10.1071_ISSN0311-4546EC106p32

anti acids

Researchers at CSIRO Plant Industry are tackling the management of soil acidity on Australian farms in two ways. They're refining a farm management tool that helps landowners to understand, predict and prevent its spread, and are seeking a genetic route to aluminium-tolerant crop varieties.

With funding from The Vincent Fairfax Family Foundation, Drs Joerg Braschkat, Richard Simpson, Andrew Moore and Peter Randall are developing a computer model that simulates the causes, development and consequences of soil acidification.

The soil acidity model slots into GrassGro, the pasture growth and animal production module of a farm management program called GrazPlan (see diagram).

GrazPlan can simulate cumulative interactions between 'big-picture' factors such as pasture growth, climate variability, nutrient cycling and financial management.

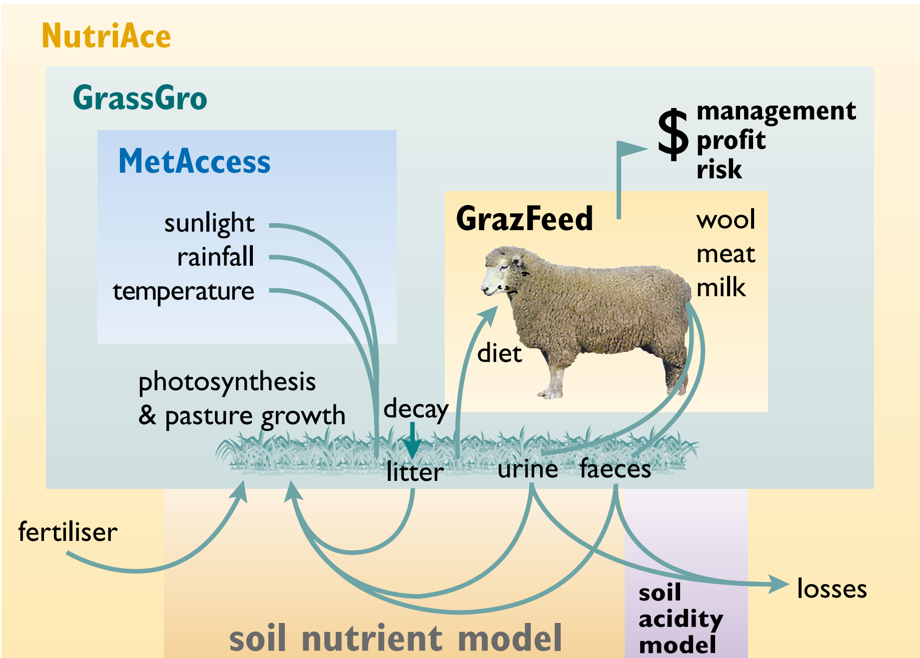
The user can specify the breed of sheep or cattle, the species composition of the pasture, various stocking rates, fertiliser type and rate, soil properties, initial soil pH, and so on! Historic weather records from the Bureau of Meteorology can accessed through software called MetAccess.

In this way, landowners can explore the future impact of different farm management decisions on soil acidity, and the likely consequences for the productivity of grazing enterprises.

Importantly, they can also predict the future effects of soil acidification, and counter-measures, on the soil environment. This should enable more sustainable agriculture, and less risk of further environmental degradation.

Exploring strategies

The ability of the model to simulate soil acidity was tested by the scientists using the results of field studies near Crookwell in New South Wales. Model simulations of acidity and key nutrient values down the soil profile agreed well with the field experiments.



Incorporation of the soil acidity module into a broader suite of livestock management software allows graziers to test management scenarios on soil acidification, and on farm profit and risk.

Leaching the landscape

SOIL acidification is a natural process that is accelerated by agriculture . . . with insidious consequences. It is a serious hazard for rural landscapes and farm productivity.

Some 33 million hectares of farmland soils are estimated to be highly acidic. Another 55 million hectares are classed as moderately acidic and at risk of more severe degradation. The problem mainly affects higher and moderate rainfall areas of southern Australia, and parts of Queensland, where many of our most productive cropping and livestock grazing enterprises occur.

The processes leading to soil acidity have long been known. Agricultural practices that raise the soil nitrogen content, such as pasture improvement with subterranean clover and superphosphate, and grain legume cropping, are major culprits. Removal of relatively alkaline products such as hay, grains and livestock also contributes.

The main immediate acidifying processes in soil are: acid generation when organic forms of nitrogen are converted, via ammonium, to nitrate, and acid excretion by roots to balance the uptake of soil cations including calcium, magnesium and potassium.

Rainfall is important because nitrate is readily leached away, leaving behind the acidity generated when the nitrates are formed. Sandy and loam soils are more vulnerable to degradation because leaching is easier and they have a lower pH buffering capacity than clay soils.

Acid soils are often infertile because soluble nutrients, such as potassium, calcium, magnesium and sulfate, have been leached away and others, for example phosphate, are tightly bound in the soil and so unavailable to plants.

As soil acidity increases, aluminium and manganese minerals in the soil are rendered more soluble and, as these elements dissolve in soil water, they become toxic to plants and begin to damage root tips and inhibit plant growth. So high soil acidity (low pH) mainly limits farm production indirectly through mobilisation of aluminium and manganese that are toxic to plants, and through poor nutrient supply.

A computer model developed by Dr Peter Randall, Dr Joerg Braschkat and their colleagues at CSIRO Plant Industry enables landowners to simulate the development of soil acidity, its effects on soils and farm productivity, and the costs and outcomes of preventative strategies.

They have also tested the model's strategic value, by simulating the consequences of doubling the stocking rate (from 9–18 sheep per hectare) and superphosphate application (from 125 to 250 kilograms per hectare) on an 850-hectare 'cyber-farm'.

The more intensive system of pasture improvement proved twice as productive as the lower input system, but also more than doubled the acidification rate.

But Randall says the implications for the environment are not as clear-cut as these figures suggest. He says it could be argued that because net farm profitability in the the high-fertility scenario is nearly three-and-a-half times greater, the farmer could better afford the cost of applying lime to neutralise acid soil.

Indeed, the model shows that in the case of the lower fertility scenario, 9% of the modest net farm income would need to be allocated to liming, while for the higher fertility farm the figure is only 6.6% of a larger net income.

'It could be worth exploring the notion that profitable, intensively managed agriculture may be more sustainable than a low-input system,' Braschkat says.

'That is, provided the farmer puts aside funds for environmental rehabilitation, and provided these measures are successful.'

At this stage, the scientists are not treating the results of such scenario modelling as gospel, as they are still fine-tuning the model. But they are confident that the program will develop into a fully-fledged decision-support model to assist farmers make sound and informed decisions to ensure a sustainable future for agricultural lands.

Good and bad acids

With Dr Manny Delhaize and Dr Peter Ryan, Peter Randall has been tackling another aspect of the soil acidity problem: the question of why some plants are more tolerant of acid soils than others.

Some wheat varieties, for example, are 10 times more tolerant of aluminium than others, and this resistance is known to be conferred by a single gene.

Close investigation using x-ray micro-analysis has revealed that aluminium-tolerant wheat plants had less aluminium in their root tips.

The scientists wondered whether the roots of tolerant wheat plants could be releasing molecules that bind to aluminium ions in the soil so that they could not be taken up by the roots. This would render them harmless to the plant.

When they followed this up, the team found that aluminium-tolerant wheat varieties indeed secrete an organic substance called malate or, ironically enough, malic acid.

Malate occurs naturally in plant cells, but it is only in acid-tolerant wheat lines that the roots secrete it and, remarkably, only in the presence of aluminium ions. So toxic aluminium solutions trigger a 'defensive' mechanism in tolerant wheat plants.

Cross-breeding experiments showed that the gene conferring acid tolerance is probably the one responsible for controlling malate secretion and the scientists believe that it is somehow involved in the passage of malate across cell membranes in the plant roots.

'If we can work out what protein the gene is coding for, and isolate the gene, we open the way to the exciting prospect of inserting it into other plants to produce aluminium tolerant varieties of canola, lucerne, barley, and the like,' Delhaize says.

'We don't want to encourage complacency about the value of minimising rates of soil acidification or the need to apply lime, but deep-rooted, acid-tolerant crops should be able to exploit water and nutrients deep in the soil profile even where subsoil acidity is a problem. They could be used with applications of lime which mainly counter topsoil acidity.'

The scientists say the use of aluminium-tolerant, deep-rooted perennials in pastures, rather than shallow-rooted annuals, holds the promise of reducing acidification rates, since more nitrate will be absorbed by plants rather than leached down the profile. Consequently, less lime may be needed.

Certainly, new more-tolerant crop and pasture cultivars will give land managers greater flexibility as they attempt to deal with a very real threat to Australian agriculture.

More about acid soil strategies

Verburg K Braschkat J Hochman Z Moore AD Helyar K Probert ME Hargreaves JNG and Simpson RJ (in press) Acidification under pasture: simulations with the GRAZPLAN soil acidity model implemented in Nutriace. In Rengel Z, *Handbook of Soil Acidity*, Marcel Dekker, New York

Ryan PR Delhaize E and Randall PJ (1995) Malate efflux from root apices and tolerance to aluminium are highly correlated in wheat. *Australian Journal of Plant Physiology*, 22:531–536.

Steve Davidson