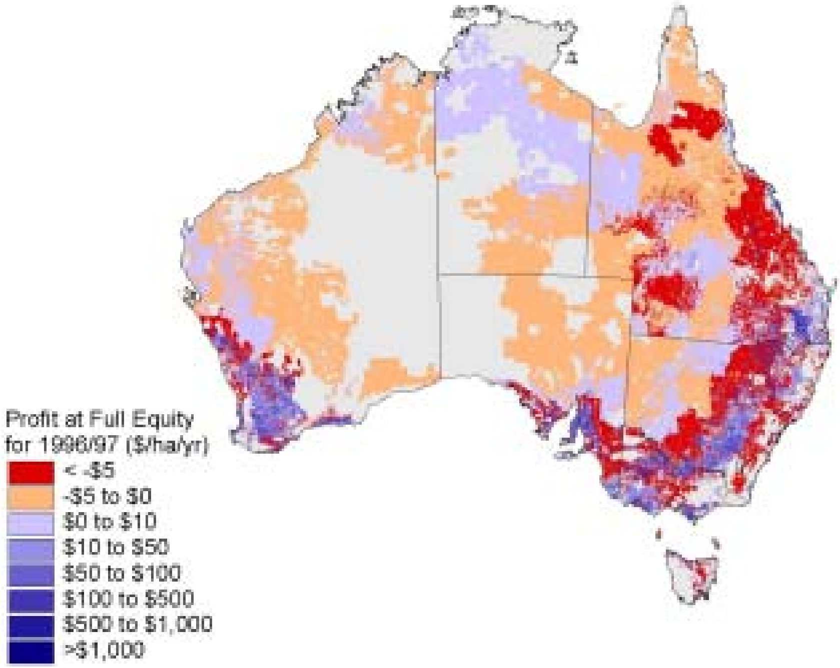
Economic Returns to the Natural Resource Base

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).

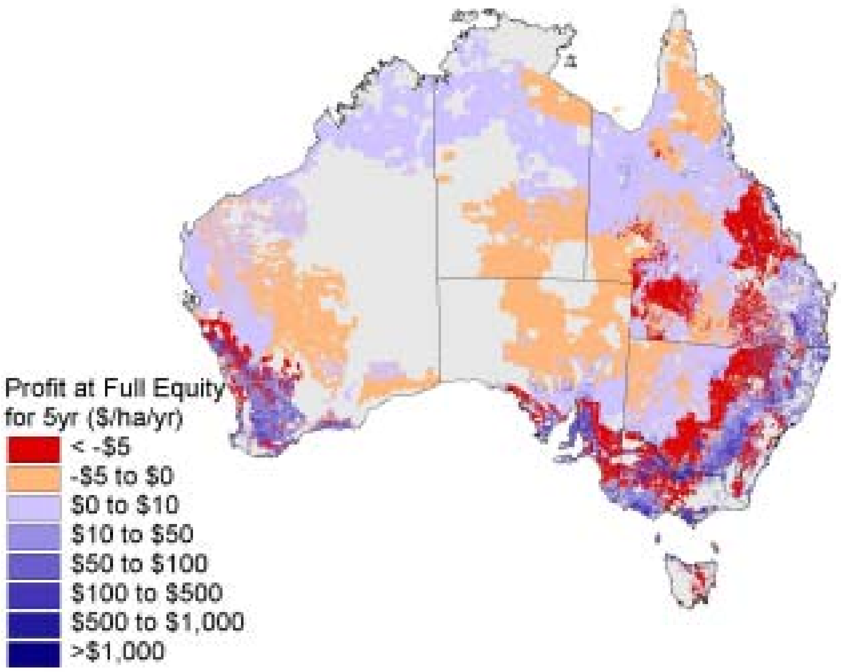
Profit at full equity measures presented in this report are derived from survey data, satellite data, government reports, gross margin handbooks and other sources. Profit has been mapped on a 1km by 1km grid covering the nation, although underlying source data is accurate at coarser levels of spatial 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:

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

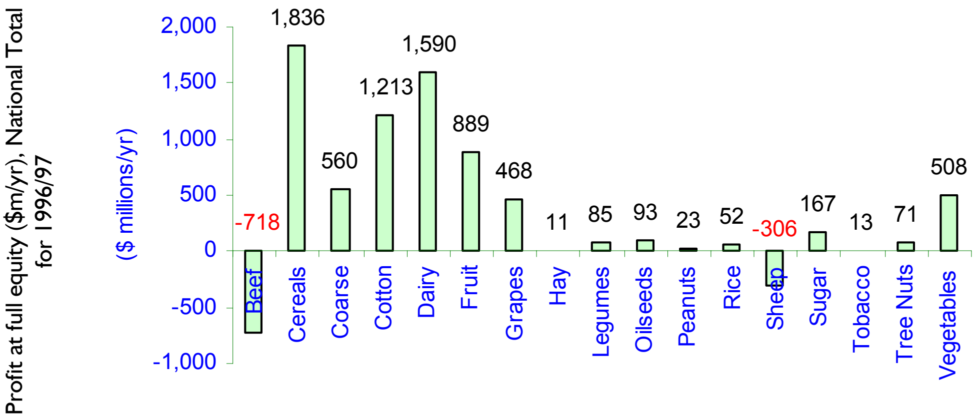
To gain an appreciation for how economic returns to agriculture varied across Australia, profit at full equity was computed based both on 1996/97 prices and at average prices over the period 1992/93 to 1996/97.
Using 1996/97 prices and yields, the estimated total profit at full equity was roughly $6,555 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.

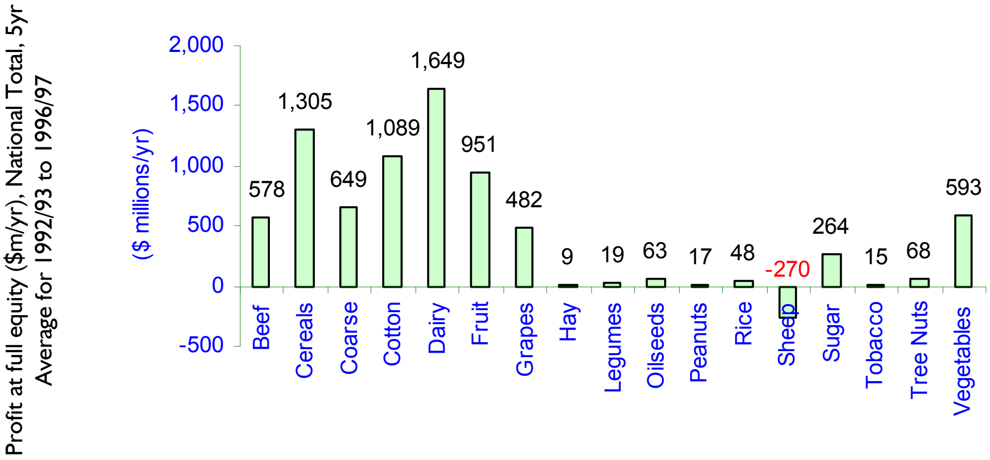


Mean prices and yields were used to estimate average profit at full equity over the five year period 1992/93 to 1996/97. This provides a total profit at full equity of $7,530 million per year. Using these values sheep grazing was the only land use that made a loss, at $270 million per annum. Nationally, 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.

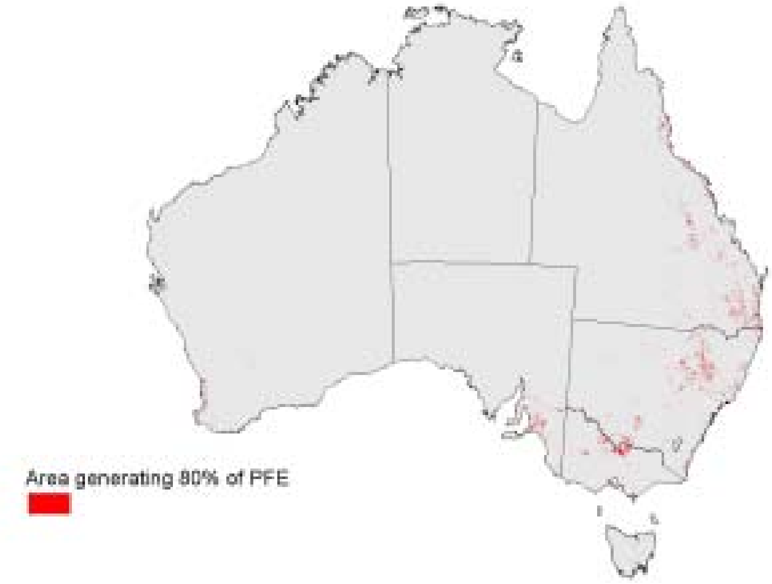


In climate terms, 1996/97 was an "average" year. Incomes in this year were lower for beef and sheep primarily due to low commodity prices. Prices for beef have since risen markedly, as can be seen in the following two charts.





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.

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[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%

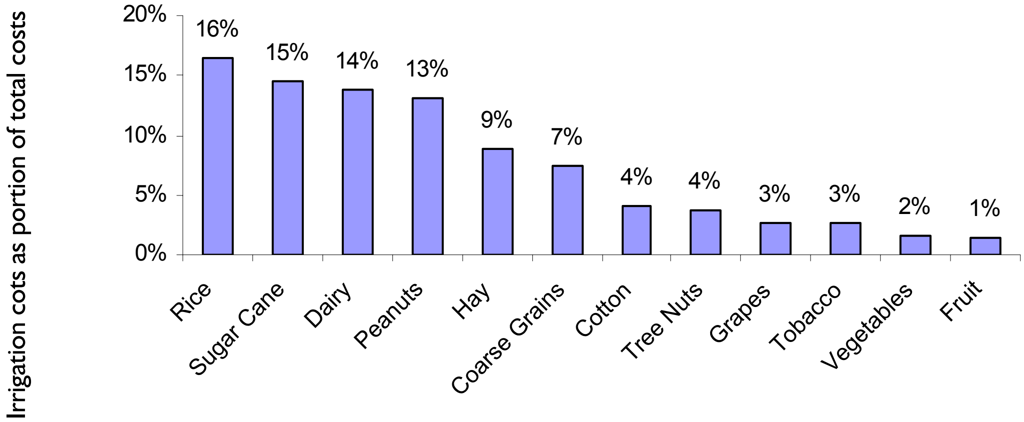
The efficiency of irrigation water use varies from land use to land use. In the past, it has been common to report water use efficiency in terms of the dollar gross return per megalitre used. In this report, an estimate of profit at full equity per megalitre used is provided. Intensive land uses, like 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.

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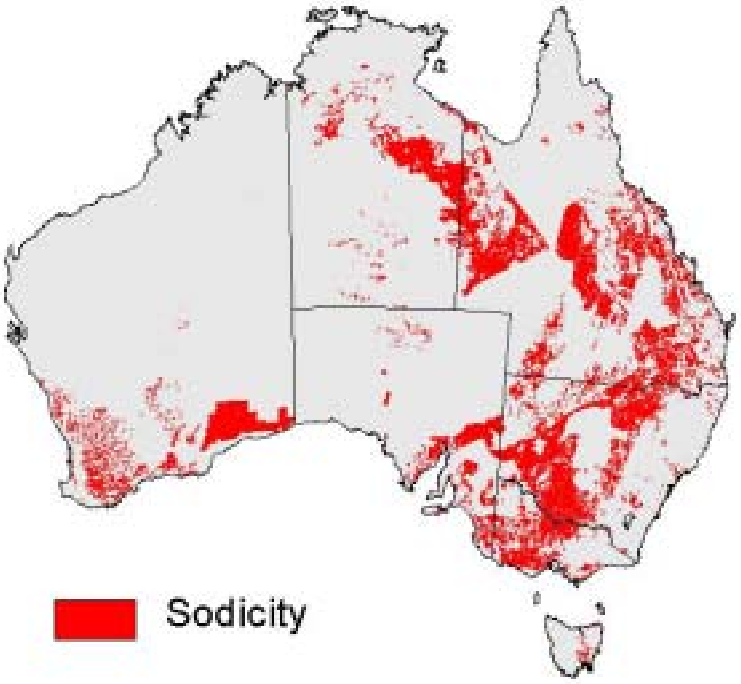
[3] No allowance is made for the cost of water purchased by buying water and trading it into the area where the production occurs. In all cases, it is assumed that all water rights are owned by the managing entity.

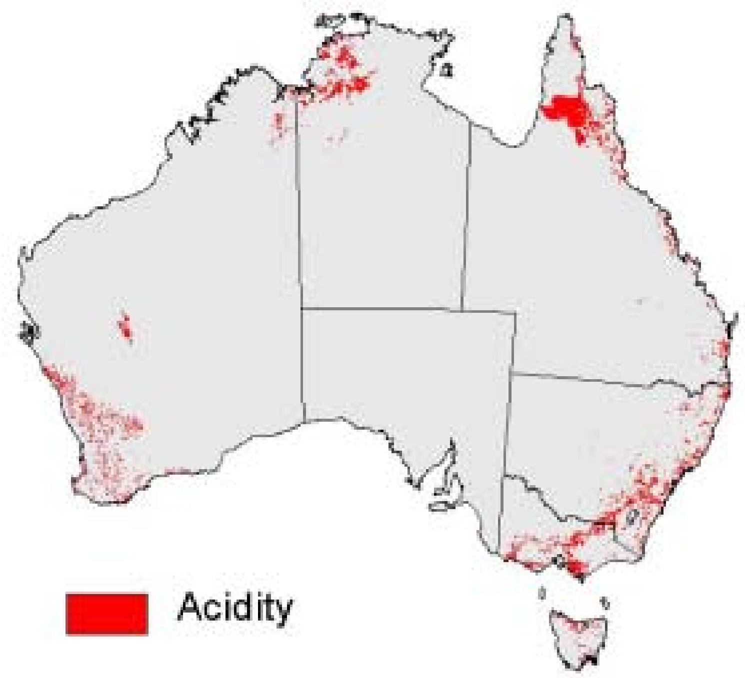
Soil Sodicity

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

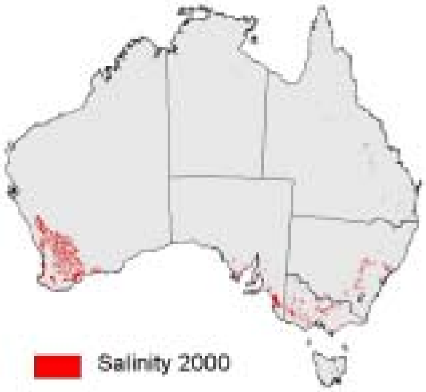
Soil acidity, both induced and natural, constrains production opportunities in Northern Australia, South Eastern Australia, Western Australia and the Queensland Coast. The following map shows areas where soil acidity reduces crop/pasture potential productivity by over 5%.

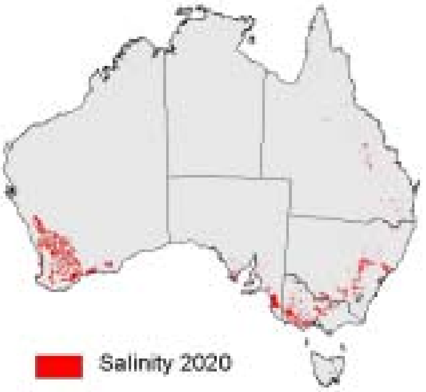


Soil Salinity

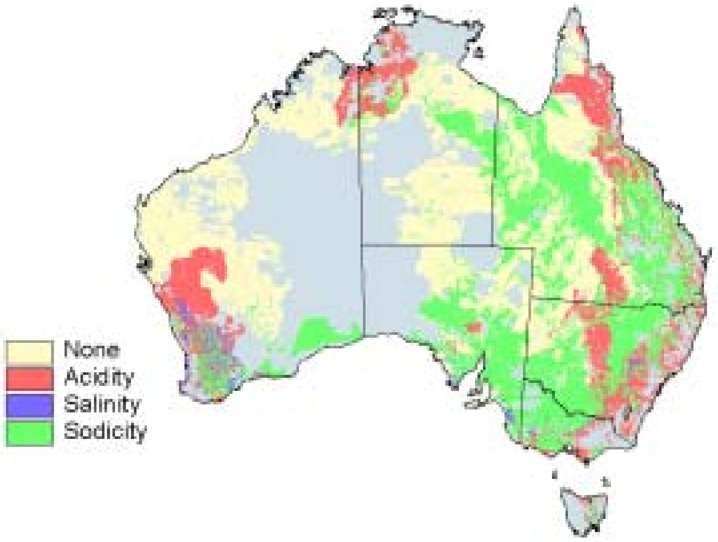
Across the nation there has been much discussion about the extent that the area of saline soils is expected to increase. In the Audit's *Dryland Salinity Assessment* salinity hazard, rather than salinity extent, was mapped using different definitions of hazard in each State and Territory. As economic 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

	Area	
Optimal soil treatment[1]	**('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	227,857[2]	100%

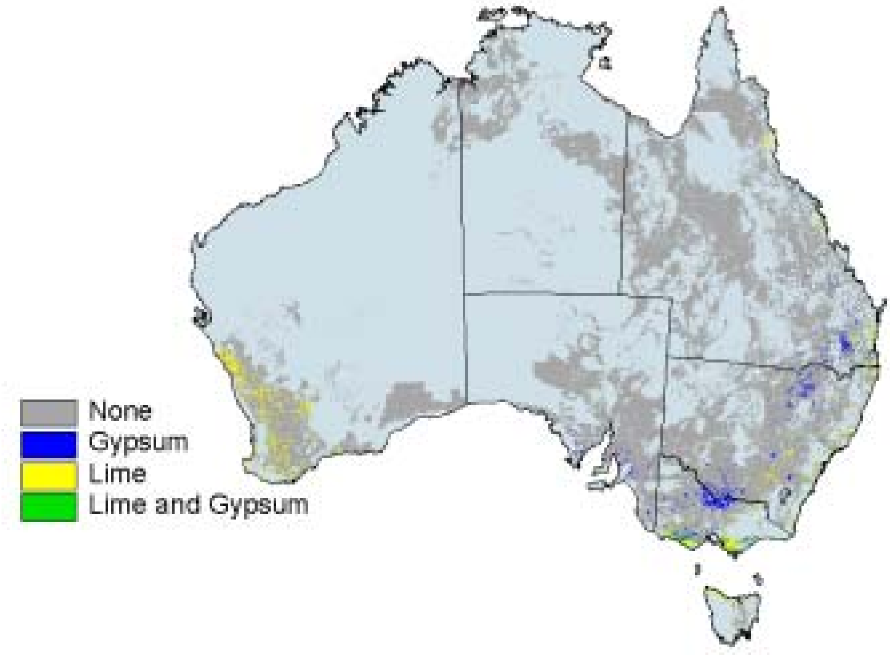
[1] The optimal soil treatment is the one that provides the highest net present value. At any given location where yield loss is occurring, four soil treatment options are available. These include doing nothing, applying lime, applying gypsum, applying lime and gypsum together.

[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.

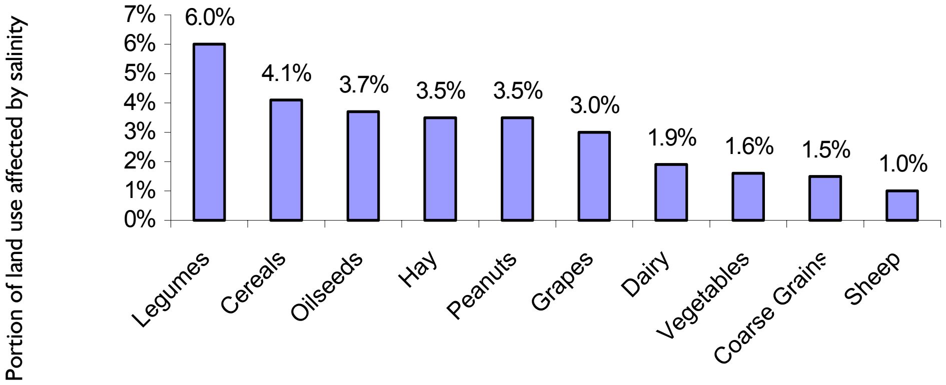
It is also worth noting that the net present values resulting from this analysis are attainable only with optimal soil treatment, i.e. applying precisely the soil ameliorants where they will have the optimum affect. In reality we would expect much lower net present values because there would be considerable 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 1km^2 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.

	Salinity		Sodicity		Acidity		Combined Impact	
Land Use	**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;

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[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%).

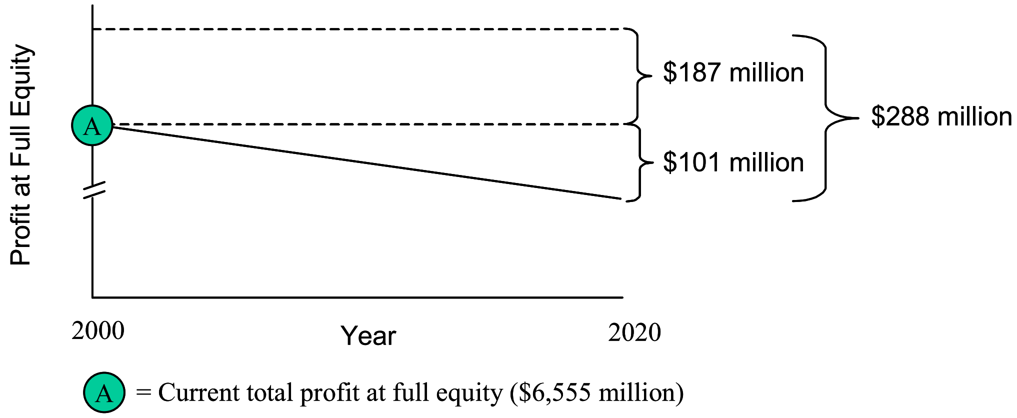
In practice, however, we would expect farmers to adopt a suite of strategies to avoid some of these costs and, hence, this is probably an over-estimate of the cost. In relative terms, the maximum expected decline in agricultural profits represents around 1.5% of the nation's total agricultural profits. 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]

	Present Values ($m)			% Loss in PFE
Discount rate	**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;

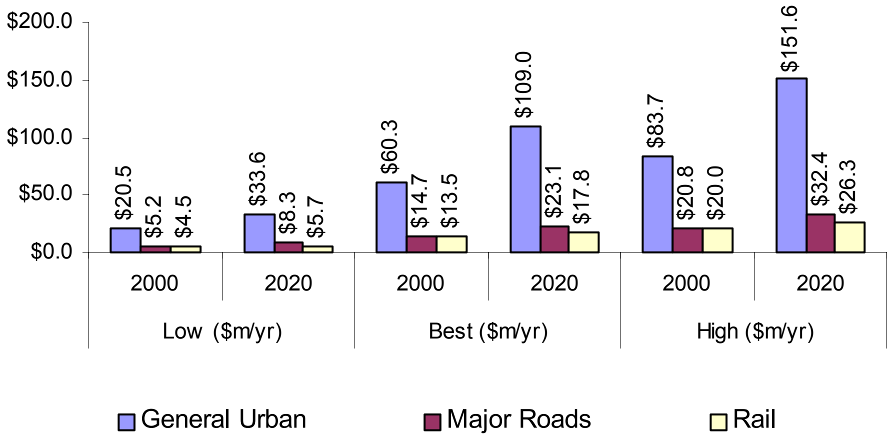
- Major roads, including national highways, rural arterials and urban arterials and bridges associated with these;
- Railways; and
- Power and communication infrastructure: power transmission, pipelines etc.

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.

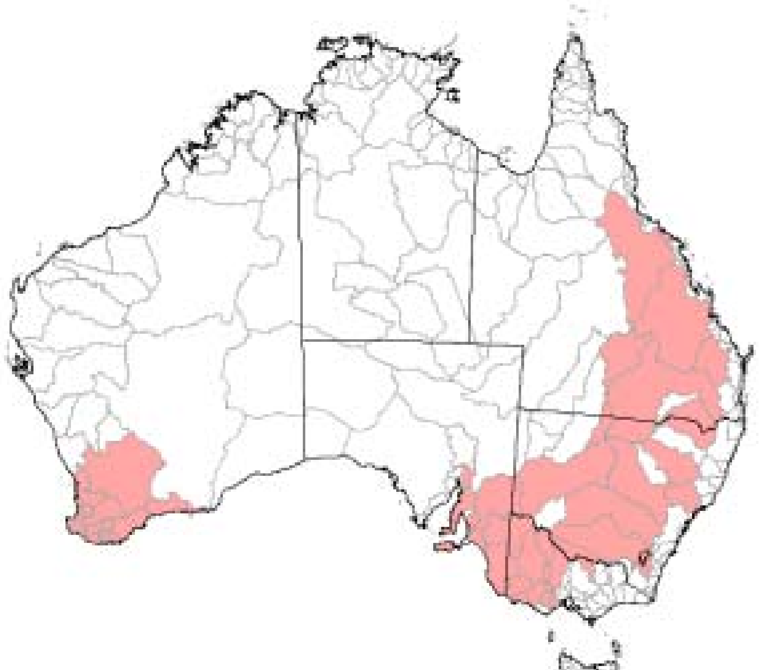


Downstream Costs

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

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[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.

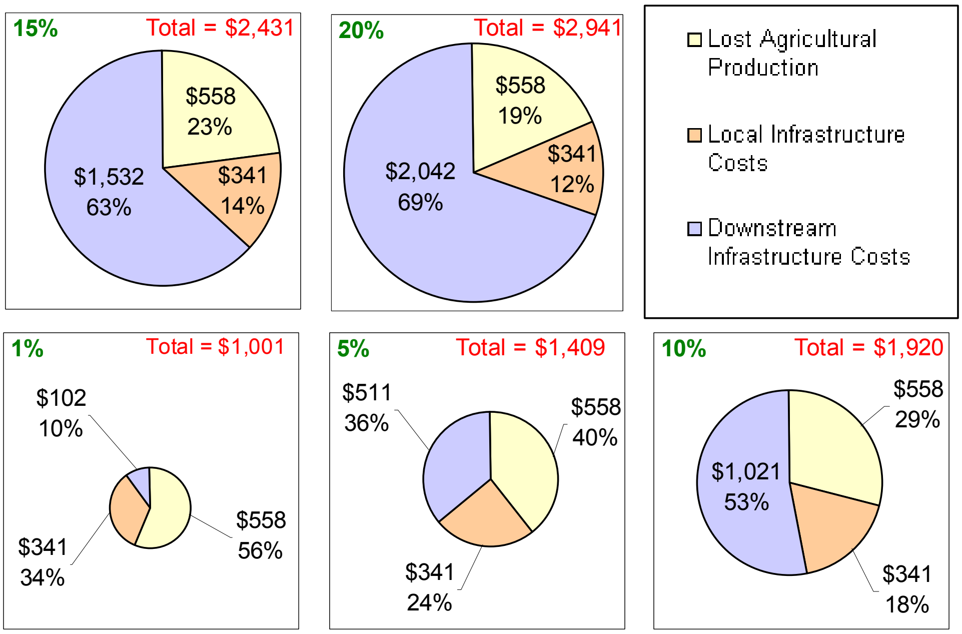
It is stressed that the program described above is very large. For example, “50 species” is 13% of the 381 plants and animals listed as endangered; “2 million hectares” is roughly equivalent to all the irrigated land or one third of the current area of land identified as High salinity hazard; “1,500 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

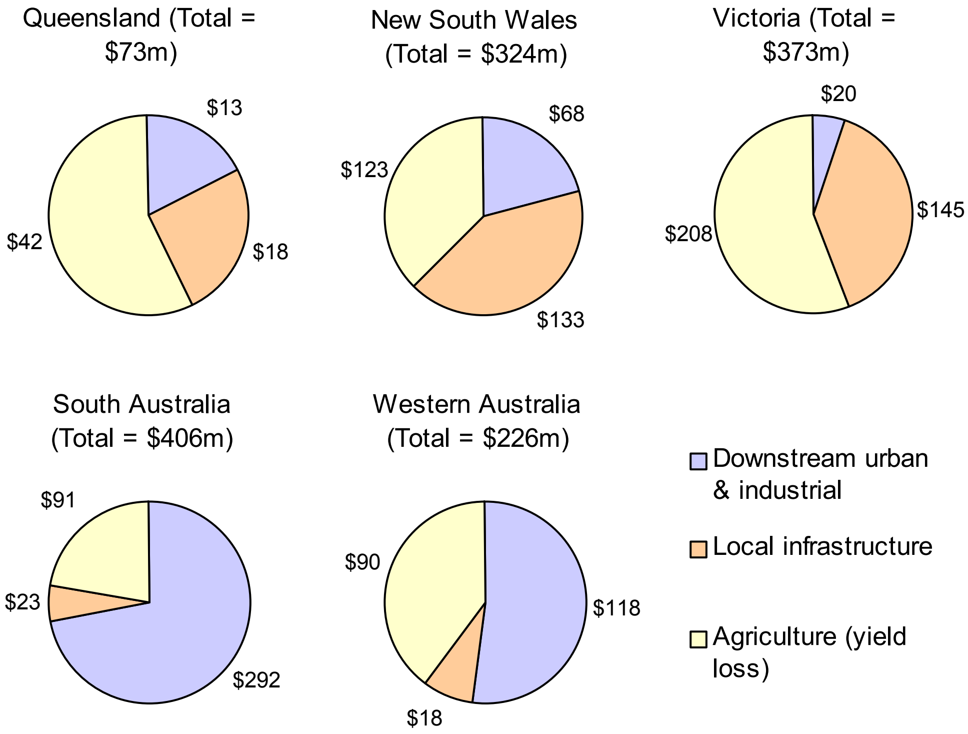
A comparison of national salinity cost increases, above and beyond current levels, over the next 20 years (2000 – 2020), provides insights regarding where defensive expenditure may be most needed. The division of cost increases is heavily influenced by the extent to which water and stream salinity is 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.



If water salinity increases above 5% over the next 20 years the bulk of the impact costs from salinity will be to downstream water users. If data on the impact costs of increased salinity through irrigation were added to this analysis the cost burden on downstream water users would increase. Economic assessment of impacts on wetlands, recreation opportunities and other non-market goods would further increase the magnitude of downstream costs.

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 1km^2 grid. The database contains:

a. 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.

b. 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.

While we accept responsibility for the general content of this report, on behalf of all the people involved, we would first like to thank our Technical Reference Group – Jason Crean, NSW Agriculture; Thilak Mallawaarachchi, James Cook University; Warwick McDonald, NLWRA Management Unit; Colin Mues, ABARE; David Pannell, University of Western Australia; George Reeves, Centre for International Economics; and, Gary Stoneham, Victorian Department of Natural Resources and Environment. Each of these people gave us very useful advice as we proceeded to develop the project and helped us as we consulted people about the methodology to pursue.

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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- Project 6.1.4 – Martin van Bruenen and Jeff Bennett from Unisearch

Mike Young and Stefan Hajkowicz

Policy and Economic Research Unit
CSIRO Land and Water
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Glossary of Terms and Conversions

Amortisation	Conversion of a lump sum to an annual value at a given discount rate.
Control cost	Costs incurred by government, individuals, industries, or infrastructure providers to control or improve the condition of the natural resource.
Damage cost	Costs incurred by industries, infrastructure providers or households, as a result of the degradation of natural resources: these costs are divided into (a) recurrent damage costs in the form of loss of income from impaired economic activity, additional repair or maintenance expenditure, reduced service life of capital items, and (b) non-recurrent investment costs on such items as additional water treatment plants or provision of replacement reservoir capacity.
Discount rate	The rate of time preference for real income expressed as a percentage. The discount rate can be thought of as the rate at which we devalue economic costs or benefits that occur in the future. In this report results of analyses are generally reported at three discount rates: 6%, 5% and 3%. In some cases a private landholder discount rate of 10% or 15% has been used.
EC units	Electrical conductivity units, μSm^{-1}, a measure of water salinity: equals approximately 1.6 times TDS. The World Health Organisation considers 800 EC the maximum desirable salinity level for drinking water. At 1,500 EC many crops cannot be irrigated and 5,000 EC is often considered the threshold for 'saline water'.
Fixed cost	These are costs of agricultural production that do not vary as a consequence of quantity produced or area harvested. They must be met in order to allow an enterprise and cannot be adjusted in the short-term. In this study fixed costs are equal to the sum of fixed depreciation costs, fixed labour costs and fixed operating costs. Fixed costs are adjustable in the long term.
Gross benefit	The gross benefit is the additional profit at full equity attainable in a given year if yield constraints (salinity, acidity, sodicity) were costlessly removed.

Gross revenue	In general terms, the gross revenue is equal to the price multiplied by quantity of agricultural product sent to market.
Impact cost (salinity)	In this report, the impact cost of salinity is the decrease in agricultural profit at full equity as a consequence of salinity induced yield decline from 2000 to 2020 in crops and pastures.
Marginal cost	The marginal cost is the additional cost resulting from an extra unit of degradation.
Net economic returns	This is equal to the profit at full equity for agricultural production less any government support in the form of tax subsidies, extension advice and other forms of support.
Non market goods and services	A non-market good or service cannot easily be priced because it is not traded in the market place. This includes goods such as biodiversity or clean air. These goods are sometimes valued using non-market valuation techniques.
Profit at full equity (PFE)	Profit at full equity is a measure of the economic returns to the natural resource base and management practice through agriculture. It is equal to gross revenue less fixed and variable costs.
Relative yield	Relative yield is expressed as a percentage and is equal to the actual yield divided by the potential yield. For example, a crop currently yielding 2 t/ha with a potential yield of 4t/ha would have a relative yield of 50%.
Soil sodicity	Soil sodicity is caused by the presence of sodium attached to clay in soil. A sodic soil has reduced infiltration and drainage of water, which can result in crop/pasture yield loss. Exchangeable sodium percentage is a measure of soil sodicity.
Salinity of water	Four quality classifications are used: ▪ Fresh (TDS < 500 mgL^{-1}) ▪ Marginal (TDS 500 to 1,500 mgL^{-1}) ▪ Brackish (TDS 1,500 to 5,000 mgL^{-1}) ▪ Saline (TDS >5,000 mgL^{-1}).

Social welfare	Social welfare can be considered the well-being of the community as a whole. In this report the term is used with reference to results derived from a non-market valuation of environmental resources. The welfare impacts of a policy that affects those non-market values can be considered the impacts to society's overall well-being.
TDS	Total dissolved solids in a water sample, in mgL^{-1}: equals approximately 0.625 EC Units.
TFS	Total Filterable Solids
TSS	Total soluble salts in a water sample, in mgL^{-1}: a "true" measure of salinity, but in practice this measure is very similar in value to TDS; TSS is not used in this report.
Variable costs	Variable costs are those costs that change as a function of the quantity of an agricultural commodity produced or as a function of the area farmed. They are adjustable in the short term.

1 Introduction

Mike Young

Economic issues are a dominant factor driving public and private natural resource management (NRM) decisions in Australia. However, NRM decisions are often made with inadequate information relating to the economic value of natural resources, the costs of resource degradation and the benefits of remedial action. This information deficiency can result in inefficient allocation of limited public and private resources for natural resource management. Without adequate biophysical and economic information it is difficult to appropriately target NRM funds made available through government programs.

The primary purpose of this study is to provide economic information and a framework that will help Australia's natural resource managers identify, develop and implement efficient strategies to address land and water degradation problems and improve the management of natural resources. It can be used within a conceptual framework for policy analysis of natural resource management issues (see Figure 1.1).

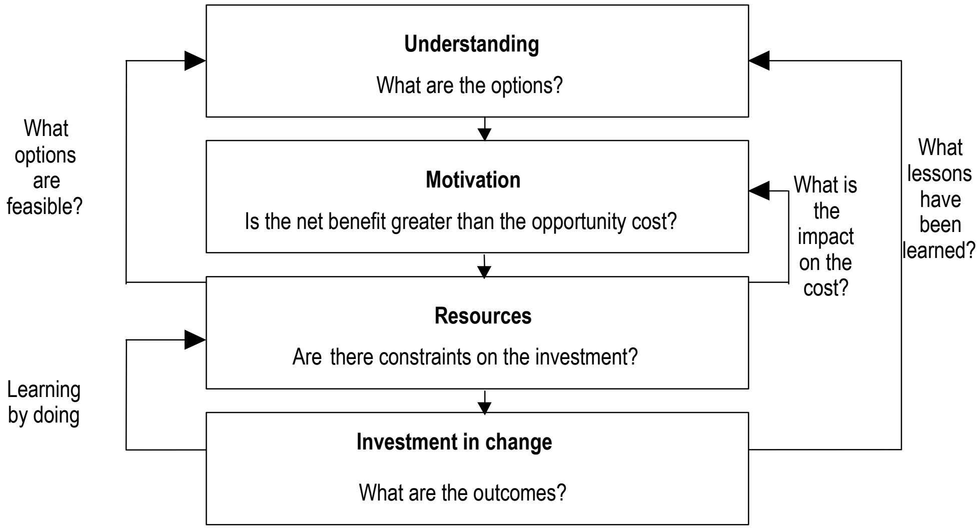

Figure 1.1 A process for assessing the economic merits of natural resource management investment **(Source: George Reeves, Centre for International Economics)**

This report attempts to provide the information necessary to answer questions about trends and opportunities associated with the future use of Australia's land and water resources. The focus is on non-urban areas that are primarily used for agricultural purposes. The framework offered, however, is broader than this and facilitates examination of the impacts of agricultural practice on other areas and resources used in other sectors. No consideration is given for land use issues associated with urban land use.

Information is classed as economic if it relates to the value of natural resources to humans and how natural resources can be managed to satisfy human needs as efficiently as possible. It is worth emphasising that value is derived from natural resources in many ways including those values which are often expressed in dollar terms (market values) and those values which cannot easily be monetised (non-market values). Defined as such, economic information is a primary input to decisions that are based on value systems. The economic information considered of most relevance to Australian natural resource management provided in this report includes:

- the economic value of the natural resource base used for agriculture;
- the impacts of changes in the condition of soil and water on agricultural income and extent of some remedial opportunities;
- the impacts of salinity, sedimentation and turbidity on infrastructure and non-agricultural industries;
- willingness to pay for changes in non-market values associated with species protection, landscape aesthetics, water quality and the retention of people in rural landscapes;
- perspectives on the likely range of economic opportunities associated with major resource management options being considered by government and private land managers.

One of the prime building blocks for this project is a geographic information system that enables detailed mapping and analysis of Australia's natural resources. The system is allows assessment of the magnitude and spatial extent of economic issues by virtually any form of spatial aggregation.

1.1 Objectives

This project focuses on returns to the resource base and costs of degradation. A primary aim is "to assess the value of the natural resource base and costs of degradation now and in the future".

It was essentially this project's responsibility to provide the integrative economic information necessary to deliver the National Land and Water Resources Audit's second objective:

> *"to provide an interpretation of the costs and benefits—economic, environmental and social—of land and water resource change and any remedial actions."*

The objectives for this project were to:

1. assess and estimate the value of agricultural production attributable to the natural resource base;
2. assess and estimate the costs of resource degradation to non-agricultural users including consideration of recreation and aesthetic values, ecology, conservation and biodiversity values; and
3. establish a comprehensive, nationally consistent framework and process for valuation of resource change in future years.

1.2 Project structure

The Project underpinning this report was divided into 4 sub-projects:

Sub-Project 6.1.1 is assembling data on the "Value of returns to land and water resources used in agriculture "and was led by John Fargher and Bruce Howard from URS.

Sub-Project 6.1.2 is assembling data on the "Cost of degradation to agriculture" and was led by Mike Young and Stefan Hajkowicz from CSIRO Land and Water's Policy and Economic Research Unit.

Sub-Project 6.1.3 is assembling data on the “Market value of damage to infrastructure caused by agriculture" and was led by David Young from Dames and Moore NRM and Jon Thomas from the Resource Economics Unit.

Sub-Project 6.1.4 is assembling data on the "Non-market value of changes to the environment caused by agriculture" and was led by Jeff Bennett and Martin van Bruenen from UniSearch.

1.3 Story Line

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

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.

1.4 Data Reporting

The database developed in this project was constructed using a 1km^2 grid across the nation. Interpretation of the data will typically need to be undertaken at a much coarser resolution. Using the 1km^2 grid it is possible to aggregate the data according to a wide variety of regional frameworks and land use groupings. A regional framework frequently used to aggregate the data throughout this report is shown in Figure 1.2. This regional framework is based on an aggregation of river basins and seeks to identify broad areas with similar agricultural, climatic and environmental characteristics. A detailed listing of all the data by river basin, lying within each of these reporting regions is provided in Appendix J.

Unless otherwise stated all dollar values derived from this project are given in 1996/97 dollars.

Figure 1.2 Data reporting regions

1.5 Links With Rest of the Audit

For planning and administrative purposes, the National Land and Water Resources Audit has been organised into 7 themes, a data management project and a set of implementation projects. As indicated in Figure 1.3, Project 6.1 builds upon all the biophysical information being collected by other projects. *We have assumed that the information supplied is the best available and that it is our role to place the best economic interpretation on these data.*

Other parts of Theme 6 provide the social information necessary to provide the final integrated analysis, as will be reported in the upcoming publication "Australians and Natural Resources Management 2001".

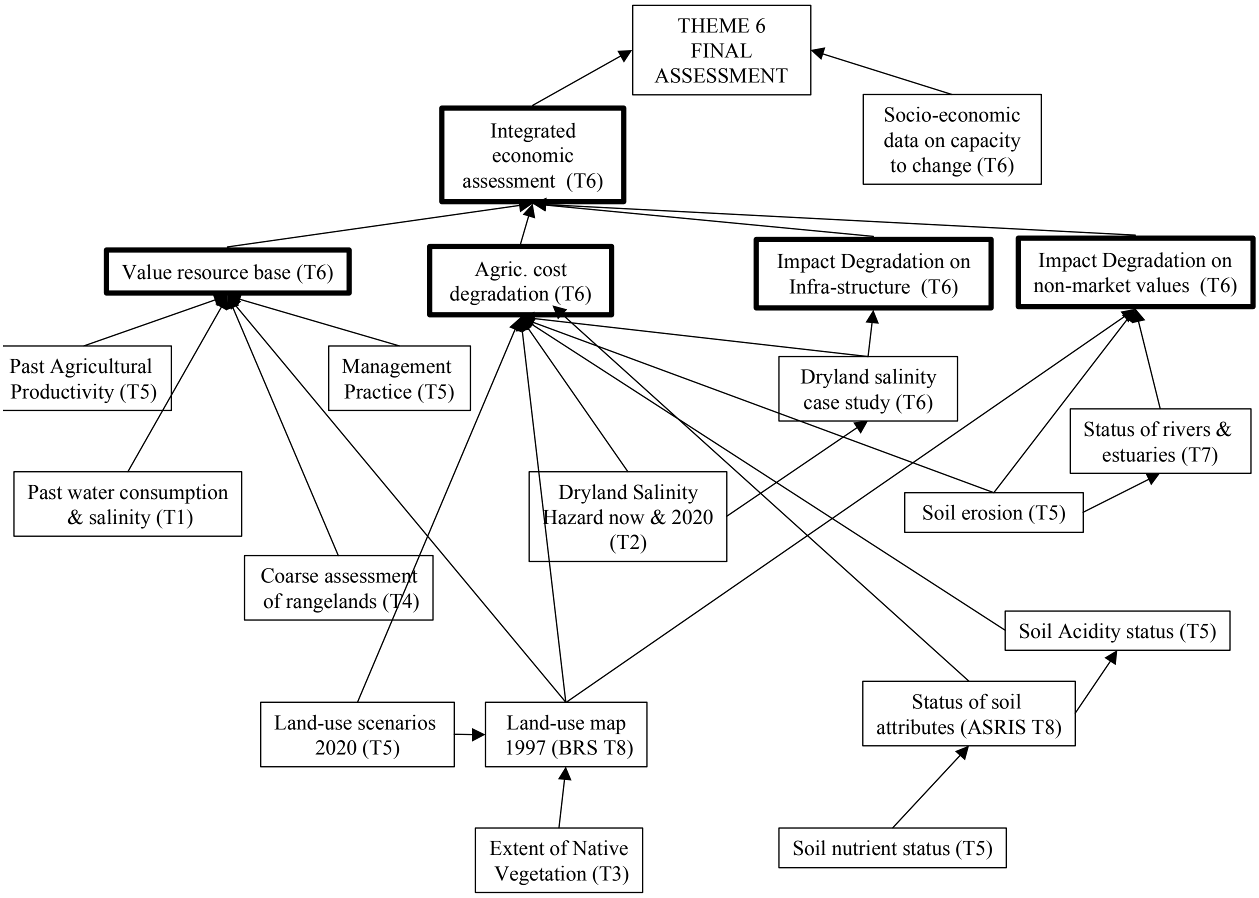

Figure 1.3 Data sources for Project 6.1 (Numbers are the Audit theme numbers. Boxes in bold are the responsibility of this project. Not shown are direct and indirect contributions from State and Territory Implementation Projects)

2 Value of Returns to the Agricultural Resource Base

Bruce Howard and Stefan Hajkowicz

2.1 Synopsis

Profit at full equity provides an indicator of the nature of returns to land and water resources used for agriculture. Profit at full equity is revenue less costs less depreciation less an imputed estimate of the value of labour supplied by farmers. Interest costs are not included as interest is a return to the capital deployed on the land. Profit at full equity provides a different measure to the commonly used gross margin as it includes fixed costs of production, not just variable costs.

Irrigation is very important to the agricultural economy but occurs over a very small area—less than 1 per cent of land used for agriculture is irrigated—however it contributes roughly 50% of profit at full equity ($6,555 in 1996/97).

Only relatively small areas of Australia have high returns per hectare and these are confined largely to the southern regions and parts of southeast Queensland. Intensive land uses such as horticulture generally give the highest returns per hectare. In fact, 80% of profit-at-full-equity—the return to land, water, capital and managerial skill—comes from roughly 4 million hectares–less than 0.8% of the area used for agriculture.

The Audit identifies over 240 river basins in Australia. In 1996/97 ten of these basins produced just under half of all the profits from Australian agriculture. The five-year period (1992/93 to 1996/97) was similar with around 50% of profits drawn from 14 catchments.

The efficiency of 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, we provide an estimate of profit-at-full-equity per megalitre used. 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, uses 40% of Australia's irrigation water and returns the most profit at full equity nation's land and water resources.

From an economic perspective, it is necessary to recognise the costs of direct support to agricultural production via government subsidies, tariff protection, etc. This provides an estimate of Net Economic Return per hectare (in 1996/97 this was $4,316). For the 1996/97 financial year the average annual cost of agricultural protection, using the OECD's definition of producer subsidy equivalents, was $2,239 million. This is equivalent to 34% of profit-at-full-equity in 1996/97. This does not include the cost of government contributions to environmental and natural resource programs such as Landcare, the Natural Heritage Trust, etc. 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 in recent years—has been reduced. Thus, the 34% estimate is now an overestimate.

2.2 Background

This component of the Audit involved the development of a spatially explicit data set, relating economic returns to agricultural land uses and the natural resource base. Data sets of this nature provide a critical link between land management strategies and their economic consequences. Accordingly, such data sets have much value to policy makers concerned with attaining more efficient use of Australia's natural resources.

The types of questions frequently asked include: In what regions and in which industries do natural resources provide the greatest economic returns? What would be the economic impact of policies for land use change over time? What are the economic costs and benefits associated with strategies aimed at addressing land degradation? How might land use change in response to a change in commodity prices or costs of production?

Whilst this task has not been previously undertaken in a comprehensive and spatially defined sense, there have been many partial estimates, and much existing data was used to generate the full picture. Information on the economic implications of changes to agricultural land use and land management practice is highly sought after by natural resource managers.

This section of the report describes and summarises a set of national data layers that can be used to determine the net economic returns from agricultural production (at a broad regional scale). These data layers provide information on the economic opportunities for natural resource management in Australia by combining:

- Satellite data, incorporating a measure of vegetation vigour referred to as the normalised difference vegetation index (NDVI);
- A national map of land use representing 67 land use types derived from the 1996/97 Land Use Map of Australia;[6]
- Price and production data for agricultural commodities recorded by the Australian Bureau of Statistics at the Statistical Local Area level;

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[6] This represents the major form of commodity production on a grid, with a cell (pixel) resolution of approximately one square kilometre.

- Data on fixed and variable costs of production recorded by ABARE at a regional level;
- State government gross margin handbooks listing the quantity dependent and area dependent variable costs of agricultural production;
- Broad consultation on production costs, yields and commodity prices with farm management experts throughout Australia.

2.2.1 Comparison With Other Data Sets

Data on gross income, costs and net returns from agriculture in Australia are available from ABARE and the ABS. Values for income, costs and the net value of production generated in this project are commensurate with ABS and ABARE estimates (Table 2.1). Part of the difference in absolute values is due to the different areas involved. The Audit data set maps all known agricultural land, the ABS only identifies establishments whose gross annual estimated value of economic operations exceeds $22,000. ABARE also provide a different area estimate and does not cover the same range of commodities.

Table 2.1 Comparison of Data Sets

	ABS(a)	CSIRO (NLWRA)	ABARE(b)
Revenue ($m)	$24,694	$28,419	$28,040
Costs ($m)	$18,317	$21,865	$23,808
Net Value of Production ($m)	$6,377(c)	$6,555	$4,232
Area of Ag. Land (ha millions)	453.7	472.7	466.1

(a) Derived from: ABS (1998) "7507.0 *Agricultural Industries, Financial Statistics, Australia, Final Issue (1996/97)*", Australian Bureau of Statistics, Canberra. ISSN: 0810-459X. These values are only for industries that are also represented in this project.

(b) Derived from ABARE (2000) "1999 Australian Commodity Statistics", Australian Bureau of Agriculture and Resource Economics, Canberra. ISSN 1325-8109.

(c) Determined by subtracting ABS costs from ABS revenue.

2.3 Methods

Full details of the method used to prepare the economic data that underpin Project 6.1 are contained in Appendix A. The methods integrate a spatial description of land use and the associated productivity yields for all major agricultural activities (as described by ABS production statistics), with data describing variable and fixed costs of production (including labour and capital), government support, and potential benefits from addressing degradation issues. The result is a fine scale data set with all information stored on a 1km^2 grid.

It is worth noting that many alternatives to the spatially explicit natural resource accounting framework, as developed in this project, are available for analysing economic aspects of agriculture and natural resource condition. One important perspective analyses changes in resource condition by assessing welfare impacts, through changes to consumer and producer surplus. From this, perspective, the economic value of agriculture could be represented as the producer and consumer surplus on a supply and demand model. Changes to either prices or quantities, through government policies or land degradation, would lead to changes in social welfare.

2.3.1 The Profit Function

A profit function was developed to provide a consistent approach that was capable of calculating; gross local value of agricultural production; profit at full equity; net economic return to land and water resources; and net social return to land and water resources. This approach enables easy integration with other components of the Audit. In addition, the structure is designed so that it can be incorporated into the full suite of natural resource issues associated with Australian agriculture.

The main measure of performance is “Profit at Full Equity”. This provides an estimate of the financial return to land, water and capital plus managerial skill. All production costs and an imputed estimate of the value of farm labour is deducted.

The profit function is written as:

$$PFE = ((P1 \times Q1 \times TRN) + (P2 \times Q2 \times Q1)) - ((QC \times Q1 + AC) + (WR \times WP) + (FOC + FDC + FLC))$$

Where:

PFE = Profit at Full Equity ($/ha/yr)

P1 – Farm Gate Price ($/ha or $/DSE)

Q1 – Yield or Stocking Rate ($/ha or $/DSE)

TRN – Turn-off Rate (Ratio)

P2 – Price of secondary product ($/litre or $/kg)

Q2 – Yield of secondary product (litres/DSE or kg/DSE)

QC – Quantity Dependant Variable Costs (\$/t or \$/DSE)

AC – Area Dependant Variable Costs (\$/ha)

WR – Water Requirement of Land Use (ML/ha)

WP – Water Price (\$/ML)

FOC – Fixed Operating Costs (\$/ha)

FDC – Fixed Depreciation Costs (\$/ha)

FLC – Fixed Labour Costs (\$/ha)

2.3.2 Assistance to Agricultural Production

In international analyses of agricultural support and protection it is conventional to estimate nominal rates of assistance and then convert them into subsidy and/or tax equivalents. The nominal rate assistance on outputs is the percentage change in gross returns per unit of output relative to the (hypothetical) situation of no assistance. The nominal rate measures the extent to which consumers pay higher prices and taxpayers pay subsidies to support local output.

To gain insights into the extent of assistance, government support data to land uses were determined from Productivity Commission reports (Industry Commission 1996, Productivity Commission 1998). These data were presented as industry and or state aggregates, they were converted for the Audit either as a value per hectare or a percentage of gross product value. Rates were subdivided down to each commodity type as far data permitted. A surface of government support and net economic returns in dollars per hectare per year (for 1996/97) was created on a 1km^2 grid.

Net Economic Return (NER) = PFE – Government Support

Assistance includes expenditure items such as direct expenditure on research, advisory/extension services, drought assistance and indirect support through taxation subsidies and the impacts of tariffs. It is provided by the Productivity Commission, formerly the Industry Commission, for different land use types. These land use types were matched to the land uses in the 1996/97 land use map of Australia, allowing the production of a 1km grid indicating government support in each grid cell in dollars per hectare.

The estimates are for the total of Commonwealth, State, Territory and Local Government assistance to agriculture. They have been determined from nominal rates of Commonwealth assistance on outputs and State Government outlays calculated as a portion of farm gate value. Nominal rates of assistance, matched to land use types, were multiplied by gross revenue within each 1km grid cell to obtain an estimate of government assistance.

2.3.3 Data Time Periods

The base year for the Audit is 1996/97, both 1996/97 prices and mean prices for the five years up to and including 1996/97 are used. The prime data set supplied to the Audit is in real 1996/97 prices. This is the primary data set because the land use map was also generated for 1996/97, the year of an agricultural census. All dollar values are given in 1996/97 dollars.

The five-year data assumes static land use over the period 1992/93 to 1996/97. Fixed and variable costs of production over the five-year period are also held constant. All variables used to derive gross revenue were collated for each of the five years and a mean was taken to produce a single profit-at-full equity map for Australia. Five year mean profit at full equity is expressed in 1996/97 dollars.

2.3.4 Land use Map

The Bureau of Rural Sciences produced a land use map for the Audit as a 1km grid covering Australia for the year of 1996/97. Commodities were then assigned to each land use. The resulting land use map describes the location and extent of over 60 categories of agricultural commodities produced across Australia (see Appendix A). All land uses are partitioned into dryland and irrigated categories. For different analyses we have aggregated this map on the basis of major land use groupings (see Figure 2.1). These major land use groupings also form the basis of tabulated data.

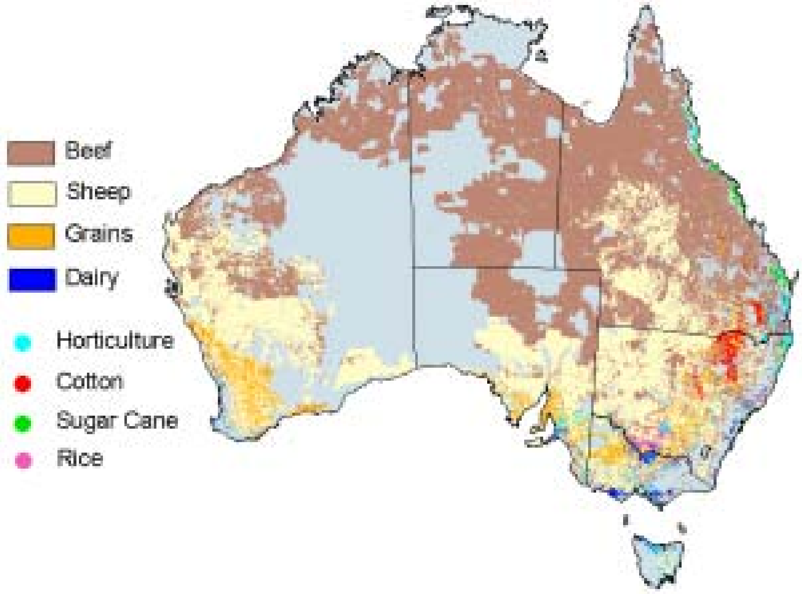

Figure 2.1 Agricultural land use map of Australia (horticulture, cotton, sugar cane and rice are graphically exaggerated to depict general location)

Table 2.2 Areas of major land use groupings

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 major changes made to the original Audit 1996/97 Land Use map was the assignment of beef, sheep or dairy to pasture land and the assignment of wheat to barley pixels in Western Australia.

Livestock were assigned using ABS production data at the statistical local area (SLA) level. Livestock numbers per SLA were converted to common units using Dry Sheep Equivalents (DSE). The conversions for the three types of livestock were:

- 1 Sheep = 1.5 DSE

- 1 Dairy Cow = 10 DSE
- Beef Cow = 8 DSE

With livestock in common units it was possible to assign pasture on a pro-rata basis. For example, if 80% of the livestock were sheep then 80% of the pasture was assigned to sheep. The normalised difference vegetation index data was used to assign the greener (healthier) pastures in priority order to dairy, beef and sheep.

Assigning profit function variables to a 1km grid, based on the land use map, has strengths and weaknesses as an approach for building a set of natural resource accounts. The main strength is that it allows explicit spatial comparison of the data with other spatial datasets relating to the biophysical condition of the landscape. However, this approach does not model the farm business unit. This makes it difficult to account for variations in managerial skill, debt level and day-to-day variations in costs and prices.

2.3.5 Crop Yields and Stocking Rates

A surface of crop yields and stocking rates was generated from production data supplied by the Australian Bureau of Statistics within Statistical Local Area (SLA) regions and satellite data. The satellite data used was cloud-adjusted, growing season normalised difference vegetation index (NDVI), supplied for the nation on a 1km grid by *Environment Australia*.

Crop and horticulture yields were determined by dividing the quantity produced by the area of the crop per SLA. The land use map was then used to assign those yields to individual 1km grid cells within the SLA.

Rather than just assigning yield evenly to all pixels, the yields were weighted with the NDVI data. The NDVI provides a measure of vegetation vigour, and is often referred to as a 'greeness index'. Higher NDVI scores are indicative of better crop yields, all else being equal. Yield was determined as:

$$q1 = \frac{NDVI_i}{\sum_{i=1}^{SL} NDVI_i} \times P$$

Where:

q1 = The yield of the crop in tonnes, or number of livestock in DSE, within the 1km grid cell;

NDVI = The NDVI score for the pixel *i*;

SL = The total number of pixels in the Statistical Local Area

P = The total production in tonnes for the commodity in the Statistical Local Area

2.4 Economic Returns

Data relating to the value of economic returns to the resource base, through agricultural production, are presented as:

- Gross Local Value of Production (Revenue);
- Profit at Full Equity; and
- Net Economic Return.

These results are presented spatially as a dollar value per hectare for each land use mapped at the 1km grid scale. Data is also tabulated to provide detailed summaries of state, regional and land use aggregations.

2.4.1 Revenue, Costs and Profit

Revenue, costs and profit at full equity are aggregated by State/Territory, land use grouping and reporting region (Table 2.3, Table 2.4 and Table 2.5). Profits for the five-year mean are generally higher than for 1996/97. This suggests that 1996/97 was a poor year for many land uses. For example, beef in 1996/97 had a net loss of $718m and over the five-year mean beef had a net gain of $578m. Prices for beef in 1996/97 were particularly low.

Table 2.3 Revenue, costs and profit at full equity (PFE) by States and Territories

	Revenue ($m)		Costs ($m)		PFE ($m)	
	1996/97	5yr	1996/97	5yr	1996/97	5yr
New South Wales	9,153	9,235	7,118	6,994	2,035	2,240
Victoria	5,440	5,652	4,303	4,278	1,137	1,374
Queensland	6,127	6,548	4,817	4,748	1,310	1,800
South Australia	3,190	3,186	2,248	2,246	942	940
Western Australia	3,479	3,462	2,513	2,515	966	947
Tasmania	858	925	743	737	115	187
Northern Territory	168	155	118	116	50	39
Australian Capital Territory	4	6	4	4	1	2
Australia	28,419	29,168	21,865	21,638	6,555	7,530

In 1996/97 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.

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.

Table 2.4 Revenue, costs and profit at full equity (PFE) by land use groupings

	Revenue ($m)		Costs ($m)		PFE ($m)	
	1996/97	**5yr**	**1996/97**	**5yr**	**1996/97**	**5yr**
Beef	3,497	4,791	4,215	4,213	-718	578
Cereals	5,689	5,113	3,853	3,807	1,836	1,305
Coarse Grains	1,040	1,127	480	478	560	649
Cotton	2,412	2,207	1,199	1,118	1,213	1,089
Dairy	5,208	5,143	3,618	3,495	1,590	1,649
Fruit	2,193	2,261	1,304	1,309	889	951
Grapes	1,078	1,092	610	610	468	482
Hay	69	68	59	58	11	9
Legumes	487	418	402	399	85	19
Oilseeds	288	257	195	193	93	63
Peanuts	46	41	24	24	23	17
Rice	279	271	227	224	52	48
Sheep	3,391	3,443	3,696	3,713	-306	-270
Sugar Cane	1,177	1,290	1,010	1,027	167	264
Tobacco	34	36	21	21	13	15
Tree Nuts	197	194	126	126	71	68
Vegetables	1,334	1,417	826	823	508	593
All land uses	28,419	29,168	21,865	21,638	6,555	7,530

It can be seen that in 1996/97 the largest contributors to total profits were cereals, dairy and cotton. Sheep and beef made a loss in this year. It is worth noting that since 1996/97 beef prices have risen markedly. This would improve the performance of beef in the above table.

Table 2.5 Revenue, costs and profit at full equity (PFE) by reporting regions

	Revenue ($m)		Costs ($m)		PFE ($m)	
	1996/97	5yr	1996/97	5yr	1996/97	5yr
Burdekin	252	338	315	316	-63	22
Carpentaria	243	397	306	305	-63	92
Darling	6,112	5,822	4,317	4,208	1,796	1,614
Far North Queensland	49	56	41	42	8	14
Fitzroy	733	849	655	653	78	196
Goldfields	79	77	76	76	3	1
Gulf	31	45	34	34	-3	11
Indian North	40	58	48	48	-8	11
Indian South	262	272	226	226	36	45
Inland	441	538	572	572	-131	-33
Moreton	762	733	476	447	286	286
Murray	7,781	7,928	5,830	5,807	1,951	2,121
NSW North	681	810	545	565	137	246
NSW South & Central	886	896	741	696	145	200
North Queensland	916	996	716	714	200	282
Queensland South & Central	936	1,015	726	715	210	300
SA Gulf	1,132	1,095	692	688	440	407
South East Corner	1,122	1,207	944	927	178	280
Southern	1,694	1,758	1,457	1,457	237	301
Tasmania	858	925	743	737	115	187
Timor Sea	145	174	86	85	59	89
WA South	2,998	2,912	2,088	2,090	910	823
Western Eyre Peninsula	267	267	231	231	36	36
Australia	28,419	29,168	21,865	21,638	6,555	7,530

A visual comparison between maps of profit at full equity generated in this study and profit at full equity from ABARE is provided in Figure 2.2 and Figure 2.3. The ABARE map contains only the profits generated from broadacre agricultural land uses such as cereals, beef and sheep. It does not include intensive forms of production such as horticulture. Nevertheless, as the broadacre land uses occupy by far the greatest area on both maps a visual comparison is useful. It shows that both data sets identify large loss-making areas in 1996/97, mostly in the low-rainfall regions of the interior. The ABARE map is at a much coarser level of spatial detail than the maps developed in this project.

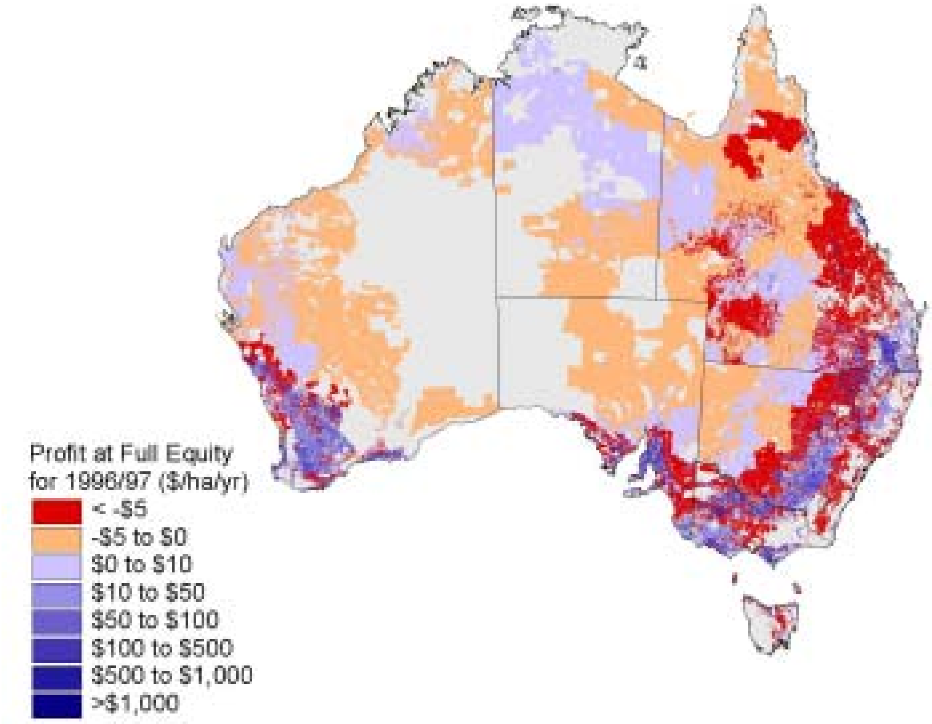

Figure 2.2 Profit at full equity (1996/97, $/ha/yr)

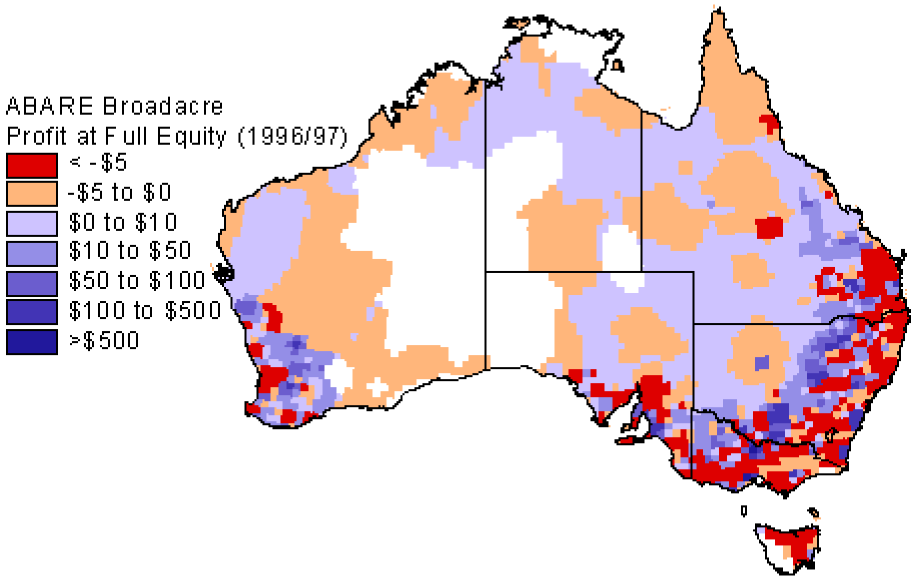

Figure 2.3 Broadacre land use profit at full equity 1996/97 from ABARE datasets ($/ha/yr).

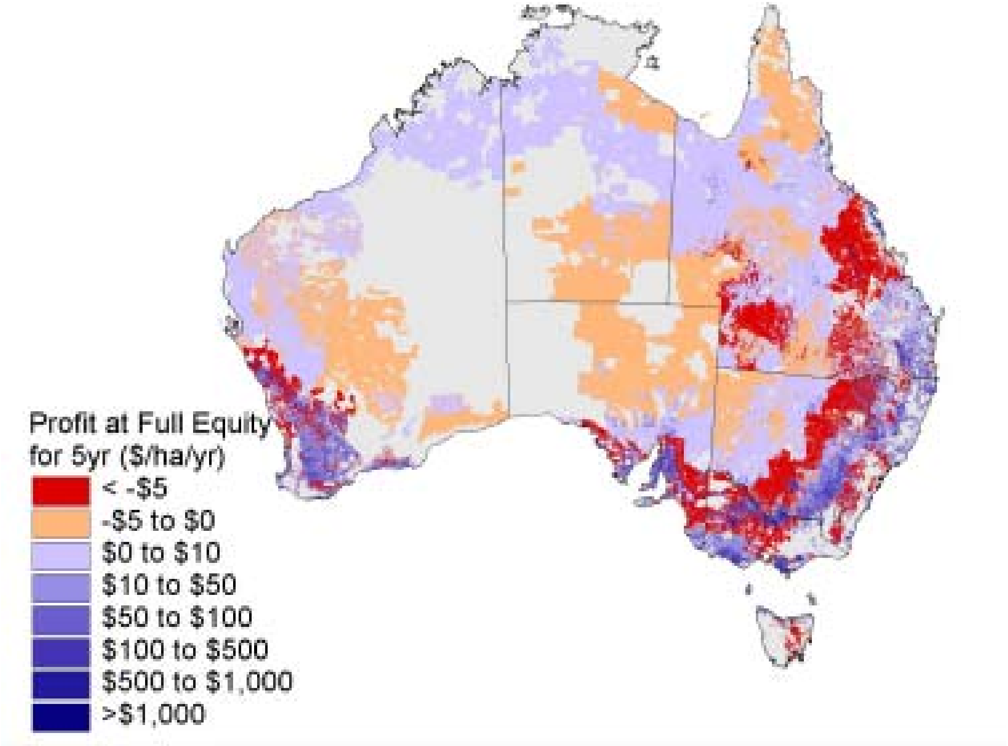

Figure 2.4 Five year mean profit at full equity for 1992/93 to 1996/97 ($/ha/yr)

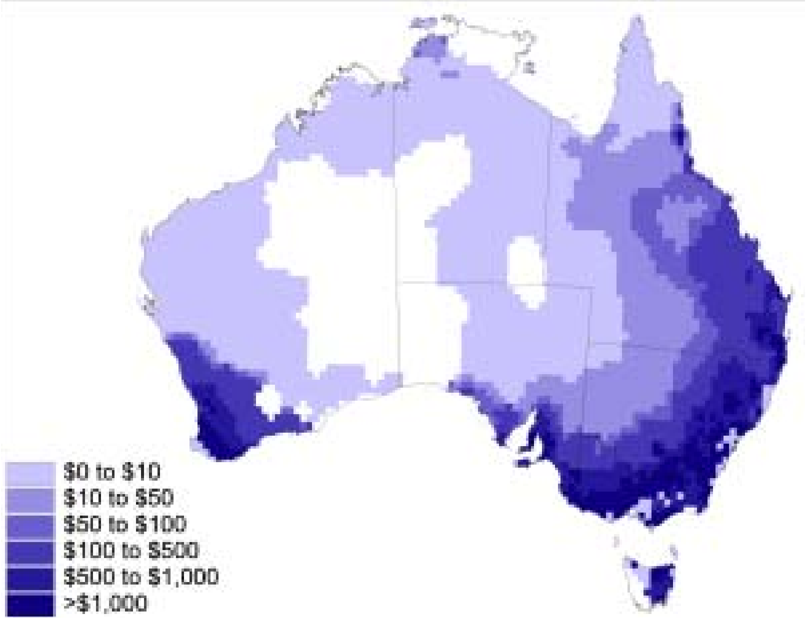

Figure 2.5 Broadacre land values for the 5yr mean (1992/93 to 1996/97) derived from ABARE data ($/ha/yr)

As illustrated in Figure 2.6, only relatively small areas of Australia have high returns per hectare and these are confined largely to the southern regions and parts of southwest Queensland. That is, the returns made in most areas were not sufficient to cover production costs and pay land managers a wage. In 1996/97 80% of profit at full equity —the return to land, water, capital and managerial skill — comes from roughly 4 million hectares – less than 1% of the area used for agriculture. Taking out the rangelands, using a definition of the area based on river basins, around 3% of agricultural land produces 80% of profit at full equity.

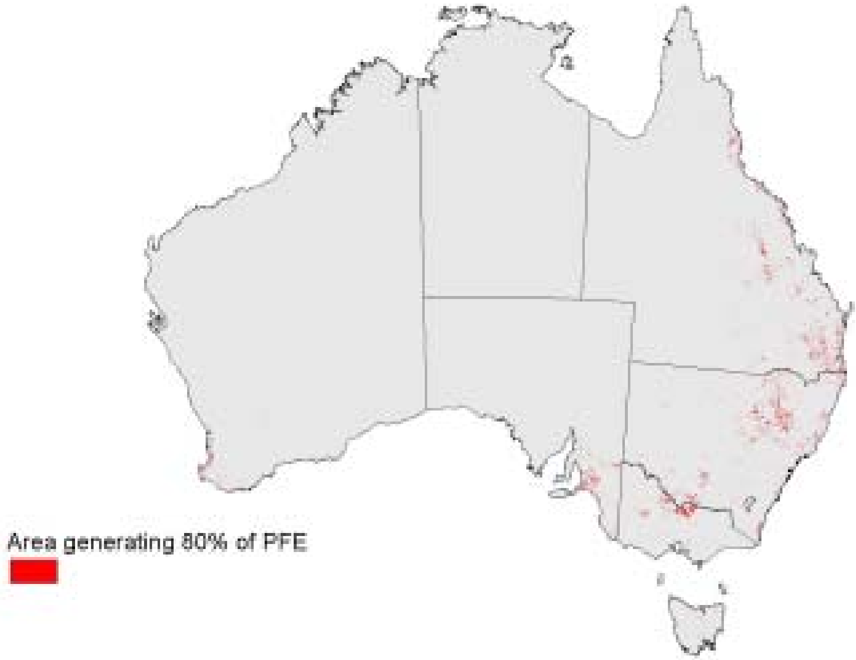

Figure 2.6 Location of the most profitable areas of land in Australia, showing the smallest area required to produce 80% of the nation's total profit at full equity.

2.4.2 Net Economic Return

Net economic return is profit at full equity less government support received. Examples of government support include government funded research and extension services, taxation assistance, rural adjustment funding, price support mechanisms. The total value of support to agriculture was derived from data supplied to the Organisation of Economic Cooperation and Development (OECD) as part of their process used to define producer subsidy equivalents for each member country and from data published by the Productivity Commission (Industry Commission 1996, Productivity Commission 1998). The total value of production support to agriculture using internationally agreed definitions in 1996/97 is estimated at $2,239 million or 34% of the profit.

Net economic returns are presented spatially for Australia for 1996/97 (see Figure 2.7). Tabulated aggregates for major regions, and for land use groupings are presented in Table 2.6 and Table 2.7.

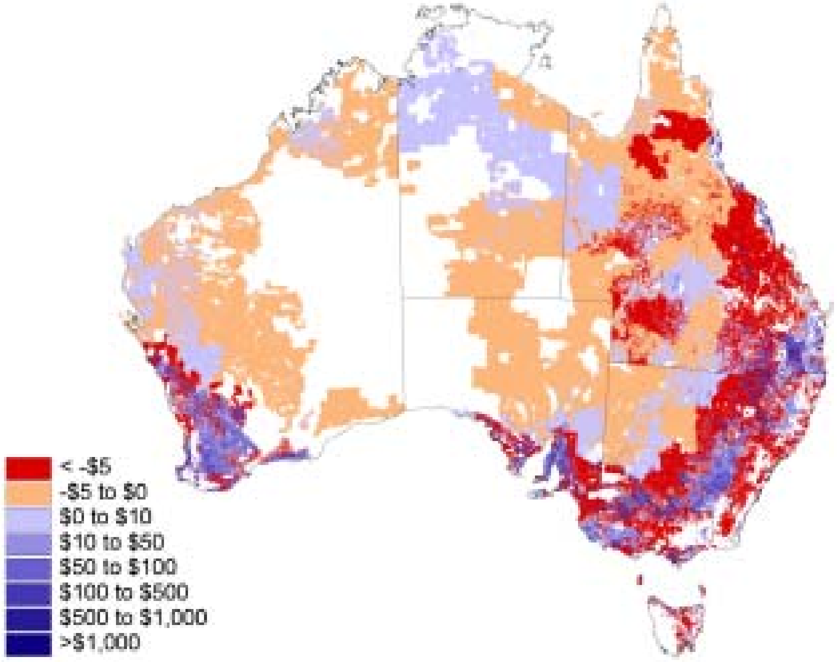

Figure 2.7 Net Economic Returns ($/ha/yr)

Table 2.6 Net Economic Returns by reporting region

Reporting region	Government Support in 1996/97 ($m)[1]	Support as portion of profit at full equity (%)[2]	Share of total support (%)	Net economic returns in 1996/97 ($m)[3]
Burdekin	14	-23	1	-78
Carpentaria	20	-32	1	-83
Darling	289	16	13	1,507
Far North Queensland	7	91	0	1
Fitzroy	41	53	2	36
Goldfields	4	115	0	0
Gulf	1	-44	0	-5
Indian North	2	-20	0	-10
Indian South	13	36	1	23
Inland	19	-15	1	-150
Moreton	97	34	4	189
Murray	664	34	30	1,287
NSW North	59	43	3	78
NSW South & Central	145	100	6	0
North Queensland	68	34	3	131
Queensland South & Central	87	41	4	123
SA Gulf	76	17	3	364
South East Corner	160	90	7	18
Southern	175	74	8	62
Tasmania	86	75	4	29
Timor Sea	12	21	1	47
WA South	187	21	8	723
Western Eyre Peninsula	12	35	1	23
Totals	2,239	34	-	4,316

1. This includes Commonwealth, State, Territory and Local Government support to agriculture. It has been determined from nominal rates of Commonwealth assistance on outputs and State Government outlays calculated as a portion of farm gate value. Data on nominal rates of assistance are assembled and published by the Productivity Commission.
2. Negative percentages are given in regions where the total 1996/97 profit at full equity is also negative.
3. Net economic return is equal to profit at full equity less government support.

Table 2.7 Net Economic Returns by Land use

Land Use	Government Support in 1996/97 ($m)[1]	Support as portion of profit at full equity (%)[2]	Share of total support (%)	Net economic returns in 1996/97 ($m)[3]
Beef	157	-22	7	-876
Cereals	272	15	12	1,564
Coarse Grains	69	12	3	492
Cotton	63	5	3	1,150
Dairy	1146	72	51	444
Fruit	113	13	5	776
Grapes	73	16	3	395
Hay	3	25	0	8
Legumes	32	38	1	53
Oilseeds	19	20	1	74
Peanuts	0	2	0	22
Rice	8	16	0	44
Sheep	129	-42	6	-434
Sugar Cane	62	37	3	104
Tobacco	10	80	0	3
Tree Nuts	2	3	0	69
Vegetables	80	16	4	428
Total	2,239	34	100	4,316

1. This includes Commonwealth, State, Territory and Local Government support to agriculture. It has been determined from nominal rates of Commonwealth assistance on outputs and State Government outlays calculated as a portion of farm gate value. Data on nominal rates of assistance are assembled and published by the Productivity Commission.

2. Negative percentages are given in regions where the total 1996/97 profit at full equity is also negative.

3. Net economic return is equal to profit at full equity less government support.

2.5 Water's Contribution to the Economy

Due to the importance of water resource issues and the high value industries associated with irrigated agriculture a specific analysis of the contribution that water makes to the economy was undertaken. Table 2.8 provides a comparison between dryland production (for both pastoral and dryland agricultural areas) and irrigated production. In 1996/97 the value of production from irrigated agriculture, as measured by profit at full equity, is $3.7 billion. The contribution of water is emphasised by the observation that irrigated agriculture, which uses less than 1 per cent of the area, produces more than 50 per cent of the profit at full equity.

Table 2.8 Dryland Irrigation Comparison

	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	2,357	0.5%	3,667	56%	3,839	51%
All agricultural land	472,016	100%	6,555	100%	7,530	100%

The profit generated for each ML of water used is indicated by Table 2.9. This indicates the activities that generate the highest profit for each unit of scare resource used, it also serves to show those industries that are vulnerable to increases in the price of water. For example an increase of $31 per ML would reduce returns from rice to zero, within the constraints of the profit function[7]. The sensitivity of different industries to water price increases is also a factor of the share of production costs that water represents.

Table 2.9 Profits per mega litre of irrigation water (PFE/ML 96/97)

Irrigated land Use	Water Returns ($/ML)	Total Water Use (GL)	Percent of total water use	Water Use (ML/ha)
Beef (irrigated only)	14	1,080	7.2%	4
Cereals	-9	87	0.6%	3
Coarse Grains	116	518	3.5%	3
Cotton	452	2,314	15.5%	7
Dairy	94	5,902	39.5%	7
Fruit	1276	665	4.4%	7
Grapes	600	781	5.2%	8
Hay	54	20	0.1%	4
Legumes	24	33	0.2%	3
Oilseeds	10	85	0.6%	3
Peanuts	90	25	0.2%	3
Rice	31	1,696	11.3%	11
Sheep	23	13	0.1%	4
Sugar Cane	21	1,195	8.0%	7
Tobacco	985	13	0.1%	4
Tree Nuts	507	140	0.9%	6
Vegetables	1295	392	2.6%	3
All irrigated land uses	193	14,959	100.0%	7

Figure 2.8 shows water costs as a portion of total costs for major irrigated land uses. Where the water costs are a higher portion of total costs, the

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[7] If water price were increased in reality, industry adjustment would be expected. For example, water use efficiency may increase and production practices may change in other ways. Modifying the price of water in the profit function can only provide a broad generalisation of the industry adjustment that may need to occur.

land use is more sensitive to changes in water price. This could be important for those industries if a full cost recovery policy for water supply is pursued.

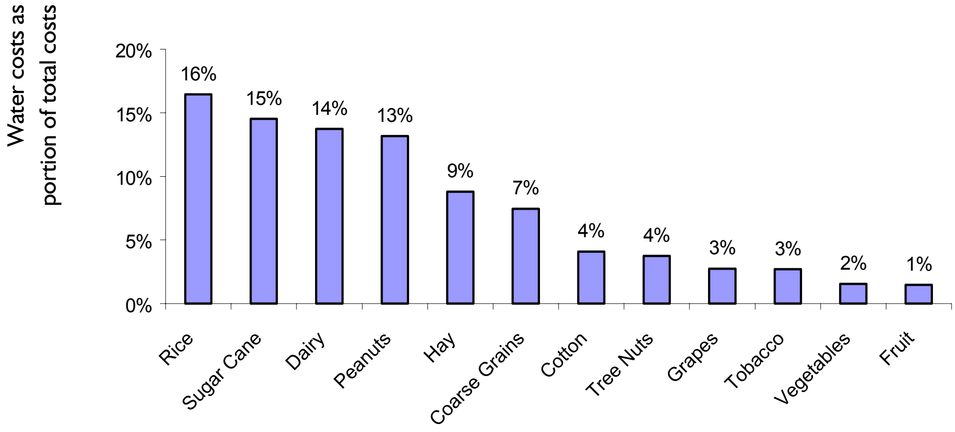

Figure 2.8 Water charges as a portion of total fixed and variable costs

2.5.1 What if the Water Price Doubled?

A detailed analysis would require a dynamic model that allows for changes in land use. Doubling the water price would be expected to result in improved water use efficiency and changes in land use patterns. A detailed assessment of the impacts of water price increases would require analysing demand curves, elasticities and structural adjustments.

A preliminary impression of the nature of structural adjustment (long-term and short-term) that could occur in irrigation industries is provided by adjusting the water price in the profit function. For this analysis the water price was doubled, a realistic scenario in some regions for full cost recovery policies.

The results of this simple analysis indicate that total net economic returns (PFE) of Australian agriculture will decrease by around $371 million (5.7%) based on 1996/97 data. Around 412,700 ha of irrigated land uses (18% of irrigated land) will become unprofitable. Table 2.10 shows how these increased costs would impact on different industries.

Table 2.10 What if irrigation water price doubled?[1]

Land Use	Base PFE/ML/yr ($)	PFE with Increased Cost PFE/ML/yr ($)	Increased Water Cost ($m)
Dairy	94	70	142.4
Sugar Cane	21	-26	56.4
Cotton	452	432	45.2
Rice	31	9	37.3
Beef	14	-8	23.4
Grapes	600	578	16.7
Fruit	1276	1251	16.5
Vegetables	1295	1262	12.8
Coarse Grains	116	98	9.6
Tree Nuts	507	473	4.6

1. This is a simple analysis based on multiplying the water price in the profit function by two. It provides an impression of how much adjustment would be required. In practice, considerable changes in water use efficiency and other industry adjustments would be expected.

2.6 Potential Extensions and Uses of the Data

2.6.1 Uses of the Data

The datasets developed through this project provide a foundation for economic analyses of natural resource management policy. Whilst there are many policy questions the datasets cannot answer by themselves, they can provide useful inputs to other models and analyses. Some of the uses to which the data could be put include:

- Assessing the impact of changes to the biophysical condition of the landscape on profit at full equity. The yield term in the profit function provides an avenue for linking biophysical data, such as soil attributes or climate, to profit at full equity.
- Assessing the implications of regional land use change on agricultural profitability.
- Comparing economic returns to the natural resource base derived through agriculture against other uses, such as water provision and amenity values.
- Analysing the relationships between profits and other spatial data such as landscape health or demographic data.
- Assessing regional implications for changes to commodity prices or costs of production.

2.6.2 Extensions of the Data

- Development of a land use map for 2000/01 based on the next agricultural census. It would also be possible to use updated prices, yields and costs of production data.
- Using control points from the fine scale land use map being developed by BRS for the Audit (especially in Western Australia).
- Reducing the pixel size from 1 km^2 to $250m^2$ in intensively used irrigation areas.
- Adding additional decision rules to the SPREAD program so, for example, preference is given to the allocation of irrigation to known irrigation.
- Developing synthetic “mixed” control points so that areas where the actual land use is 50% of one crop and 50% of another is more accurately represented.
- Using vegetation data from other sources to help identify areas that are either residual (not used for agricultural production) or native pasture areas.

3 Economic Status of Agricultural Soils: Acidity, Salinity and Sodicity

Stefan Hajkowicz and Mike Young

3.1 Synopsis

Biophysical data sets prepared by the Audit show that dryland human-induced salinity affects a relatively small portion of agricultural land. Increases in salinity costs to agricultural production from 2000 to 2020 will be relatively minor compared to the total economic returns from agriculture. Salinity causes significant yield loss over 0.7% of agricultural land and, if no action is taken, will cause profit at full equity to decline by 1.5% by 2020.

The findings on salinity need to be tempered by the presence of regional variations where the increase in salinity may be severe. The results are also dependent on the accuracy of predicted salinity extent increases, for which there exists much uncertainty.

Sodic and acidic soils constrain yields over much larger areas covering 23% and 4.5% of agricultural land, respectively. The economic benefits of closing the yield gap caused by sodic and acid soils (without consideration of the costs) are $1,035m/yr (15.8% of total profits) and $1,585m/yr (24.2% of total profits). While sodic soils cover a larger area, acid soils impact more higher value crops.

Additional soil treatment (application of lime and gypsum to manage acidic and sodic soils) above current applications was found financially worthwhile for around only 4% of agricultural land. However, within this area soil treatment, above and beyond current lime/gypsum application, has the potential to provide large financial net-benefits to farmers. Nationally, the total net present value of lime and/or gypsum applications, modelled in perpetuity and where these treatments have only a net financial benefit, is estimated at $16,463 million at a discount rate of 10%, and $10,783 million at a discount rate of 15%. It should be noted that lime and gypsum application are generally private-benefit activities that individual farmers can choose to adopt or not.

3.2 Background

Acidity, salinity and sodicity are three of the primary soil constraints to crop and pasture yield in Australia. In some areas these soil constraints have been caused or exacerbated by human actions. For example, salinity can result from the removal of native deep-rooted perennial vegetation, leading to changed hydrological process and the relocation and concentration of salt in the landscape. However, acidic, sodic and saline soils can also be a natural component of the Australian landscape, existing prior to the introduction of widespread European-style agriculture.

Whether human induced or naturally occurring, from a practical perspective acidity, sodicity and salinity represent constraints on potential crop/pasture yields for farmers. As such, the removal of these soil constraints represents an economic, and private financial, opportunity. The size of the economic opportunity will be dependent on the extent to which benefits of remedial actions, as expressed through increased yield, exceed the costs.

A variety of other soil factors and land resource conditions also limit yield. For example, nutrient depletion through erosion or leaching, soil compaction, weeds, pest species and plant disease can all restrict plant growth and yield of harvestable product. Whilst of recognised importance, these constraints have not been included in this report due to lack of reliable data and models linking the biophysical process to the yield impact. Further research is required to better understand how these processes impact yield and/or to develop data sets that can be interpreted at national and regional scales.

3.3 Defining Degradation

Early in this project there was considerable debate about the most appropriate way to define “degradation” and to measure cost. Dictionaries define degradation as loss against a benchmark measure. Our experience gained during consultations, held at the commencement of the project, is that there is no agreed benchmark that should be used. Some people prefer to use the time when Europeans arrived in Australia (1788), some the recent past and others this year. Having considered all the options in this report we chose to focus on the value of current and potential opportunities. As a result we avoid using the word “degradation” and instead refer to the value of potential changes in costs and benefits.

Our aim is to focus on opportunities and to provide information to those interested in shaping the future. We see little value in assigning blame for judgements that, with the benefit of hindsight, seem undesirable.

3.4 Objective and Rationale

The objective of this section is to present and describe data relating to on-farm economic opportunities associated with the treatment of soil salinity, sodicity and acidity. It also seeks to demonstrate the power and value of the soil condition assessment framework. The main analyses conducted in this section include:

- A benefit cost analysis of lime and gypsum application to combat sodic and acid soils;
- An assessment of potential to increase profit at full equity through the removal of constraints to crop/pasture yield; and
- An assessment of the losses in profit at full equity over 20 years (2000 – 2020) due to worsening of dryland secondary salinity.

The modelling is undertaken on a 1km^2 grid aligned to the land use map and profit function surfaces as described in the previous section. Consequently, the underlying spatial data sets can be aggregated according to any regional framework or land use classification, albeit with spatial accuracy constraints.

Whilst the results presented in this section do not provide regionally specific benefit cost analyses of soil remediation options, they do provide insights into where economic opportunities are likely and where further, more detailed, investigation may be worthwhile. Estimates of gross benefits associated with soil treatment options will provide policy makers with information on investment ceilings, beyond which further investment in a particular area is unlikely to provide return. Net present values emerging from the benefit cost analysis provide an impression of the extent to which additional soil treatment will provide financial benefit.

In addition, the results will allow comparisons of the relative economic importance of salinity, sodicity and acidity against each other, against other land degradation issues and against other factors that influence profit at full equity.

3.5 Prior Estimates

The first published nation-wide study on costs associated with acidic, sodic and saline soils was undertaken by the Cooperative Research Centre for Soil and Land Management (CRCSLM 1999). The CRCSLM report provides estimates of the economic gain associated with treatment of acidity, sodicity and salinity (see Table 3.1).

Table 3.1 Comparison of data from the Cooperative Research Centre for Land Management and the Audit relating to economic costs and benefits of treating acidic, sodic and saline soils at a national scale.

	CRCSLM ($m/yr)	**Audit ($m/yr)**
Extra production from correction of soil acidity	933	1,585[b]
Net gain from correction of soil acidity	630	841-855[a]
Extra production from correction of soil sodicity	2,379	1,035[b]
Net gain from correction of soil sodicity	1,334	317-436[a]
Losses from secondary salinity (Hayes, 1997)	130	187[b]

a. Conversion of net present values to an annuity at discount rates of 10% and 15%.

b. Equals the gross benefit of correcting the soil constraint, discussed later.

The CRCSLM estimates can be compared with estimates of gross benefit, impact cost and net present values of soil treatment provided in this study. At a national scale, tables of gross benefit (from this study) show commensurable amounts for each of the three soil constraints.

The combined cost (gross benefit) of treating all three soil constraints is not assumed additive in this study. This study is based on a limiting factor model whereas the CRCSLM report assumes the costs of acidity, salinity and sodicity are additive. Values in this study also differ from use of recent data sets on the biophysical and economic status of the nation's soil resources, made available through the Audit.

Another recent study into the costs of land degradation, and benefits of remediation, at a national scale was prepared by The Virtual Consulting Group and Griffin NRM for the Australian Conservation Foundation and National Farmers Federation (Madden et al. 2000). Some key findings of this study are that the annual cost of degradation in rural landscapes is at least $2 billion annually (including market costs of $1,365 million), and with no action this will rise to over $6 billion annually by 2020. The study found that many remedial activities delivered benefits in excess of costs.

Estimates of local (and downstream) degradation costs in this project are based on recent data sets and models, not available for the study by Madden et al. or the CRCSLM. In this project an integrated GIS database has been developed which allows spatially explicit analysis of soil conditions and agricultural profitability at a finer scale than previously possible. For example, relative yield models developed in this project explain physical relationships between crop/pasture yield and soil properties. These, in turn, are linked to economic impacts through mapped surfaces of the 12 profit function variables. The database has also been constructed in such a way that new spatial data layers can be inserted and assumptions systematically varied.

3.6 Relative Yield

Measures of economic opportunities associated with soil constraints are dependent on an assessment of relative yield. Relative yield is measured as a percentage and equals the actual yield, as currently recorded, divided by the potential yield that would occur if the soil constraint(s) were not present. For example, a crop yielding 2t/ha with a relative yield of 50% due to constraints associated with salinity, acidity and/or sodicity, would have a full potential yield of double its current amount of 4t/ha (2/0.5 = 4). Relative yield can be expressed as:

$$\text{Relative Yield} = \text{RY} = \frac{\text{Actual Yield}}{\text{Potential Yield}}$$

3.6.1 Relative Yield for Acidity

Relative yield from acidity was derived using a model developed under the Audit's soil acidification project. Original documentation describing the functioning of this model is provided in Dolling *et al.* (2001). The model requires the following main inputs:

- Soil aluminium and manganese solubility class;
- Soil pH at depths of 0-10cm, 10-20cm and 20-30cm;
- Acid tolerance class (1 to 6) of the plant dominating the land use;

From these inputs the model can determine relative yield (an example is shown in Figure 3.1). All of the data for the acid yield model was assembled on a 250m grid covering the intensively used agricultural land areas of Australia. The aluminium and manganese solubility maps were obtained at this scale from the Australian Soil Resources Information System (ASRIS). Surfaces of pH at the three depths were also obtained from ASRIS. Each land use in the land use map, was classified into one of six acid tolerance classes. The surface of relative yield from acidity, resampled to a 1km^2 grid to match the land use map, is shown in Figure 3.2

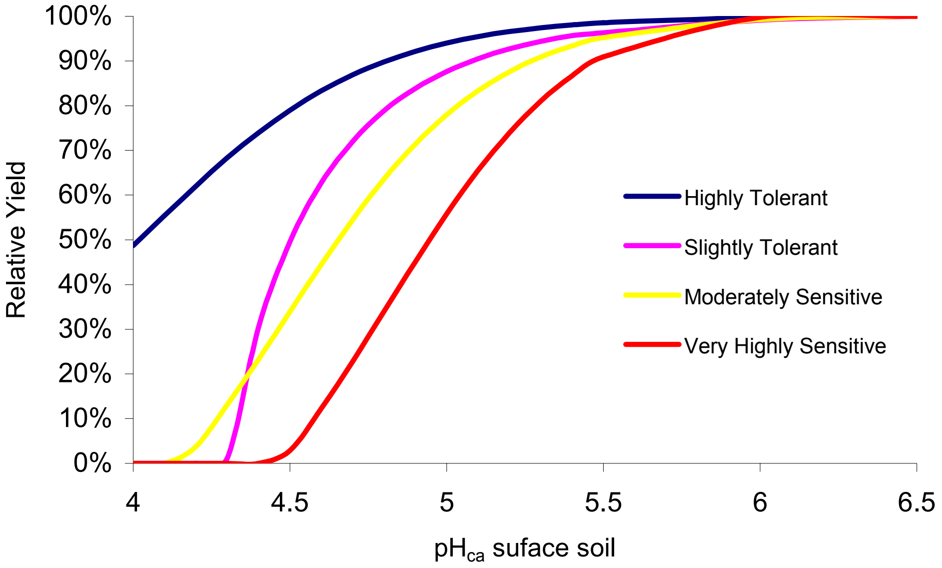

Figure 3.1 Example of output from the acidity relative yield model for four plant tolerance classes within a given Al/Mn solubility class (Dolling *et al.* 2001).

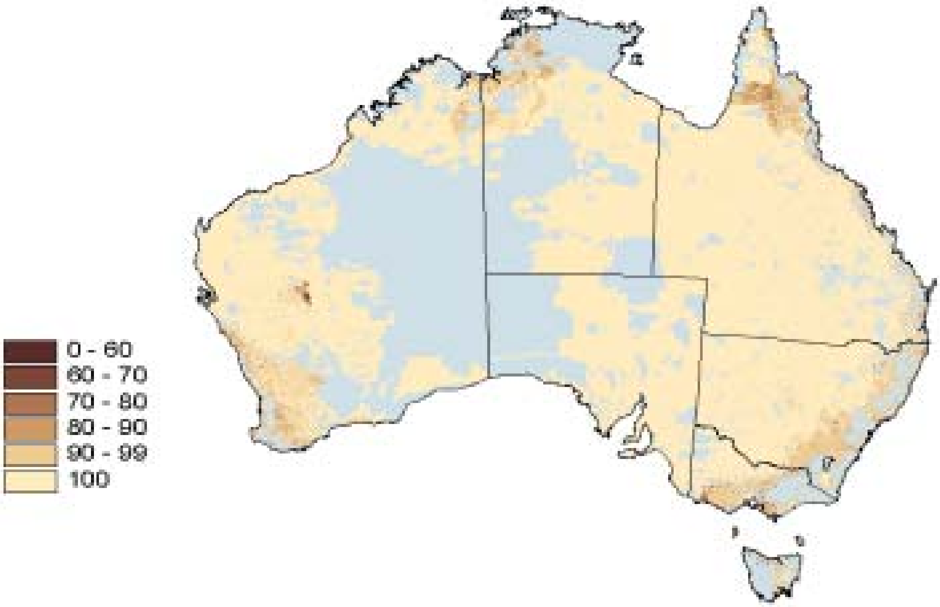

Figure 3.2 Relative yield from acidity (%)

3.6.2 Relative Yield for Salinity

The relative yield for salinity was determined using data produced under theme two of the Audit, published in the Australian Dryland Salinity Assessment (NLWRA 2000). The primary sources of data were maps of dryland salinity for 2000 and 2020 prepared by State and Territory agencies. These maps delineated regions of high risk or hazard. It was necessary to reinterpret the maps in terms of yield impacts. This procedure was complicated by the use of different methods for mapping salinity in the States and Territories.

A detailed description of how the State and Territory data was re-interpreted into relative yield is provided in appendix B. The basic approach involved determining the extent of each polygon subject to five classes of yield loss, thereby imputing salinity extent. The area of each polygon assigned to these five classes differed for each State and Territory depending on the mapping and scale method. Maps of relative yield for salinity in 2000 and 2020 are shown in Figure 3.3 and Figure 3.4.

The striking feature of the salinity relative yield maps is the highly pinpointed locations of yield loss. Areas of severe yield loss are barely visible at a national scale. There is also little discernable visual difference between the maps for 2000 and 2020.

Figure 3.3 Relative yield from salinity in 2000 (%)

Figure 3.4 Relative yield from salinity in 2020 (%)

3.6.3 Relative Yield for Sodicity

Relative yield for sodicity was modelled using a series of functions that related exchangeable sodium percentage (ESP) in the soil surface with relative yield for 30 different crop/pasture types. An example of a sodicity relative yield function, used for tree crops, is provided in Figure 3.5. All of the sodicity relative yield functions are contained in appendix C.

A gridded surface of ESP was derived from soil test data compiled from commercial soil testing laboratories under theme five of the Audit. The surface was also based on mapped regions of sodic soils. A surface of ESP was constructed from the soil test point data using a Triangular Irregular Network (TIN), a method for constructing surfaces in a geographic information system. The extent of the TIN was limited by sodic soil polygons (a more detailed description of how the ESP surface was constructed is provided in appendix D). Combined with the land use map and 30 relative yield functions these data enabled the generation of relative yield from sodicity, as shown in Figure 3.6.

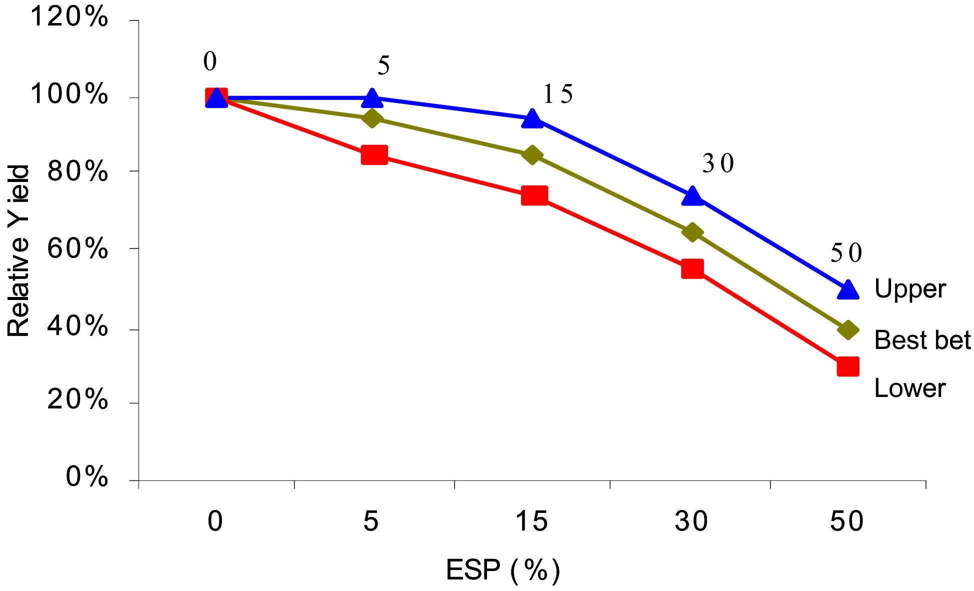

Figure 3.5 An example of a sodicity relative yield function for tree crops (the central line represents the best estimate and the outer lines represent high/low estimates).

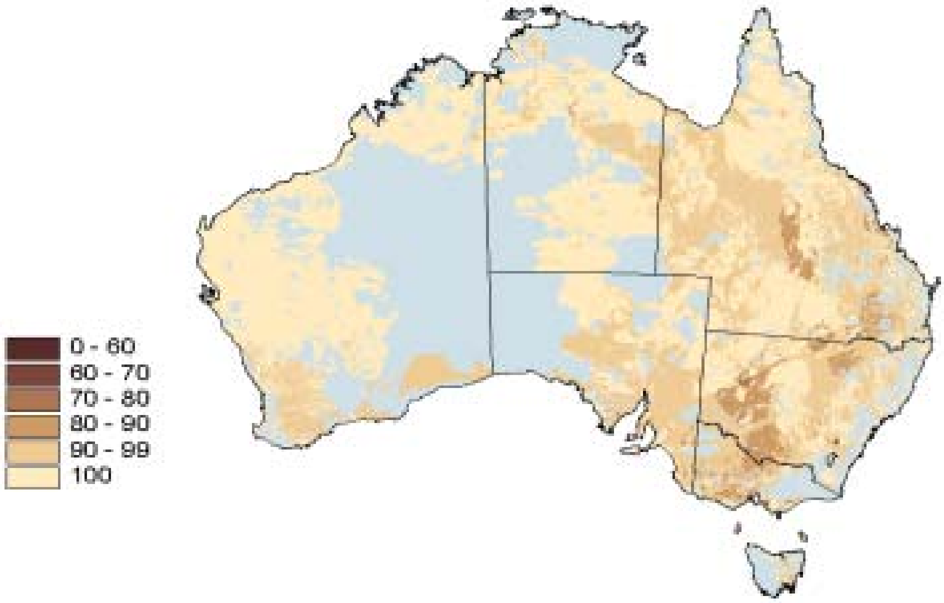

Figure 3.6 Relative yield from sodicity (%)

3.6.4 Limiting Factor Relative Yield

The limiting factor relative yield is equal to the minimum relative yield associated with salinity, acidity and sodicity. The full opportunity (i.e.

maximum gross benefit) for increasing yield is determined by the limiting the factor relative yield. Where yield loss occurs as a consequence of multiple soil constraints the recovery of that yield requires addressing each soil constraint. For example, an area subject to a relative yield of 50% due to salinity and 70% due to acidity requires the treatment of salinity up until the 70% relative yield mark, before any benefits of liming (commonly used to treat acid soils) can be attained. A map of the limiting factor relative yield is shown in Figure 3.7.

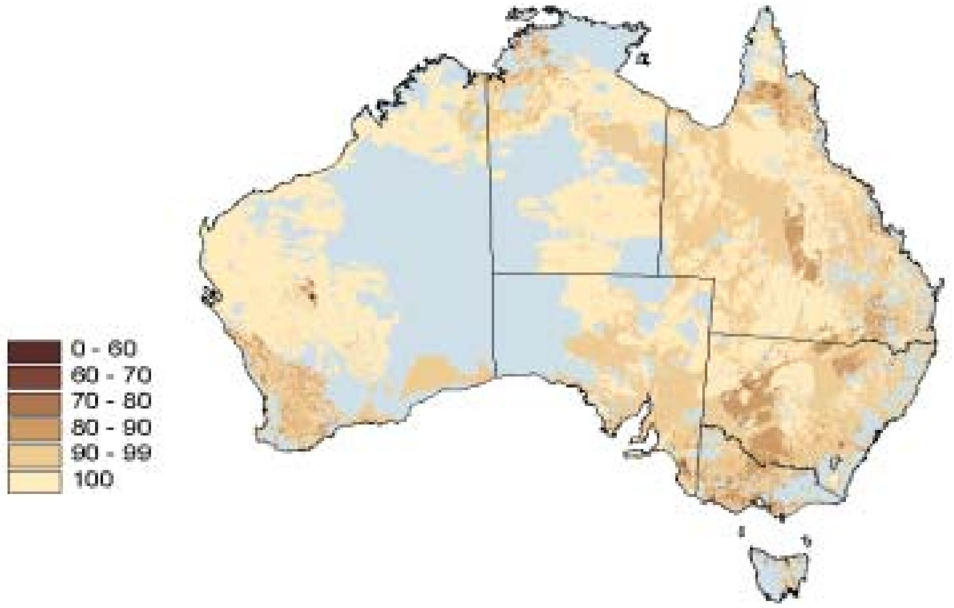

Figure 3.7 Relative yield of the limiting factor of salinity, acidity and sodicity (%)

Figure 3.8 contains a map showing which of salinity, acidity and sodicity is the most limiting factor. The map is limited to the extent of agricultural land use. It can be seen that the largest areas of opportunities for yield gain are associated with the treatment of sodic soils. This drives larger estimates of gross benefit associated with sodic soil treatment, compared with the other soil constraints.

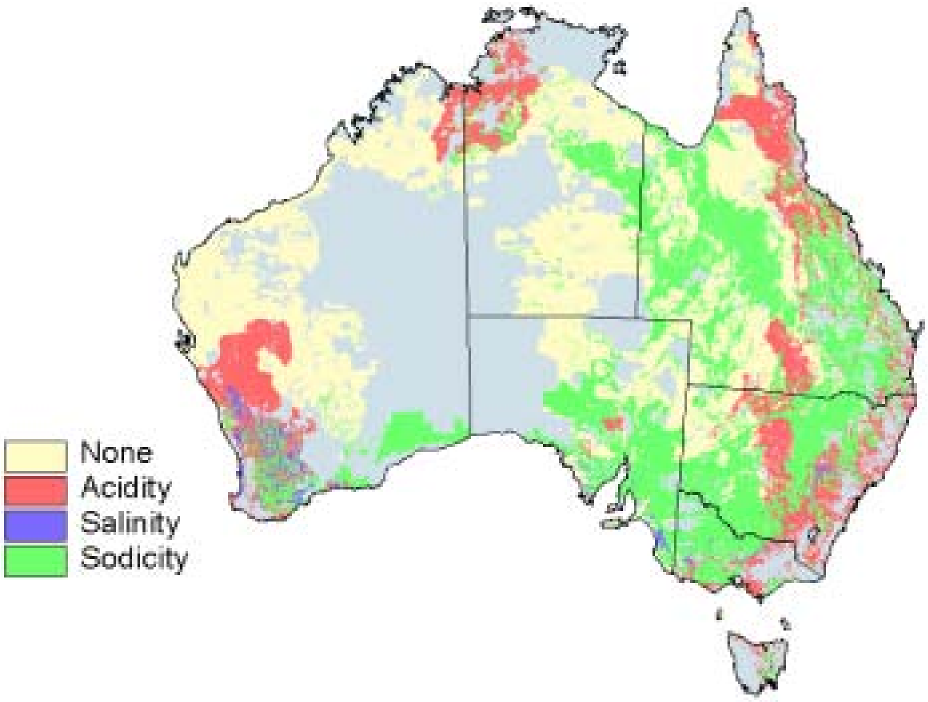

Figure 3.8 Map showing the most yield-limiting soil factor per 1km grid cell

3.7 Areal Extent of Yield Limitations

The extent of yield loss associated with the soil constraints was determined by identifying all areas where relative yield fell below a given threshold. In the case of salinity all land areas in relative yield classes 2-5 were selected. These classes incur at least some yield loss due to salinity. Assessments of salinity extent are approximated using the area adjustment factors used to estimate relative yield, as discussed above. For acidity and sodicity areas where relative yield was less than or equal to 95% were selected.

The extent of yield loss was estimated for land use categories, States/Territories and reporting regions (see Table 3.2 to Table 3.4). It can be seen that salinity affects relatively small areas of agricultural land in each State and Territory. A greater area is affected by acidity (3.9% nationally) and sodicity (23.1% nationally). These extents of yield loss associated sodicity and acidity, drive large estimates of economic opportunity.

Estimates of yield loss areas differ from estimates of actual extent. Yield loss estimates include only areas in which a soil constraint and a potentially vulnerable land use coincide. The estimates of yield loss areas will, therefore, be limited by the extent of agricultural land use.

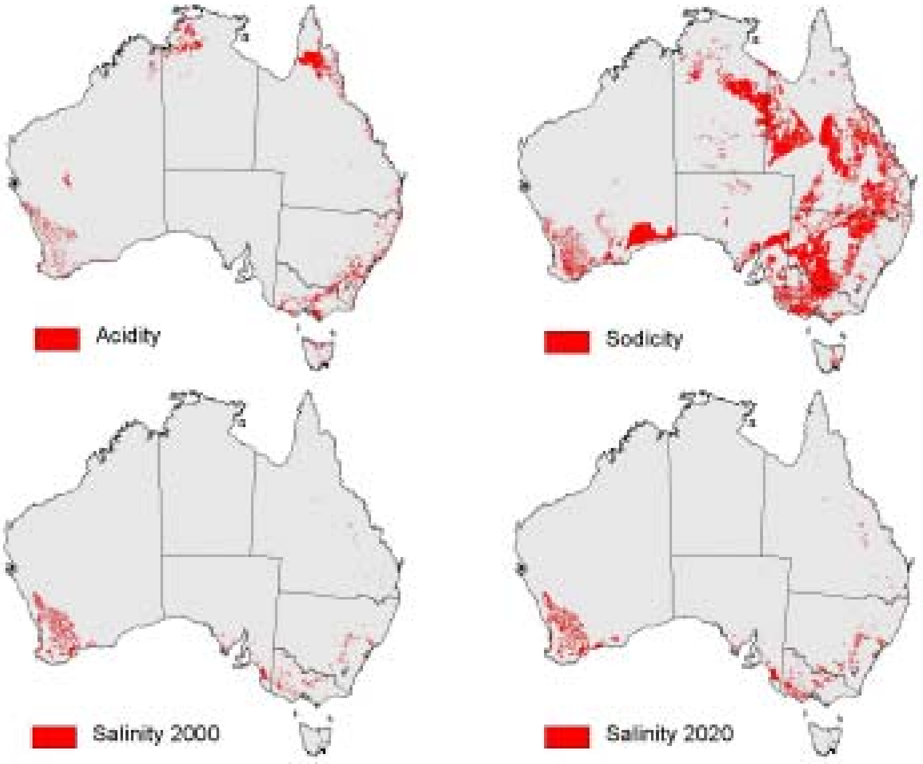

Figure 3.9 Areas of significant yield loss associated with the soil constraints

Table 3.2 Extent of yield loss by State and Territory

	Saline Soils				Acidic Soils		Sodic Soils	
	2000		2020					
	Area (ha, 000)	% of Ag. Land	Area (ha, 000)	% of Ag. Land	Area (ha, 000)	% of Ag. Land	Area (ha, 000)	% 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%

Table 3.3 Extent of yield loss by land use grouping.

	Salinity 2000	Salinity 2020	Acidity	Sodicity	Salinity 2000	Salinity 2020	Acidity	Sodicity
	000 ha				%			
Agroforestry	1	1	7	1	4.5	6.4	32.8	6.6
Beef	570	812	13,796	53,327	0.2	0.3	4.8	18.5
Cereals	703	1,002	2,980	1,898	4.1	5.9	17.6	11.2
Coarse Grains	21	30	13	222	1.5	2.2	1.0	16.4
Cotton	1	2	0	89	0.3	0.5	0.0	22.0
Dairy	65	92	1,309	1,442	1.9	2.6	37.3	41.2
Fruit	1	1	51	37	0.6	0.8	44.4	32.1
Grapes	3	4	21	43	3.0	4.2	21.5	43.3
Hay	4	5	11	19	3.5	5.0	10.8	19.0
Legumes	134	190	490	148	6.0	8.6	22.0	6.6
Oilseeds	23	33	230	73	3.7	5.2	36.8	11.8
Other	0	0	5	4	1.0	1.4	16.3	13.5
Peanuts	1	2	3	9	3.5	4.9	9.1	24.7
Rice	1	1	0	10	0.5	0.6	0.0	6.5
Sheep	1,574	2,242	2,123	51,793	1.0	1.4	1.3	32.8
Sugar Cane	3	4	162	46	0.6	0.8	33.1	9.4
Tobacco	0	0	3	0	0.0	0.0	83.7	12.9
Tree Nuts	0	0	13	3	0.4	0.6	55.7	13.4
Vegetables	3	4	99	53	1.6	2.3	59.3	32.0
All land uses	3,106	4,426	21,317	109,219	0.7	0.9	4.5	23.1

Table 3.4 Extent of yield loss by reporting region

	Area				Portion of agricultural land			
Reporting Region	**Salinity**	**Salinity 2020**	**Aciditiy**	**Sodicity**	**Salinity**	**Salinity 2020**	**Aciditiy**	**Sodicity**
	000 ha				**%**			
Burdekin	13	33	56	3,644	0.1	0.3	0.5	30.3
Carpentaria	5	14	3,896	2,595	0.0	0.0	11.1	7.4
Darling	39	99	511	21,723	0.1	0.2	0.9	38.7
Far North Queensland	0	1	996	123	0.0	0.0	38.8	4.8
Fitzroy	24	51	130	4,965	0.2	0.5	1.2	44.2
Goldfields	0	113	2	1,934	0.0	0.5	0.0	8.1
Gulf	0	0	4	2,346	0.0	0.0	0.0	14.6
Indian North	0	0	0	0	0.0	0.0	0.0	0.0
Indian South	76	76	1,080	145	0.7	0.7	10.2	1.4
Inland	0	0	1	37,464	0.0	0.0	0.0	25.9
Moreton	1	2	215	262	0.1	0.1	16.2	19.8
Murray	272	559	2,543	15,567	0.8	1.7	7.5	46.2
NSW North	1	1	630	172	0.0	0.1	31.6	8.6
NSW South & Central	25	57	1,379	309	0.8	1.8	43.4	9.7
North Queensland	1	4	497	510	0.0	0.2	25.3	25.9
Queensland South & Central	6	15	350	1,501	0.2	0.4	8.8	38.0
SA Gulf	92	92	12	1,569	1.3	1.3	0.2	22.8
South East Corner	9	15	1,050	704	0.4	0.6	45.8	30.7
Southern	368	791	797	4,021	6.1	13.0	13.1	66.1
Tasmania	26	35	677	504	1.4	1.9	36.9	27.5
Timor Sea	0	0	3,464	1,624	0.0	0.0	11.2	5.3
WA South	2,094	2,413	3,024	6,713	9.5	11.0	13.8	30.5
Western Eyre Peninsula	54	54	5	825	0.4	0.4	0.0	6.3
Australia	3,106	4,426	21,317	109,219	0.7	0.9	4.5	23.1

Nationally, a small portion of agricultural land (0.7%) is incurring yield loss as a result of dryland salinity. Acidity affects a somewhat larger area (4.5%) and yield loss associated with sodic soils covers almost one quarter of agricultural land (23%). It should, however, be noted that these are broad national estimates of aerial extent. Where salinity does occur, it can be devastating for the local regional community and economy.

3.8 Measurements of Economic Impact

Having assessed the biophysical impact of the soil constraint through the measurement and mapping of relative yield, it is possible to make an economic interpretation. Yield impacts of sodicity, acidity and salinity are measured using gross benefit and impact cost. Both have subtly different meanings.

3.8.1 Gross Benefit

This equals profit at full equity attainable without the soil constraint less the profit at full equity attainable under current conditions. It can be thought of as the dollar value of the yield gap (caused by the soil constraint). Gross benefit is equal to the amount of additional profit attainable, were the soil constraint removed without cost. In simplified form, gross benefit can be determined by:

$$\Pi_{with} = P \times Q - (QC * Q) - OVC - FC$$

$$\Pi_{without} = P \times \frac{Q}{RY} - (QC * \frac{Q}{RY}) - OVC - FC$$

$$\text{Gross Benefit} = \Pi_{without} - \Pi_{with}$$

Where:

P = price of product ($/t or $/DSE)

Q = yield of product (t/ha, DSE/ha)

QC = quantity dependent variable costs ($/t or $/DSE)

OVC = all non quantity dependent variable costs ($/ha)

FC = fixed costs ($/ha)

Π_{with} = profit at full equity under current conditions, with the soil constraint present.

$\Pi_{without}$ = profit at full equity with the soil constraint removed (without cost).

For acidity and sodicity gross benefit provides the ‘benefit side’ of the benefit cost analysis. It is the amount recoverable if the soil constraint is successfully treated.

The policy relevance of gross benefit is that it provides a ceiling on investment. From an economic perspective it would be irrational to spend more on fixing a problem associated with acidity, salinity or sodicity than its associated gross benefit. To do so would mean more is being spent than can be gained. As such gross benefit can be considered an investment ceiling on correcting soil constraints. It should be noted, however, that many other benefits (both monetary and non monetary) arise from soil amelioration. For example, correction of soil salinity will not only improve yields, it will also have significant downstream benefits for biodiversity and urban water users. All these issues need to be considered in the formulation of policy and expenditure of public funds.

Table 3.5 Gross benefits associated with soil constraints by State and Territory.

	Salinity		**Sodicity**		**Acidity**		**Limiting Factor**	
	$m	**% of PFE**	**$m**	**% of PFE**	**$m**	**% of PFE**	**$m**	**% of PFE**
New South Wales	6.3	0.3%	280.3	13.8%	378.7	18.6%	624.1	30.7%
Victoria	18.5	1.6%	342.5	30.1%	471.1	41.4%	757.4	66.6%
Queensland	10.2	0.8%	180.3	13.8%	232.5	17.7%	392.9	30.0%
South Australia	39.1	4.1%	126.4	13.4%	2.9	0.3%	162.0	17.2%
Western Australia	111.0	11.5%	89.7	9.3%	226.1	23.4%	341.6	35.4%
Tasmania	1.9	1.7%	12.3	10.8%	214.8	187.6%	220.3	192.4%
Northern Territory	0.0	0.0%	3.0	6.0%	58.2	117.0%	61.1	122.8%
Australian Capital Territory	0.0	0.0%	0.0	7.6%	0.2	28.5%	0.2	29.9%
Australia	187.0	2.9%	1,034.6	15.8%	1,584.5	24.2%	2,559.5	39.0%

Table 3.6 Gross benefits associated with soil constraints by land use grouping.

	Salinity		**Sodicity**		**Acidity**		**Limiting Factor**	
	$m	**% of PFE**	**$m**	**% of PFE**	**$m**	**% of PFE**	**$m**	**% of PFE**
Beef	15.8	2.2%	138.0	19.2%	95.0	13.2%	220.5	30.7%
Cereals	70.6	3.8%	168.0	9.1%	156.7	8.5%	337.9	18.4%
Coarse Grains	2.9	0.5%	28.9	5.2%	5.4	1.0%	34.0	6.1%
Cotton	2.1	0.2%	75.8	6.3%	1.8	0.1%	77.8	6.4%
Dairy	24.0	1.5%	224.4	14.1%	255.0	16.0%	451.5	28.4%
Fruit	3.2	0.4%	93.2	10.5%	515.7	58.0%	594.8	66.9%
Grapes	6.0	1.3%	53.8	11.5%	117.9	25.2%	167.4	35.7%
Hay	1.8	17.0%	1.9	17.9%	2.1	19.6%	5.5	51.0%
Legumes	9.6	11.2%	13.1	15.4%	12.7	14.9%	28.1	32.9%
Oilseeds	2.4	2.6%	8.4	9.0%	22.5	24.2%	28.8	31.0%
Peanuts	0.9	3.8%	1.6	7.2%	0.9	3.8%	2.9	13.1%
Rice	0.1	0.1%	1.8	3.5%	0.2	0.4%	2.0	3.9%
Sheep	38.9	12.7%	168.6	55.2%	50.5	16.5%	223.2	73.0%
Sugar Cane	0.6	0.3%	8.2	4.9%	27.8	16.7%	32.1	19.3%
Tobacco	0.0	0.0%	0.1	0.6%	17.8	139.1%	17.8	139.1%
Tree Nuts	0.1	0.1%	3.9	5.5%	12.2	17.2%	15.8	22.2%
Vegetables	8.1	1.6%	44.8	8.8%	290.5	57.2%	319.5	62.9%
All land uses	187.0	2.9%	1,034.6	15.8%	1,584.5	24.2%	2,559.5	39.0%

Figure 3.10 Gross benefit associated with saline soils ($/ha/yr)

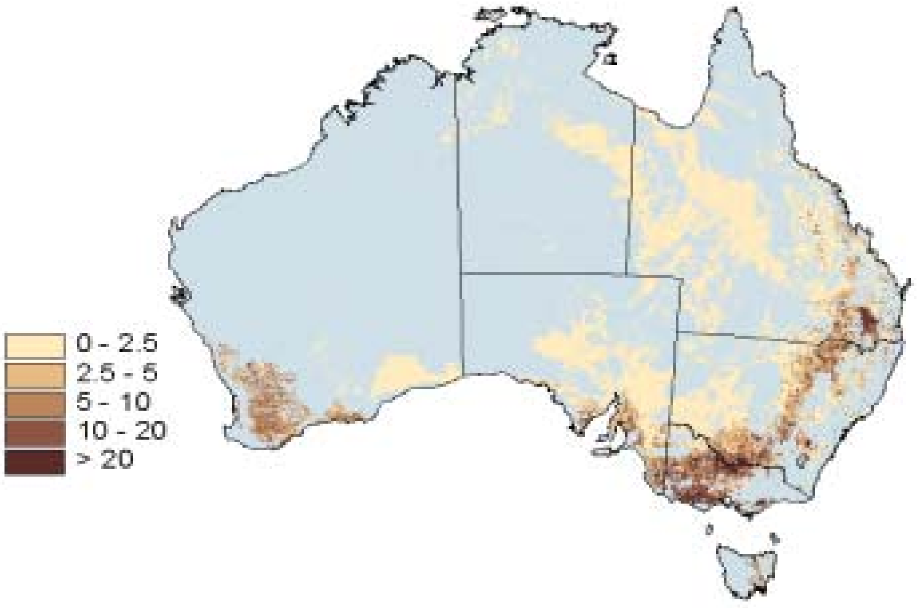

Figure 3.11 Gross benefit associated with sodic soils ($/ha/yr)

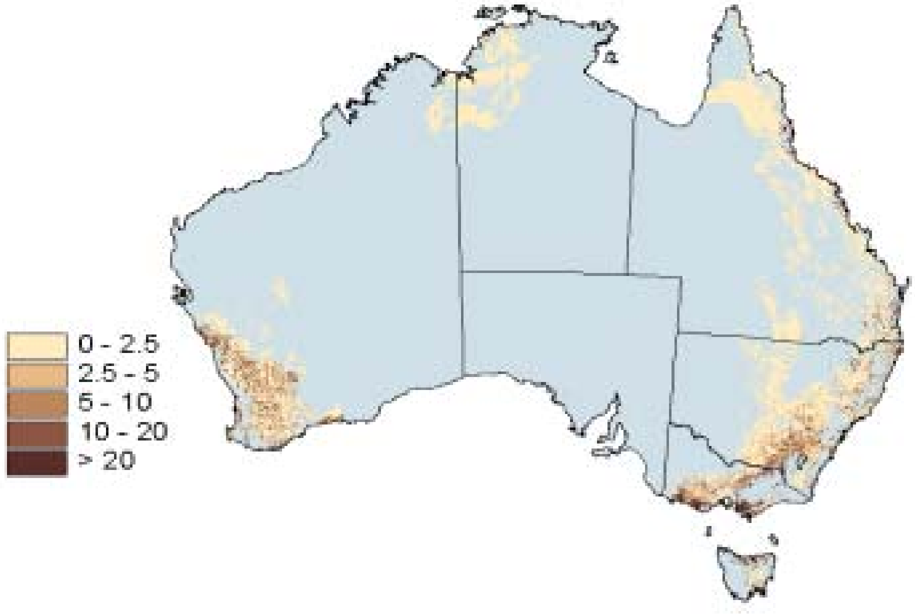

Figure 3.12 Gross benefit associated with acidity ($/ha/yr)

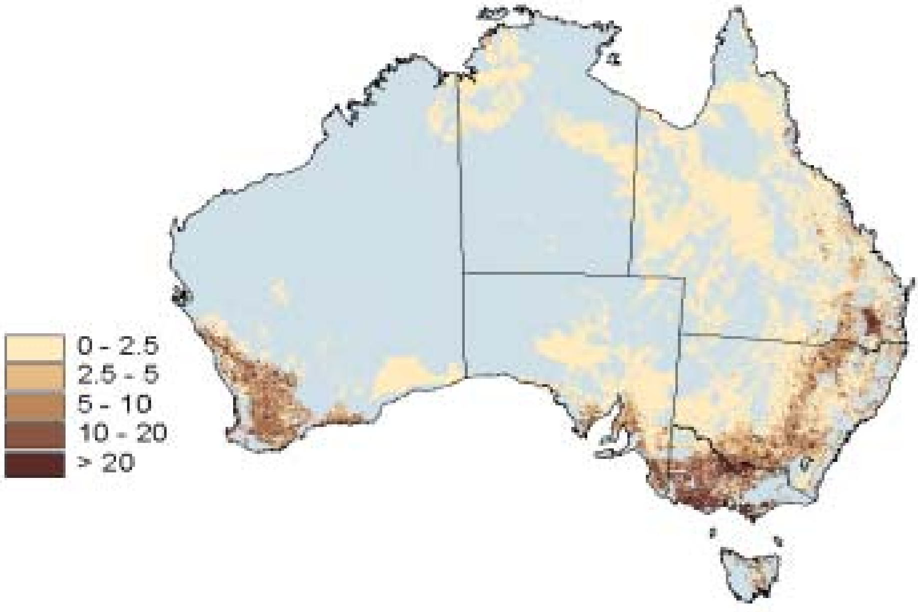

Figure 3.13 Gross benefit associated with the limiting factor (acidity, sodicity and salinity) in $/ha/yr

3.8.2 Impact Cost

Impact costs result from marginal increases in soil constraints from 2000 to 2020. Impact costs are calculated for salinity as this is the only soil constraint for which requisite time series data (a snapshot of 2000 and 2020) is available. The impact cost of salinity over the 20-year time period is equal to the decrease in profit at full equity due to decreasing yields resulting from worsening salinity.

As with other data presented in this section, impact costs are calculated on a 1km^2 grid covering the nation. For each grid cell, impact cost is determined by:

$$\prod_{2000} = P \times Q - (QC * Q) - OVC - FC$$

$$\prod_{2020} = P \times Q * \alpha - (QC * Q * \alpha) - OVC - FC$$

$$\text{Impact Cost} = \prod_{2000} - \prod_{2020}$$

Where:

$\alpha = \left(\frac{\text{Relative Yield Salinity 2020}}{\text{Relative Yield Salinity 2000}} \right)$

P = price of product (\$/t or \$/DSE)

Q = yield of product (t/ha, DSE/ha)

QC = quantity dependent variable costs (\$/t or \$/DSE)

OVC = all non quantity dependent variable costs (\$/ha)

FC = fixed costs (\$/ha)

Π_{2000} = profit at full equity under current conditions (\$/ha/yr)

Π_{2020} = profit at full equity in 2020, with the possibility of decreased yields from salinity (\$/ha/yr)

Impact Cost = loss in profit at full equity (\$/ha/yr) in year 2020 due to salinity increases from 2000 to 2020.

The present value of the salinity impact cost is calculated over the twenty-year period assuming a linear increase from zero in the first year to the impact cost (as defined above) in year 20. Table 3.7and Table 3.8**Error! Not a valid link.** present values of impact cost and have been determined for discount rates at 3%, 5% and 6%.

Table 3.7 Present values of dryland salinity impact costs (2000 – 2020) by States[1]

	Present Values ($m)			**% Loss in PFE**
Discount rate	**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%
Northern Territory	0	0	0	0.0%
Australian Capital Territory	0	0	0	0.0%
Australia	712	558	496	1.5%

[1] Data shows no impact costs in the Northern Territory and Australian Capital Territory

Table 3.8 Present values of dryland salinity impact costs (2000 – 2020) by land use groupings

	Present Values ($m)			**% Loss in PFE**
Discount rate	**3%**	**5%**	**6%**	
Beef	101	79	70	2.0%
Cereals	153	120	107	1.2%
Coarse Grains	22	17	15	0.6%
Cotton	8	7	6	0.1%
Dairy	184	144	128	1.6%
Fruit	20	16	14	0.3%
Grapes	26	20	18	0.8%
Hay	1	1	1	1.7%
Legumes	12	10	9	2.0%
Oilseeds	10	8	7	1.5%
Peanuts	4	3	3	2.6%
Rice	6	5	4	1.7%
Sheep	132	104	92	6.1%
Sugar Cane	9	7	7	0.8%
Tobacco	0	0	0	0.0%
Tree Nuts	0	0	0	0.0%
Vegetables	22	17	15	0.6%
All land uses	712	558	496	1.5%

As impact cost increases linearly to 2020, a higher discount rate produces a lower present value. Compared against the total profit at full equity from agricultural production that could be reasonably expected for the 20-year period, salinity impact costs are relatively minor. For example, across the entire nation profit at full equity is expected to decline by only 1.5% due to worsening dryland salinity problems.

The present values of impact costs, shown above, represent the on-farm benefits of dryland salinity control over the next 20 years. Nationally these benefits have present values in the realm of $712 to $496 million (3% and 6% discount rate respectively). Comparison of impact costs against the present value of costs associated with remedial actions will assist economic evaluation of national salinity programs.

3.9 Benefit Cost Analysis

Treatment of sodic and acidic soils by applying gypsum and lime, respectively, was assessed using benefit cost analysis (BCA). Benefit cost analysis was not undertaken for treatment saline soils due to the current lack of remedial options, or the unavailability of reliable data on salinity management options. The discount rate and time period used in the BCA model are as follows:

- Discount rate set at 10% and 15%, considered representative of private discounting. Lime and gypsum application generally represents private investment. For this reason the discount rates were set well above the rate of social discounting.
- The lime and gypsum application cycles are modelled in perpetuity (99 years). This means that it is assumed that current farming practice is replaced by a new-farming practice involving the application of lime and/or gypsum.

Results of the BCA are reported in terms of net present value. Net present value is equal to the time-discounted benefits minus the time-discounted costs.

3.9.1 Determining Benefits

The full benefit of soil treatment is equal to the gross benefit, as described above. The gross benefit is the additional profit at full equity if the soil constraint were removed. The value of the benefit was determined using a limiting factor model (see Figure 3.14). Salinity created an absolute limit on benefits from treatment of both acidic and sodic soils. This was due to the lack of feasible remedial actions for saline soils and a lack of information on how these options would influence agricultural profitability and crop/pasture yields. In the BCA model it was assumed that if the relative yield from salinity was below that for both acidity and sodicity, then the benefit was equal to zero.

Within the salinity constraint, if only lime was applied to the soil, the benefit was limited by soil sodicity. Conversely, if only gypsum was applied to the soil the benefit was limited by acidity.

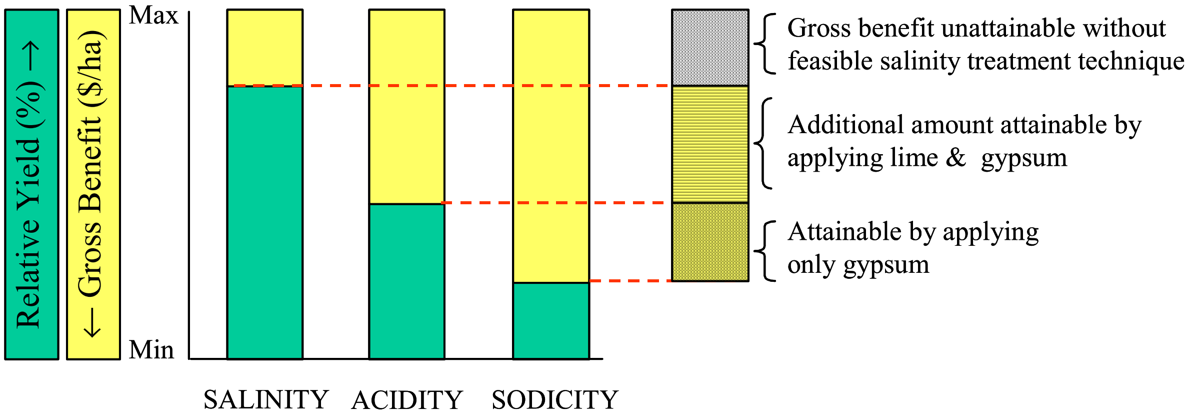

Figure 3.14. Example of limiting factor model used in benefit cost analysis.

Costs are based on the cost of purchasing, transporting and spreading soil ameliorants. Current market prices were used for costs, as determined through interviews with private firms and data supplied by State Agencies to the Audit.

3.9.2 Lime Application

Remediation of acidic soils is commonly undertaken by applying lime. In the BCA model, lime was applied to all agricultural soils incurring yield loss associated with acidity. The buffering capacity and current pH (supplied by the Australian Soil Resources Information System) were used to determine the amount of lime required to raise the pH to 5.5. At this level most crops and pastures have negligible yield loss from acidity. Lime requirement (t/ha/yr) was determined by:

$$\text{Lime Requirement} = [5.5 - \text{pH (0-10cm)}] \times \text{pH Buffering Capacity}$$

Buffering capacity is the unit increase in pH per unit of lime applied. The lime requirement was assumed to correct acid soils, returning relative yield to 100% in the first year of application.

Due to re-acidification of soils following an initial application of lime, the BCA model applied a maintenance lime application of 250kg/ha/yr every year after the first application. This is a commonly prescribed lime application maintenance rate. In the BCA, 250kg/ha/yr was assumed sufficient to prevent any recurrence of yield loss from acidity.

3.9.3 Gypsum Application

Numerous field trials have demonstrated the crop/pasture yield benefits of applying gypsum to sodic soils. Farm management brochures from the Cooperative Research Centre for Soil and Land Management recommend the application of gypsum to increase the productivity of sodic soils (CRC 1994).

In comparison to lime application, knowledge on rates of gypsum application required to ameliorate sodic soils is poor (Rengasamy and Churchman 1999). A study by Ellington *et al.* (1997) on red-brown earths in northeastern Victoria found significant crop yield increases at gypsum application rates of 2.5 t/ha/yr. Experts in sodic soils consulted through this project suggested that 2.5/t/ha/yr was by far the most common rate of application. It was also suggested that this amount need only be applied once every three years, as a rough guide. Accordingly, the BCA model simulated the application of 2.5t/ha/yr once at the beginning of every three year period. This was assumed sufficient to lift relative yields for crops/pastures affected by sodicity to 100%, fully closing the yield gap.

3.9.4 Lime Purchase, Transport and Spreading Costs

Data on the costs of purchasing, transporting and spreading lime was supplied to the Audit for most States and Territories (Dolling *et al.* 2001). Different estimates of transport cost were supplied. Based on consultation with the data providers the most likely transportation cost was considered to be $0.08/km/t. This was also the same transport cost given by suppliers of gypsum. Costs of lime purchase and spreading are given below.

Table 3.9 Cost of purchasing lime at the mine site ($/t)

	Low	Midpoint	High
NSW	27	30.50	34
VIC	20	32.50	45
QLD	25	31.50	38
WA	8.5	13.25	18
SA	15	18.50	22
TAS	18	20.00	22
ACT[1]	27	30.50	34
NT[2]	16.17	21.08	26.00

1. Data unavailable, assumed equal to NSW.
2. Data unavailable, assumed mean of neighbouring States (WA, SA and QLD)

Table 3.10 Cost of spreading lime and gypsum[1] in \$/t/ha.

	Low	Midpoint	High
NSW	10	12.50	15
VIC	12	13.50	15
QLD	12	13.00	14
WA	8	9.00	10
SA	8	9.00	10
TAS[2]	12	13.50	15
ACT[3]	10	12.50	15
NT[4]	9.33	10.33	11.33

1. Data was only supplied on lime spreading cost. Due to the similar nature of the activities gypsum spreading was assumed to incur the same cost as lime spreading.
2. Data on spreading costs in Tasmania was not available and was assumed equal to Victoria (the nearest State).
3. Data on spreading costs in the Australian Capital Territory was not available and was assumed equal to New South Wales.
4. Data on spreading costs in the Northern Territory was not available and was assumed equal to neighbouring States (WA, SA and QLD).

3.9.5 Gypsum Purchase, Transportation and Spreading Costs

Data on gypsum purchase, transportation and spreading costs were obtained by telephone interviews with three major gypsum suppliers located in Western Australia, Victoria and South Australia. Discussions were also held with agricultural scientists with expertise in sodic soils and gypsum application. Information from these sources led to the following values for gypsum application:

- Transport costs were set at \$0.08/t/km. This value was given by two of the gypsum suppliers and is also identical to lime transport costs given in some documentation supplied through the Audit.
- Spreading costs were assumed equal to those given for lime (in Table 3.10, above). This was considered likely, as lime spreading and gypsum spreading are very similar activities.
- Purchase costs were set at \$12.75/t. Gypsum suppliers quoted a range of costs as shown in Table 3.11 below. The value used was derived as the average of the midpoint values, given by each gypsum supplier.

Table 3.11 Costs of purchasing gypsum at mine site given by gypsum suppliers in South Australia, Western Australia and Victoria.

	Estimated Purchase Cost ($/t)		
	Low	Midpoint	High
Supplier One (SA)	12	14	16
Supplier Two (WA)	10.75	12.75	14.75
Supplier Three (Vic)	8	11.5	15
Mean	10.25	12.75	15.25

A map showing national deposits of gypsum used in agriculture was unavailable for this project. This necessitated an assumption of the distance from each field site, where gypsum could be applied, to the mine site. Without better data, it was assumed that the distance from agricultural land to gypsum mines was equal to the distance from agricultural land to lime mine sites.

3.9.6 Other Assumptions

1. The distance along a road (from the lime deposit to the farm) is 1.3 times the straight-line distance. The straight-line distance from every site, where lime or gypsum could be applied, was readily calculated in a geographic information system. Difficulties of determining an ‘along-the-road’ distance to these sites, in nationally consistent manner, required an assumed straight-line multiplier.
2. Where ranges (high - low) were given for costs of buying, transporting and spreading soil ameliorants the midpoint value was used.

3.9.7 Net Present Values of Soil Treatment

Net present values show that additional soil treatment by farmers is financially worthwhile for around only 4% of agricultural land (see Figure 3.15). However, within this area soil treatment, above and beyond current lime/gypsum application, has the potential to provide large financial net-benefits to farmers (see Table 3.12 and Table 3.13).

Nationally, the total net present value of lime and/or gypsum applications, where these treatments have a net financial benefit, is estimated at $16,463 million at a discount rate of 10%, and $10,783 million at a discount rate of 15%. Whilst many assumptions have been used in the benefit cost analysis model, which need to be taken into account, this represents a substantial return on investment.

Table 3.12 Net present values of soil treatment options (discount rate of 10%, with treatments run in perpetuity)

Optimal soil treatment[1]	Area ('000 ha)	 % of Total	NPV (Total, $m)
Do nothing	218,524	95.9%	
Apply lime and gypsum	782	0.3%	4,421
Apply lime only	5,377	2.4%	8,553
Apply gypsum only	3,174	1.4%	3,490
TOTALS	227,857	100%	16,463

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

Table 3.13 Net present values of soil treatment options (discount rate of 15%, with treatments run in perpetuity)

	Area ('000 ha)	 % of Total	NPV (Total, $m)
Do nothing	219,160	96.2%	
Apply lime and gypsum	689	0.3%	2,887
Apply lime only	5,104	2.2%	5,605
Apply gypsum only	2,906	1.3%	2,290
TOTALS	227,857	100%	10,783

The net present values given above are for areas where each soil treatment is optimal. It would be unlikely that application of lime and gypsum would always be targeted to these regions. In practice, there would most likely be considerable misapplication. This means that the net present values given above represent those attainable with perfectly optimal application, and in reality the net present values attainable would be much lower.

The assumptions, described above also place some limitations on the BCA results. The economically optimum rate of lime/gypsum application is likely to be less than that which provides a relative yield of 100%. This benefit cost analysis has made an assessment of how much soil ameliorant is required to bring crop/pasture yields to their full potential. In practice the optimum rate of application would be considerably less. Generalisations of this nature have been required by the national scale of the analysis and the limited availability of national data sets and models relating soil acidity and sodicity to crop/pasture yields.

Figure 3.15 shows the locations where lime and/or gypsum application is profitable. It can be seen that for large areas of Australia, additional application of lime and gypsum is not financially worthwhile. However, in those areas where soil treatment provides a positive net present value there are large potential financial gains.

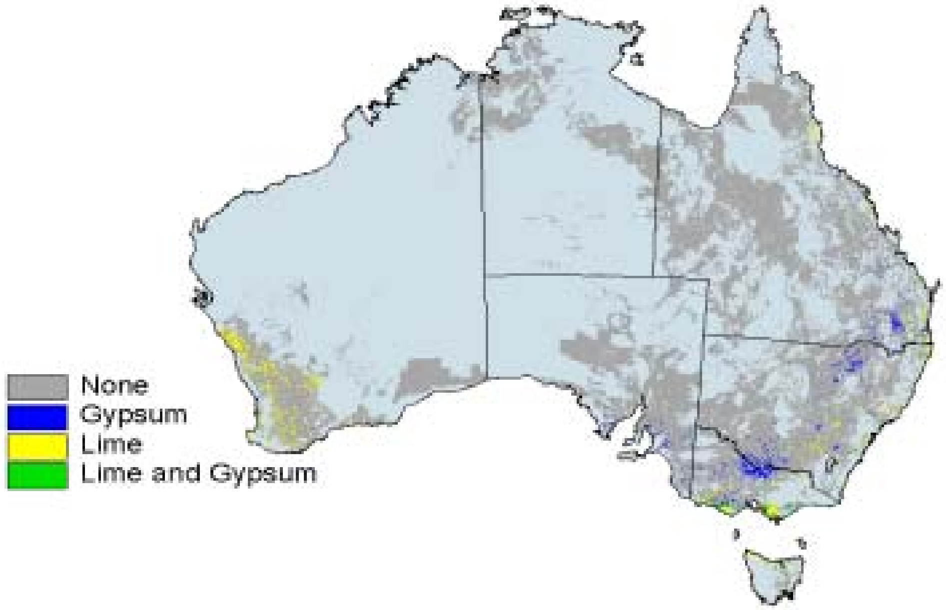

Figure 3.15 Locations where soil treatment options are most profitable, mapped on a 1km grid and derived using a 10% discount rate,

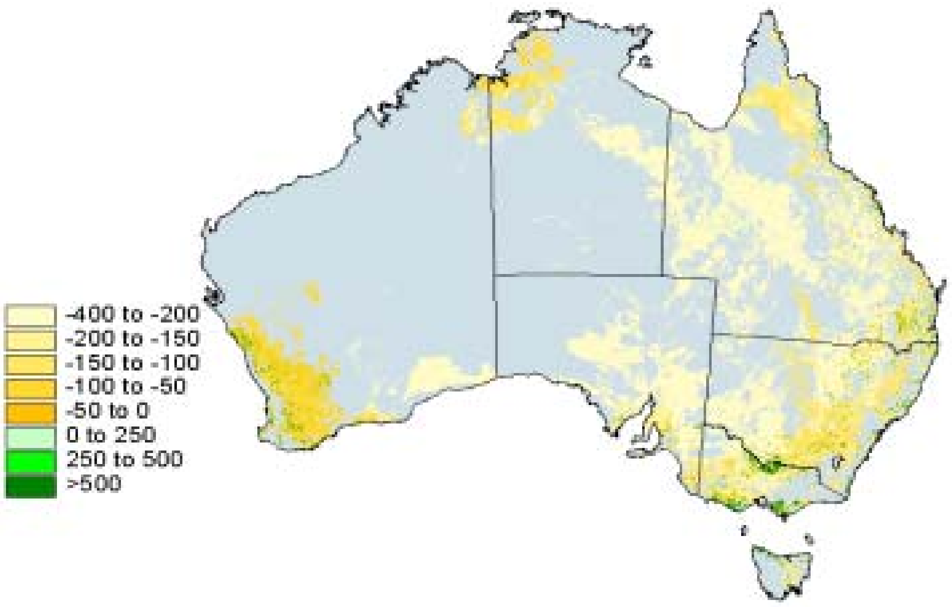

Figure 3.16 Maximum net present value attainable from lime and/or gypsum application, at 10% discount rate ($/ha)

The only other national benefit-cost analysis of lime application, found through a review of the literature, was undertaken by the Cooperative Research Centre for Soil and Land Management (CRCSLM 1999). Their findings were that liming to correct acid soils had a net benefit of $630m/yr and application of gypsum to correct sodic soils had a net benefit of $1,334m/yr, a total net benefit of $1,964 million per year. Expressed as a net present value, accrued in perpetuity at a 10% discount rate, this is equivalent to $21.6 billion - an estimate of the net benefits somewhat above that given here. The differences between the CRCSLM results and those obtained here can be explained by the use of vastly different datasets and different methodological approaches, as described earlier.

In a perfect market farmers would already be applying the optimal rate of lime and gypsum. If a case for market failure relating to lime and gypsum application were made, it would most likely be based on information failure. In other words, farmers may not have adequate knowledge or information to assess the financial net-benefits of lime or gypsum application. Despite increasing use of the soil treatments over the past decade, there are some reports that current lime and gypsum application may be below optimal rates. For example, the Standing Committee on Agriculture and Resource Management (SCARM 1998, cited in CRCSLM 1999, p35) suggests only 5% of land that would benefit from lime or gypsum application are actually being treated.

If information failure is occurring, i.e. farmers are unaware of the benefits of applying soil treatment, the results presented here suggest it affects only a relatively small area, 4% of the total area with sodicity and acidity related yield constraints. In the remaining 96%, no further soil treatment, i.e. doing nothing above current actions, is the most profitable option.

3.10 Other Forms of Degradation

It is worth noting that this report has not presented an exhaustive assessment of all land degradation forms and soil conditions that constrain agricultural yield or cause costs to agricultural industries in other ways. Some of the issues not considered in this section include:

- Groundwater depletion
- Soil nutrient loss
- Soil structure decline and compaction
- Pest plants and animals
- Contaminants
- Loss of remnant vegetation

- Plant disease.

Estimates of economic costs associated with these problems depend on the availability of data sets and reliable biophysical models applicable at the national scale. The key difficulty is relating these issues to crop yield loss, and thereby, impacts on profit at full equity. Whilst data on soil nutrient loss, eg nitrogen and phosphorus, are available there are few models that reliably link these issues to crop/pasture yield loss for the variety of land uses and climatic conditions that occur over Australia.

3.11 Uses and Extensions of the Data

The data presented in this section will provide natural resource managers with foundation information to better target responses to land degradation and soil amelioration.

Gross benefit surfaces provide spatial information on investment ceilings for the treatment of sodic, acid and saline soils. They can be interpreted nationally or at a broad regional scale. With knowledge on how much economic benefit is attainable by treating soils, the acceptability of costs can be better appraised.

The salinity impact cost surfaces give information on where salinity will cost agricultural producers most over the next 20 years. This information can be used for more detailed assessments at the local level of the benefits and costs of salinity management strategies.

The benefit cost analysis provides mapped surfaces of net present value of soil treatment options (lime and gypsum application). It also provides a grid showing which soil treatment option provides the greatest returns. Using a 10% and 15% discount rate, the benefit cost analysis provides information relevant to private decision-making. As with the other data layers, the net present value surfaces need to be verified by more detailed, regionally specific assessments.

Even without an economic interpretation, mapped surfaces of relative yield provide land management agencies with insights for remedial actions. The relative yield data can be used to assess where, and what types of remediation is most appropriate.

As with any database development project, there exist opportunities for continual strengthening and improvement of these data sets. Some of the major ways forward include:

- Obtaining a more detailed understanding of how a wide variety of soil conditions and degradation processes affect crop yield;

- Developing improved maps of soil nutrient status and general soil condition that can be more precisely related to crop/pasture health and land uses; and
- Broadening the economic impact of soil properties and degradation processes beyond that associated with yield to include product quality and increased operating costs.

4 Local Infrastructure Costs of Degradation

Bruce Howard and David Young

4.1 Synopsis

Local or In situ impacts are defined as those that occur in local association with land degradation processes. For example, the impacts of rising groundwater on infrastructure are treated as local impacts. Local costs include damage to roads, bridges and houses.

No attempt is made to estimate what proportion of these costs are recoverable or avoidable. The current impact of water table rise and dryland salinity in non-metropolitan Australia is estimated to range between $30 million and $125 million with a best-bet estimate of $89 million.

Over the next 20 years, local infrastructure maintenance costs are estimated to increases as a result of damage from dryland salinity and rising water tables by between $17 million/yr and $86 million/yr with a best-bet estimate of $62 million/yr. The greatest cost increases over the next 20 years can be expected to occur in New South Wales and Victoria.

4.2 Background

Change in the status of land and water resources is not just an issue facing agricultural industries. Salinity, for example, is causing significant damage to roads, buildings and other infrastructure. It is also degrading the quality of urban water supplies.

Some of the major rivers in the Murray Darling Basin from which drinking water is extracted are likely to exceed World Health Organisation (WHO) minimum acceptable salt content standards. This will potentially have significant economic impacts on some of Australia's larger coastal population centres.

Recognition that salinity, and other forms of land and water degradation, are having significant cost impacts on industries other than agriculture is critical to developing appropriate management responses backed by all sections of the community. Information on non-agricultural degradation costs, provided in this section of the report, will help determine the extent to which changes in land and water may benefit others. It will assist urban communities and non-agricultural industries assess the extent to which it is in their interests to influence land and water use in other areas, even when the primary factors influencing the change occur some distance away from the impact.

4.2.1 Objective

The overall objective for this section, using a consistent method across all regions, was to describe and estimate the cost of land and water degradation, limited to salinity and waterlogging, to built infrastructure and non-agricultural industries. The costs estimated are marginal impact costs; no attempt is made to estimate what proportion of these costs are recoverable.

4.2.2 Nature of impacts

The following forms of degradation are considered:

- Salinity and waterlogging induced affects on industry, water suppliers, tourism, local government, and households;
- Erosion and sedimentation induced affects on dam storages, lakes and estuaries requiring engineering works or dredging, deposition on roads.

Factors not considered include

- Raised nutrients and eutrophication effects on water quality and recreational opportunities;[8]
- Impacts from acid sulphate soils usage in agriculture;
- Land and water (including groundwater) contamination by toxics (pesticides, herbicides, oils, solvents, heavy metals, other chemicals);
- Altered hydrological regimes, increased flooding risks.

For the purposes of clarity and because different techniques are required to collect the data, infrastructure cost estimates have been partitioned into local and downstream (chapter five) impacts.

The overall methodology for this part of the study was to

- Derive standardised cost functions;
- Combine these cost functions with data from other parts of the Audit to obtain national estimates of impact cost;

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[8] These are considered, however, in the following chapter on non-market values.

- Convert these estimates of impact cost into estimates of marginal cost.

4.2.3 Previous Studies

This study represents the first nation wide mapping and assessment of dryland salinity costs to local infrastructure. Some studies have been conducted within catchments (MDBC 1999). For example, the Loddon-Campaspe catchment in Victoria estimates that local government spends an average of $77,000 on salinity related repairs and that salinity costs to other government agencies exceed $1.9 million in the year 1993/94. The latter of these estimates includes expenditure on research, education, planning and extension. In the south-western portion of New South Wales it is estimated that 21% of highways are affected by salinity, causing damage costs of $9m/yr.

Guidelines for assessing the impact costs of dryland salinity, through agricultural yield loss, local infrastructure and downstream infrastructure have been previously been released (Wilson 1999). These guidelines are mainly for catchment management groups to guide the development of local actions plans. Through this project, costing functions applicable at national and regional scales were developed based on engineering reports. The cost functions differ by providing more detail on road/rail costs and link general urban infrastructure to population density.

4.3 Methods

Two approaches were taken to estimate the cost of degradation to local infrastructure: a survey of local government cost estimates; and use of a standard measure of impacts on infrastructure and their associated costs that was developed by a team of engineers.

All local governments in Australia and the state authorities responsible for major roads, railways, power and communications were surveyed to obtain their estimates for costs associated with their infrastructure stocks. In addition to the survey, the engineering team developed a standard measure of impacts on infrastructure and their associated costs for two primary degradation issues at three levels of severity for a suite of infrastructure types. These measures of impact level and costs will then be aggregated by intersection of maps and data describing the location of infrastructure and Audit estimates of the location and severity of degrading agents.

Because the information received from the survey process was extremely patchy and of limited use the cost estimates are therefore mainly based on engineer's assessments of the impact on annual maintenance costs for the various types of infrastructure considered.

Types of local degradation considered

The cost of degradation to infrastructure was estimated by considering the impacts caused primarily by

a) rising water and

b) salinity.

Although rising water and salinity occur together in most instances, their effects on infrastructure are completely different. Rising water reduces the structural capacity of soils beneath the infrastructure, whereas salinity is a corrosive agent that produces very different effects. In almost all cases, the increase in maintenance costs associated with each process is additive.

Rising Water impacts

Rising water has a range of impacts on infrastructure and many are poorly understood. Our survey and consultation process coupled with a review of the literature suggest the following conclusions.

- *Rising Water Impact on Rural Roads.* Slight damage, such as patching potholes, is assumed to be undertaken by a road patrol covering 75km of road per week. Moderate damage would require more substantial repairs, involving additional plant and materials and the coverage per week is assumed to be 20km. Some pavement reconstruction would be required in the case of severe damage, with again, additional plant, labour and materials involved. The team would cover 5km per week.
- *Rising Water Impact on Bridges.* Damage would be largely to the foundations of the structure. The rates consider a team of two people undertaking increasing amounts of remedial work to exposed concrete surfaces. An additional amount is also included for an increased level of inspection. All bridges are assumed to have concrete foundations, although in rural areas, this would not necessarily be the case.
- *Rising Water Impact on Urban Roads.* Slight damage, such as repairing potholes, is assumed to be repaired in a similar manner to the rural road item, with additional costs for repairing an asphalt layer and some minor kerb and channel repair. Moderate damage is assumed to involve considerable repairs to 180m^2 pavement per kilometre. This includes additional plant and labour and may involve stabilisation. Severe damage is assumed to be similar in nature to moderate damage, but affecting 360m^2 per kilometre.

- *Rising Water Impact on Underground Drainage*. Slight damage is assumed to involve a repair crew maintaining 50km of drain per week, repairing minor leaks caused by moving pipe joints and some minor concrete repairs. Moderate damage to the underground drainage system results in an increased level of attention, some pipe replacement and a coverage of 30km per week. Severe damage is assumed to involve the same work as for moderate, but with the coverage reduced to 20km per week.
- *Rising Water Impact on Aerodromes*. The repair work to be undertaken is assumed to be confined generally to a sealed runway pavement of 1.0-2.0km length. Repair of moderate damage involves say 100 (single unit size)-400m^2 of pavement reconstruction per kilometre and severe damage is assumed to be 200 (single unit size)-800m^2 of runway. Slight damage is assumed to include minor potholes, repaired by a small work crew whilst more significant damage would include pavement replacement work.
- *Rising Water Impact on Public, Commercial and Industrial Buildings.* Costs supplied by respondents were reviewed and used as a guide to assign costs.
- *Rising Water Impact on Parks and Gardens*. Costs are assumed to include additional drainage works and repair to damaged sealed and unsealed tracks and footpaths.
- *Rising Water Impact on Sporting Fields*. Costs are assumed to include additional underground drainage works, repair to pavements and carparks and to some degree of repair to playing surfaces.
- *Rising Water Impact on Domestic Buildings.* Costs are assumed to include repairs to foundations and above-ground structure and are based on data contained in section 4.2.1 of the report, "Dryland Salinity – What are the impacts and how do you value them?" prepared by the Murray-Darling Basin Commission 1999.
- *Rising Water Impact on Septic Systems.* It has been assumed that all domestic dwellings have a septic system and nominal costs have been included for rising water only.

Salinity impacts

The range of impacts that salinity has on infrastructure are many and complex. Our survey and consultation process coupled with or literature review suggest the following conclusions can be made:

- *Salinity Impact on Rural Roads.* Some minor damage may occur to the pavement surface and a nominal amount has been allocated treat this for each level of severity.

- *Salinity Impact on Bridges.* It is assumed that increased oxidation would occur around the "splash zone" of concrete foundations. The maintenance regime is similar to that for rising water.
- *Salinity Impact on Urban Roads.* Damage would be expected to occur to the pavement surface and costs are for varying amounts of asphalt re-sheeting. The assumed areas are as for rising water.
- *Salinity Impact on Underground Drains.* A nominal amount is assumed to cover isolated pipe replacement due to excessive oxidisation of exposed pipe reinforcement and damage to receival structures and waters from inflows of saline water. The costs have been assumed to be 25% of those for rising water.
- *Salinity Impact on Aerodromes.* Damage would be expected to occur to the runway pavement surface, with areas as for rising water. In addition, an allowance has been made for the replacement of water supply pipelines.
- *Salinity Impact on Public, Commercial and Industrial Buildings.* Costs for repairs to piped systems have been assumed to be similar to those for rising water.
- *Salinity Impact on Parks and Gardens.* Costs are assumed for repairs to irrigation reticulation systems.
- *Salinity Impact on Sporting Fields.* Costs are assumed for repairs to irrigation reticulation systems and repairs to pavement surface seals.
- *Salinity Impact on Domestic Buildings.* Costs include repairs to water supply pipe work, filters and hot water system components and are assumed to be similar to those for rising water.
- *Salinity Impact on Service Stations.* Nominal underground storage tank replacement costs are included for salinity only. The tank replacement cost has been estimated at $30,000 with a life of 20 years.

Infrastructure Stock Classification System

To organise the above conclusions into a manageable framework, a classification system was necessary to enable estimation in areas where data on each of the above forms of infrastructure is limited. The system identified five categories:

- *Category 1*—Local Government Infrastructure in non-metropolitan towns: rural roads, bridges, urban roads, underground drainage, aerodromes, public buildings, parks and gardens, and sporting fields.

- *Category 2*—Private Non-Agricultural Assets in non-metropolitan towns: domestic buildings, commercial/retail buildings, industrial buildings, septic systems and service stations.
- *Category 3*—Major Roads: national highways, rural arterials and urban arterials and bridges associated with these.
- *Category 4*—Railways
- *Category 5*—Power and Communication Infrastructure: power transmission, pipelines etc.

The impact of rising water tables and salinity on power and communication infrastructure was assessed to be minimal and, hence, for Audit purposes the cost is assumed to be zero. For categories 1 and 2, data on the stock or amount of infrastructure was found to be limited. Consequently, we developed estimates of the extent of this stock using data estimated for three typical township sizes, with populations of 5,000, 20,000 and 100,000 as summarised in Table 4.1

Table 4.1 Estimates of stock likely to be susceptible elements to water rise and/or salinity in nominated township sizes.

Township Population	No	5,000	20,000	100,000
Area of Township	sq km	15	35	125
Rural Roads	km	10	20	296
Bridges	No	1	4	6
Urban Roads	km	60	150	875
Underground Drainage	km	30	110	650
Aerodromes	Units	1	2	4
Public Buildings	No	10	70	250
Parks and Gardens	No	10	40	100
Sporting Fields	No	3	10	40
Domestic Buildings	No	2,500	8,000	35,000
Commercial Buildings	No	150	500	1,300
Industrial Buildings	No	30	250	750
Septic Systems	No	2,500	8,000	35,000
Service Stations	No	3	10	20

Severity of impact classification system

Details of the methodology used to estimate the extent of water table rise and salinity are summarised in Appendix B. For both water rise and salinity impacts, four levels of degradation severity were considered against each of these agents:

- No impact
- Slight impact

- Moderate impact
- Severe impact.

Each of these levels was chosen so that they could be combined with Theme 2 maps of dryland salinity hazard. Table 4.2 summarises the classification chosen for both rising water and salinity.

Table 4.3 shows that slight impacts are judged to occur when soil and water conditions are such that agricultural productivity has been reduced to around 65% of potential under non-limiting soil conditions.

Table 4.2 Classes of impact severity for rising water and salinity problems

Agent	Severity	Description
Rising Water	Severe: <1m	Water at less than 1.0 m below surface
	Moderate: 1-2m	Water at 1-2m below surface
	Slight: >2m	Water at more than 2m below surface
Salinity	Severe: Crusting	Salt crusting on the soil surface
	Moderate: Solution	Identifiable salt in solution in groundwater
	Slight: Seasonal	Seasonal salinity of groundwater

Table 4.3 Comparison of agricultural and infrastructure impact class (For more information, see Appendix B)

Dryland Salinity Impact Class	Assumed Impact on Agricultural Productivity			Impact on Infrastructure
	Description	Yield reduction	Assumed relative productivity	
I	No Impact	None	100%	None
II	Slight Ag. Impact	1-20%	90%	None
III	Moderate Ag. Impact	21-50%	65%	Slight
IV	Severe Ag. Impact	51-70%	40%	Moderate
V	Extreme Ag. Impact	71-100%	15%	Severe

4.3.1 Unit Costs of Rising Water Tables and Salinity

Categories 1 and 2 unit costs

Essentially, categories 1 and 2 cover assets in towns under the control of local government or owned managed by people. For each case, engineering consultants estimated the incremental operation and maintenance costs for each type of infrastructure, for each degradation agent, at three different levels of severity, and for communities of 5,000, 10,000 and 100,000 people. The results are presented in Table 4.4.

Table 4.4 Estimated cost per person of Category 1 and 2 infrastructure assuming the entire town falls in one severity class[1] ($/annum per capita of population).

Degradation agent	Small Town (5,000 people)	Medium Town (20,000 people)	Large Town (100,000 people)
Rising Water – Severe	1,911	1,524	1,334
Rising Water – Moderate	1,097	879	761
Rising Water – Slight	347	286	239
Salinity – Severe	1,488	1,219	1,027
Salinity – Moderate	887	727	610
Salinity – Slight	302	249	207

[1] No towns were found in this situation.

The data contained in Table 4.4 can also be expressed in terms of the following cost functions:

Cost of Rising Water Table = 556 x Severity Level – {3.63 x Population ('000)}

$R^2 = 0.94$

Cost of Salinity = 442 x Severity Level – {2.87 x Population ('000)}

$R^2 = 0.95$

Using these equations, a map of population density (Figure 4.1) and salinity hazard maps, the following section presents estimate of impact cost and changes in impact cost for Australia.

Most of the costs are incurred in building maintenance. Table 4.5, Table 4.6 and Table 4.7 show the costs ($/annum per capita) for different types of infrastructure for in a medium sized town with severe levels of rising water table, and severe salinity.

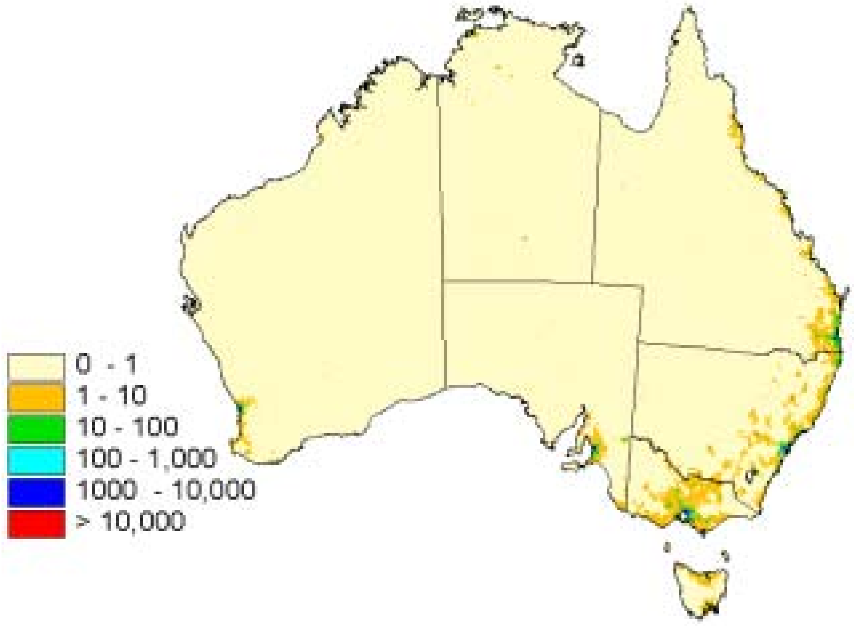


Figure 4.1 Population density of Australia (persons per square kilometre)

Table 4.5 Summary of increase in maintenance costs per capita for a medium size town where rising water table and salinity impacts are severe

Local Government Assets	**Rising Water**	**Salinity**
Urban Roads	150	47
Public Buildings	11	11
Rural Roads	4	0
Underground Drainage	4	1
Parks and Gardens	3	6
Bridges	1	1
Aerodromes	1	0
Sporting Fields	1	3
Sub-total	174	68
Private Non-Agricultural Assets	**Rising Water**	**Salinity**
Domestic Buildings	1,000	1,000
Septic Systems	200	0
Commercial/Retail Buildings	100	100
Industrial Buildings	50	50
Service Stations	0	1
Sub-total	1,350	1,151
Total	**1,524**	**1,219**

Table 4.6 Impact on local government assets for nominated township sizes

					Maintenance Cost ($000 per year)					
Receptors	**Degradation Agent**	**Severity**	**Impacts**	**Unit Cost $**	**Pop'n 5,000**	**Pop'n 20,000**	**Pop'n 100,000**	**Pop'n 5,000**	**Pop'n 5,000**	**Pop'n 5,000**
Rural Roads	Rising Water	<1m	Severe	4,000	40.0	80.0	1184.0	8	4	12
		1-2m	Moderate	750	7.5	15.	222.0	2	1	2
		>2m	Slight	100	1.0	2.0	29.6	0	0	0
	Salinity	<1m	Severe	25	0.3	0.5	7.4	0	0	0
		1-2m	Moderate	25	0.3	0.5	7.4	0	0	0
		>2m	Slight	25	0.3	0.5	7.4	0	0	0
Bridges	Rising Water	<1m	Severe	3,000	3.0	12.0	18.0	1	1	0
		1-2m	Moderate	2,000	2.0	8.0	12.0	0	0	0
		>2m	Slight	1,000	1.0	4.0	6.0	0	0	0
	Salinity	<1m	Severe	3,000	3.0	12.0	18.0	1	1	0
		1-2m	Moderate	2,000	2.0	8.0	12.0	0	0	0
		>2m	Slight	1,000	1.0	4.0	6.0	0	0	0
Urban Roads	Rising Water	<1m	Severe	20,000	1,200.0	3,000.0	17,500.0	240	150	175
		1-2m	Moderate	10,000	600.0	1,500.0	8,750.0	120	75	88
		>2m	Slight	550	33.0	82.5	481.3	7	4	5
	Salinity	<1m	Severe	6,300	378.0	945.0	5,512.50	76	47	55
		1-2m	Moderate	3,200	192.0	480.0	2800.0	38	24	28
		>2m	Slight	1,000	60.0	150.0	875.0	12	8	9
Underground Drainage	Rising Water	<1m	Severe	700	21.0	77.0	455.0	4	4	5
		1-2m	Moderate	450	13.5	49.5	292.5	3	2	3
		>2m	Slight	200	6.0	22.0	130.0	1	1	1
	Salinity	<1m	Severe	175	5.3	19.3	113.8	1	1	1
		1-2m	Moderate	110	3.3	12.1	71.5	1	1	1
		>2m	Slight	50	1.5	5.5	32.5	0	0	0
Aerodromes	Rising Water	<1m	Severe	18,400	8.4	27.6	73.6	4	1	1
		1-2m	Moderate	11,000	11.0	16.5	44.0	2	1	0
		>2m	Slight	4,000	4.0	6.0	16.0	1	0	0
	Salinity	<1m	Severe	6,300	6.3	9.5	25.2	1	0	0
		1-2m	Moderate	3,300	3.3	5.0	13.2	1	0	0
		>2m	Slight	1,250	1.3	1.9	5.0	0	0	0
Public Buildings	Rising Water	<1m	Severe	3,000	30.0	210.0	750.0	6	11	8
		1-2m	Moderate	1,000	10.0	70.0	250.	2	4	3
		>2m	Slight	500	5	35	125	1	2	1
	Salinity	<1m	Severe	3,000	30	210	750.	6	11	8
		1-2m	Moderate	1,000	10	70	250	2	4	3
		>2m	Slight	500	5	35	125	1	2	1
Parks and Gardens	Rising Water	<1m	Severe	1,500	15	60	150	3	3	2
		1-2m	Moderate	1,000	10	40	100	2	2	1
		>2m	Slight	500	5	20	50	1	1	1
	Salinity	<1m	Severe	3,000	30	120	300	6	6	3
		1-2m	Moderate	1,500	15	60	150	3	3	2
		>2m	Slight	500	5	20	50	1	1	1
Sporting Fields	Rising Water	<1m	Severe	2,000	6	20	80	1	1	1
		1-2m	Moderate	1,500	4.5	15	60	1	1	1
		>2m	Slight	500	1.5	5	20	0	0	0
	Salinity	<1m	Severe	5,000	15	50	200	3	3	2
		1-2m	Moderate	2,500	7.5	25	100	2	1	1
		>2m	Slight	1,000	3	10	40	1	1	0

Table 4.7 Impact on private non-agricultural assets for nominated township sizes

Receptors	Degradation Agent	Severity	Impacts	Unit Cost $	Maintenance Cost ($000 per year)					
					Pop'n 5,000	Pop'n 20,000	Pop'n 100,000	Pop'n 5,000	Pop'n 5,000	Pop'n 5,000
Domestic Buildings	Rising Water	<1m	Severe	2,500	6,250	20,000	87,500	1,250	1,000	875
		1-2m	Moderate	1,500	3,750	12,000	52,500	750	600	525
		>2m	Slight	500	1,250	4,000	17,500	250	200	175
	Salinity	<1m	Severe	2,500	6,250	20,000	87,500	1,250	1,000	875
		1-2m	Moderate	1,500	3,750	12,000	52,500	750	600	525
		>2m	Slight	500	1,250	4,000	17,500	250	200	175
Commercial/ Retail Buildings	Rising Water	<1m	Severe	4,000	600	2,000	5,200	120	100	52
		1-2m	Moderate	2,500	375	1,250	3,250	75	63	33
		>2m	Slight	1,000	150	500	1,300	30	25	13
	Salinity	<1m	Severe	4,000	600	2,000	5,200	120	100	52
		1-2m	Moderate	2,500	375	1,250	3,250	75	63	33
		>2m	Slight	1,000	150	500	1,300	30	25	13
Industrial Buildings	Rising Water	<1m	Severe	4,000	120	1,00	3,000	24	50	30
		1-2m	Moderate	2,500	75	625	1,875	15	31	19
		>2m	Slight	1,000	30	250	750	6	13	8
	Salinity	<1m	Severe	4,000	120	1,00	3,000	24	50	30
		1-2m	Moderate	2,500	75	625	1,875	15	31	19
		>2m	Slight	1,000	30	250	750	6	13	8
Septic Systems	Rising Water	<1m	Severe	500	1,250	4,000	17,500	250	200	175
		1-2m	Moderate	250	625	2,000	8,750	125	100	88
		>2m	Slight	100	250	800	3,500	50	40	35
	Salinity	<1m	Severe	0	0	0	0	0	0	0
		1-2m	Moderate	0	0	0	0	0	0	0
		>2m	Slight	0	0	0	0	0	0	0
Service Stations	Rising Water	<1m	Severe	0	0	0	0	0	0	0
		1-2m	Moderate	0	0	0	0	0	0	0
		>2m	Slight	0	0	0	0	0	0	0
	Salinity	<1m	Severe	1,500	4.5	15	30	1	1	0
		1-2m	Moderate	1,000	3	10	20	1	1	0
		>2m	Slight	500	1.5	5	10	0	0	0

Category 3 and 4 unit costs

For categories 3 and 4, good spatial data was available on the extent and quality of roads, Railways and Bridges (See Figures 4.2 to 4.5). No reliable bridge data was available. It was developed by overlaying the road network for Australia over the river network. For the purposes of this study, we assume that there is a bridge or ford at every intersection of a road and river/stream.

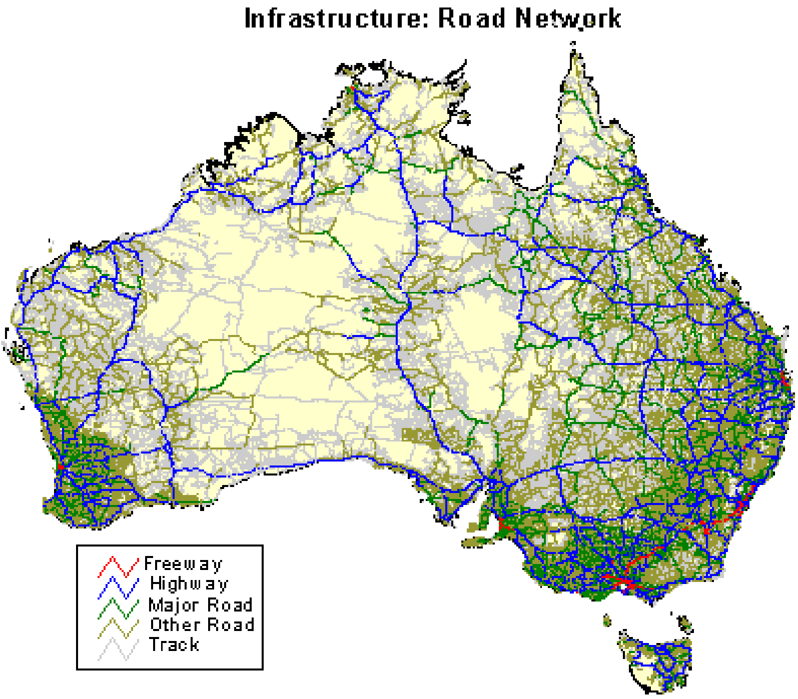


Figure 4.2 Location of roads by category in Australia

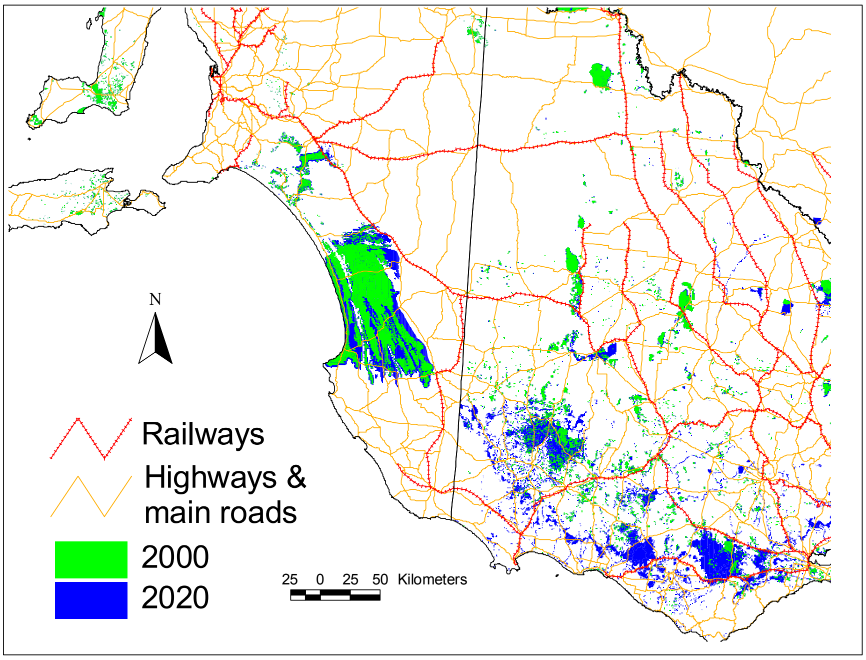


Figure 4.3 Intersection of salinity hazard with highways, main roads and railways in the South East of Australia

Table 4.8 Impact of rising water table and salinity on major roads and bridges

Receptors	Degradation Agent	Severity	Impacts	Unit	Unit Cost $
National Highways	Rising Water	<1m	Severe	km	37,440
		1-2m	Moderate	Km	20,800
		>2m	Slight	Km	8,320
	Salinity	<1m	Severe	Km	4,140
		1-2m	Moderate	Km	2,300
		>2m	Slight	Km	920
	Rising Water	<1m	Severe	Bridge	2,880
		1-2m	Moderate	Bridge	1,600
		>2m	Slight	Bridge	640
	Salinity	<1m	Severe	Bridge	26,640
		1-2m	Moderate	Bridge	14,800
		>2m	Slight	Bridge	5,920
Rural Arterials	Rising Water	<1m	Severe	km	5,940
		1-2m	Moderate	Km	3,300
		>2m	Slight	Km	1,320
	Salinity	<1m	Severe	Km	720
		1-2m	Moderate	Km	400
		>2m	Slight	Km	160
	Rising Water	<1m	Severe	Bridge	1,080
		1-2m	Moderate	Bridge	600
		>2m	Slight	Bridge	240
	Salinity	<1m	Severe	Bridge	9,900
		1-2m	Moderate	Bridge	5,500
		>2m	Slight	Bridge	2,200
Urban Arterials	Rising Water	<1m	Severe	km	36
		1-2m	Moderate	Km	20
		>2m	Slight	Km	8
	Salinity	<1m	Severe	Km	0
		1-2m	Moderate	Km	0
		>2m	Slight	Km	0
	Rising Water	<1m	Severe	Bridge	0
		1-2m	Moderate	Bridge	0
		>2m	Slight	Bridge	0
	Salinity	<1m	Severe	Bridge	0
		1-2m	Moderate	Bridge	0
		>2m	Slight	Bridge	0

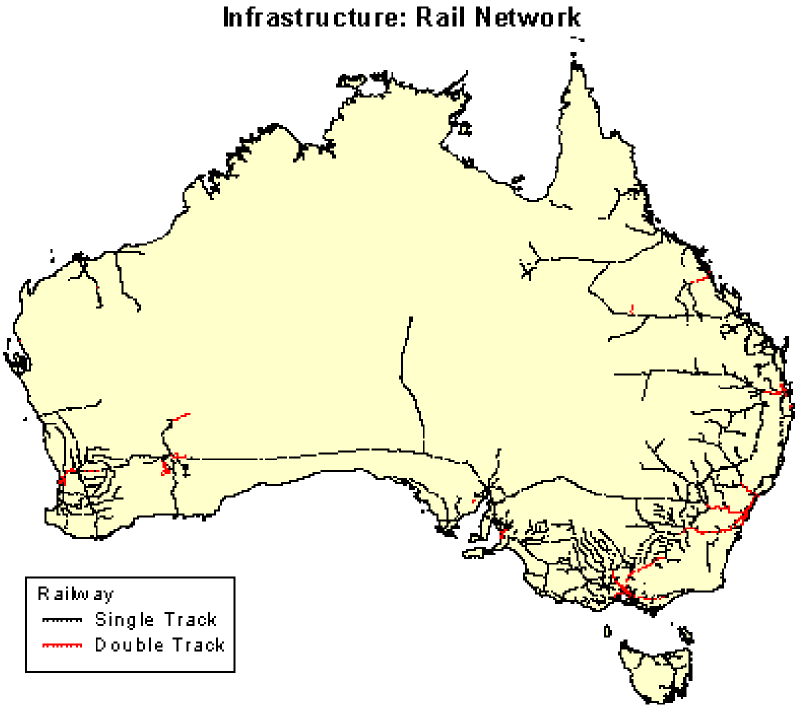


Figure 4.4 Location of railways by category in Australia

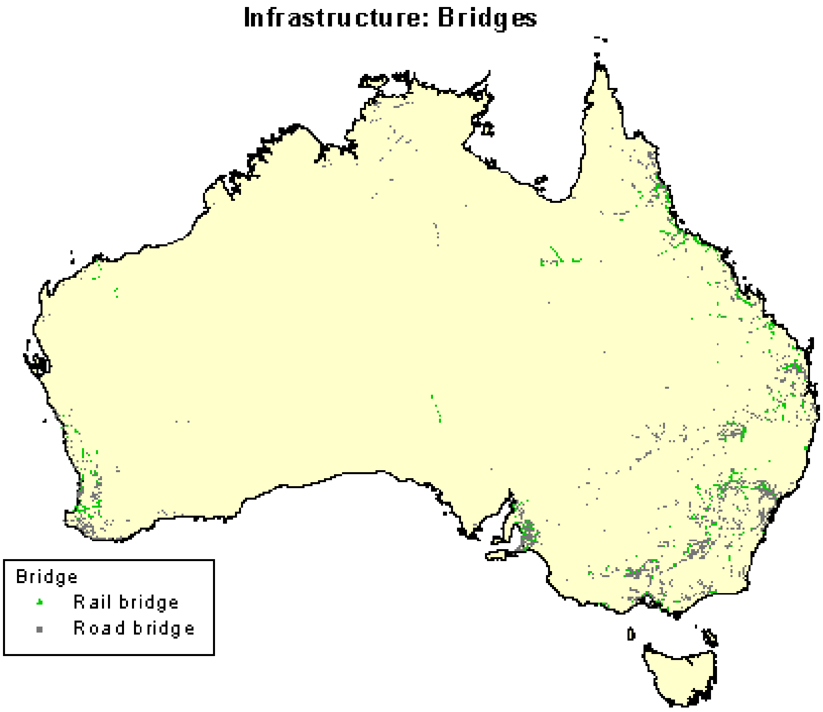


Figure 4.5 Location of bridges by category in Australia

Table 4.9 Impact of water table on railway infrastructure

Receptors	Degradation Agent	Severity	Impacts	Annual Cost $/km
Fences	Rising Water	<1m	Severe	500
		1-2m	Moderate	20
		>2m	Slight	10
	Salinity	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
Pole Lines	Rising Water	<1m	Severe	120
		1-2m	Moderate	18
		>2m	Slight	10
	Salinity	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
Access Roads	Rising Water	<1m	Severe	28,000
		1-2m	Moderate	14,000
		>2m	Slight	7,000
	Salinity	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
Signals	Rising Water	<1m	Severe	15
		1-2m	Moderate	2
		>2m	Slight	1
	Salinity	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
Cess Drains	Rising Water	<1m	Severe	250
		1-2m	Moderate	125
		>2m	Slight	0
	Salinity	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
Formation	Rising Water	<1m	Severe	4,000
		1-2m	Moderate	2,000
		>2m	Slight	500
	Salinity	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
Track Structure	Rising Water	<1m	Severe	21,000
		1-2m	Moderate	5,000
		>2m	Slight	1,600
	Salinity	<1m	Severe	16,000
		1-2m	Moderate	8,000
		>2m	Slight	4,00
Buried Conduits	Rising Water	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
	Salinity	<1m	Severe	0
		1-2m	Moderate	0

Receptors	Degradation Agent	Severity	Impacts	Annual Cost $/km
		>2m	Slight	0
Concrete Culverts	Rising Water	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
	Salinity	<1m	Severe	600
		1-2m	Moderate	400
		>2m	Slight	350
Steel Culverts	Rising Water	<1m	Severe	600
		1-2m	Moderate	400
		>2m	Slight	350
	Salinity	<1m	Severe	600
		1-2m	Moderate	400
		>2m	Slight	350
Bridges	Rising Water	<1m	Severe	0
		1-2m	Moderate	0
		>2m	Slight	0
	Salinity	<1m	Severe	90
		1-2m	Moderate	30
		>2m	Slight	10
Other Elements	Rising Water	<1m	Severe	5,500
		1-2m	Moderate	2,000
		>2m	Slight	950
	Salinity	<1m	Severe	2,000
		1-2m	Moderate	900
		>2m	Slight	500
Total	Rising Water	<1m	Severe	59,985
		1-2m	Moderate	23,565
		>2m	Slight	10,421
	Salinity	<1m	Severe	19,290
		1-2m	Moderate	9,730
		>2m	Slight	5,210

4.3.2 Regional, State and National Impacts

Estimates of the cost of local impacts of salinity and water table rise were calculated using the above equations. The salinity and rising water data for these equations was sourced from the Audit (theme 2, dryland salinity), as published in NLWRA (2000). The costs are shown as surfaces (Figure 4.6 to Figure 4.8) and are summarised by reporting regions.

Figure 4.6 Distribution of local impact costs of salinity and rising water tables in 2000 ($/sq. km)

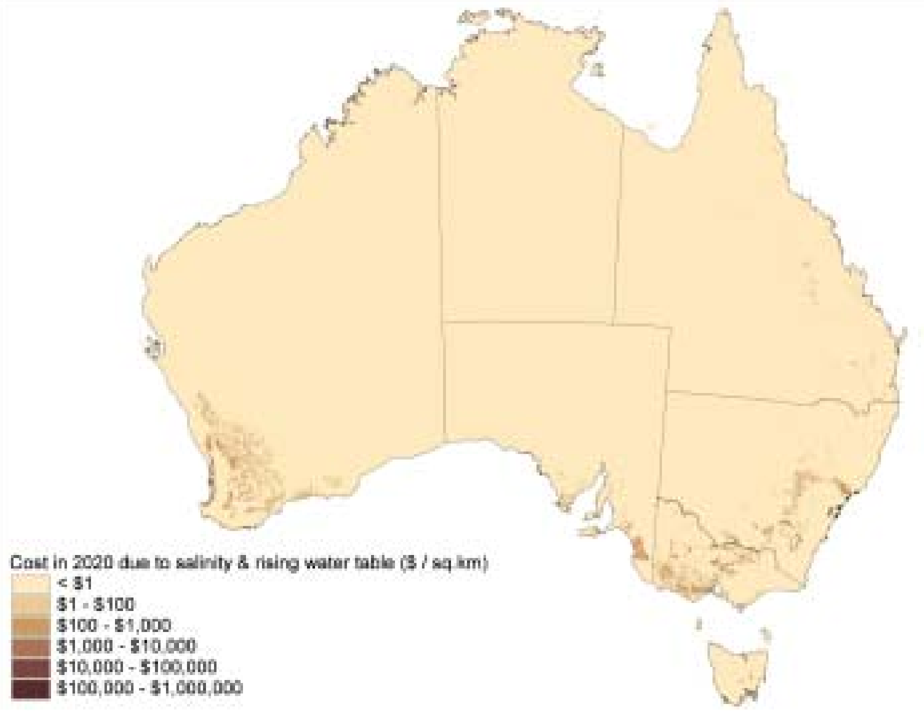


Figure 4.7 Distribution of local impact costs of salinity and rising water tables in 2020 ($/sq. km)

Figure 4.8 Location of increases in local impact costs of salinity and rising water tables, 2020 - 2000 ($/sq. km)

Table 4.10 Low best and high estimates for 2000 & 2020 by reporting region

Region	**Low 2000 ($000/yr)**	**Low 2020 ($000/yr)**	**Best 2000 ($000/yr)**	**Best 2020 ($000/yr)**	**High 2000 ($000/yr)**	**High 2020 ($000/yr)**
Burdekin	22	37	72	159	107	233
Carpentaria	-	1	1	6	2	8
Darling	478	1,516	1,545	4,948	2,197	7,007
Far North Qld	28	91	88	395	123	554
Fitzroy	152	195	488	836	704	1,207
Goldfields	-	11	-	46	-	64
Indian South	199	151	645	645	939	939
Inland	-	-	-	-	-	-
Moreton	159	266	497	1,155	697	1,619
Murray	4,410	9,969	12,268	31,692	17,064	44,076
North Queensland	58	177	182	768	255	1,081
NSW North	14	32	44	102	63	143
NSW South & Central	2,975	6,903	9,500	21,715	13,338	30,489
Qld South & Central	200	374	631	1,616	893	2,283
SA Gulf	1,806	1,806	2,638	2,639	3,237	3,239
South East Corner	137	641	429	2,779	603	3,897
Southern	2,452	7,008	5,923	23,148	8,090	31,956
Tasmania	600	800	1,911	2,506	2,684	3,524
WA South	16,101	12,603	51,134	54,378	72,894	77,564
Western Eyre Peninsula	540	540	779	779	980	980
Total	30,331	43,121	88,774	150,310	124,869	210,864

An important question is where infrastructure impact costs are likely to increase. This was estimated by considering the difference between costs calculated for 2020 costs and costs for 2000. In presenting these data, *it is stressed that no adjustments have been made to the data to allow for the effectiveness or otherwise of the National Action Plan for Salinity and Water Quality or any other salinity mitigation programs being introduced by the governments of Australia.*

Table 4.11 shows, in decreasing order, the NPV of increasing costs for the regions where the greatest impact of local cost to infrastructure can be expected. The Murray, Southern, NSW South & Central, Darling, and WA South are indicated as the top five.

Table 4.11 Present values of change in annual costs by region

Region	Increase in Annual Costs 2000 to 2020 ($000)	Present Value of Costs ($000)		
Discount Rates		**3%**	**5%**	**6%**
Murray	19,424	137,596	107,755	95,858
Southern	17,225	122,019	95,556	85,006
NSW South & Central	12,215	86,529	67,763	60,281
Darling	3,403	24,106	18,878	16,794
WA South	3,244	22,980	17,996	16,009
South East Corner	2,350	16,647	13,037	11,597
Queensland South & Central	984	6,970	5,459	4,856
Moreton	659	4,668	3,656	3,252
Tasmania	596	4,222	3,306	2,941
North Queensland	586	4,151	3,251	2,892
Fitzroy	348	2,465	1,931	1,717
Far North Queensland	307	2,175	1,703	1,515
Burdekin	86	609	477	424
NSW North	57	404	316	281
Goldfields	46	326	255	227
Carpentaria	5	35	28	25
SA Gulf	1	7	6	5
Indian South	-	-	-	-
Inland	-	-	-	-
Western Eyre Peninsula	-	-	-	-
	61,536	435,909	341,373	303,681

Local annual infrastructure costs for each state are presented in Table 4.12. In descending order the highest "best" estimate of costs is shown to occur in Western Australia. However, in terms of the per cent change from 2000 costs to 2020 costs the greatest proportional increase is indicated to occur in Victoria and New South Wales (see Table 4.13).

The Net Present Value of *increased* costs between 2000 and 2020 for local infrastructure damage is estimated at $436 million and the annual cost at 2020 is $150 million.

Table 4.12 Local annual infrastructure costs per State/Territory

	Low Estimate				**Best Estimate**				**High Estimate**			
	2,000	**2,020**	**Increase**		**2,000**	**2,020**	**Increase**		**2,000**	**2,020**	**Increase**	
State	**$m/yr**	**$m/yr**	**$m/yr**	**%**	**$m/yr**	**$m/yr**	**$m/yr**	**%**	**$m/yr**	**$m/yr**	**$m/yr**	**%**
New South Wales	4.4	12.0	7.7	175	14.0	37.9	23.9	171	19.7	53.4	33.7	171
Victoria	3.9	8.9	5.0	129	12.2	38.5	26.3	215	17.3	54.3	37.0	214
Queensland	0.7	1.3	0.6	84	2.2	5.5	3.3	151	3.1	7.8	4.7	150
South Australia	4.5	7.4	2.9	64	6.7	10.9	4.2	63	8.3	13.3	5.1	61
Western Australia	16.3	17.3	1.0	6	51.8	55.1	3.3	6	73.8	78.6	4.7	6
Tasmania	0.6	0.8	0.2	33	1.9	2.5	0.6	31	2.7	3.5	0.8	31
Total	30.3	47.7	17.4	57	88.8	150.3	61.5	69	124.9	210.9	86.0	69

Table 4.13 Present value of local infrastructure costs by State and Territory

State	**2000-2020 Increase (%)**	**Change in Annual Costs ($m)**	**Present value of increase in costs ($m)**		
Discount rates ->			**3%**	**5%**	**6%**
Vic	215%	26.3	$186	$146	$130
NSW	171%	23.9	169	133	118
SA	63%	4.2	30	23	21
Qld	151%	3.3	23	18	16
WA	6%	3.3	23	18	16
TAS	31%	0.6	4	3	3
ACT	-	0	0	0	0
Total	69%	61.5	436	341	304

4.4 Extensions and Uses of the Data

This data provides estimates of non-agricultural infrastructure damage costs associated with salinity, which occur within the same location as the salinity problem. It will assist Local and State governments in determining appropriate levels of defensive expenditure. Possible improvements to the data would include more detailed mapping of shallow water tables and salinity and more detailed specification of the functional relationships between salinity and infrastructure damage.

5 Downstream Costs of Degradation

Jon Thomas and Stefan Hajkowicz

5.1 Synopsis

Downstream or Ex situ impacts are defined as phenomena that occur away from the original source of the impact. This typically occurs because the problem arises only after a water supply is contaminated. A classic example of a downstream impact is the cost of boiler corrosion in a city factory several hundred kilometres from the place where salt entered the river supplying water to the city. Downstream costs considered here include the impact of salt in water used in urban areas, water turbidity costs and sedimentation 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, we began our analysis with an assessment of incremental costs associated with declines in water quality. Plausible scenarios were then used to estimate total downstream costs in urban areas. No estimate was made of the increased costs that rising salinity levels impose on irrigated agriculture.

Incremental cost estimates were derived using a methodology essentially developed by GHD and used for two previous studies of costs for the Murray Darling Basin (MDB). Review of previous work and the collection of addition data revealed that the economic assessments made had used straight line discounting methods rather than standard amortisation techniques used for cost estimation by economists; and identified some assumptions that no longer appear to hold.

Amortisation alone doubles the impact cost of many items. Amortisation requires recognition of the opportunity cost of capital. Opportunity cost can be considered the value of that which must be forgone as a result of a particular action. 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 assumed to be correct.

Aggregate Net present values of downstream (or ex-situ) costs of degradation were determined for marginal cost increases associated with salinity, erosion, sedimentation and turbidity over the next 20 years (2000 to 2020) using data available from the Audit. We assumed that salinity will only increase in the basins identified as ‘at risk’ of salinisation (see Figure 5.1). Each of these basins contains significant areas of dryland salinity that are expected to increase in extent and severity over the next 20 years.

As trend data on changes in water quality are not available, we model 1%, 5%, and 10% declines in water quality over the next 20 years. In lieu of reliable trend data, this presents the as a range of ‘what-if’ scenarios. The national present value of downstream infrastructure impact costs, determined using this approach, is in the range of $778 million to $1,959 million.

Previous estimates of downstream costs 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 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. 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.

5.2 Quantifying Downstream Costs

This section presents standardised cost functions summarising the downstream impacts of land and water salinity on non-agricultural industries and households. For the purposes of the report these impacts have been defined as phenomena that occur away from the original site of degradation, by processes of water transfer. Note that the impacts of rising groundwater tables (saline and fresh) on infrastructure are excluded, and are treated in the report as local or *in situ* impacts.

Estimates of national marginal costs due to water degradation from salinity, turbidity and erosion/sedimentation in Australia are presented. The estimates employ the standardised unit cost functions presented in the previous REU and PPK reports:

- Unit damage cost functions for the ex-situ impacts of salinity (REU, February 2001)
- Unit damage cost functions for the ex-situ impacts of erosion and sedimentation (REU February 2001)
- Industrial and commercial impacts of impaired water quality (PPK, March 2001)

The unit cost functions have been combined with data on resource condition supplied by the National Land and Water Resources Audit, and supplementary data on affected activities and infrastructure to provide the total national cost estimates.

This assessment represents the first attempt to apply the large amount of data on resource condition assembled by the National Land and Water Resources Audit to estimate downstream costs of land and water degradation in Australia.

It is paradoxical that in many regions that suffer from severe resource degradation the impacts in terms of user costs can be quite modest. If reliable estimates of costs and decisions about worthwhile investments are to be made, the richness of the database of usage patterns, infrastructure and inter-basin water transfers has to match the data for resource condition. Even after the Audit, that database still does not exist.

Estimates of downstream costs are based on a range of assumptions. Methodological details and an assessment the significance of these functions are presented in appendices E, F, G and H.

5.2.1 Downstream cost functions for salinity

For downstream salinity costs, marginal recurrent damage cost functions were developed by the Resource Economics Unit in partnership with PPK for

(i) households,

(ii) manufacturing industry, and

(iii) commercial activities.

These are presented in Table 5.1, and discussed in the following summaries. The recommended total marginal cost function is summarised in Table 5.2. Salinity is measured in terms of total dissolved solids (TDS) measured by weighing the residue left after evaporation of a filtered water sample. While this is the most common measure for urban and domestic water supplies, it is often necessary to convert TDS units to the more common measure used for rivers – Electrical Conductivity (EC). While the relationship between EC and TDS varies with concentration and proportion of ions, for general purposes, GHD (1999) report that

$$1 \text{ TDS in water (mg/L)} = 0.6 \text{ EC } (\mu\text{S/cm}).$$

It is noted that the results below are derived from total cost functions. They do not differentiate between "human induced" costs and natural costs.

Table 5.1 Recurrent marginal damage costs for urban and industrial water users

Sector	Sectoral Marginal Damage Costs ($/kL/year) T = mgL-1 TDS	Typical proportional weighting	Weighted Marginal Damage Cost ($/kL/year) T = mgL-1 TDS
Households	0.001147T	.60	0.000688T
Industry	0.005478T	.30	0.000329T
Commerce	0.002370T	.10	0.000237T
Total recurrent costs		1.00	0.001254T

The "typical" proportional weightings given in Table 5.1 are based on South Australia water use estimates by ABS. South Australia has been used here, as it is the biggest receptor of rising salinity from a single source, namely the Murray-Darling system. Where possible, the damage costs should be calculated for the individual sectors, but the total recurrent cost may be used as a default value.

To avoid double counting it is recommended that marginal recurrent costs be calculated first. In some cases these costs are avoided by making non-recurrent investments. For example, a water supply authority may source water through a different, less-saline system. Where this occurs, the recurrent cost should be adjusted to account for the lesser costs of this alternative.

Domestic Sector

Salinity cost functions for the domestic sector are summarised in Table 5.2. *The marginal damage function for domestic items of 0.281/household/year/ mgL^{-1} increase in TDS, is almost double that developed by GHD (1999)*. This is despite the fact that the REU estimates are essentially a re-working of the GHD data set based on economic amortisation and some new supplementary data. Only in the case of domestic plumbing items has new data, from Western Australia, been used. Two items dominate the domestic costs of salinity according to both the GHD and REU estimates, namely domestic plumbing items (43%) and water heaters (31%).

The main difference between the two sets of estimates is the use of standard economic amortisation procedures in the work undertaken by REU and simple straight line depreciation by GHD. Straight-line depreciation methods make no allowance for 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".

Table 5.2 Recommended cost functions for domestic impacts of salinity

Item	Marginal Damage Cost (a) ($/household/year) T= mgL^{-1} TDS	Marginal Damage Cost (b) ($/kL/year) T = mgL^{-1} TDS	Percent of Marginal Damages (%)
Soaps & detergents	Nil	Nil	0
Domestic plumbing	0.121T	0.000494T	43.1
Hot water systems:	0.086T	0.000351T	30.6
Bottled water	Nil	Nil	0
Domestic filters	0.009T	0.000037T	3.2
Rain water tanks	0.065T	0.000265	23.1
Water softeners	Nil	Nil	0
Total domestic costs	0.281T	0.001147T	100.0

A comparison of the REU cost functions for marginal damages to domestic items against calculations based on Tihansky (1974) and AMDEL (1982) is shown in Table 5.3. A number of household items, which were found to be significant in the literature, were judged by GHD and accepted by REU to be insignificant or not investigated. Soaps, detergents and purchases of bottled water were judged to be insignificant, while fabrics, washing machines, cooking utensils, and garbage grinders, which contribute significantly to Tihansky's damage functions, were not investigated. In addition, a number of water-contacting domestic items, which have become common since Tihansky (1974), were not considered by GHD: for example, dishwashers and coffee machines. Car radiators and engines were not investigated in the literature or by GHD: while special coolant mixtures are standard for new motor vehicles, these are not universally used. On the other hand, expenditure on water softeners, which according to GHD is significantly affected by salinity, was thought by Tihansky (1974) to be entirely related to water hardness.

Table 5.3 Percentage of total marginal damages due to each item: REU compared with GHD (1999), Tihansky (1974) and AMDEL (1982)

Item	REU (%)	GHD (%)	Tihansky (%)	AMDEL (%)
Soaps & detergents	0	0	5	51
Domestic plumbing	43	55	38	33
Hot water systems:	31	35	17	13
Bottled water	0	0	11	0
Domestic filters	3	6	0	0
Rain water tanks	23	4	0	0
Water softeners	0	0	0	3
Washing machines	0	0	11	0
Fabrics	0	0	13	0
Other	0	0	5	0
Total domestic costs	100	100	100	100

The AMDEL (1982) estimates were heavily influenced by their estimate of the effect of salinity on purchases of soaps and detergents. Both GHD and Tihansky considered a larger range of other items than AMDEL, but there was a complete mis-match comparing the “other items” in Tihansky (bottled water, washing machines, fabrics, and other) with those in GHD (domestic filters, rain water tanks, and water softeners).

Industrial and Commercial Sectors

Previous studies of the costs of salinity to water users (Cruickshanks-Boyd, 1983 and GHD, 1999) have been updated by PPK Environment & Infrastructure Pty Ltd, and are reported in full in a separate document (PPK Environment & Infrastructure, 2001). New cost functions have been developed, expressed as costs per kL of water used per year. These cost functions are given in Table 5.4.

Table 5.4 Summary of industrial and commercial damage cost functions

Purpose of Water Use	Proportion of industrial water use (based on Adelaide)	Individual Use marginal damage cost ($/kL/year) T = TDS (mg/L)	Weighted marginal damage cost $/kL/year T = TDS (mg/L)	Percent of weighted marginal damage costs (%)
General (e.g. washing, cleaning, site maintenance)	0.50	0.0003T	0.000150T	2.7
Cooling towers	0.13	0.0096T	0.001152T	21.0
Boiler feed water	0.23	0.0162T	0.003726T	68.0
Process water	0.14	0.0030T	0.000450T	8.3
Total	1.00		0.005478T	100.0

The marginal damage costs presented above for industrial water users are significantly higher than those estimated in GHD (1999), mainly because GHD assumed a much lower cost rate for supplied water (40c/kL compared with 92 c/kL in the current study based on prices used by *SA Water*). The current study also considered the differing abatement strategies used for boiler water treatment by small, medium and large industries, whereas the GHD study assumed that all industries would use capital-intensive reverse osmosis water treatment technology above a salinity level of 265 mg/L TDS (for which the operational costs are largely independent of salinity). In practice, many small and medium size industries have not, and are unlikely to, install reverse osmosis water treatment technology due to the capital cost. In the case of cooling tower operation, the current study assumed a blowdown salinity of 2000 mg/L, which is more representative of industry practice than the figure of 2500 mg/L used by GHD.

Service Sector

A review has been made of water use patterns within service sector activities, to determine which water uses within the sector could face industrial-type damage costs, from uses in boilers, cooling towers etc.

In the case of commercial water users (eg. offices, shopping centres, hotels, hospitals, public buildings) the cost function derived in the current study (refer Table 1) is similar to that derived by GHD. Discussions with energy providers have suggested that salinity is not a cost issue for hydro-electric schemes. A sample survey of local councils indicated that, while salinity is having a significant impact, this is confined to *local* infrastructure impacts. *Downstream* impacts on local government are not significant.

Water Utilities

A detailed case study was conducted on the cost impacts of salinity on the Western Australian Water Corporation. It has found that, while the utility is in many respects protected from increasing salinity, due to its forested catchments and groundwater reserves, nevertheless:

- increased costs have been incurred for additional source development following salinisation of one large surface reservoir: estimated at $0.53/household served /year/mg/l change in TDS (alternatively, $0.00177/year/kL supplied/ mg/l change in TDS)
- increased catchment management costs are being incurred
- higher costs of water treatment will be experienced in future because new diversions of brackish or saline surface water will require desalination: estimated at $0.025/household/year/mg/l change in TDS for the particular catchment (alternatively, $0.000083/year/kL supplied/ mg/l change in TDS)

Water utilities in other salt-affected regions, such as the Loddon-Campaspe catchment in Victoria, reported only minor cost implications from salinity, because of their capacity to withdraw fresh water for urban supply from major irrigation channels. GHD (1999) concluded that salinity had no measurable cost impacts on water utilities that withdraw water from the Murray Valley (Murray-Darling Basin).

In regions constructing replacement infrastructure or desalinating their water supply as a result of salinity an additional $0.1/household/year/mg/L TDS should be allowed as an indicative estimate (alternatively, $0.000333/year/kL supplied/ mg/l change in TDS). However, it is recommended that, where possible, information on specific catchments should be used rather than a standardised function.

5.2.2 Downstream cost functions for Sediments and Turbidity

This section presents standardised cost functions for downstream costs of erosion and sedimentation.

Causes and spread of sedimentation

Many Australian waters receive large quantities of sediment, and are in general highly turbid. The main problem areas are in coastal Queensland, the Murray Darling basin, the South Australian Gulf and the South East Coast Drainage Divisions. Parts of the south west of Western Australia and northern Australia are also affected.

Farming practices such as widespread tree clearing, mould-board ploughing, and large flocks of sheep or cattle have increased the natural rates of sediment movement and inland water turbidity. Inadequate earth moving practices and failure to provide sediment traps along stream banks and silt traps in river channels exacerbate the problem. However, in river systems that have experienced a history of erosion and sedimentation over decades or more, the relative contribution of freshly eroded material and remobilised channel materials is difficult to ascertain.

Measurement Units

Sediment concentration is normally measured as mgL^{-1}, with long-run average concentrations in the range 0 – 1,000 mgL^{-1}. Turbidity is measured by photometric means, the result being expressed in “National Turbidity Units” (NTU), with 5 NTU being the maximum recommended for potable water supply.

The relationship between NTU’s and total solids content varies for different kinds of water. Nevertheless, the two are broadly correlated. Using the data given in Brown (op cit) the following relationship was obtained, and used in all necessary conversions.

$$\mathrm{Log}_{10}(\mathrm{NTU}) = 0.1517 + 0.533\mathrm{Log}_{10}(\mathrm{SC})$$

Or, conversely:

$$\mathrm{Log}_{10}(\mathrm{SC}) = -0.2846 + 1.8762\mathrm{Log}_{10}(\mathrm{NTU})$$

Where:

NTU = National Turbidity Units

SC = Sediment Concentration (mg/L)

Types of **downstream** *impact*

Four categories of *downstream* impacts of erosion, sedimentation and turbidity leading to cost increases to households, industry and infrastructure are identified:

- Sedimentation of reservoirs
- Impacts of sediments and turbidity on water treatment costs
- Costs of sediment clean-up by local government and road and rail operators
- Costs to navigation authorities.

Costs of replacing reservoir storage capacity

It is assumed that all dams are designed to cope with the sediment loads expected at the time of construction, and that capacity loss will be associated with any *increases* in sediment loads beyond the sedimentation design capacity. The recommended indicative damage cost function is:

$$C_R = 0.35 * \Delta SL$$

Where:

C_R = Cost of lost reservoir capacity ($)

0.35 = Average replacement cost per unit of reservoir capacity ($/cu.m): it is assumed that 1 cu.m. of sediment displaces 1 kL of storage capacity

ΔSL = Change in sediment load (cu.m/year), equal to streamflow (kL/yr) times the increase in sediment concentration (kg/cu.m.)

The coefficient 0.35 ($/unit of capacity lost) has been obtained from an analysis of data on the costs of dam/weir raising from Queensland.

The estimate given here should be reduced by a "bleed factor' where data is available, to allow for operator discharges of increased sediment loads below the dam or weir. Clearly, the estimate of costs of lost reservoir capacity applies only to existing dams or weirs. Data on dams and their capacities are available within the Audit database from Theme 1 studies.

Costs of additional water treatment

The costs of water treatment due to increased sedimentation/turbidity must be divided into three cost components:

- The “Base” capital costs of installing new water treatment plants where they were not previously needed. These costs depend on the size of plant, measured in terms of its capacity (annual throughput), and are calculated at the minimum sediment concentration. For Audit purposes, it can be assumed that a treatment plant needs to be installed if raw water quality exceeds a sediment concentration of 10mg/L, because at that level the National Water Quality Management Guideline value of 5 NTU’s (National Turbidity Units) is likely to be exceeded.
- An additional “marginal” capital component, which depends on the actual sediment concentration of the raw water.
- The operating costs for new or already-installed treatment plants

Base capital cost function for water treatment plants

Un-amortised capital cost function for a new plant (gives cost as a function of the treatment plant capacity):

$$\mathrm{Log}_{10}\,(CC_{TP})\_ \quad = \quad -1.4 + 0.611\ \mathrm{Log}_{10}\,(W)$$

Where:

CC_{TP} = Capital cost of a treatment plant ($ Million)

W = Water throughput (kL/d)

This cost function has been obtained by fitting a curve to the results of an engineering-type model of water treatment plant costs, with throughput being varied, but assuming a low level of sediment throughput.

Marginal capital cost function for raised sediment concentration

The marginal capital cost function adds an additional capital cost, which is due to the sediment concentration of influent. The indicative marginal capital cost function for a water treatment plant is:

$$M_{CC} \quad = \quad (W*365) \times (0.000222 + [0.000895 \times f(SC)])$$

$$F(SC) \quad = \quad 8.5/(1 + 2 \times e^{(-0.45SC)})$$

Where:

MCC = Marginal capital cost ($)

W = Capacity of the plant (daily throughput in kL)

SC = Sediment concentration of influent (mg/L)

This cost function has been obtained by fitting a logistic curve to the results of an engineering-type model of water treatment plant costs, using parameters for a medium-sized treatment plant, and varying the values for the sediment concentration of influent.

Water treatment plant operating cost function

For a new treatment plant that has to be constructed because of turbidity problems the total annual operating cost should be counted. An indicative order of magnitude for operating cost would be 0.5% of the capital cost.

For an existing treatment plant, the *marginal* operating cost attributable to increased dissolved organic carbon, based on the additional cost of alum, is:

$$M_{OC} = W*365 * 3.6164 * 10^{-6} DOC$$

Where:

MOC = Annual marginal treatment plant operating cost ($)

W = Capacity of the plant (daily throughput in kL)

DOC = Concentration of Dissolved Organic Carbon (mgL^{-1})

It is suggested that, as a default value, DOC can be taken as 20% of the influent sediment concentration. Thus the marginal operating cost function may be changed to:

$$M_{OC} = W* 365 * 0.72328* 10^{-6} (SC)$$

Where:

SC = Sediment concentration (mg/L)

If the capacity of treatment plants is not known, the total diverted stream flow may be substituted.

Cost function for costs to local governments

Queensland data were taken to reflect costs in regions where long term average river sediment concentrations are of the order of 250mg/L. Assuming a linear correlation between (i) costs to local government and (ii) river sediment concentration in the particular region, the implied cost per mg/L of sediments to local government is:

$0.02888/capita/yr/$mgL^{-1}$ sediment concentration in local rivers

Cost function for road and rail operators

Data on total costs were obtained for Victoria and South Australia. However, it was not possible to relate these to relative levels of soil erosivity. As a guideline value, it is suggested that costs of sedimentation to road and rail operators be taken a 50% of the costs to local authorities.

Costs to Navigation Authorities

Using the data reported in Zvirbulis (1994), and adjusting for year 2000 values, it is recommended that an indicative cost for navigation is:

> $20/cu.m of sediment load to restricted navigational channels

5.3 Results

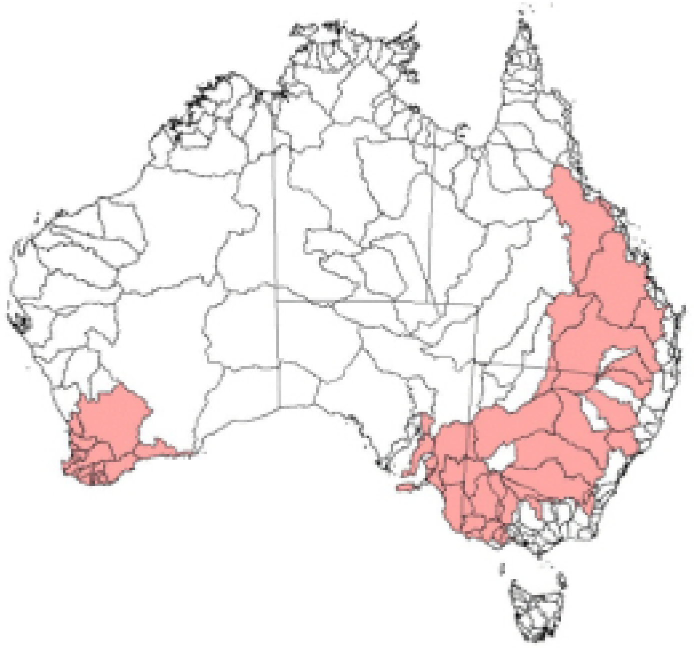
The water quality data assembled through the Audit is of variable quality and, hence, the estimates of downstream costs need to be treated with caution. An important recommendation arising is that estimates of damage costs being used by the Murray Darling Basin Commission be revised by amortising costs so that the estimates are consistent with economic theory.

The main differences between this and the previous GHD study are the use of

- standard economic amortisation procedures in this work rather than the straight line depreciation approach used by GHD;
- the use of updated water use data for Adelaide;
- the revision of cost estimates for industry.

Straight-line depreciation methods make no allowance for 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".
GHD (1999) estimated the costs of a 1 EC unit increase in the River Murray in South Australia to be between $93,000 and $142,000. If this annual cost is doubled, the range rises to between $186,000 and $284,000 per EC per year.

Net present values of downstream (or ex-situ) costs of degradation were determined for cost increases associated with salinity, erosion, sedimentation and turbidity. The costs calculated are for increases in these problems over the next 20 years (2000 to 2020) and are referred to as marginal costs, i.e. the costs associated with additional units of degradation. The precision of the estimates is limited by the extent of data on each of the water quality problems and the categories of the cost functions. There are many additional costs, both market and non-market, associated with these water quality problems that have not been measured due to lack of data availability or suitable costing functions, e.g. degraded drinking water quality or damage to wetland habitats. These costs have much societal significance and should be given consideration along with the economic cost estimates presented here.



Albany Coast (WA), Avoca (Vic), Avon (WA), Barwon (Vic), Blackwood (WA), Border Rivers (NSW), Border Rivers (QLD), Broken (Vic), Broughton (SA), Burdekin (QLD), Burnett (QLD), Busselton Coast (WA), Collie (WA), Condamine (NSW), Condamine-Culgoa (QLD), Darling River (NSW), Denmark (WA), Don (QLD), Donnelly (WA), Esperance Coast (WA), Fitzroy (QLD), Frankland (WA), Gawler (SA), Glenelg (Vic), Harvey (WA), Hopkins (Vic), Hunter River (NSW), Kangaroo Is (SA), Kent (WA), Lachlan River (NSW), Lk Corangamite (Vic), Loddon (Vic), Lower Murray (SA), Macquarie - Bogan Rivers (NSW), Mallee (SA), Mallee (NSW), Millicent (SA), Murray (WA), Murray Riverina (Vic), Murray Riverina (NSW), Murrumbidgee River (NSW), Myponga (SA), Namoi River (NSW), Onkaparinga (SA), Portland Coast (Vic), Preston (WA), River Murray Lock 9 upper pool (NSW), Shannon (WA), Swan Coast (WA), Torrens (SA), Warrego (NSW), Warren (WA), Willochra Creek (SA), Wimmera (Vic)

Figure 5.2 Drainage basins identified as “at risk” for river salinisation, based on available data. Estimates of saline water costs are derived from cost functions applied to these basins only.

Whilst the methodology identified a variety of options for deriving national figures on downstream infrastructure costs of degradation, the most reliable data was considered to be that derived from applying the cost functions to a selection of drainage basins identified as “at risk”. Those basins identified as at risk included (also shown in Figure 5.2):

- A number of Queensland basins in Division I, the North East Coast, that were identified in the Audit Dryland Salinity Assessment as likely to be affected by increasing dryland salinity.
- A number of basins in Division II, the South East Coast, where salinity is already a significant issue, including the Hunter Basin in New South Wales, the Latrobe Valley in Victoria, the Victorian coastal basins west of the Otways, and the Millicent Basin in South East of South Australia.
- All basins in Division IV, the Murray-Darling Basin, that had evidence of increasing trend in the publication by Williamson et al "*Salt Trends: Historical trend in salt concentration and saltload of streamflow in the Murray-Darling Basin*" (MDBC Dryland Technical Report No 1, 1997).
- All basins in Division V, the South Australian Gulf.
- All basins in Division VI, the south west of Western Australia (note, however, that current land use management policies will limit actual increases).

Two of the major input variables that control cost estimates are the discount rate and the percentage increase in severity of water quality problems. Low and high estimates are based on variations of the percentage increase in water quality problems, ranging from 1% to 20%. Table 5.5 to Table 5.8 summarise the data based on these ranges.

Table 5.5 National summary of downstream water degradation costs for four scenarios of water quality deterioration[1]

Water Parameter Increase	**1%**	**5%**	**10%**	**20%**
		$ millions		
Water Cost				
Salinity	102	511	1,021	2,042
Turbidity				
Upgrades to existing water treatment plants	614	614	614	614
Upgrades for specified increase in turbidity	8	41	81	155
Operating Cost impacts	12	60	119	238
Total Turbidity	634	715	814	1,007
Erosion and Sedimentation				
Reservoirs	6	28	55	110
Local Government, Road and Rail	33	33	33	33
Channels	4	18	35	71
Total Erosion & Sedimentation	42	78	123	214
Totals	778	1,304	1,959	3,264

1. Present value of costs over 20 year period, 2000 to 2020, in 1996/97 dollars at a discount rate of 5%.

With water parameter increases of 5% and below, the majority of costs are expected to come from turbidity. For rises in water quality parameters of 10% and above river salinity incurs most of the cost. For all scenarios, the data suggest that erosion and sedimentation costs will be relatively minor. However, the cost functions for salinity are more comprehensive than those for turbidity and, more so, sedimentation. The salinity cost functions cover a wide range of household and industrial impacts. Cost functions for turbidity and sedimentation are more limited in scope.

Some of the cost impact categories for turbidity and sedimentation are insensitive to variations in the percentage increase of water quality parameters. These include upgrades to existing water treatment plants and costs imposed on local government, road and rail operators. This results from the nature of the cost functions.

An upgrade to a water treatment plant occurs when a water quality threshold is reached. The threshold, set by National Water Quality Management Guidelines, is 50 mg/L of sediment. A sediment concentration above this level makes the water too turbid for potable use. Therefore, once this threshold is crossed the costs rise regardless of the quantum of the increase.

The cost functions for local government, road and rail operators were based on surveys of engineers and managers. These surveys did not produce data that were sufficient to relate a unit increase in sedimentation to a unit increase in cost. Rather, they provide single cost estimates as rates per kilometres of roads, or number of culverts etc, affected by sedimentation.

Table 5.6 Downstream water salinity costs by State/Territory for four scenarios of water salinity increase[1, 2, 3]

Increase in salinity	**1%**	**5%**	**10%**	**20%**
		$ millions		
Queensland	3	13	26	52
New South Wales	14	68	137	274
Victoria	4	20	39	79
South Australia	58	292	584	1,167
Western Australia	24	118	235	471
TOTAL	102	511	1,021	2,042

1. Expressed in 1996/97 dollars.
2. Present values were determined using a social discount rate of 5% over a 20 year period 2000 to 2020.
3. Data for Tasmania, Australian Capital Territory and Northern Territory are unavailable.

4. 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.

Under each scenario salinity increases are predicted to be greatest in South Australia followed by Western Australia. South Australia's costs largely result from Adelaide being a major water user of the Murray River, with known salinity problems predicted to increase over the next 20 years. For the States/Territories with data the lowest costs are predicted for Queensland.

Table 5.7 Downstream water turbidity costs by State/Territory for four scenarios of water turbidity increase[1, 2, 3]

Increase in turbidity	**1%**	**5%**	**10%**	**20%**
		$ millions		
Australian Capital Territory	7	8	9	10
Queensland	254	278	307	365
New South Wales	136	161	193	253
Victoria	109	122	137	166
South Australia	104	119	137	174
Western Australia	23	27	31	40
TOTAL	634	715	814	1,007

1. Expressed in 1996/97 dollars.
2. Present values were determined using a social discount rate of 5% over a 20-year period 2000 to 2020.
3. Data for Tasmania and Northern Territory are unavailable.

Turbidity cost increases are predicted to be greatest for Queensland. Much of these costs come from the Brisbane River Basin, which contains a high population and has significant issues of turbidity and sedimentation. The Audit's Australian Water Resources Assessment (NLWRA 2001) indicates that of Queensland's 69 river basins 11 have major, and 3 have significant, exceedances of turbidity water quality guidelines.

Erosion and sedimentation costs are significantly less than those estimated for turbidity and salinity. This partly arises from restrictions on the cost functions used for sedimentation. The sedimentation cost functions do not cover as many types of cost impacts and are less sensitive to variations in the water quality parameters compared to the other cost functions. As with turbidity, Queensland has the highest sedimentation costs with much of these coming from the Brisbane River.

Table 5.8 Downstream water erosion and sedimentation costs by State and Territory for four scenarios of water erosion and sedimentation increase [1, 2 and 3]

Increase in erosion and sedimentation	**1%**	**5%**	**10%**	**20%**
		$ millions		
Australian Capital Territory	0	0	1	1
Queensland	27	52	84	147
New South Wales	13	22	34	57
Victoria	1	3	4	7
South Australia	0	1	1	2
Western Australia	0	0	0	1
TOTAL	42	78	123	214

1. Expressed in 1996/97 dollars.
2. Present values were determined using a social discount rate of 5% over a 20-year period 2000 to 2020.
3. Data for Tasmania and Northern Territory are unavailable.

At a 5% increase in turbidity levels upgrades to existing water treatment plants will be the highest turbidity-related infrastructure cost item. The data available suggest that most of these costs will be incurred in Queensland and Western Australia will have the lowest costs associated with upgrading water treatment plants.

Table 5.9 Present value of cost increases for a five percent increase in turbidity over 20 years by infrastructure category (2000 to 2020) [1, 2, 3]

	Australian Capital Territory	**Queens-land**	**New South Wales**	**Victoria**	**South Australia**	**Western Australia**	**Total**
Existing water treatment plant upgrades	7	248	130	106	101	22	614
Upgrades for increases in turbidity	1	11	11	11	3	4	41
Operating cost impacts	0	19	21	4	15	1	60
Total turbidity cost	8	278	161	122	119	27	715
Turbidity cost in river basins showing an increasing trend in turbidity levels	0	0	40	4	64	0	108

1. Expressed in 1996/97 dollars.
2. Present values were determined using a social discount rate of 5%.
3. Data for Tasmania and Northern Territory are unavailable.

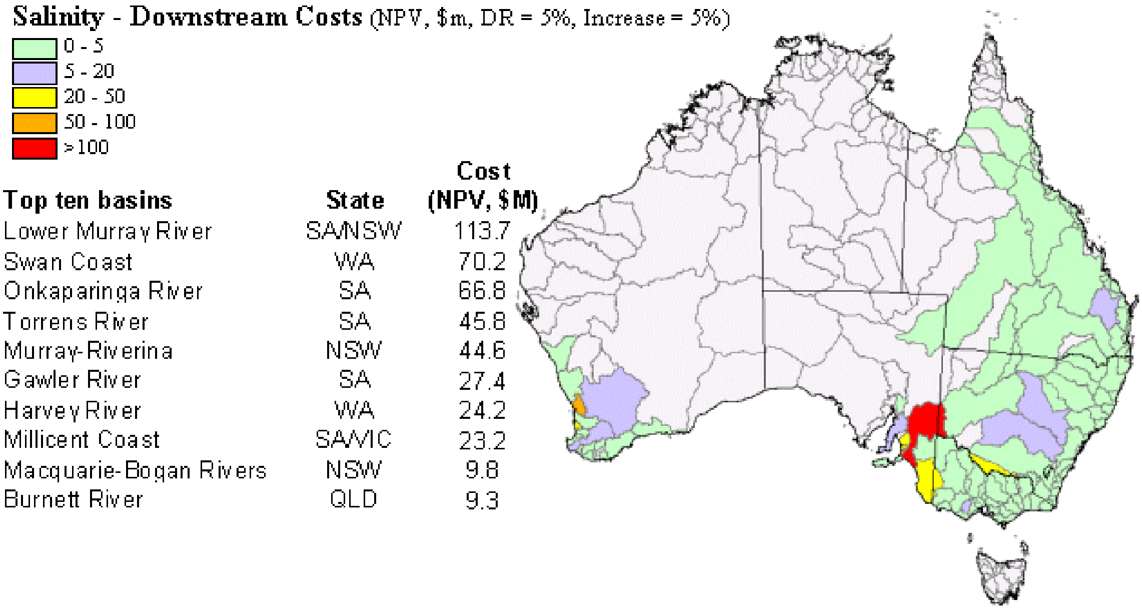
At a 5% increase in the water quality parameters, erosion and sedimentation costs are also predicted to be greatest in Queensland. In all States and Territories the erosion and sedimentation costs will be greatest to local government, road and rail operators.

Table 5.10 Present value of cost increases for a five percent increase in erosion and sedimentation over 20 years by infrastructure category (2000 to 2020)[1, 2, 3]

	Australian Capital Territory	Queens-land	New South Wales	Victoria	South Australia	Western Australia	Total
Reservoirs	0	19	7	1	0	0	28
Local Government, Road and Rail	0	21	11	1	0	0	33
Channels	-	13	4	0	0	-	18
Total Erosion & Sedimentation	0	52	22	3	1	0	78

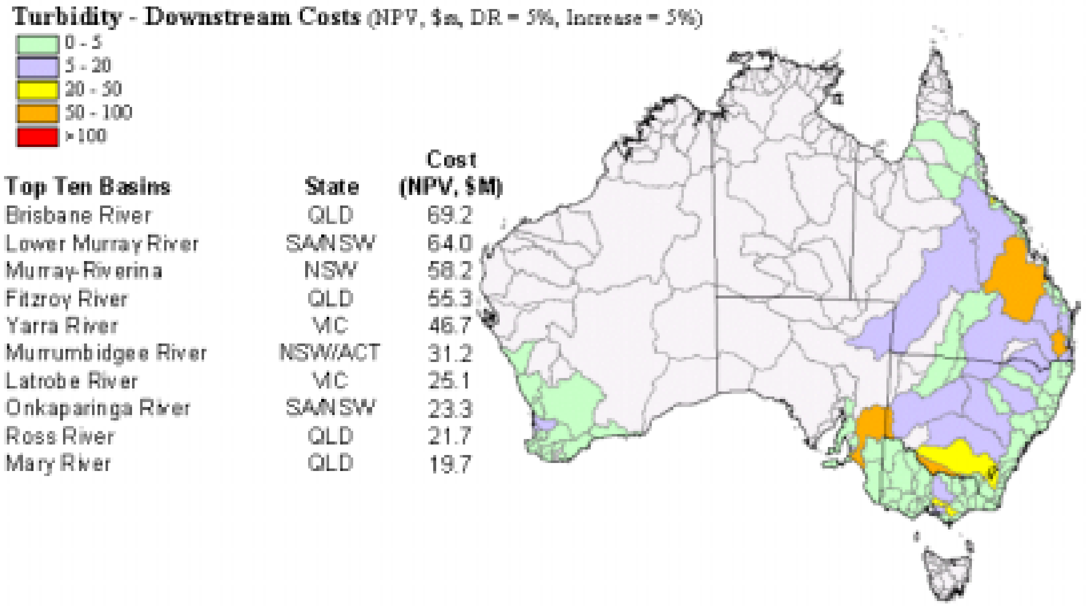
1. Expressed in 1996/97 dollars.
2. Present values were determined using a social discount rate of 5%.
3. Data for Tasmania and Northern Territory are unavailable.

Since the data were compiled for individual basins, it is possible to map the net present values of deteriorating water quality by drainage basin (see Figure 5.3 to Figure 5.6). It is worth noting that the extent of these maps is limited by the extent of data and not necessarily real problems of water quality degradation. The costs of the water quality degradation are limited to an area within the drainage basin, in other words costs in one basin are not assigned up stream to other basins.



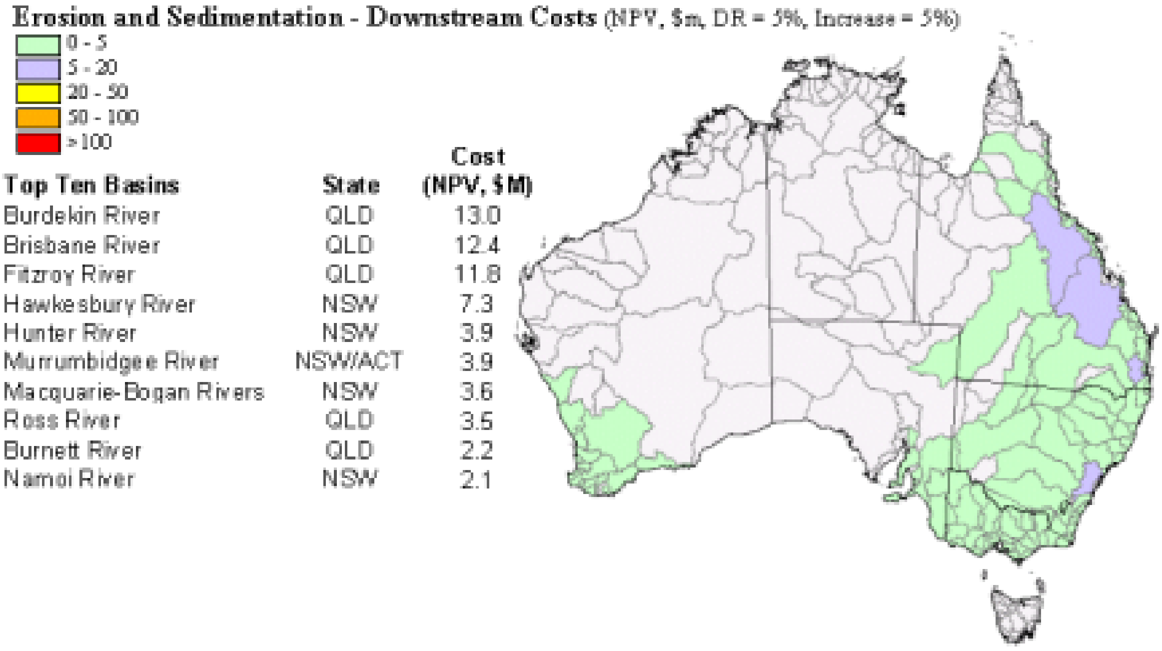
Top ten basins	State	Cost (NPV, $M)
Lower Murray River	SA/NSW	113.7
Swan Coast	WA	70.2
Onkaparinga River	SA	66.8
Torrens River	SA	45.8
Murray-Riverina	NSW	44.6
Gawler River	SA	27.4
Harvey River	WA	24.2
Millicent Coast	SA/VIC	23.2
Macquarie-Bogan Rivers	NSW	9.8
Burnett River	QLD	9.3

Figure 5.3 Downstream costs of saline water



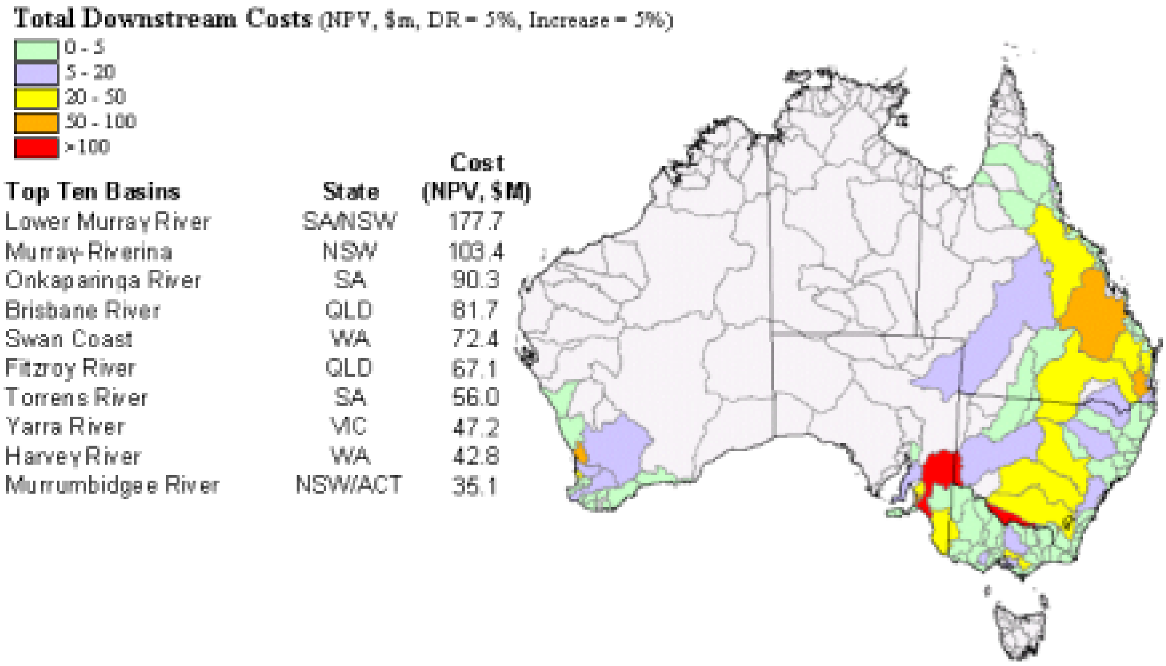
Top Ten Basins	State	Cost (NPV, $M)
Brisbane River	QLD	69.2
Lower Murray River	SA/NSW	64.0
Murray-Riverina	NSW	58.2
Fitzroy River	QLD	55.3
Yarra River	VIC	46.7
Murrumbidgee River	NSW/ACT	31.2
Latrobe River	VIC	25.1
Onkaparinga River	SA/NSW	23.3
Ross River	QLD	21.7
Mary River	QLD	19.7

Figure 5.4 Downstream costs of water turbidity.



Top Ten Basins	State	Cost (NPV, $M)
Burdekin River	QLD	13.0
Brisbane River	QLD	12.4
Fitzroy River	QLD	11.8
Hawkesbury River	NSW	7.3
Hunter River	NSW	3.9
Murrumbidgee River	NSW/ACT	3.9
Macquarie-Bogan Rivers	NSW	3.6
Ross River	QLD	3.5
Burnett River	QLD	2.2
Namoi River	NSW	2.1

Figure 5.5 Downstream costs of erosion and sedimentation



Top Ten Basins	State	Cost (NPV, $M)
Lower Murray River	SA/NSW	177.7
Murray-Riverina	NSW	103.4
Onkaparinga River	SA	90.3
Brisbane River	QLD	81.7
Swan Coast	WA	72.4
Fitzroy River	QLD	67.1
Torrens River	SA	56.0
Yarra River	VIC	47.2
Harvey River	WA	42.8
Murrumbidgee River	NSW/ACT	35.1

Figure 5.6 Total downstream costs salinity, turbidity, erosion and sedimentation

5.3.1 Scenarios for Salt Load Increases

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 (MDBC 1999). 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 and the majority of salinity costs would be assigned to problems of deteriorating water quality.

5.4 Uses and Extensions of the Data

In this report, we have focused on impact costs that occur beyond the farm gate. The revised estimate of impact costs per EC on urban households and industry is much higher than previous estimates. This is due to the introduction of amortisation and the revision of key assumptions. Changes of this magnitude made in this report, 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.

6 Estimating Non-market Values

Martin van Bruenen and Jeff Bennett

6.1 Synopsis

This chapter provides a summary of a non-market valuation study[9] undertaken by Martin van Bueren and Jeff Bennett of Unisearch. The study aimed to estimate non-market values associated with possible changes to the way Australia's land and water resources are used.

The technique used to estimate these values was Choice Modelling, a "stated preference" method by which a sample of people are asked to make choices between alternative future resource management options. Detailed information on the choice modelling technique and process of non-market valuation in this study is available in appendix I.

Through a series of workshops, the environmental and social attributes found to be most important to people in selecting between potential resource management options were:

- The number of species protected;
- The aesthetics of repairing farmland and protecting bush;
- The length of waterways restored for fishing or swimming; and
- The net loss of people from country towns each year.

The results of the national questionnaire demonstrate that respondent households, drawn from the national population, value improvements in each of the environmental attributes and perceive rural depopulation as a cost. The following attribute prices were estimated:

- 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;

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[9] The study is reported in full in van Bueren and Bennett (2000). Readers are advised strongly to read this report before attempting to use the estimates summarised here.

- 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 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

produces an aggregate welfare benefit of $3.1 to 6.3 billion in present value terms, or a best-bet value of $4.6 billion. However, if the same environmental improvements could be achieved while reversing the decline in rural communities by 10,000 people per year, the best estimate increases to $6.7 billion.

It was recognised that people living in different regions may have different values for different contexts of land and water degradation. To understand these differences, separate but otherwise identical choice modelling applications were carried out in Brisbane, Perth, Albany, Rockhampton and nationally, for cases of degradation involving the Fitzroy Basin Region (QLD), the Great Southern Region (WA) and the whole nation. As a result, a procedure was developed for transferring nationally derived value estimates to regions.

The study reveals that the estimated implicit prices vary across different population samples and geographic contexts. In particular, unit values for policies that involve regional changes were found to be significantly larger than the unit values estimated for changes in the national context. Hence, attribute implicit prices derived from the national questionnaire must be scaled up if they are to be used as a source of estimates for transfer to a regional context. The size of these adjustments are reported below.

6.2 Study objectives and scope

6.2.1 Overarching goal

Land and water degradation in Australia imposes a range of impacts on the environment and rural communities. Some of these impacts are 'non-market' in nature, meaning that they are not exchanged in markets. For instance, endangered species of plants and animals that may be harmed by land and water degradation are not bought and sold. While it is generally acknowledged that such non-market goods and services are important and valued by the Australian community, there is relatively little information on the magnitude of the values. Furthermore, little is known about:

- the values associated with specific attributes of the environment; and
- the variability of values held by different communities in different policy contexts.

Without this basic information it is difficult to evaluate the environmental and social impacts of alternative public investment strategies for addressing land and water degradation. If such non-market values are omitted from consideration or not adequately taken into account, it is likely that too much land and water resource degradation will occur and that public expenditure to correct the degradation will be misdirected.

Hence, this non-market valuation study is aimed at estimating dollar values for a range of environmental and social attributes of land and water degradation. These can be used to facilitate cost-benefit analyses of alternative resource management options. The non-market values of resource degradation are measured by estimating community willingness to pay for options that involve environmental and social changes relative to a 'business as usual' outcome.

6.2.2 Identification of attributes

The fundamental building blocks of this non-market valuation study are a number of selected environmental and social attributes of land and water degradation. These attributes were selected to reflect the non-market outcomes of alternative resource management policies. The attributes were designed to capture both the use and non-use elements of non-market values. People derive use values from activities such as outdoor recreation and the passive enjoyment of scenic beauty, while non-use values accrue in the absence of any tangible, current interaction with the environment. For example, people may benefit from knowing that a natural area exists in a 'healthy' state even if they never intend to visit the area. Similarly, a non-use benefit may stem from the knowledge that rural communities are viable.

The attributes of interest to this study are those which are not marketed. For example, while water degradation causes costs to the community in the form of machinery and pipe corrosion, agricultural production losses, and possibly higher prices for household water, all these values can be inferred from market information. These marketed aspects of water quality are outside the scope of this study. Attention here is focused on the non-marketed environmental and social attributes that are affected by degradation such as natural bushland areas, native species, recreation opportunities, and rural community viability.

6.2.3 Transferability of attribute values

Whilst the overarching goal of the non-market valuation study is the estimation of values for multiple attributes in the national context, it also has the goal of determining the extent to which the national estimates can be 'transferred' to different regions and communities within Australia. The practice of benefit transfer, as it has come to be known, is not new. However, few studies have examined rigorously the validity of using value estimates from a source study to inform policy that is targeted at a different geographic region and/or community. While the concept of benefit transfer is appealing, it can lead to significant errors if the source values obtained from a pre-existing study are context-dependent and that context does not match the conditions which prevail at the target area of interest (Brouwer, 2000). Consequently, this study is also aimed at developing an understanding of how value estimates vary under different contexts, so that an appropriate procedure can be devised for undertaking benefit transfer.

To achieve this aim, a research design was used in the study to 'control' for two main elements of context: The frame of reference and the population of people whose values are being estimated. Tests are conducted to examine how value estimates vary between different combinations of frame and population. These tests are used to develop a set of guidelines that outline a procedure for selecting and applying value estimates that are appropriate for the policy issue under investigation.

Important framing factors include the scale of attribute impacts, the number of attributes affected by the policy, and the geographic location of the impacts. In this non-market valuation study, two different frames of reference are developed: A national frame, which involves Australia-wide impacts, and a regional frame that involves localised impacts. Population factors include socio-economic characteristics, attitudes and social norms. The influence of these factors was tested by surveying households from a number of different communities.

6.3 Analytical technique

6.3.1 Non-market valuation techniques

The task of estimating values for non-marketed, environmental and social impacts is challenging because market price and demand information is not available. Instead, specifically designed non-market valuation techniques must be used to estimate community preferences and values. A variety of non-market valuation methods have been developed for estimating the amount an individual is willing to pay for improvements in environmental or social outcomes[10].

There are two categories of non-market valuation techniques: Revealed preference and stated preference methods. The former uses observations of people's behaviour to infer values for environmental goods. Examples include visits to recreation sites (the travel cost method) or the selection of residential locations in close proximity to scenic views (the hedonic price technique). While revealed preference techniques are useful for estimating use values, they cannot be used to estimate non-use values and are limited to valuing existing outcomes or attribute levels. Stated preference techniques do not suffer from these limitations because they involve a sample of people being asked about their preferences for hypothetical outcomes. The added flexibility of these techniques allows both use and non-use values to be estimated for existing or proposed policy outcomes.

The family of stated preference techniques include Contingent Valuation, Conjoint Analysis, and Choice Modelling. The Contingent Valuation (CV) technique involves asking a sample of respondents how much they are willing to pay to prevent or obtain a specified environmental outcome. Applications of this technique are usually limited to an examination of one or two resource use options. Conjoint Analysis requires respondents to rank or rate alternative options rather than nominate a specific payment amount or make a discrete choice between alternatives. The technique has been applied to environmental valuation but it suffers a number of weaknesses, which are outlined in Morrison *et al.* (1996). Choice Modelling involves a sample of people being asked to choose between alternative resource use options. The choices made enable the estimation of respondent values for the attributes used to describe the alternatives. Choice Modelling (CM) was selected as the preferred method for this study.

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[10] These methods produce marginal values because they concentrate on the value of incremental changes in the level of an outcome.

CV and CM can also be used to estimate people's willingness to accept compensation for an adverse environmental outcome. In this non-market valuation study only willingness to pay to achieve an environmental improvement is estimated. In willingness to accept studies the baseline proposition is that people have a prior right to the proposed environmental outcome and should be compensated financially if it is proposed to vary that social contract. In willingness to pay studies respondents are asked how much money they are willing to pay to secure an environmental improvement.

6.3.2 What is choice modelling?

Choice modelling was the chosen technique for this study. In a CM application, respondents are presented with a series of questions, each containing a set of options known as a choice set. Typically, five to eight choice sets are included in a questionnaire. In each choice set, respondents are asked to choose their preferred option from a range of alternatives. The options can be viewed as separate management policies, the outcomes of which are described in terms of a standard set of attributes or characteristics. The options are differentiated from one another by the levels assigned to the attributes. An experimental design is used to ensure that the range of alternative options presented to respondents in the choice sets is adequate. See Volume 2 of this report for further details about experimental design.

Each choice set includes a 'business as usual' option that describes the outcome associated with a 'no change' policy. It serves as a base against which respondents' willingness to make trade-offs in securing change can be measured. The other options are deviations from the no change policy. The choices made by respondents enable the estimation of the relationship between respondents' choices, the levels of the attributes describing the choice outcomes, and the socio-economic characteristics of the respondents. This 'model' of choice allows the analyst to estimate the extent to which individuals are prepared to trade-off one attribute against another. Provided one of the attributes is measured in dollar terms (eg a tax, levy, or entry fee), it is possible to estimate the amount of money people are prepared to pay for improving a non-monetary attribute by one unit. This value is known as the implicit price of the attribute.

In addition to implicit prices, the CM technique enables welfare impacts to be estimated for various changes in resource use scenarios. Valuation is not restricted to the set of scenarios presented in the questionnaire. Rather, the costs or benefits associated with a whole range of scenarios of change away from the 'business as usual' case can be calculated once the model of respondent choice has been estimated. The CM application need only employ a range of attribute levels sufficient to cover the range of scenarios that are of interest.

Choice Modelling has a number of potential strengths over the other stated preference techniques (Box 6.1). It is particularly suited to the role of providing value estimates that can act as a source of data for the benefit transfer process. This is because it enables better control over the way impacts are framed and allows the total value of a resource use change to be broken down into its component attribute values. For these reasons, CM was used in this study.

Box 6.1 Strengths of Choice Modelling

Forces respondents to consider trade-offs between attributes.

- Makes the policy frame explicit to respondents via the inclusion of an array of options.
- Enables implicit prices to be estimated for individual attributes.
- Enables welfare impacts to be estimated for multiple scenarios.
- Can be used to estimate the level of community support for alternative scenarios in non-monetary terms.
- The contribution of each attribute to the total value of a resource use change can be estimated, which facilitates benefit transfer.
- Potentially reduces the incentive for respondents to behave strategically.

6.4 Attribute selection

A survey of resource managers and researchers was conducted to establish a list of attributes considered important by those with experience in formulating policy. This list served as a starting point for discussions with members of the public in structured focus groups. A total of seven focus group meetings were held in city and regional centres, with an average of ten persons per group. The services of market research firms were contracted to recruit participants from a cross section of socio-economic and occupational backgrounds. This consultation revealed that people have five main environmental and social concerns related to land and water degradation:

- Native species and ecosystem functioning
- Landscape aesthetics
- Outdoor recreation opportunities
- Productivity of the land and quality of drinking water
- Viability of country communities.

These concerns were consistent across most of the focus groups, albeit with differing degrees of emphasis depending on geographical location. A clear result from this initial scoping phase was that people hold both use and non-use values. For example, landscape aesthetics, recreation, and productivity all represent use value. Concerns about native species and the viability of rural townships reflect non-use values.

The survey of resource managers and researchers revealed that policy makers ‘think’ of degradation impacts in terms of processes rather than biophysical outcomes. They tended to describe impacts in terms of the area of land affected by salinity, the intensity of weed infestation or the severity of soil loss. This differs from the perspective of the general community, who tend to be more concerned about the impacts that these processes have on ‘goods and services’ that matter to them, such as the opportunity to go fishing or the enjoyment of walking in a forest. While the attributes of land and water degradation could be defined either in terms of processes or biophysical impacts, the latter approach was adopted because biophysical impacts are ‘what matter’ to the general community. Furthermore, defining attributes in this way enabled different types of degradation processes occurring in various regions to be adequately described.

Another aspect of attribute selection is the issue of causality. Attributes are said to be causally related if a change in the level of one attribute is viewed, by respondents, to cause a change in the level of other ‘downstream’ attributes. Causal attributes complicate the modelling of choice behaviour because there is evidence that these attributes depress the values estimated for downstream attributes (Blamey, et *al.* 1998). In this non-market valuation study, efforts were made to minimise causality by selecting attributes that are distinctly separate.

The four attributes that were selected for the questionnaire include; *Species Protection*, *Landscape Aesthetics*, *Waterway Health*, and *Social Impact*. The unit of measurement for each attribute is defined in Table 6.1. Production-related effects of land and water degradation were omitted from the questionnaire because the purpose of the study was to estimate non-market values. The *Social Impact* attribute was included to 'force' respondents to consider the social dimensions of conservation policies, some of which may lead to a reduction in the viability of country communities. Use values are captured in the *Waterway Health* and the *Landscape Aesthetics* attributes, while non-use values are captured in the *Species Protection* and *Social Impact* attributes.

Table 6.1 Environmental and social attributes selected for the choice modelling questionnaire

Attribute	Unit of measurement
Species protection	The number of native species protected from extinction.
Landscape Aesthetics	The area of farmland repaired or bushland protected (ha)*
Waterway Health	The length of waterways restored for fishing or swimming (km).
Social Impact	The net loss of people from country towns each year.

* Different definitions of landscape aesthetics were used in the national and regional surveys. In the Great Southern region of Western Australia people were asked about willingness to pay for farmland repair; in the Fitzroy Basin people were asked about willingness to pay for bushland protected; and in the national survey, people were asked about willingness to pay for bushland protected or farmland repaired. These variations were necessary to reflect the differing resource status of each case study area.

6.5 The survey

6.5.1 Application of choice modelling in this study

The choices presented to respondents in this study represent the outcomes of alternative land and water management options, expressed in terms of the levels of attributes that are expected to occur 20 years from today, above and beyond current environmental programs. The options presented to respondents in the choice sets were generic, meaning that they were not ascribed a label to indicate the type of management practices underpinning the outcomes. Labels were omitted because previous research has shown that labels can prompt respondents to trivialise the attributes when making their choice, thereby reducing the statistical explanatory power of the attributes in the choice model (Blamey *et al.* 1999). This would have been undesirable for this study where the objective was to estimate attribute values for the purposes of benefit transfer.

The choice task was introduced to respondents by explaining that public money is currently being spent on a wide range of environmental projects and that this level of action would result in a specific set of future outcomes. Respondents were told that additional investment would be required to secure an improvement above this business as usual scenario. An environmental levy on households was proposed as a means of funding this extra action. The questionnaire introduced the concept of a household levy to be paid each year for the next 20 years. A specific level of payment was associated with each choice option, being zero for the business as usual scenario and $20 to $200 for the ‘change’ options.

The attribute levels associated with each option, including the business as usual scenario, were expressed relative to a benchmark, namely a ‘do nothing’ scenario. Under this scenario, even the current level of resource remediation would not be undertaken. In Figure 6.2, an example is given for the *Species Protection* attribute.

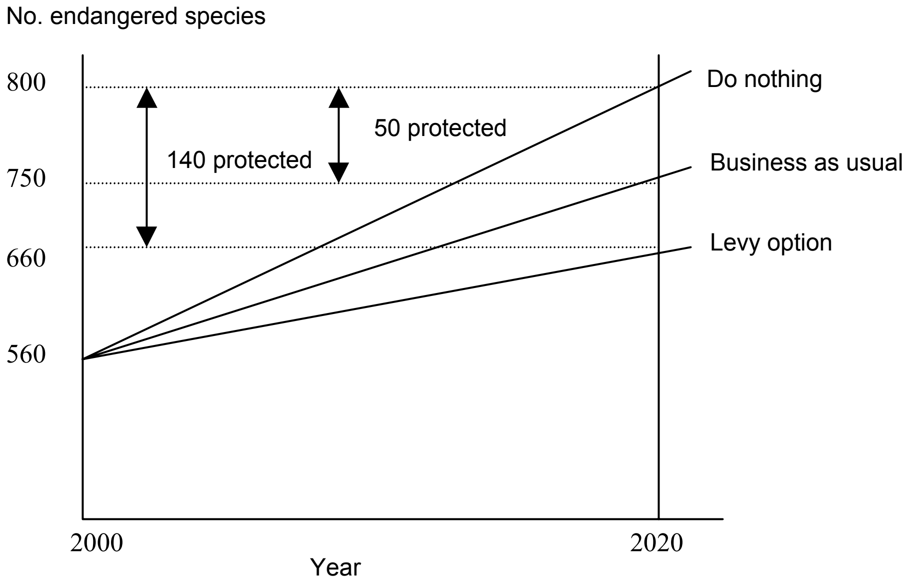


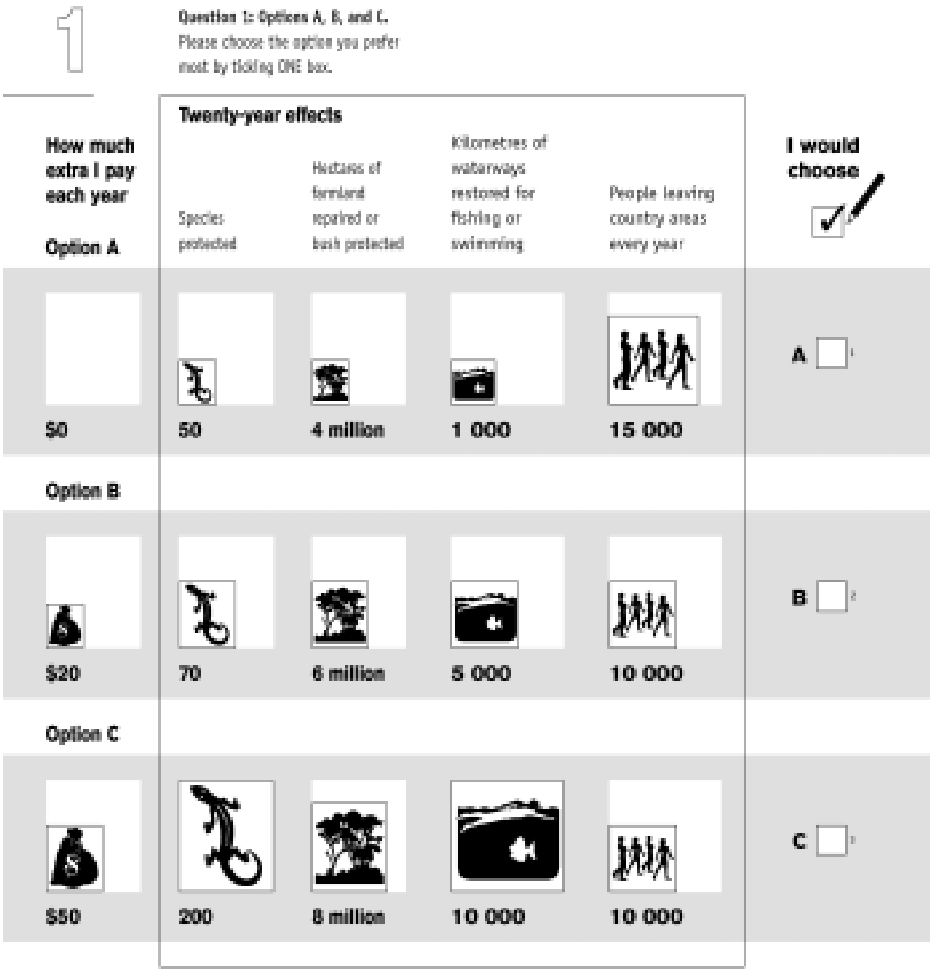
Figure 6.1 An example of policy outcomes for the *Species protection* attribute.

6.5.2 Choice set design

The questionnaire consisted of five choice sets with three alternatives per choice set. The alternatives included a 'business as usual' option (Option A) and two different 'change' options (Options B and C). The change options were generated by combining attribute levels systematically according to a fractional factorial experimental design. Three levels were assigned to each attribute, the upper and lower levels being chosen so as to encompass the range of potential outcomes that could eventuate from alternative policies. Stylised pictures, or icons, were used in the choice sets to represent each attribute and the size of the icons were scaled in approximate proportion to the attribute levels. The levels were also depicted in numerical form below each icon. An example of a choice set used in the questionnaire is given in Figure 6.2.

6.5.3 Supplementary questions and information

A pamphlet containing background information was provided with the questionnaire to assist respondents with their deliberations. The pamphlet contained information about the survey and an explanation of the attributes and their current levels. A copy of the pamphlet is contained in van Bueren and Bennett (2000).



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Question 1: Options A, B, and C.
Please choose the option you prefer most by ticking ONE box.

		Twenty-year effects				
	How much extra I pay each year	Species protected	Hectares of farmland repaired or bush protected	Kilometres of waterways restored for fishing or swimming	People leaving country areas every year	I would choose ☑
Option A	$0	50	4 million	1 000	15 000	A ☐ 1
Option B	$20	70	6 million	5 000	10 000	B ☐ 2
Option C	$50	200	8 million	10 000	10 000	C ☐ 3

Figure 6.2 Example choice set

In addition to the choice set questions, respondents were asked a number of 'follow-up' questions that were designed to explore the motivations behind respondents' choices. The questions sought to detect whether respondents were protesting against the levy proposal or whether they were displaying 'free-riding' behaviour. Some of the questions were designed to check whether respondents were confused by the choice task, perceived bias in the questionnaire, and whether the options were perceived to be plausible. In the survey, no questions were asked to determine how many people consider that existing land and water users have a duty to meet part or all of the costs of restoration and protection. Similarly, no questions were asked about the manner in which existing tax revenues should be spent.[11] What is estimated is the value of additional projects that could be funded if a levy was introduced. Care must be taken to avoid confusing these estimates with those associated with the value of existing environmental and social welfare programs.

A final set of questions was devoted to collecting socio-economic data (age, sex, educational status, income, etc.) and information regarding the respondents' attitudes toward the environment. This information was used as an input into the modelling phase of the study and to cross check the validity of the value estimates. The data also served as a means of checking whether the sample was representative of the population of interest.

6.5.4 Research design

In order to test the effects of frame and population, separate versions of the CM questionnaire were developed for two case-study regions, the Fitzroy Basin Region (FBR) in Central Queensland and the Great Southern Region (GSR) in Western Australia. The regional questionnaires were identical in every respect to the national version (same attributes and question format) with the exception that:

- the levels of the social and environmental attributes were varied to reflect the conditions that prevail in each region (the range of levels used for the monetary attribute were the same across all versions); and
- the background information accompanying each questionnaire version was tailored to reflect the issues and policies that are pertinent to each study area.

The case-study questionnaires were issued to households living in the vicinity of each region. Two population sub-samples were drawn for each case-study region, one from the region's main population centre and the other from the region's state capital city population. The main population centres for the GSR and FBR are Albany and Rockhampton respectively. The capital cities are Perth and Brisbane respectively. The overall framing and sampling strategy is shown in Table 6.2. This research design allowed an investigation of seven different combinations of frame and population. These are indicated by the ticks in Table 6.2.

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[11] This issue, however, was explored in the focus group meetings. For information on these see van Bueren and Bennett (2000)

Table 6.2 The framing and sampling strategy

		POPULATION				
		Regional sample		Capital city sample		National sample
		Rockhampton	Albany	Brisbane	Perth	National
FRAME	Fitzroy Basin	✓		✓		
	Great Southern		✓		✓	
	National	✓	✓			✓

6.5.5 Case-study regions

The location of the case-study regions is shown in Figure 6.3. The Great Southern Region of Western Australia (GSR) comprises an area of 8.3 million hectares, and the Fitzroy Basin of Central Queensland (FBR) comprises 14.3 million hectares.

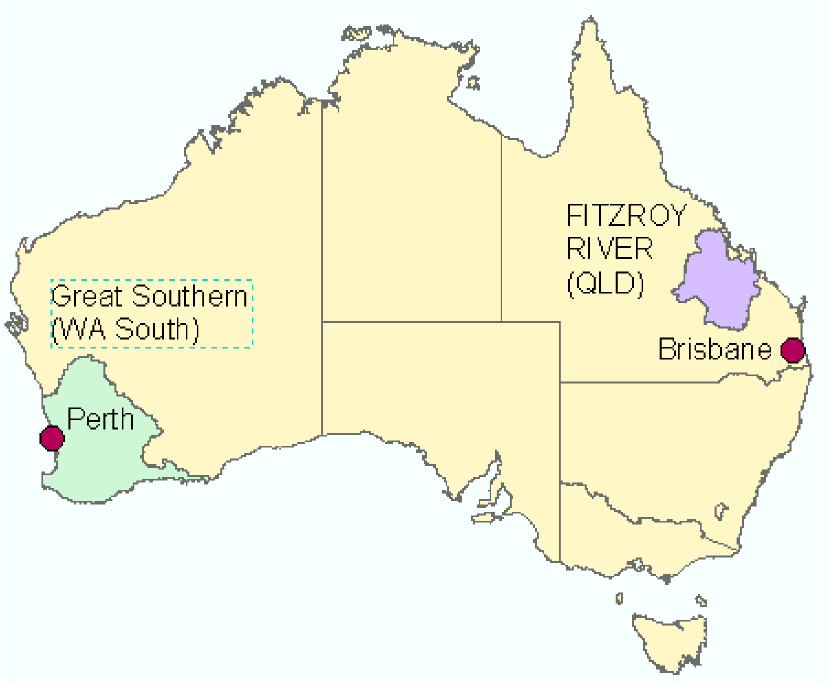

Figure 6.3 Location of case-study regions and capital cities corresponding to each region.

The degradation issues in each of the regions are markedly different. Over 90 per cent of original vegetation in the GSR has been cleared for agriculture. Dryland salinity is now emerging as a prominent problem, with approximately ten per cent land area salt-affected. In contrast, the FBR is still undergoing development and over 20 per cent of the region's native vegetation remains intact. Whilst degradation is less advanced in this region, some ecosystem types are not protected from clearing and concerns have been expressed about the pollution of waterways by agricultural activities (Queensland SOE Report, 1999).

In addition to these physical differences between the two regions, there is evidence to suggest that Queenslanders have different attitudes towards the environment to Western Australians (ABS, 1999). Thus, the case studies provide a means of testing the transferability of the national estimates over a wide range of circumstances.

6.5.6 Survey logistics

The questionnaire was pre-tested over two days using a door-to-door, drop off and pick up delivery method. Twenty-five households were selected for the pre-test. Households from a broad range of socio-economic strata were included in the pre-test sample. Only minor modifications were made to the questionnaire following the pre-testing phase as debriefs with the respondent households did not reveal any significant communication problems.

A market research firm (Barbara Davis and Associates) was contracted to administer the main questionnaire as a mail-out mail-back survey. A random sample of households was drawn from "Australia on Disk," a telephone directory based data base of the Australian population. The size of the total sample was 10,800 households, comprising a main national sample and smaller samples for each case-study region (Table 6.3).

Table 6.3 Sample sizes

	Questionnaire Frame		
	National	Great Southern	Fitzroy Basin
Population sample			
National	3200	-	-
Albany	1200	1200	-
Rockhampton	1200	-	1200
Perth	-	1400	-
Brisbane	-		1400

6.5.7 Response rate and description of data

The overall response rate to the survey was 16 per cent, which equated to 1569 completed questionnaires. This response rate is net of the questionnaires that were undeliverable due to outdated address details[12]. Within the national sample there was a large degree of variation in response rate across the States (Table 6.4). Owing to the small sample size for some States, not all the differences are statistically significant. However, the response from the ACT sample was significantly higher than that of NSW and WA.

Of those respondents who completed a questionnaire, the majority (89 per cent) answered all five choice sets, while a small proportion (8 per cent) only answered a subset of the five choice set questions. Three per cent of respondents failed to complete any of the choice sets. A majority (80 per cent) of respondents who answered all the choice questions opted for a levy option in at least one of the choice sets. The remaining 20 per cent consistently selected the business as usual (no levy) option.

Table 6.4 Response rate for the national sample, by State and Territory.

State or Territory	Total mailout	Delivered	Completed	Response rate
	No.	No.	No.	%
NT	20	16	2	13
ACT	54	47	13	28
TAS	73	67	11	16
SA	266	246	50	20
WA	307	264	35	13
Qld.	592	534	95	18
Vic.	800	719	131	18
NSW	1088	944	153	16
	3200	**2837**	**490**	**17**

A summary of key socio-economic characteristics for each of the five samples is contained in Table 6.5. The proportion of respondents with pro-environment sentiment (measured by whether or not an individual donates money to a conservation group or is a member of such an organisation) differs considerably across the samples. Proportions range from 13 per cent for Rockhampton up to 27 per cent for Albany. There is evidence to suggest that this level of commitment to the environment exceeds the national average. Whilst directly comparable statistics are not available, the Australian Bureau of Statistics has estimated that only nine per cent of Australians rank environmental problems as their top social issue (ABS,

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[12] This accounted for approximately 10 per cent of mail-outs.

1999). The Australian Conservation Foundation estimates that five per cent of the national population belong to at least one environmental organisation (M. Fogarty pers. comm. 2000). Therefore, the survey appears to have self-selected for respondents with a pro-environment disposition. Further details about self-selection and correction mechanisms are provided in van Bueren and Bennett (2000).

Table 6.5 Selected socio-economic characteristics of the samples

	National	Perth	Brisbane	Albany	Rock'n
Modal income category	$36,400-51,999	$52,000-77,999	$36,400-51,999	$6239-15,599	$6239-15,599
Modal education category (highest qualification)	Tertiary degree	Tertiary degree	Tertiary degree	Diploma / certificate	Tertiary degree
Modal age group	45-54	45-54	35-44	65 +	35-44
% supporting green group(s)	24%	22%	22%	27%	13%
Male to female ratio	1.6 to 1	1.5 to 1	1.8 to 1	1.3 to 1	1.3 to1
Sample size	490	217	170	356	336

6.6 Community values in the national context

The results presented here relate to the national questionnaire in which respondents were asked to make choices between policy outcomes that have an impact at a national level. Two types of value estimates are provided: Implicit prices and welfare impacts per household.

Attribute implicit prices are a measure of the willingness of respondents to trade-off household income to secure a single unit increase in a particular environmental or social attribute. Implicit price estimates are most useful when assessing the non-market impact of policies that have single-attribute outcomes. If a management policy is expected to affect the levels of multiple attributes, then an approximation of the benefit generated can be obtained by aggregating the implicit prices of all the attributes affected.

However in such circumstances, particularly when the changes in attributes are relatively large, more accurate estimates of changes in welfare can be achieved using the full choice model. This welfare measure is known as 'compensating surplus' and represents the total value of a change in the levels of multiple attributes away from the business as usual scenario. Use of the full choice model incorporates the impacts of the attributes, as well as the factors influencing choice that have not been defined in the choice sets. In other words, the implicit prices of the attributes alone do not account for the total compensating surplus.

Attribute implicit prices

Implicit price estimates for each of the attributes are summarised in Table 6.1. The estimates from the national sample of respondents, comprising 68 per cent metropolitan city households, are compared with the values held by households sampled from the regional centres of Rockhampton and Albany. Across all samples, the environmental attributes have positive implicit prices, whilst negative values are estimated for the social impact of increases in the number of people leaving country communities, indicating that population decline in country areas is perceived as a cost.

For the national sample, respondent households are willing to pay, on average, 68 cents per annum over the next 20 years for every species that is protected from extinction. The value of Landscape Aesthetics is estimated to be 7 cents per 10,000 hectares of bushland protected or farmland restored, while a similar amount (8 cents) is estimated to be the value for every 10 kilometres of waterway restored. A negative implicit price of 9 cents is estimated for every 10 people leaving country communities.

Table 6.6 Implicit prices estimated for attributes in the national context

	Species protection	Landscape Aesthetics	Waterway Health	Social Impact
	$ per species protected	*$ per 10,000 ha restored*	*$ per 10 km restored*	*$ per 10 persons leaving*
National sample				
Lower estimate	0.47	0.02	0.04	-0.11
Best estimate	0.68	0.07	0.08	-0.09
Upper estimate	0.88	0.14	0.16	-0.07
Albany sample				
Lower estimate	-0.03	0.14	0.00	-0.14
Best estimate	0.27	0.21	0.00	-0.11
Upper estimate	0.51	0.29	0.00	-0.08
Rockhampton sample				
Lower estimate	0.03	0.12	0.01	-0.09
Best estimate	0.28	0.20	0.07	-0.06
Upper estimate	0.58	0.30	0.14	-0.08

The implicit price estimates assume non-diminishing values for additional improvements in attribute levels. While a non-linear relationship would be expected, at least beyond a certain level of improvement, transforming the data to allow for non-linearity did not improve the model fit. Therefore, it is concluded that implicit prices are constant for changes in the attributes over the range of levels used in the choice sets.

The values held by Albany and Rockhampton respondents are of a similar order of magnitude but some differences are evident. Differences that are statistically significant include:

- Species Protection (more highly valued by the national sample of households compared to the regional samples); and
- Landscape Aesthetics (more highly valued by regional respondents than the national sample).

Given that the national sample comprises a majority of households from metropolitan city areas, these differences could indicate that city dwellers place a higher weighting on species protection (a non-use value) relative to country dwellers and a lower weighting on Landscape Aesthetics.

Welfare impacts

The choice model was used to estimate the welfare impacts (compensating surpluses) of four alternative resource use scenarios. The impacts are measured relative to a fifth scenario; the 'business as usual' option. The four change scenarios are indicative of the twenty-year outcomes that could eventuate under alternative management regimes (Table 6.7). This analysis demonstrates how the choice model can be used to estimate the benefits of environmental and/or social improvements (benefits gross of the costs of implementing the changes). Results of the analysis are summarised in Table 6.8 and are described below.

Table 6.7 Four hypothetical scenarios developed to demonstrate ways that the choice model could be used to estimate the welfare impacts of changes away from the business as usual scenario

Attributes	Business as usual Scenario	Biodiversity Protection Scenario	Waterway Restoration Scenario	Negative social impacts scenario	Positive social impacts scenario
Species Protection (Number of species protected)	50	150	75	100	100
Landscape Aesthetics (Hectares of farmland repaired and bushland protected)	4 mill.	5 mill.	4.5 mill	6 mill	6 mill
Waterway health (Kilometres of waterways restored for swimming and fishing)	1,000	1,200	5,000	2,500	2,500
Social impact (No. of people leaving country areas per year.)	15,000	15,000	15,000	20,000	5,000

Biodiversity protection scenario

This scenario describes the possible outcomes from policies designed to promote biodiversity protection. It is assumed that an additional 100 species would be protected relative to the business as usual outcome, together with an additional one million hectares of improved landscape aesthetics and 200 kilometres of waterway restoration. The annual value of this policy is estimated to range from $88 to $142 with a best estimate of $112 per annum for 20 years. Expressed as a lump sum present value[13] the best estimate is equivalent to a one off payment of $1,466.

Waterway restoration scenario

This scenario involves policies that focus on restoring waterways. It is assumed that an additional 4,000 kilometres of waterways would be rehabilitated by 2020 relative to the business as usual scenario. More modest improvements are assumed for landscape amenity and species protection. Respondent households are estimated to be willing to pay $104 per year for 20 years for the outcomes of this policy, which equates to a lump sum present value of $1,361.

Negative social impacts scenario

This scenario involves improvements to all environmental attributes and does not target a particular environmental outcome. However, the policies used to achieve these environmental improvements are assumed to lead to an additional 5,000 people leaving country communities each year relative to the business as usual scenario. Such a scenario could be encountered if trade-offs exist between conservation objectives and regional development. The welfare impact of this scenario is estimated to be $92 per annum per respondent household, which equates to a lump sum present value of $1,204 per household.

Positive social impacts scenario

This scenario consists of a set of policies that deliver both environmental and social improvements relative to the business as usual scenario. It is assumed that the number of people leaving country areas is reduced by 10,000 per year so that only 5,000 rather than 15,000 people leave per year. Measured against the business as usual scenario, this is a gain of 10,000 people per year. This outcome could eventuate if conservation management policies were adopted that stimulated regional employment. Households would be willing to pay $136 per annum for 20 years for such an outcome, or $1,780 per household when expressed as a lump sum.

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[13] Assumes a five per cent discount rate.

Table 6.8 Estimated welfare impacts per household for each of the four hypothetical scenarios *

	Biodiversity Protection Scenario	Waterway Restoration Scenario	Negative social impacts scenario	Positive social impacts scenario
Estimated annual welfare gain per household*				
Low estimate	$88	$77	$63	$114
Best estimate	$112	$104	$92	$136
Upper estimate	$142	$136	$128	$164
Estimated mean lump sum present value per household [A]				
Low estimate (@3%)	$1,348	$1,180	$965	$1,747
Best estimate (@3%)	$1,716	$1,594	$1,410	$2,084
Upper estimate (@3%)	$2,176	$2,084	$1,961	$2,513
Low estimate (@5%)	$1,152	$1,008	$824	$1,492
Best estimate (@5%)	$1,466	$1,361	$1,204	$1,780
Upper estimate (@5%)	$1,858	$1,780	$1,675	$2,146
Low estimate (@6%)	$1,070	$936	$766	$1,386
Best estimate (@6%)	$1,362	$1,264	$1,119	$1,654
Upper estimate (@6%)	$1,726	$1,654	$1,556	$1,994

* Estimates derived using a full choice model not the simple multiplication of attribute values

[A] Discount rates shown in parenthesis

Aggregate impacts of degradation

The ‘negative social impacts’ scenario described above is used to illustrate the process of calculating the aggregate non-market impacts of land and water degradation in Australia. This scenario is chosen because the changes in land use required to deliver significant environmental improvements are likely to involve a trade off between agricultural development and conservation. It is assumed that an outcome of this trade-off is an increase in the number of people leaving country areas for larger regional or urban centres.

The aggregate impact of this scenario is estimated to be $3.9 billion in present value terms (5 per cent discount rate). This is an estimate of the community’s maximum willingness to pay for the specified set of environmental improvements or, alternatively, the size of benefits foregone if these improvements are not undertaken. The estimated is calculated by extrapolating the per household estimate of $1204 (from Table 6.8) to 45 per cent of the Australian population of 7,185,540 households (ABS, 2000). It is not valid to simply aggregate the value estimates to the entire household population because only 17 per cent of households responded to the questionnaire. A conservative approach to aggregation is to assume that all non-respondents have zero values, thus limiting the extrapolation of benefits to just 17 per cent of the population. However, this would almost certainly be an underestimate of the true aggregate benefits.

The aggregation factor of 45 per cent is an estimate derived from a follow-up survey of 75 non-respondent households. This survey revealed that 37 per cent of people indicated an interest in the questionnaire but had been too busy to answer it. Another 32 per cent were interested in the topic but felt that the questions were inappropriate. Only seven per cent of the respondents replied that they had no interest in land and water degradation issues. On the basis of these results it appears reasonable to assume that at least 37 per cent of non-respondents hold non-zero values. If this proportion of non-respondents is added to the 17 per cent of households who responded, the aggregation factor is calculated to be 48 per cent of the total household population[14]. A slightly more conservative figure of 45 per cent is adopted for this analysis as a best-bet measure. Table 6.9 summarises the aggregate welfare impacts for each of the four scenarios.

Table 6.9 Estimated aggregate welfare impacts for each of the four hypothetical scenarios *

	Biodiversity Protection Scenario	Waterway Restoration Scenario	Negative social impacts scenario	Positive social impacts scenario
Estimated lump sum present values (billions)				
Low estimate (@3%)	$4.36	$3.81	$3.12	$5.65
Best estimate (@3%)	$5.55	$5.15	$4.56	$6.74
Upper estimate (@3%)	$7.04	$6.74	$6.34	$8.13
Low estimate (@5%)	$3.72	$3.26	$2.67	$4.82
Best estimate (@5%)	$4.74	$4.40	$3.89	$5.75
Upper estimate (@5%)	$6.01	$5.75	$5.42	$6.94
Low estimate (@6%)	$3.46	$3.03	$2.48	$4.48
Best estimate (@6%)	$4.40	$4.09	$3.62	$5.35
Upper estimate (@6%)	$5.58	$5.35	$5.03	$6.45

* Estimates derived using a full choice model not the simple multiplication of attribute values

A Discount rates shown in parentheses.

6.7 Valuation of impacts at a regional level

The results from the questionnaires demonstrate that community values for environmental and social attributes are significantly higher when attributes are presented to respondents for valuation in a regional context as opposed to a national context. Furthermore, there are significant differences between the case-study regions in terms of the values estimated for some attributes. These differences demonstrate that framing and population effects are influential in determining values. The implication of these results

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[14] (0.17+[1.00-0.17]*0.37)=0.48.

is that care must be taken in transferring value estimates from one context to another.

6.7.1 Transferability of national value estimates

The implicit household prices estimated for attributes in a national context are significantly lower than those obtained for the same set of attributes in a regional context. For example, in the case of the Great Southern region, respondents from Albany and Perth have values for farmland aesthetics, waterway health, and country community viability that are 10 to 20 times greater than the values estimated for these attributes in the national context (Table 6.10). A similar result was obtained for the Fitzroy Basin study. Consequently, it is necessary to scale up the national value estimates if they are to be validly transferred to regional areas.

Table 6.10 Comparison of implicit household prices estimated for attributes in a regional and national context.

	Species protection	Landscape Aesthetics	Waterway Health	Social Impact
	$ per species protected	$ per 10,000 ha protected or repaired	$ per 10 km restored	$ per 10 persons leaving each year
Great Southern region				
Albany sample	1.55	1.84	1.56	-0.55
Perth city sample	1.27	1.40	0.91	-0.71
Fitzroy Basin region				
Rockhampton sample	0.00*	1.57	2.02	-2.24
Brisbane city sample	0.00*	1.30	0.79	-1.03
National context				
Albany sample	0.27	0.21	0.00*	-0.11
Rockhampton sample	0.28	0.20	0.07	-0.06
National sample	0.68	0.07	0.08	-0.09

* This attribute is 'not statistically significant' from zero

A number of factors could be responsible for the different value estimates obtained for attributes in the national and regional contexts. The case studies differ from the national study in terms of:

- the respondent's frame of reference for valuing attributes;
- the population sampled[15]; and

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[15] Whilst some socio-economic and attitudinal characteristics of the different populations are 'controlled for' in the modelling process, a wide range of other population characteristics remain unexplained and exogenous to the model.

- the scope of changes being presented to respondents for valuation.

Of these three factors, tests indicate that framing and/or scope effects are the predominant cause of the observed differences in value estimates.

6.7.2 Consistency of value estimates across case studies

Comparisons between the two case studies indicate that the implicit prices estimated for some attributes in the Fitzroy Basin and the Great Southern are significantly different. For example, respondent households from Rockhampton hold significantly higher values for social impacts in their local region relative to the values held by Perth and Albany respondents for social impacts in the Great Southern Region (Table 6.10Table 6.6). Conversely, species protection is not valued in the Fitzroy region but it is a significant attribute in the Great Southern.

These differences in values could be caused by population and/or framing effects. The disparities demonstrate that the value estimates obtained in one region do not necessarily reflect community values in a different region, although there is a degree of consistency for some attributes.

6.7.3 Values of city and regional communities

The values held by respondents living in each case-study region were found to extend beyond the region to city households. The results indicate that, with the exception of the *Social Impact* attribute, implicit prices for the attributes are statistically equivalent[16] for regional and city households (Table 6.10Table 6.6). In the case of *Social Impact*, respondents from Rockhampton have significantly higher values than Brisbane respondents.

The finding that city respondents have similar values to people living in regional areas is contrary to the common presumption that use values (eg. recreation and landscape aesthetics) decrease with distance from the site of interest. This finding is important from a policy perspective because it implies that the 'geographic extent of the market' for environmental and social impacts in rural areas extends to city populations. In the National context, however, there is divergence in values held by city and regional respondents for some attributes. Typically, species protection is more highly valued by city people and landscape aesthetics more highly valued by regional people.

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[16] Using a Krinsky Robb test, see van Bueren and Bennett (2000).

6.8 Guidelines for applying the value estimates

The attribute implicit prices estimated in this non-market valuation study are useful for making a 'first pass' assessment of the size of non-market values associated with policies that have particular environmental and social impacts. The estimates are suitable for establishing the impacts of management decisions that affect major regions or the nation as a whole, and that can be described using one or more of the generic attributes. That is, the estimates can be used wherever impacts can be described in terms of changes in:

- the number of species protected;
- the hectares of farmland repaired or bush protected;
- the kilometres of river restored for recreation; and
- the size of rural population.

The estimates are inappropriate for assessing impacts at the individual catchment level, or for valuing resource use changes that have very narrow and specific outcomes. Nor are the estimates suitable for determining the impact of policies that affect environmental assets that are considered to be national or regional 'icons', such as the protection of Koalas.

6.8.1 Implicit price transfer guidelines

The guidelines below demonstrate how the implicit price estimates can be used to evaluate the non-market impacts of different policies. In circumstances where a more detailed and accurate assessment is warranted, the choice models estimated for the national study and regional case-study regions can be used to evaluate the welfare impacts (compensating surplus) of alternative scenarios.

Step 1: Defining the policy context

The first step is to determine whether the management policy is targeted at a particular region or whether it involves projects Australia-wide. If resource-use policies involve changes at a national level, then the set of attribute values estimated using the national sample of households is appropriate. For regional assessments that do not correspond to one of the case study regions, it will be necessary to use the national estimates. Under these circumstances, the national estimates must be scaled up before being transferred to a region. The set of scaling factors for calibrating the national estimates is given in Table 6.11. A range of scaling values is given for each attribute to allow for a margin of variability between different regions and populations.

Table 6.11 Scaling factors for calibrating national value estimates to a regional context

Attribute	National Implicit prices ($)	Scaling Factors
Species Protection	0.68	X 2
Landscape Aesthetics	0.07	x 20-25
Waterway Health	0.08	x 20-25
Social impact	-0.09	x 6-26

Step 2: Defining the attribute changes

This step involves determining which attributes are impacted by the policy under investigation, and identifying the expected change in the attribute levels over a given time period relative to a 'business as usual' policy.

Step 3: Aggregating the attribute values

Each attribute change caused by a particular policy (defined in Step 2) is then multiplied by its scaled implicit price (defined in Step 1). These so-calculated attribute values are then summed to yield an approximation of the average per household benefit to be derived from the implementation of the proposed policy.

Step 4: Defining the target population

If the policy under investigation involves resource use changes at a national level, then the appropriate population for aggregating implicit prices is the population of Australian households. The impacts of changes implemented in particular regions should be restricted to the rural and city populations adjacent to the region in question. Extrapolation of values to other populations is speculative and not recommended.

Step 5: Aggregation

It is recommended that household values be aggregated to 45 per cent of the target population and that the range of plausible values be based on an estimate of the 95 percentile range of values. Because the implicit household prices are annual willingness to pay values for a unit attribute change, it is necessary to consolidate these values to a lump sum present value if the analysis calls for an estimate of the full impact of a resource use change over a number of years.

A regional policy assessment example

Consider the case of a proposal to redress land and water degradation in a region located in NSW. Under the proposal, 20,000 hectares of rural land will be rehabilitated, and 160 km of waterways will be restored. Analysis of the policy proposal by scientists indicates that the policy will ensure that three (3) additional species will be protected. Furthermore, it is predicted that 50 additional people per annum will leave the region because of the lower farming intensities the proposal involves.

As a regional project, the implicit prices to be used in the valuation exercise will be scaled from the national estimates. Using the scaling factors in Table 6.11, the best estimate implicit prices are:

- Species Protection = 0.68 * 2 = $1.36 per species;
- Landscape Aesthetics = 0.07 * 20 = $1.40 per ten thousand hectares;
- Waterway Health = 0.08 * 20 = $1.60 per 10 kilometres;
- Social Impact = –0.09 * 6 = – $0.54 per 10 persons leaving rural areas per year.

Given the changes in attribute levels specified then the best estimate of the aggregate attribute value estimate

= (1.36 * 3) + (1.40 * 2) + (1.60 * 16) + (–0.54 * 5)

= $29.78 per household per year for 20 years

This estimate is the amount, on average, *a household* is willing to pay each year for twenty years to see the project proposed implemented. To estimate an aggregate value it is necessary to multiply the household value by an estimate of the size of the relevant population. This process includes making an adjustment to the survey estimates, via an aggregation factor, to allow for non-respondents in the sample. The following assumptions are used in this example:

1. the relevant population includes metropolitan Sydney and proximate areas of rural NSW, which amounts to four million persons;
2. the number of people per household is 2.5; and
3. the aggregation factor is 45 per cent.

Based on these assumptions, the best estimate of annual value would be

= $29.78 * (4,000,000/2.5) * 0.45

= 21,441,160 per annum for 20 years.

Where it becomes clear that the magnitude of the value estimated using this process of attribute value aggregation is critical in the assessment of a policy, a more detailed analysis may be required. That analysis in the first instance may involve a refinement of the scaling factors used.

By gaining a better understanding of the characteristics of the population to be affected by the policy under consideration, it can be assessed if the situation is closer to the Fitzroy Basin or the Great Southern case studies.

Further analysis may also involve the use of a complete choice model rather than the aggregation of attribute values. As a general rule, if the project is justified when lower bound estimates are used, one can be very confident in recommending the project be accepted. Conversely, if a project can be justified only if the best-bet estimate is used, then more analysis is probably needed.

6.9 Conclusions

The results summarised in this chapter and the report that underpins it (van Bueren and Bennett 2000) indicate that the Australian community holds values for the non-marketed, environmental and social outcomes of policies that impact on the nation's land and water resources. Put simply, the community is willing to pay a substantial amount over and above what is already being spent to have policies implemented that halt or reverse land degradation processes. Furthermore, the results show that where such policies would result in the depopulation of rural areas, people are willing to pay to provide support for the people so affected.

The process of assessing whether or not people's willingness to pay exceeds the costs of undertaking such policies is facilitated by the reported results because they allow the quantification of the benefits of redressing resource degradation in dollar terms. The non-market value estimates reported are suitable for inclusion in benefit cost analyses of proposed policies.

The ability of Choice Modelling, the non-market valuation technique used for this study, to provide estimates of value that can be "disassembled" into the contributions made by environmental and social characteristics or attributes is highlighted in this report. This capability further assists in the transference of values estimated in this study to other contexts. The outcomes of new policy options that are under consideration can be described in terms of the attributes defined in this study. Values for the new policy outcomes can then be "assembled" with reference to the per unit attribute values estimated here.

A further important contribution of the results of this non-market valuation study is the identification of differences in value estimates arising because of differences in the location and characteristics of the people whose values are of interest and because of differences in the context or frame of the resource degradation under consideration. An understanding of the nature and extent of these differences is most important if the value estimates reported here are to be "transferred" to cases where different populations and contexts are involved. The "scaling factors" detailed in this report are critical in this regard.

The results of this study therefore provide policy makers with an important input into the assessment of potential policies that have impacts on land and water degradation processes.

7 An Integrated Overview

Mike Young and Stefan Hajkowicz

Through Theme 6.1 of the Audit spatial and non-spatial economic databases of Australia's natural resources and a framework compiling economic data have been developed. This database will allow integrated assessment of natural resource management issues. It use is illustrated below in making comparisons between salinity cost estimates accruing to agriculture, local infrastructure and downstream infrastructure over the next 20 years. A comparison is also made of salinity costs between States and Territories of Australia.

7.1 Natural Resource Accounts

This assessment represents the first attempt, at a National scale, to build a spatially explicit set of natural resource accounts. If the estimates of the return to the Nation's land and water resources are adjusted for subsidies and taxes, then an estimate of the net economic value per square kilometre of agricultural production in Australia could be provided. These accounts could be extended if costs of land and water degradation costs could be reassigned to the year when they occurred and matched to the other profit/cost data.

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

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

While the data currently available does not allow a fully integrated accounts along such lines, it is possible to present a 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.

7.2 The available data

The information that we have collected focuses on the relative size of impact costs and opportunities associated with:

- Agricultural production;
- Local infrastructure costs;
- Downstream impacts; and
- Non-market values.

In an ideal situation, the biophysical data collected by the Audit would be robust enough for a fully integrated overview relating to a diverse set of land and water management issues. To do this, however, it is necessary to have consistent information of scenarios into the future. It would also be necessary to have information on likely effects of land-use change. However, information on the relative magnitude of costs and benefits and a range of tentative scenarios for salinity is available. It is stressed that the estimates made are, at best, first order estimates made using national data sets and without the opportunity to check regional detail in all but a few locations.

7.3 Comparison of Salinity Cost Increases

7.3.1 A national perspective

A comparison of national salinity cost increases, above and beyond current levels, over the next 20 years (2000 – 2020) provides insights to 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.

In Figure 7.1 the split among impacts on agriculture, local infrastructure and downstream impacts on urban and industrial water users are shown for five scenarios for future water quality. These scenarios are a 1%, 5%, 10%, 15% and a 20% increase in water salinity in those catchments where dryland salinity is already an issue.

Great care, must be taken in interpreting these baseline results because the data are impact costs and take no account of cause. Moreover, they do not include any attempt to quantify downstream impact costs associated with irrigated production. Similarly, we do not make any attempt to include non-market values in the assessment. As a result, the relative assessment of downstream impact costs must be regarded as conservative.

Consistent with our earlier estimates, all dollar values are given as net present values at a discount rate of 3% in $millions. At water salinity increases above 5% and at a National Scale, the bulk of the impact costs from salinity will be to downstream water users.

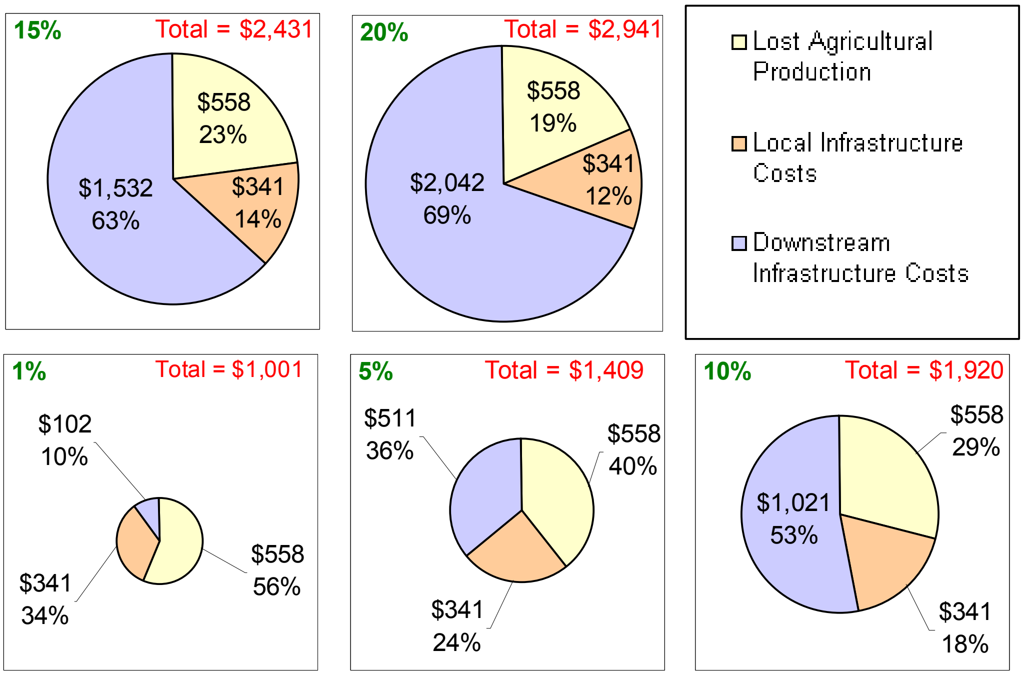

Figure 7.1 Distribution of Impact costs among Agricultural production, local infrastructure and downstream water users (present values at a discount rate of 5% in 1996/97 $millions). The percentage increase in river/stream salinity is given at the top left of each pie chart.

Some insights into what might be a likely increase in national river salinity can be drawn from data prepared for the Murray Darling Basin's Salinity Audit. Under this Audit and for business-as-usual, 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 the 5% and 10% scenarios is likely to provide a very conservative estimate.

The estimated downstream economic damages that would be incurred by non-agricultural industries, infrastructure and households as a result of an across-the-board increase of 10% in salinity, turbidity and erosion total an estimated $4.161 billion, in Net Present Value, when discounted at 3%.

This is equal to $212 million per year. The comparable figures for a 7% discount rate are $3.174 billion and $256 million/year.

7.3.2 A State/Territory perspectives

These National data mask considerable variation among States and Territories. As indicated in Figure 7.2, downstream impacts on urban areas are greatest in those areas where downstream populations are high. At a State and Territory level and as would be expected, the highest downstream impact costs occur in South Australia. This occurs because of the large number of people and considerable investment in industrial processing that occurs in Adelaide, Port Pirie, Port Augusta, Whyalla and the Upper South East and the expected future of River Murray Water Quality.

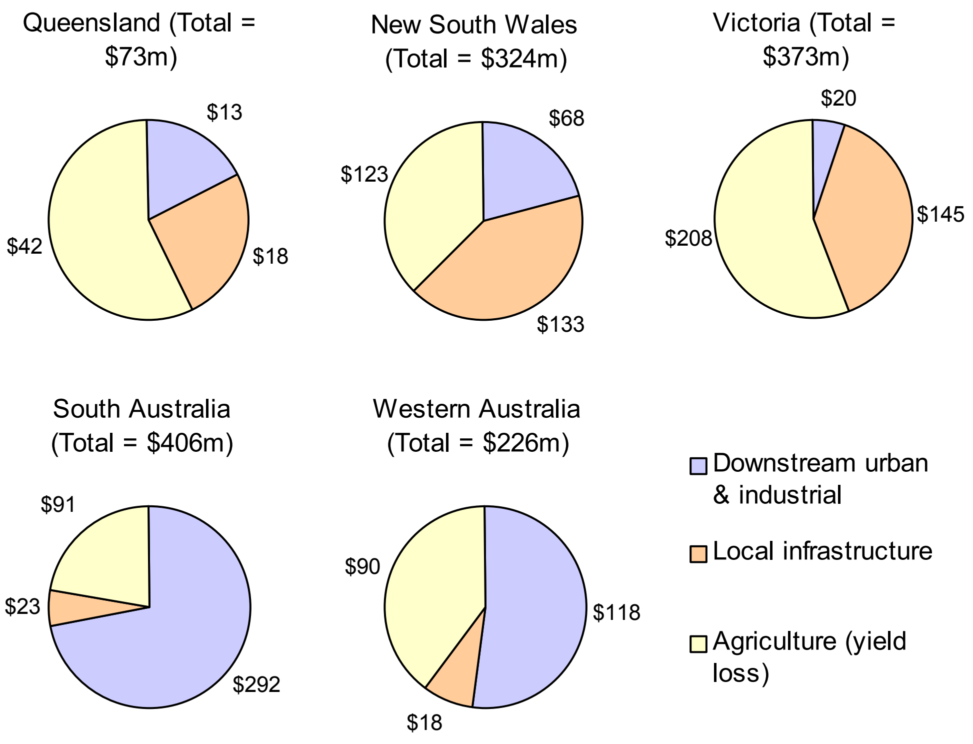

Figure 7.2 Distribution of relative impact costs by State and Territory for three types of impact assuming a 10% increase in salinity loads to 2020

7.3.3 Potential extensions and uses of our data

In the course of preparing the above integrated assessment, we attempted to assign downstream costs upstream in proportion to salinity load. Having tried this, we came to the conclusion that the water quality data available to the Audit was not robust enough to allow this do be done with confidence. There was insufficient water quality data to allow trends in water quality parameters to be established. Consequently, the data are not presented. In areas like the Murray Darling Basin, for example, reliable data on both current and expected future salinity levels are available. Full incorporation of these data into the Audit water quality data would significantly improve the quality of analysis possible.

Another issue is the lack of information on expected future impacts of salinity etc on non-market values. Data in this form would significantly increase the quality of analysis possible and, hence, the insights gained.

7.4 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.

This has allowed the development of an economic database of Australia's natural resources. With few exceptions the maps in this database have national coverage and represent data using a 1km^2 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).
- A set of functions that relate relative yield in different crop/pasture types to soil attributes for salinity, sodicity and acidity.
- 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.
- 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.
- A land use map showing over 60 categories of commodity production, classified into irrigated and dryland categories.

- 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.
- A set of functions and tables to determine the local infrastructure cost impacts of rising water tables and salinity.
- 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.
- 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.

As indicated in the introductory chapters to this report, 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.

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.

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