Chapter 6

Major land use practices that acidify the soil

Over the past 25 years there has been much research focused on the impact that different farming systems have on soil acidification. These findings can be summarised in the following major points.

- **Broadacre crop management practices**
- **Plant species**
- **Use of fertilisers**
- **Forestry**

Broadacre crop management practices

Acidification rates for different crop management practices can be summarised for the four major tillage operations, conservation tillage (stubble retained either completely or partially), stubble shredding, stubble burning and cultivation. All tillage management practices give similar rates of acidification however, the distribution of acidity within the surface soil layers will vary between practices. (Slattery 2000)

For example stubble burning practices will develop a soil with a higher surface pH, but lower subsoil pH than the conservation tillage practice. Acidification due to tillage practice is largely attributed to the stratification and development or destruction of soil structure that develops over time. For this reason nitrate leaching will be higher under conservation tillage practices where good soil structure has developed and water infiltration has improved compared with stubble burning or cultivation.

In any farming system the best management practices will be those that take into account the long-term sustainability of the natural resources. For the stubble management practices of burning and cultivation the losses of soil through exposure to rain and wind are very high. Therefore continuous cropping systems that have adopted these practices over the past 30-40 years are now seriously deficient in topsoil and as a consequence, soil carbon levels. (Slattery & Surapaneni 2002). This leads to poor soil fertility unable to support healthy plants, resulting in further exposure of the soil surface to wind and water erosion. Under these soil conditions water use will be lowered, allowing for increased runoff and soil loss as well as reduced water use by plants growing poorly in recharge areas, with the potential to increase salinity.

The four crop management practices are summarised in Table 18 below, identifying their acidifying effect on the soil, the level of soil carbon loss and quantity of surface soil lost annually. It can be seen that although the acidification rates are similar for each of these crop management practices the rate of soil and carbon loss is significantly higher for cultivation practices compared with conservation cropping. (Slattery 2000).

Table 18. Soil acidification, carbon loss and soil loss data, as influenced by crop management practice (data from Slattery 2000).

Management practice	Acidification Rate	Carbon loss	Soil loss (t/ha/yr)
Conservation cropping (stubble retained)	Low	low	4
Stubble shredded (on the surface)	Low	low	6
Stubble burnt	Low	medium	18
Cultivation (excluding sowing operations)	Low	high	50

Plant species

The acidifying effect of different plant species has been well documented in recent years. Of particular importance is the influence that legume crops have in accelerating the rate of acidification above that of cereals and grasses. This is due to the production of nitrate nitrogen and subsequent leaching losses below the root zone. Acidification due to plant species is attributed to two major factors, firstly the species of plant and whether it is a legume and secondly the quantity of plant material removed at harvest.

Farming systems that are dominated by perennial permanent pastures generally have lower rates of acidification than permanent annual pastures (Ridley *et al*.1990a). It is important to note however, that different environmental factors such as rainfall and soil texture play a major role in determining how much nitrate nitrogen will be leached and thus determine the rate of decline in lower surface soil pH. Table 19 provides a snapshot of acidification rates for a number of farming systems. From this Table it can be seen that the acidification rates are higher in the high rainfall environments of Australia compared to low rainfall environments. Acidification rates are determined by measuring initial and final pH after varying periods (years) of a given farming system. It is worth noting that the acidification rate is a combination of factors relating to nitrate leaching and cation replacement by hydroxyl ions in the surface soil layers, one such factor being the removal of alkali product in the form of farm or forest produce.

Table 19. Acidification rates and annual lime requirements for different farming systems in high (annual rainfall >550 mm) and low (annual rainfall < 300 mm) rainfall environments (Data from Slattery *et al.* 1999).

	Plant species	Acidification rate	Lime equivalent (t/ha)
High rainfall	Lucerne hay	High	0.60
(annual rainfall	Crop/pasture	High	0.35
>550 mm)	Grass/legume (hay)	High	0.30
	Annual pasture	Medium	0.25
	Wheat/lupin	Medium	0.20
	Perennial pasture	Medium	0.20
	Grapes	Low	0.10
	Eucalyptus	Low	0.07
	Eucalyptus/Acacia	Low	0.04
	Tobacco	Not acidifying	-0.02
Low rainfall	Wheat/legume	Medium	0.15
(annual rainfall	Annual pasture	Low	0.05
<300 mm)	Wheat/pasture	Low	0.02

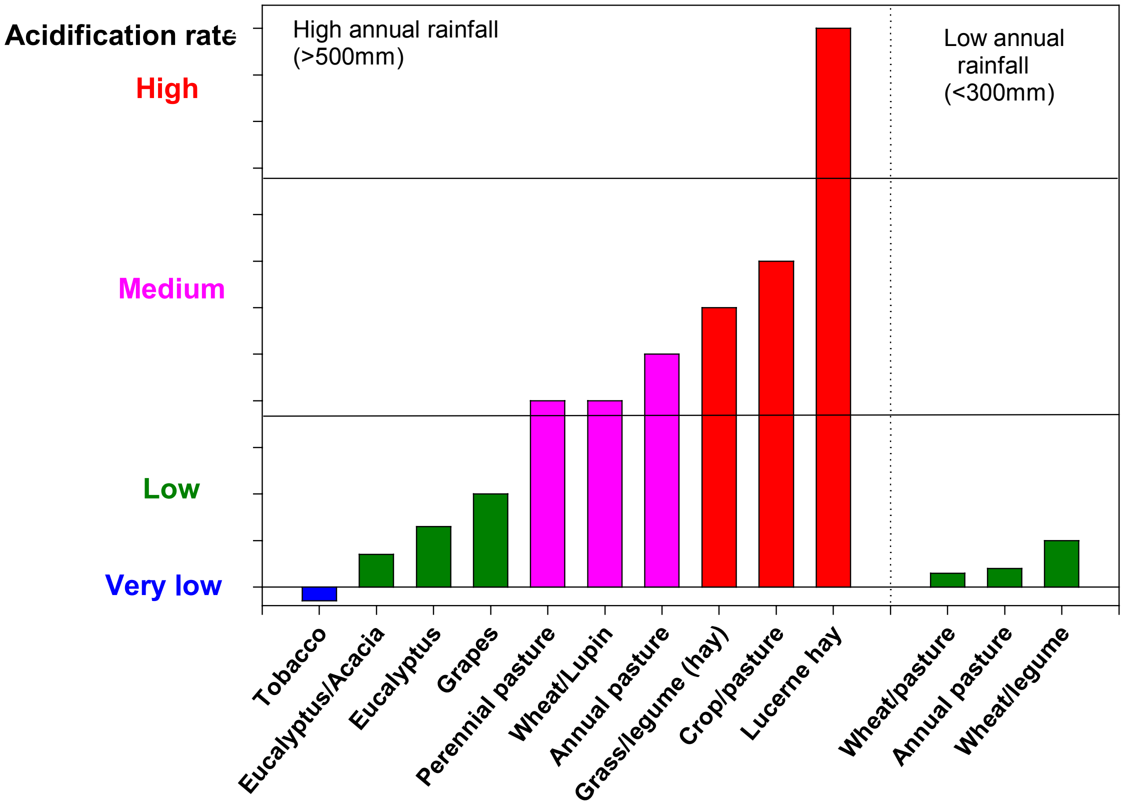


Figure 14. Acidification potential for a range of plants in high (>500mm) and low (<300mm) rainfall environments (for specific values of acidification see Appendix 1).

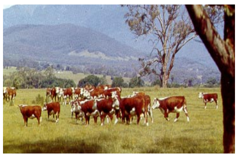
Use of fertilisers

For the first half of the last century, after the introduction of superphosphate fertiliser, crop and pasture yields rose steadily until nitrogen became limiting. Nitrogen fertility was improved with clover ley farming in the early 1960's to be replaced by legume crops in the rotation in the late 1970's. This led to increased soil acidification and the need to lime in acid soil environments. With the introduction of new acid tolerant varieties and better weed control, grain yields have risen even higher, placing a larger demand on the use of nitrogen fertilisers. The introduction of high value crops such as canola have raised the stakes in terms of nitrogen supply and soil acidification. Soils not previously considered to be limiting to plant growth have been re-evaluated due to the highly sensitive nature of these high value crops such as canola and lucerne. This has led to a demand driven need to introduce a liming strategy to prevent some soils from becoming strongly acidic.

In the horticultural industry the use of nitrogen fertilisers in irrigation lines has caused the acidification of sub-surface soil horizons within the crop rows. Some of these soils are now so acidic that surface incorporation of lime is inadequate to prevent production losses. Alternative technologies that can supply alkaline materials below the surface are required. The use of soluble organic compounds may be one solution and requires further investigation.

For many permanent pastures in high rainfall environments the application of phosphorus fertiliser provided significant gains in pasture production for the beef, sheep and dairy industries. However, following many years of continuous production and the introduction of legume pastures, many of these soils are now strongly acidic in the surface 30-60 cm soil layer. These soils will need careful assessment in order to identify the cost benefit of actions to ameliorate sub-surface soil acidity versus land use change that involves less productive acid tolerant plants.

Table 20. Land use practices and their effects on soil acidification and off site impacts and suggested actions to reduce these impacts.

Land use	Most acidifying component	Other impacts	Action
Broadacre cropping 	Use of nitrogen fertilisers Product removal Legumes in rotation	Soil loss high for cultivation and stubble burning. Salinity increased where there is low water use by plants.	Optimise lime and fertiliser use, reduce burning and cultivation. Increase the use of lucerne and other perennials in the rotation.
Grazing systems 	Legumes Product removal (especially hay)	Salinity increased where there is low water use by plants.	Replace exported alkalinity with lime and other nutrient sources eg. Organic materials. Increase the use of perennial pastures.
Forestry 	Product removal	Soil loss Loss of biodiversity	Replace exported alkalinity with lime. Leave as much biomass on site (as trash) as possible.
Horticulture 	Use of nitrogen fertilisers Product removal	Nutrification of waterways Soil loss with cultivation and bed formation	Optimise fertiliser use with crop production. Replace exported alkalinity with lime.

Recommendations

The initiation of future research, development and extension activities in acid soils will require partnerships between community and private sector groups with a clear understanding of what can be achieved by each. In order to facilitate such programs it will be important to link the outcomes from any acid soils strategy to that of other natural resource programs.

Acidification issues on soils should not be studied in isolation, but should be inextricably linked to other land degradation problems such as erosion, vegetation and soil biological biodiversity, salinity, greenhouse gas emissions and water quality. Each of these programs will involve soil processes that include the impact of acid soils on plant growth, soil biology nutrient cycling and soil structural stability. It would seem sensible to combine the resources of each of the separate programs to deliver solutions that consider the landscape as a system rather than the collection of a number of discrete outcomes. In this respect it will be necessary for government agencies, universities, other research organisations and community groups to collaborate where individual resources can be strengthened through integrated activities across programs.

The development of landuse practices will depend upon the solutions identified to tackle these multiple issues and any landuse change will require inputs from both private and community groups to affect change. Table 21 details the specific actions required to deliver outcomes based on the integration of acid soils with other programs such as biodiversity and salinity. This list is not exhaustive, rather it identifies the most urgent actions that are required to gain a much better understanding of the problem in order to act upon the needs of both the community and the private sector to contribute to vibrant and rural communities with a reduced environmental footprint.

This report collates both current knowledge and knowledge gaps on the status and effects of soil acidification in Victorian catchments. A strategic approach to controlling the threats of soil acidification might consider the tasks listed in Table 21.

Table 21. Actions required in the development of a strategy to manage acid soils.

Priorities	Task
Cost & Impact Analysis **(Identifying distribution of causes and impacts)**	Develop a concise estimate of financial costs and benefits in dealing with soil acidification with respect to the shared cost between Government and land owners in Victoria. Examples of private may include: increased production, reduced costs and production losses, and increased land value. Possible public benefits may include improved water quality, amenity values, reduced expenditure by governments on repairs to public assets damaged by land and water degradation, mantaining land-use options for future generations, and conservation of biodiversity
Community & Education Program	Develop a focused education program to increase the awareness of landholders and the general public about the causes of soil acidification, the extent of the problem and the impacts on the environment. Communities and landholders will only accept cost-sharing arrangements and acceptable rates of implementation works after trusting partnerships have been developed, and after satisfactory levels of education and demonstration have been achieved.
Adequate Monitoring Program	Understanding the currrent status of surface and subsurface soil pH. Conduct a statewide monitoring program to understand the extent of the acidification problem within each catchment, which will identify priority areas for immediate action. This data will assist in the planning of cost effective actions to protect the most valuable assets and reduce the most significant external impacts on the environment.
Identification of priority zones, regions and/or sub-catchments	For each catchment there is a need to classify and prioritise landuse on the basis of productive capacity, social and economic viability of the region.
Best practice management guidelines	Promote the use of best practice guidelines for a range of industries in order to control the current rate of acidification.
Research & development	A key outcome of R&D will be improved management of the environmental impacts of soil acidification in Victoria and the integration of these management practices with other state strategies, particularly the salinity program. • Investigate alternative strategies (other than lime) for increasing or maintaining soil pH, reduce the offsite impacts from acidifying processes, and maintain or improve productivity with minimal soil pH decline. • Define the impact of soil acidification on water quality and infrastructure • New land management practices to increase the resilience of the soil to acidification and thus allow these acid soil environments to remain economically viable. • Identify targeted programs for high risk soils under a productivity enhancement program to determine where there are off-site impacts and to decrease their impact and maintain the states water and soil resources • Use of novel plant based technologies could provide solutions for ameliorating soils without the use of lime.