1 Soil Acidity

Good soil health is essential to sustainable production and the long-term resilience of agriculture. Soil health refers to the ability of the soil to support production and maintain environmental values under the prevailing land use. Healthy soils must have favourable physical, chemical and biological properties that promote plant health and maintain environmental qualities.

There are strong interactions between physical, chemical and biological attributes of soil health. If the underlying chemical properties of the soil are unsuitable, then undesirable physical and biological attributes will inevitably also occur. For instance, sodic and saline soils low in organic carbon will have poor soil structure and subsequently limited biological activity. Acidic soils make elements such as aluminium more soluble and therefore toxic to plant roots; this limits plant growth by reducing capacity to absorb water and nutrients, in addition to greatly limiting biological activity and potentially exposing soils to a range of related physical degradation processes.

1.1 Acidification and its Management

The first step in managing good soil health is to get the fundamentals right. This means ensuring that there are no underlying physical and chemical constraints to the productive capacity of the soil.

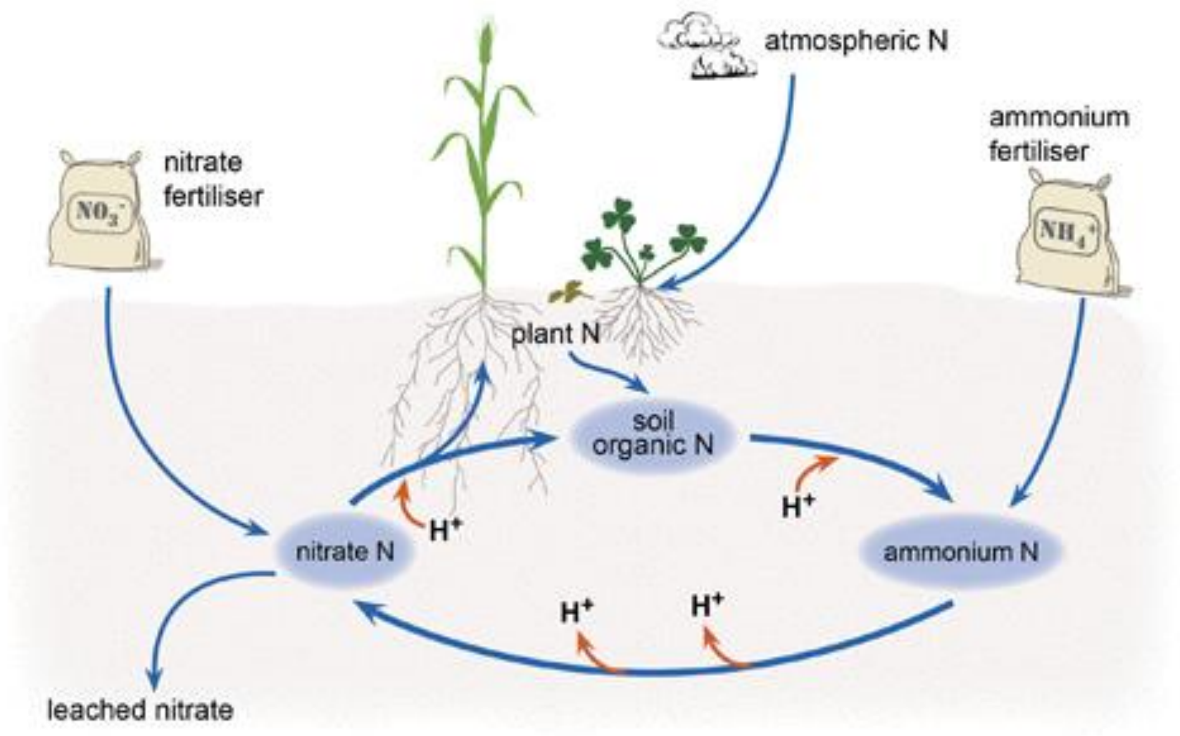
Many soils within the agricultural areas of Western Australia have become acidic over millennia, prior to clearing for agriculture. Dryland agricultural production has continued soil acidification at a far greater rate than occurred under native vegetation. Low pH soils are now widespread throughout the Wheatbelt of Western Australia and in many cases soil acidity is a major constraint on agricultural production.

Farming practices accelerate soil acidification through (refer Figure 1):

- *The application of ammonia-based nitrogenous fertilisers, particularly at rates in excess of plant requirements*
- *Leaching of nitrates, originally applied as ammonia-based fertilisers*
- *Continual removal of plant and animal produce from paddocks*
- *Inclusion of legumes in rotations.*

Soil acidity is relatively easy to treat through the application of agricultural lime, but the rates of application of lime in agricultural areas of Western Australia are currently insufficient to overcome the current extent and ongoing rate of acidification.

Figure 1. Key drivers of soil acidity (N = Nitrogen)



1.1.1 Targets and Thresholds

Aluminium toxicity at low pH is a major constraint to agricultural production. Aluminium begins to dissolve in soils at pH_{Ca} 5.5, and at pH_{Ca} 4.5 aluminium toxicity significantly impedes root growth. The well-established industry target for soil pH_{Ca} is 5.5 in topsoil (0–10 cm) and 4.8 in near-surface and subsurface soils (10–30 cm). The effects of aluminium toxicity in the subsurface soil are minimised if pH_{Ca} is maintained above 4.8. Topsoil pH_{Ca} should be in excess of 5.5 to allow sufficient alkalinity, applied through liming, to move down through the soil profile to treat subsurface acidification. When topsoil pH_{Ca} falls below 5.5, most of the lime applied to ameliorate acidic soil reacts with the topsoil, limiting the capacity of the applied lime to maintain or neutralise low pH subsurface soils.

Where the topsoil pH_{Ca} falls below the threshold of 5.5, application of lime is recommended to prevent the development of subsurface acidity. Where subsurface pH_{Ca} is below the threshold of 4.8, application of lime to firstly recover surface soils pH_{Ca} above 5.5 and then reduce subsoil acidity is essential (refer Figure 2). Topsoil and subsoil pH should be monitored at intervals of three to four years to determine if current liming rates are sufficient to maintain target soil pH (Gazey & Davies 2009).

It is estimated that approximately 78% of topsoil within the Avon River basin (ARB) has a pH_{Ca} of less than 5.5, and 50% of subsoils have a pH_{Ca} of less than 4.8 (Andrew & Gazey 2010). Given that almost 80% of topsoil within the ARB has a pH_{Ca} of below 5.5, it follows that 80% of subsoils within the region are continuing to acidify.

The Avon 2005 Natural Resource Management Strategy contained a target of eliminating soil acidity as a constraint to production by 2025. Whilst an aspirational target, the reality is that soils within the region have become more acidic since 2005, suggesting that a more concerted and effective response is required to achieve the stated objective.

Monitoring of acidity over a range of sites throughout the Wheatbelt indicates that for low to medium-buffered soils, which predominate throughout the ARB, soils are acidifying at approximately 1 pH unit per 10–15 years where liming does not take place (Department of Agriculture and Food, Western Australia (DAFWA) trial data, unpublished).

Based on the current geographical spread, the proportion of land currently impacted, and the estimated rate of decline of soil pH, soil acidity presents a clear and present danger. Failure to respond rapidly will be disastrous for the industry.

Figure 2. Simple State and Transition Model - Soil Acidity

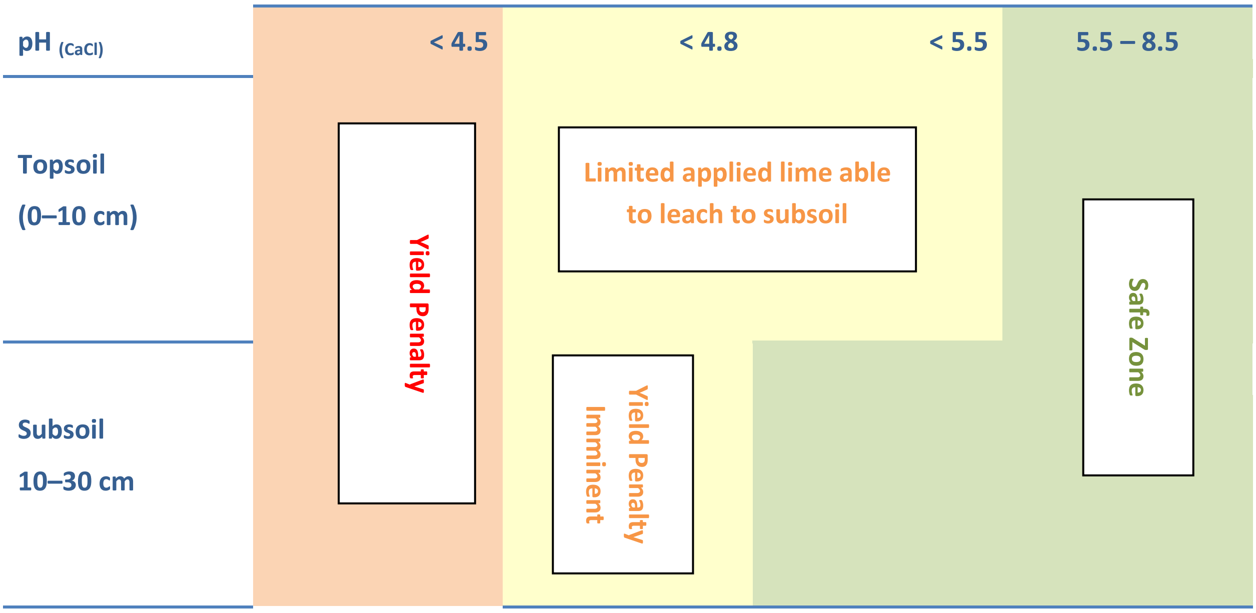
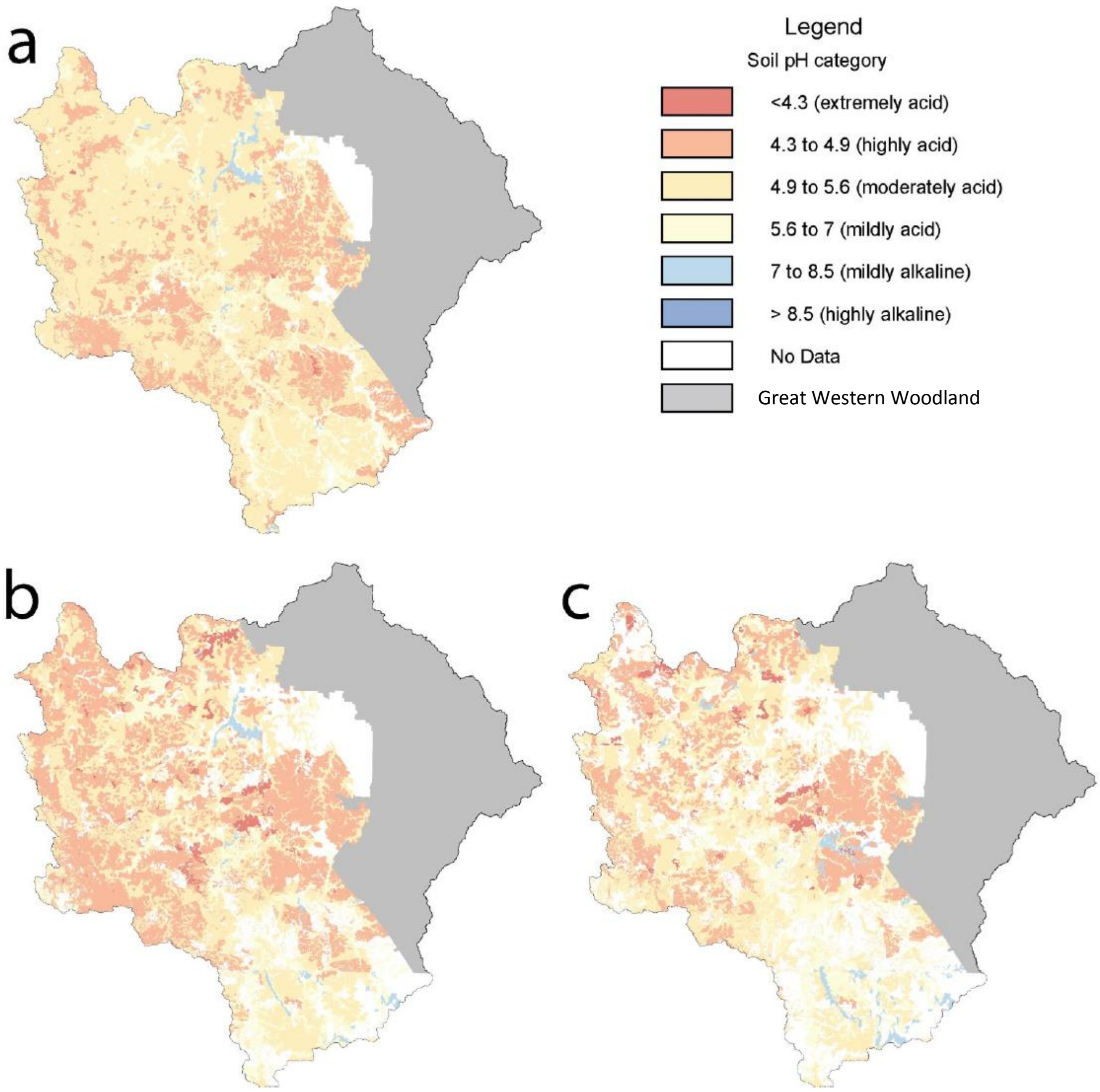


Figure 3. Extent of Low Soil pH within the Avon River basin (Andrew and Gazey 2010)

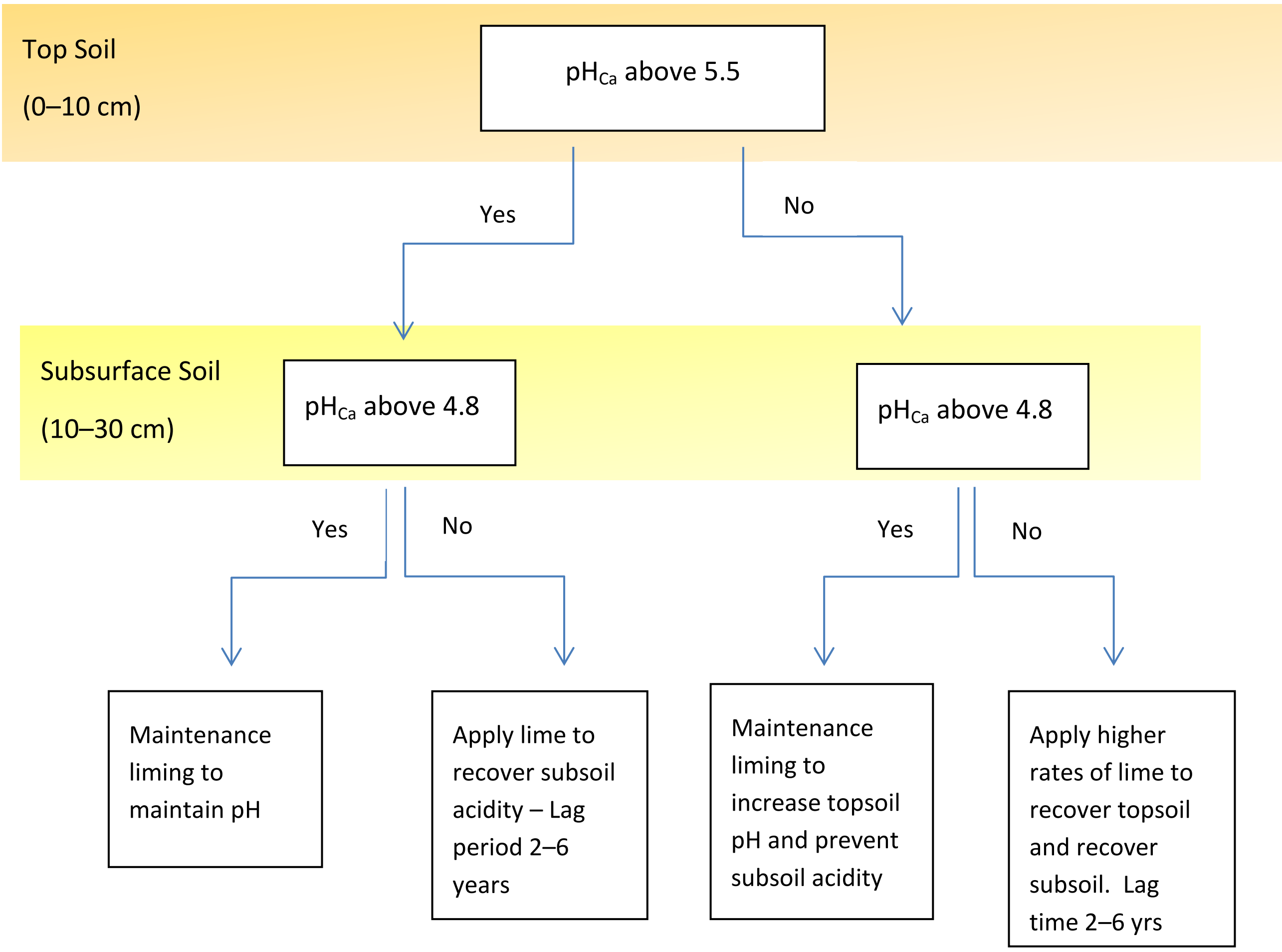


a: 0–10 cm (below natural surface)

b: 10–20 cm

c: 20–30 cm

Figure 4. Decision Model for Management of Soil Acidity



2 Impact on Industry

The cost to the agricultural industry from acidic soils is currently considered to be approximately 8–13% of the region's total agricultural production, with significant additional losses predicted to continue and increase into the future under current practices. In actual dollar terms this loss translates to approximately $400–$500 million/annum ($140–$220 million/annum for the ARB) and is increasing, yet the cost of liming to overcome the constraints is estimated to be in the order of $85–$100 million /yr (Herbert 2009, GRDC 2012).

The agricultural industry needs to apply an estimated 2.5 million tonnes of lime per annum for the next ten years to treat existing and ongoing soil acidification within Western Australia. Application of lime over the period 2000–2010 varied between 0.5–1.0 million t/annum (refer Figure 5), greatly influenced by seasonal variability, up from 0.2 million t/annum during the mid-1990s (Gazey, DAFWA unpublished).

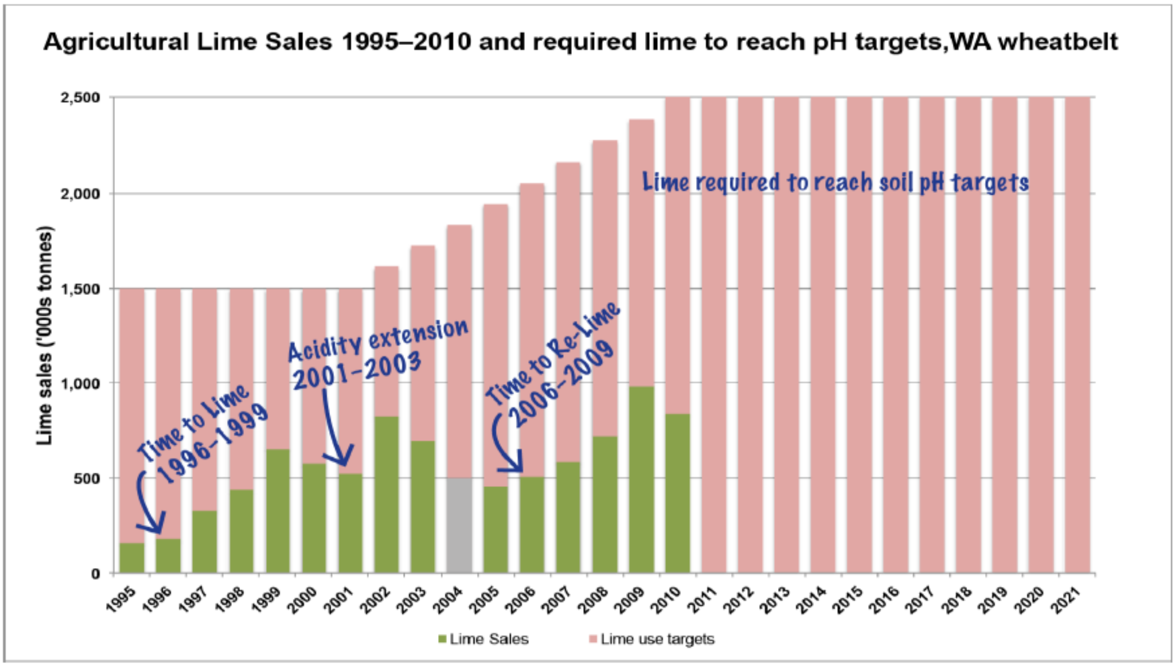
DAFWA grower surveys indicate that 75% of landholders have applied lime in recent years, but most appear to apply a blanket application of 1t lime/ha, with only a small proportion of landholders applying adequate lime based on effective soil testing. Current best estimates suggest that only about 5% of farmers are liming adequately.

3 Response

Soil acidity is a massive issue throughout the dryland agricultural region of Western Australia. Its impact on current agricultural production and threat to future production is unparalleled in terms of area of impact and financial cost, and yet the industry response to the challenge has been inadequate to date.

Previous investment through Natural Heritage Trust (NHT), NAP and DAFWA programs has been effective in increasing rates of lime application (refer Figure 5). Whilst these programs appear to have been effective in precipitating an industry response, the short-term nature of the investment appears out of step with the long-term response essential to achieving desired outcomes. Management of soil acidity requires long-term investment by landholders and support from government.

Figure 5. Agricultural Lime Sales (green bars) and Estimated Lime Requirements (pink bars) for the WA Wheatbelt. (Gazey, DAFWA unpublished)



One of the problems influencing management of soil acidity is that changes in soil pH occur slowly over time and there are limited visible signs of soil degradation. Unlike soil salinity or erosion, no clear visual landscape signs motivate landholders, with soil testing the only real signal that a management response is required. In addition, unlike in some other parts of the world, there is no well-established history of applying lime in the Western Australian Wheatbelt.

Applying adequate lime to acidic topsoil usually provides a relatively rapid yield response, but there are lag times of 2–6 years before applied lime begins to neutralise low pH subsurface soils (assuming sufficient lime has been applied). Agricultural investment decisions are often influenced by the perceived need to achieve a short-term return on investment. Many Western Australian farmers reported that the upfront cost of applying agricultural lime is a significant barrier to treating acidic soils (Fisher 2009). As the area impacted by subsurface soil acidity increases, so does the proportion of land which will experience a delayed yield response to applied lime. Delaying liming will potentially result in additional resistance to future application of lime due to a delay in landholders receiving a return on investment.

This situation is likely to be exacerbated by the current difficult economic climate faced by landholders. Yet, as a general rule of thumb, a maintenance dose of lime is approximately 2 t/ha/decade, costing $6–10/ha/annum.

3.1 Soil testing

Soil testing is essential for landholders to make informed and effective operational decisions. When you consider the amount of money spent on soil amelioration and fertilisers, soil testing to quantify the actual ameliorant requirements of different soils on the farm can have critical financial implications.

Soil testing is essential for management of soil acidity. Applying the right amount of lime to the right area of the farm is often the difference between the exercise being profitable or not. Too much lime and returns begin to diminish; too little lime and the soil remains acidic, losses continue to occur and the soil continues to acidify.

Soil testing programs have been undertaken throughout the Northern Agricultural and South West regions and on the sandy soils of the Swan coastal plain, where testing is aimed at managing acidic soils and nutrient discharge to downstream waterways. These programs have revealed that in many cases soil pH is the limiting factor to production. In the majority of cases it is simply more profitable for landholders to lime than to apply additional phosphate.

Landholders are being encouraged to undertake more effective soil sampling as innovations in controlled traffic and variable rate technology sweep through the Wheatbelt. Making more informed decisions about investment into soil ameliorants, whether fertilisers or agricultural lime, is essential to the future profitability of resilience of agriculture.

Subsurface soil testing is essential as topsoil and subsurface soil pH can be very different. Soil samples should be taken from 0–10, 10–20 and 20–30 cm to determine the pH of the soil profile effectively (Gazey & Davies 2009). Ideally soil samples should be taken during summer, when soils are hot and dry with minimal biological activity, minimising the impact of seasonal variations in pH. Under-sampling can result in over and under-application of lime, particularly if changes in soil type are not taken into account during soil sampling.

Soil sampling every three to four years is recommended to determine the rate of acidification and to better quantify liming programs required at an enterprise scale. Effective tracking of changes in soil pH requires collection of samples from the same location over time.

4 Conclusion

Managing soil acidity is an important challenge for the dryland agriculture industry of Western Australia. Soil acidity is the most pervasive, extensive, progressed and yet solvable land management issue impacting agriculture within the Avon Region.

Managing soil acidity can provide multiple benefits to agricultural enterprises and the adjacent environment. Managing soil pH is central to good soil health, allowing for a wider choice of crop and pasture rotations, increased productivity, better weed control, improved nutrient availability and microbial activity and reduced leaching of nutrients into aquatic environments. Improving soil pH leads to improved plant density and biomass cover and therefore reduced secondary soil degradation processes associated with soil erosion (Andrew & Gazey 2010). Applying lime has been shown to be economic up to approximately 5 t/ha of lime application depending on the neutralising capacity of the lime, buffering capacity of the soil and pH profile of the soil (Gazey & Andrew 2010).

It is a generally held view within the lime industry that subsidising lime application would be largely ineffective in increasing the effectiveness of the lime spread. Subsidising lime application is likely to result in an increase in the cost of liming, with at least part of the subsidy taken up within the chain of supply.

The objective of public investment should be aimed at changing land management practice. This includes increased adoption of effective soil sampling, improved landholder understanding and identification of low pH soils, and additional advice to landholders aimed at better planning and management of low pH soils.

Current projects being implemented throughout the Northern Agricultural, South West, South Coast and Swan Coastal regions include subsidised soil sampling and provide links to professional technical advice delivered through existing grower group networks and catchment groups. This model of engagement is well tested and has been demonstrated to result in a change to land management practice and tangible on-ground outcomes.

Currently, it is estimated that across the South West of Western Australia very few landholders are liming to recommendation and – based on grower surveys and soil pH profiles measured in past and current projects – many landholders are thought to have never limed (Gazey, 2012). There is strong evidence to suggest a very broad target audience for an improved response to soil acidification.

The essential components of the response are:

- *Engaging a large proportion of landholders*
- *Promoting soil sampling and pH monitoring*
- *Utilising the current grower group and community group and other industry networks*
- *Incorporating liming into the business management model of farming enterprises.*

Effective soil sampling is the key to not only understanding liming requirements, but to ensuring that lime application is undertaken in a profitable and effective manner. Undertaking topsoil and subsurface soil sampling and analysis is essential in raising landholders' awareness and ensuring that lime application is appropriate for the soil type and pH and is not undertaken in an ad hoc manner.

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