13. ACIDITY

13.1 PROCESSES
13.1.1 Cause

Soil acidity is a chemical condition of the soil which reduces crop and pasture yields. Acids enter natural ecosystems as carbonic acid in rainfall, or as sulphuric and nitric acids produced by biological processes. The acid level of soils has gradually increased in all farming land, particularly since the 1950's with the introduction of pasture improvement programs. Increased acidification can be due to the use of nitrogenous and other fertilisers, from the extensive use of legumes in pastures and from the gradual removal of alkali in hay and other products (54). The loss of nitrate from the soil due to leaching, lateral movement and decay of natural organic matter is an important process in soil acidity. It is essential that acidity is treated early because it becomes very difficult to treat once the subsoil becomes acidic (13).

13.1.2 Upstream/Downstream Inter-Relationships

Soil acidification has the potential to cause serious effects on soil and plants. As soils become more acidic, aluminium and manganese become mobilised to toxic levels which affect plant growth and, in addition, become toxic to soil micro-organisms essential for recycling nutrients. Decreases in soil pH may cause increased cadmium uptake by crops and pastures to levels where they may cause kidney and liver damage to mature grazing animals. Low pH levels can also prevent legumes from nodulating, tie up valuable phosphate and can cause trace element deficiency eg. molybdenum.

This in turn causes a reduction in plant growth, which can lead to rising water tables, dryland salinity and soil erosion. Erosion and nutrient leaching can lead to increased sediment load in the waterways and may lead to eutrophication of the water. Increased recharge into the groundwater system from deep drainage due to poor plant growth leads to dryland salinity, which may in turn increase the salt concentration in the water.

Acidic soils may have some or all of these problems, and each crop or pasture may be affected by a different aspect of soil acidity. For example, the removal of one tonne of lucerne has 20 times more acidifying effect than the equivalent harvesting of a grain crop. Perennial pastures are better at modifying the problem than annual pastures. Crops such as lupins, triticale and oats are the most tolerant crops to acid soils (54).

The major determinants of the rate of soil acidification are:

- intensity and productivity of farming systems (alkalinity lost through product removal)
- water filtration from rainfall and / or irrigation (leaching)
- the use of nitrogenous fertilisers and legumes in farming systems (nitrate accumulation in the soil)
- soil characteristics (buffering capacity and pH profile).

13.2 PRESENT CONDITIONS
13.2.1 Distribution and Severity

It has been estimated that 13.7 million hectares of agricultural land in New South Wales is seriously affected by soil acidification. A further 6 million hectares are also vulnerable to this problem (53). Soil acidification is associated with areas of high rainfall in the tablelands and coastal regions of New South Wales. Surveys have shown that the majority of the southern and central tablelands, southwest slopes and irrigation areas are in some way affected by soil acidification. Studies in the Riverina region showed that 77% of the area has an acid soil problem. These results are generally applicable to the winter dominant rainfall area, including the uplands of the Macquarie Valley (13).

The extent is likely to increase, particularly on soils that have been cultivated for many years and liming will need to become a regular management practice to maintain productivity (13).

Acid Action data has been collected for nine Landcare groups within the Little River Catchment (See Table 12). All of these Landcare areas have an average pH of less than 6, the lowest being at Saddleback (4.17). The relationship between decreasing pH and increasing Exchangeable Al is apparent in these results. The number of samples taken within each Landcare group varies and this affects the average and the range. See Appendix 9 for the results of the Acid Soils Action Monitoring Project in Little River.

Table 12: Results of Acid Soils Action Monitoring Project in Little River

Landcare Group	pH (CaCl) Topsoil Average	pH (CaCl) Topsoil Range	Exchangeable Aluminium Average	CEC Aver-age	pH (CaCl) Subsoil Average
Saddleback	4.17	4.1 – 4.2	0.98	4.72	4.63
Yahoo Peaks	4.69	4.0 – 5.7	0.27	8.12	4.82
Burgoon	4.77	4.1 – 6.1	0.23	8.71	4.92
Yeoval Central	4.77	4.2 – 6.2	0.16	9.19	5.00
Middlearm	4.74	4.0 – 5.5	0.35	5.99	4.62
Eurimbla	4.92	4.0 – 7.0	0.17	9.55	5.01
Myrangle Creek	4.92	4.2 – 5.5	0.18	5.90	5.13
Upper Buckinbah	4.95	4.1 – 6.2	0.10	10.77	5.33
Obley	5.17	4.0 – 6.4	0.15	11.95	5.47
Cumnock Village	5.95	5.8 – 6.1	0.05	9.055	5.8
Average	**4.91**		**0.26**	**8.39**	**5.07**

J. Lawrie, DLWC Wellington has classified Soil Landscapes for the Dubbo Soil Landscape Sheet into levels of acidity according to topsoil pH (56). (See Fig. 15) To reduce complexity for the purpose of this report, these have been reduced to three classes. (See Table 13)

NSW Agriculture advises that pH of 5.5 and above should not result in problems from soil acidity (60). However, M. Duncan (Acid Soils Action NSW Agriculture, Armidale) reports that recent trials have shown economic responses even in soils with pH above 5.4.

The areas in the Little River Catchment with a pH < 4.5 are found in the north of the Baldry and Yeoval subcatchments on the Yeoval Complex and in the south of the Baldry subcatchment around Yahoo Peaks on the Dulladerry Volcanics. Low pH is associated with shallow soils and siliceous sands and most of the red podzolics soils.

The red brown earths and non-calcic browns are moderately acidic, the degree dependant on previous land use. The alluvials and strongly structured red soils (euchrozems and terra rosa) are not generally showing acidity at present.

Table 13: Topsoil Acidity of Soil landscape Units

pH Range	Soil Landscape Unit	Soils Group	Symbol
< 4.5 pH	Gullengambal	Siliceous Sands	gg
V. strongly	Yahoo Peaks, Catombal, Glennie Ridge	Shallow Soils	yp, cs, gl
acidic	Splitters Hill	Red Podzolic	sh
4.5 – 5.5	Tillings Lane, Arthurville	Red Brown Earth	tl, ar
Strongly	Yeoval, Manildra	Non-Calcic Brown	yv, mn
acidic	Oxley	Siliceous Sand	ox
	Little River	Alluvial	lr
	Black Rock	Red Podzolic	br
> 5.5	Macquarie Dubbo, Mitchell Creek	Alluvials	md, mi
At risk of	Nubingerie, Wellington Caves	Euchrozem/Terra Rosa	nb, wc
acidity	Dowd	Shallow	dw
	Belowrie	Red Podzolic	bi

13.2.2 Environmental Impacts

Soil acidification has a number of environmental impacts, which can lead to other forms of land degradation. Acidification mobilizes nutrients in the soil, particularly aluminium and manganese. This can cause the soil to become toxic and reduces the potential for plant growth. Reduced plant growth may alter the water balance, allowing greater amounts of water to drain through the root zone, leading to rising watertables. The groundwater system may also be polluted by nitrates, which have been mobilized.

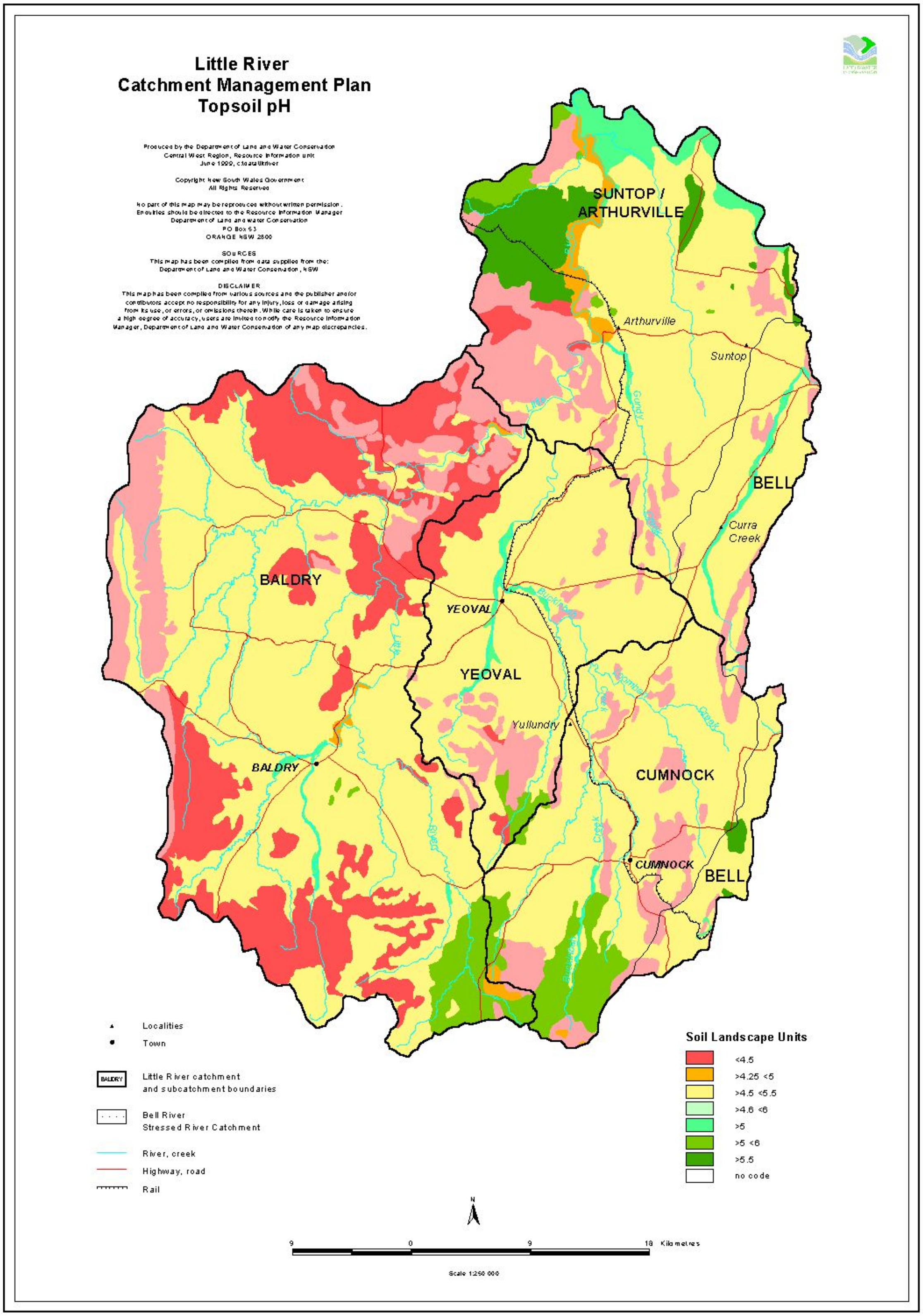
Increasing soil acidity is likely to limit the capacity of landholders to reduce or rehabilitate salinised areas because of the difficulty of getting vigorous plant growth. The establishment of lucerne is particularly difficult in acid soils - and lucerne is an extremely valuable plant for the prevention of deep drainage and utilization of soil moisture deep in the profile. Some saline sites, such as the Hervey Ranges are acidic. These sites have unusually high levels of sulphates. In the Hervey Ranges, pH has not changed greatly on cropping land when compared to tests in the National Park. However, aluminium and manganese levels are reduced but these can be corrected with lime applications.

Both acidity and salinity can increase the potential for soil erosion due to decreased groundcover. For this reason, soil acidification may lead to sedimentation of creeks and streams.

13.2.3 Social and Economic Impacts

It has been estimated that acid soils reduce farm incomes in New South Wales by $90 million per year (53). Social and economic impacts include loss of income and reduced financial viability due to reduced production and possible loss of land if salinisation occurs. The cost of remediation will have a substantial impact on cash flow, especially as enough lime is usually applied for several years. However, a response should be apparent from the first crop.

Figure 15: Topsoil Acidity



Analyses have shown that the benefits of liming are high and the risk of not breaking even after investing in lime is very low (52). The average annual cost of maintenance dressings of lime was determined to be 65% of the cost of fertilizers for cropping farming systems (52).

Costs associated with amelioration of acid soils can be determined using the cost of the lime, the Cation Exchange Capacity (CEC) and the amount of lime required to lift the pH of the topsoil to 5.2 (55). For this example, it has been assumed that the average CEC within the catchment is 9 (See Table 12) and the cost of lime is estimated at approximately $52 per tonne. Liming includes the cost of lime ($32/tonne), cartage ($10/tonne) and spreading ($12/tonne). Normal application rate of lime is 2.5 tonnes/hectare, despite NSW Agriculture recommendations. A sample calculation is set out below, using the NSW Agriculture recommendations (55).

Area (ha) x lime required (t/ha) x cost ($/t)

43090 x 4.2 x $52 = $9.41 million

Table 13A: Approximate Annual Costs of Liming in the Little River Catchment

pH range	Area (ha)	Lime Required (t/ha)	Cost ($/t)	Total ($) million pa
> 4.25 < 5	43090	4.2	52	9.41
>4.5 < 5	110070	1.8	52	10.303
> 5 < 6	11174	0	52	0
TOTAL	**164334**			**19.713**

Costs have been calculated over only 70% of the privately owned land (20, 400 ha in State Forests and National Parks) so projected costs could initially be as high as $25.63 million. Ivey ATP (40) reported there were 221 farms covering 145,000 ha (average size approx. 660 ha), then there is an estimated 350 farms in the catchment. This means each farm on average requires approximately $73000 of lime (1400 tonnes). If this cost is spread over ten years, the annual cost is around $7300.

13.3 THE FUTURE

Unless liming becomes a routine practice, soil acidification will worsen as crop and pasture production gradually lowers the pH through product removal. This will result in further leaching of nutrients and reduced plant growth leading to increased soil salinisation in areas. The low subsoil pH is a real concern as amelioration is very difficult and costly to remedy acidity that has moved into the subsoil. Current pH levels in the subsoil average from 4.6 to 5.8. Even higher rates of lime should be used in areas with low subsoil pH in order to ensure that enough lime is available to move down into the profile.

If the soil is allowed to become severely acidic before lime is applied, it will become beyond the financial capacity of farmers to raise the soil pH to a level which will correct the problems associated with soil acidity.

13.4 CURRENT ACTIVITIES
13.4.1 Planning

The "State Acid Soils Hazard Map, Management Map and Database" funded by the Acid Soils Action program aims to incorporate all available data into the NSW Soils Database held by DLWC, so it can be used to develop maps of acidification risk and management options. This work is being undertaken by Ian Beer (DLWC Parramatta) and work is currently proceeding on the Bathurst, Goulburn, Wagga and Kempsey 1:100,000 map sheets. The Wellington sheet is a high priority and may be started in 2000 if additional funds can be accessed.

This work is utilizing the Soils Landscape Units (SLU) as the boundaries as no other boundaries are available. However, this is not entirely satisfactory as landuse has a very significant impact on acidity, regardless of soil type.

A derivative map of topsoil acidity has been produced from SLU data for Dubbo and Bathurst. This map illustrates the extent of topsoil acidity across the area, and has been used to estimate the possible costs of liming.

13.4.2 Research and Development

Acid Soils Action funds have been made available for research projects as well as landholder trials and monitoring. For full details see Acid Soils Action Northern Region Program (61).

Projects in the Little River Catchment or nearby areas funded by Acid Soil Action include:

- Acid Tolerant Native grasses: harvesting and establishment
  Nicholson, DLWC, Wellington (64)
- Effects of Soil Mesafauna
  J. Lawrie, DLWC, Wellington
- Economic Issues in Managing Acid Soils
  J. Mullen, NSW Agriculture

Early results from the grass establishment trial (64) show some inconclusive results, with suppression of establishment in all species when 5 t/ha lime was applied to the surface, and many species performed better in the plots without any lime applied. The work is continuing.

NSW Agriculture has developed the *Lime It* computer program – a decision support program that gives farmers practical help in determining the rate of lime to apply to paddocks.

A number of research programs have been suggested following the AACM review of the feasibility of ameliorating soil acidification (52) which place emphasis on the causes of soil acidification and designing less acidifying farming systems. Improved nitrogen management and water use efficiency strategies should also be included in these programs (52). Suggested research programs include lime/plant nutrient interaction, monitoring the reduction in land use potential due to soil acidification, efficacy of topdressing pasture and wheat and pasture response to lime application research.

The LWRRDC Program - Resigning Agriculture in the Australian Landscape focuses on finding farming systems that prevent the loss of nutrients and water.

13.4.3 Implementation

A number of projects have been funded under the Acid Soil Action Program. These include the monitoring and soil testing program taken within the Little River Catchment, which is reported on earlier. Trial sites run in nearby areas by M. Duncan, Acid Soils Specialist based at Armidale, include Lower Talbragar, Sappa Bulga, Toongi, and Cundumbul. The outcomes of these investigations should be applicable to this region, as should some of the work overseen by Bill Schumann – Extension Specialist, Queanbeyan. Lime applied at 2.5 tonnes/hectare in the Myrangle Landcare Group area has been found to lift pH by up to one point (4.2 to 5.2). Being on the border between the two advisory regions probably disadvantages this district.

The adoption of liming as a normal management practice is far below what is required.

Future programs and investigations need to focus on: (52)

- the need to emphasize the significance of soil acidification as a short term cost to land managers in Australia
- the likelihood of long-term costs to all Australians if soil acidification is not managed and land becomes unproductive due to sub-soil acidification
- the financial benefits of using lime
- the use of lime as the primary tool to manage soil acidification
- the need to strengthen the organization and responsiveness of the Australian lime industry.

13.4.4 Monitoring and Evaluation

Acid Soil Action Program includes monitoring and evaluation for groups. This program has started in the catchment area but needs continuing. A Soil Database has been set up to incorporate results of all soil testing across NSW. However, it is not extensively used by private companies. The more information that goes into the database, the better knowledge catchment managers will have of the extent of degradation, not only soil acidity but other soils factors such as fertility, toxicity and salinity.

13.4.5 Best Management Options (BMO)

Soil acidification has been gradually increasing, particularly on soils that have been cultivated for many years and liming will need to become a regular management practice to maintain productivity. Soil testing to determine the pH levels of a soil should be a prerequisite for the treatment of other forms of land and water degradation such as salinity and sheet erosion.

BMOs for the amelioration of soil acidification need to take an integrated approach. The approach recommends:

- lime to neutralise excess acids and replace alkalinity lost in product removal
- making maximum use of soil moisture and nitrogen by using deep rooted perennials and maintaining soil organic matter
- managing fertilizer applications and other land management practices to minimise addition of acid and leaching of nitrate (52).

13.4.6 Identified or Perceived Barriers

The major barrier for ameliorating soil acidification is the financial costs to landholders, particularly in grazing areas. Producers are aware of the production benefits of applying lime, however, they see that the cost of applying lime is high, product returns and cash flow are low and there is inadequate cost/benefit information regarding amelioration of soil acidification. Some producers are also sceptical about the yield advantages of liming on properties (52).

Technological constraints are also seen as barriers. Direct drilling, which has many other soil benefits, provides limited opportunities to incorporate lime, and there are uncertainties regarding the efficacy of applying lime as a top dressing in pasture country.
Social barriers include a lack of reliable research data for yield responses and in some areas acidification is seen as a low priority. (52) Landholder surveys taken within the Little River Catchment have indicated that soil acidification is seen as a moderate to severe problem in parts of the catchment and that this problem is increasing.

13.4.7 Institutional

No legislation or regulatory policies require farmers to manage their land with respect to soil acidification. However, the law requires lime crushers to supply fineness and neutralizing values for all lime sold so the efficacy can be determined.

13.4.8 Investment

The Acid Soil Action Program is an initiative of the New South Wales Government. It involves government agencies, industry and the agricultural community and looks at the negative effects of acid soils on agricultural production and land degradation. This program aims to correct soil acidity and to reduce the effect of acidity. Outcomes of the project should be more sustainable management of acid soils in the pasture zones of the Tablelands, correction of soil acidity, improved monitoring and recognition of soil acidity and how it can be managed.

Cabonne Shire Council operate a lime quarry at Molong which produces about 75 000 tonnes/annum of agricultural lime. The quarry and production plant underwent a major expansion in 1999. This mine has a 40 year life span. Another mine owned by Cabonne Council, located at Cudal, produces around 60,000 tonnes/annum and has a 60 year life span.

Biosolids are quite widely used in the western part of the catchment. These have 40-50% lime, and have the potential to increase production by at least 1 tonne grain/hectare (pers. comm. S. Gough).

13.4.9 Cost Sharing

At present no cost sharing measures are in place to assist landholders to address soil acidification. Given the interrelationship between acidity and salinity, this should be considered if further deterioration of water quality and land capability are to be minimized. Support and incentives are required to ensure the problem is addressed immediately, as the poor cash flow position of most farmers makes the large up-front costs of purchase and spreading prohibitive to many farmers in the current economic climate. Overall spreading costs are reduced if adequate lime is applied for 3-5 years; however, this can make the up-front costs quite substantial. At present most producers spread 2.5 tonnes/hectare and consider this to be sufficient for around seven years. Changing spreading options may reduce the overall costs in the long run.

13.4.10 Financial and Benefit Cost Analysis

A study by AACM for LWRRDC (52) undertook financial analyses that show liming for wheat crops provides substantial financial benefits. The benefit/cost ratio for the southern and central tablelands area was 1.82. i.e. for every $1 invested in lime, a return of $1.82 could be expected. This means that the benefits of applying lime are high and the risk of not breaking even is very low. However, some producers feel there is a lack of substantial economic proof regarding these benefits. Consequently AACM (52) recommended that a detailed economic analysis of the relative costs of lime was required.

13.5 ANALYSIS

13.5.1 Identified or Perceived Gaps

Soil Landscape derivative maps of topsoil acidity are available for the eastern section of the catchment only. The Acid Risk maps being produced by DLWC Parramatta only cover the Bathurst sheet. At this stage no funds have been allocated to complete the work for the Wellington or Dubbo areas.

Better knowledge would be available if all soils information was made available for inclusion in the NSW Soils Database. However, commercial sensitivity is limiting the inclusion of tests from private laboratories and fertilizer companies.

Although there is strong evidence that the Benefit Cost Ratio (BCR) for liming is substantial, there is still skepticism amongst many landholders whether it is an economically viable management practice. The inability to incorporate lime in direct drilled crops and on grazing land also impedes the correction of soil acidity.

13.5.2 Key Stakeholders and Contacts

NSW Agriculture
Greg Fenton - Project Officer, Wagga Wagga
Michael Duncan – Acid Soils Specialist, Armidale (covers the Central West)
Bill Schumann – Extension Specialist, Queanbeyan
Bernie McMullen – Soils Advisory Officer (Horticulture), Bathurst
Kathy Hurtle - District Agronomist, Wellington
Col Mullins – District Agronomist, Dubbo

Department of Land and Water Conservation
John Lawrie – Lands Management Specialist, Wellington
Alan Nicholson - Salinity Investigations Officer, Wellington
Ian Beer – Acid Soil Information Officer, Parramatta

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