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Dryland salinity – the notorious consequence of land cover change in Australia – has two potentially devastating understudies: acid sulfate soils and soil acidification. **Wendy Pyper** and **Steve Davidson** profile research on these lesser-known threats to our agricultural heartlands.

bubble bubble…

Above: Dam excavation in an area affected by acid sulfate soil conditions. Black, sulfidic sediments surround the dam and the water is polluted with iron.

Below: Acid affected soils are also characterised by black sulfidic bog and gelatinous iron-rich deposits in seepage areas during the wet season, and impermeable topsoil crusts during the dry season.

Rising groundwater has brought more than the threat of salinity to inland Australia. In many parts of the country, the combination of water-logging, agriculture, and a rich geology of iron, sulfur and heavy metals, has led to the formation of acid sulfate soils.

Characterised by black bogs, slimy red ooze and scalded, infertile patches of earth, these soils have been reported in the Western Australian wheatbelt, South Australia, south-west Victoria, the Yass valley in New South Wales and south-east Queensland.

While these reports suggest that the distribution of acid sulfate soils across the country is widespread, the true extent, nature and severity of the problem are still unknown. This is because the discovery of inland acid sulfate soils is relatively recent, although the problem has been studied in coastal areas since the 1980s.

For farmers, this lack of knowledge means an inability to identify, prevent or manage acid sulfate soils on their land, resulting in erosion, acid and heavy metal run-off, and reduced water quality and crop yield.

CSIRO Land and Water pedologist, Dr Rob Fitzpatrick, is helping to reverse this trend through his work on acid sulfate soils in western Victoria and South Australia.

After a decade of research, Fitzpatrick and his CSIRO colleagues – through the CRC for Soil and Land Management – have developed manuals for identifying and managing saline and acid sulfate soils in the Dundas Tablelands and Adelaide's Mount Lofty Ranges. These manuals have been successfully field tested by community groups and agriculture advisers.

Fitzpatrick is also championing a national strategy for the Australia-wide mapping of acid sulfate soils.

'Little can be done in terms of long-term management strategies until the extent and location of acid sulfate soils is known at both catchment and property levels,' Fitzpatrick says. 'This requires risk mapping on a national basis, followed by property assessments and environmental hazard assessments at a catchment level.'

Fitzpatrick and a University of South Australia colleague, David Bruce, have begun a more detailed mapping assessment of the Mount Lofty Ranges using radar

Lofty advice averts rural disaster

Bruce Munday at a Tungkillo Landcare Group salinity site: 'We thought it (acid sulfate soils) was a variant of salinity: a bit interesting, a bit spooky'.

TEN YEARS ago, CSIRO's Dr Rob Fitzpatrick and Murray Grey cattle farmer Bruce Munday met over a patch of land in the Mount Lofty Ranges.

The land had been fenced off by the Tungkillo Landcare Group, of which Munday was a member, in an attempt to protect it from stock and manage a salinity problem. But it wasn't the salinity problem that caught Fitzpatrick's eye.

'Rob had noticed some acid sulfate soil on the block and was interested in doing more work in the area,' Munday says. 'In those days acid sulfate soils were relatively unknown except in coastal environments.

'He asked if landholders would be interested in collaborating on a project to study the soil further and we thought it would be a great opportunity. So we showed him a number of other properties, which were far more interesting, and began measuring water table levels.'

In return, Fitzpatrick produced detailed soil maps of one of the properties and came up with a model on how acid sulfate soils work. He also imparted his knowledge of the soils to the farmers, showing them how to manage affected sites and avoid environmental and financial disaster.

'Before we met Rob, we didn't know what acid sulfate soil was,' Munday says. 'We thought it was a variant of salinity: a bit interesting, a bit spooky – if you walked on it there was a danger you might disappear out of sight in the black sludge.'

'But our feeling was we could work around it. We'd even discussed draining it because it was always wet. Then Rob explained the consequences of disturbing or draining the soil and we realised the seriousness of the situation.'

As Fitzpatrick explained, disturbing or draining acid sulfate soil releases sulfuric acid and metal ions onto the soil surface and into waterways, destroying soil structure, water quality, estuarine habitat, infrastructure and farming, fishing and aquaculture industries.

Munday says the landcare group responded to this knowledge by fencing off affected areas, to ensure cattle run on the surrounding grazing properties did not exacerbate the problem.

Of the 150 square kilometres of land under the care of the Tungkillo Landcare Group (involving 43 farming families), Munday estimates 20–30 hectares is affected by acid sulfate soil, while about one hectare on his own 300-hectare property is affected.

But Munday says that although the area affected is relatively small, the impact it has on water quality is significant.

'These soils are constantly discharging toxins and acid into the watercourse, so the area affected is much greater than 20 hectares,' he says. 'And every time it rains, a lot of precipitates that accumulate on the soil surface get washed off as well.

'Aside from the fact these toxins destroy the environmental features of waterways, they can also mean the water is no longer suitable for our animals to drink.'

The Tungkillo Landcare Group is dealing with issues of salinity and acid sulfate soils in a variety of ways. Revegetation of ground-water recharge areas, to lower or stabilise rising water tables, is a way of tackling both.

Dr Rob Fitzpatrick discusses acid sulfate soils with members of the Tungkillo Landcare Group.

'Our aim is to target the recharge areas, which in the Mount Lofty Ranges are the ridgetops,' Munday says.

'We've revegetated with local native plants, which has a secondary benefit of enhancing biodiversity and restoring the native vegetation.

'We're also concentrating on the more productive parts of the landscape by planting perennial pastures and lucerne. And some farmers are developing an interest in farm forestry.'

Munday says trees planted around one area of acid sulfate soil have lowered the water table by 70 cm. And because stock have been excluded from affected areas, reeds and rushes – some of the only plants that will grow on acid sulfate soil – are also helping to stabilise the soil and prevent erosion and acid runoff when it rains.

The publication of the CRC–CSIRO manual on waterlogged, saline and acid sulfate soils in the Mount Lofty Ranges has also made land management that much easier for farmers, Munday says.

'The manual is very much a do-it-yourself kit that has enabled us to manage these things properly, rather than by trial and error,' he says. 'Trial and error has always been a great standby for farmers, but it sometimes has dire consequences.'

The legacy of rising saline sulfate-rich watertables: an island of black, acid sulfate soil in an eroded scald.

data on soils, geology, terrain and moisture, (see story below), and plan to extend this effort into Western Australia and New South Wales.

Acid soil basics

Fitzpatrick says inland acid sulfate soils are commonly associated with dryland salinity, which is caused by rising saline groundwater.

In several parts of Australia, this groundwater is rich in sulfate, which seeps up through the soil along with other ions including sodium, magnesium, arsenic, iodide and chloride, forming various mineral precipitates within and on top of the soil. If the soil is waterlogged, anaerobic bacteria use the sulfate to help degrade organic matter. This process produces an iron sulfur compound called pyrite.

Pyritic enriched soils or sediments are called ‘potential’ acid sulfate soils because they have all the ingredients necessary to create environmental havoc.

Havoc is wrought when cattle, drainage works, or other disruptive forces breathe air on waterlogged soils and the pyrite within. When this happens, pyrite is oxidised to sulfuric acid and various iron sulfate-rich minerals. ‘Actual’ acid sulfate soils form, and a chain of destruction follows.

‘If waterlogged ‘potential acid sulfate soils’ are exposed to the air, sulfuric acid forms and the soil pH can drop from neutral (pH 7) to below 4,’ Fitzpatrick says. ‘This dissolves the soil, causing trace elements, salt and metal ions such as iron and aluminium to be spewed out onto the soil surface and into stream waters.’

As the soil structure declines, it becomes clogged with clay and mineral precipitates, losing its permeability. This prevents the groundwater below from escaping and forces it to move sideways or upslope.

Soil around the clogged area soon erodes, sending acid, metal ions and salt into waterways and dams, while a new area of potential acid sulfate soils develops nearby. Salinity increases as the acidification process accelerates the decomposition of minerals in the soil and underlying rocks.

These degraded soils are difficult to treat, given that they are acidic, contain high amounts of salt, are seasonally waterlogged, and have low permeability and fertility. But Fitzpatrick says the visual soil indicators (black bog, gelatinous seepage, impermeable crusts, and scalds) can be used as a tool to devise management strategies.

Bird’s eye **electrical cues** pinpoint groundwater seepage

THE INSIDE of a NASA DC-8 jet aircraft might be an unusual place to conduct research. But for Dr Ian Tapley, a remote sensing scientist from CSIRO Exploration and Mining, it’s a good way to interrogate the earth’s surface, 8000 metres below.

Tapley, with colleagues from NASA and the University of New South Wales, has been using the AIRSAR (AIRborne Synthetic Aperture Radar) to record land-surface features – including topography, soil moisture and vegetation – in Pacific Rim countries such as Australia, New Zealand, Indonesia, Malaysia and Cambodia.

The information is used to map environmental resources, identify areas of land degradation and predict the amount of carbon stored in forests and woodlands.

Last year, Tapley identified areas of groundwater seepage associated with salinity and acid sulfate soils. These are being mapped in association with Dr Rob Fitzpatrick and his CSIRO team, and David Bruce from the University of South Australia.

‘These maps can be linked to local geology and topography using a geographic information system, allowing Rob to identify areas affected by or at risk of developing acid sulfate soils,’ Tapley says.

To identify groundwater seepage areas, the research team looks at soil ‘dielectric property’ information derived from the AIRSAR data. This information relates to the electrical potential of the soil and is directly affected by soil moisture.

The information is collected as the DC-8 aircraft flies over target terrain, while the AIRSAR instrument transmits continuous pulses of microwave energy onto the earth’s surface.

Some of this energy is reflected back (backscatter) to the radar, which sends a signal to on-board computers. This signal is then relayed to high-density tapes, which are sent to NASA’s Jet Propulsion Laboratory in the US for processing.

The aircraft has made two flights over the Adelaide Hills and into the Mallee landscapes of the Western Murray Basin, where the extent of the acid sulfate soil problem is being assessed (see main story).

Tapley says a multispectral airborne mapping system is also used during the flights. This system collects reflected electromagnetic waves from the terrain below, enabling scientists to identify where minerals occur, such as the iron oxyhydroxides and pyrite found in acid sulfate soils.

Dr Ian Tapley is part of the CRC for Landscape Evolution and Mineral Exploration. Contact: 0419 877 797, i.tapley@per.dem.csiro.au.

These strategies include stock exclusion, adding lime to the soil, planting perennial pastures and trees that use up water and planting salt tolerant vegetation such as phalaris, fescue, strawberry clover or tall wheat grass.

Eroded areas can be stabilised with salt tolerant trees, shrubs or grasses or by the construction of control weirs or gully head structures.

Bright prospects

While acid sulfate soils often spell the demise of agriculture, there is a positive side to the problem.

'The presence of acid sulfate soils tells us three things,' Fitzpatrick says. 'The soil is useless; it's going to pollute the water supply and kill the fish; and there's likely to be a mineral deposit under there somewhere, which is great news.'

Gold, zinc, lead and copper are almost always associated with sulfide ore bodies and Fitzpatrick says a knowledge of the mineral precipitates that form in acid sulfate soils could be used by mining companies to identify potential deposits.

Fitzpatrick and his colleagues from CSIRO and the CRC for Landscape Evolution and Mineral Exploration have recently shown that two bright yellow mineral precipitates – sideronatrite and natrojarosite – form in extremely acid and saline soils.

'The identification of these minerals in an eroded soil system is believed to be a new natural occurrence, and they could be used to identify concealed mineralisation or ore deposits,' Fitzpatrick says.

This work was part funded by ACIAR and the National Dryland Salinity Program.

More about acid sulfate soils

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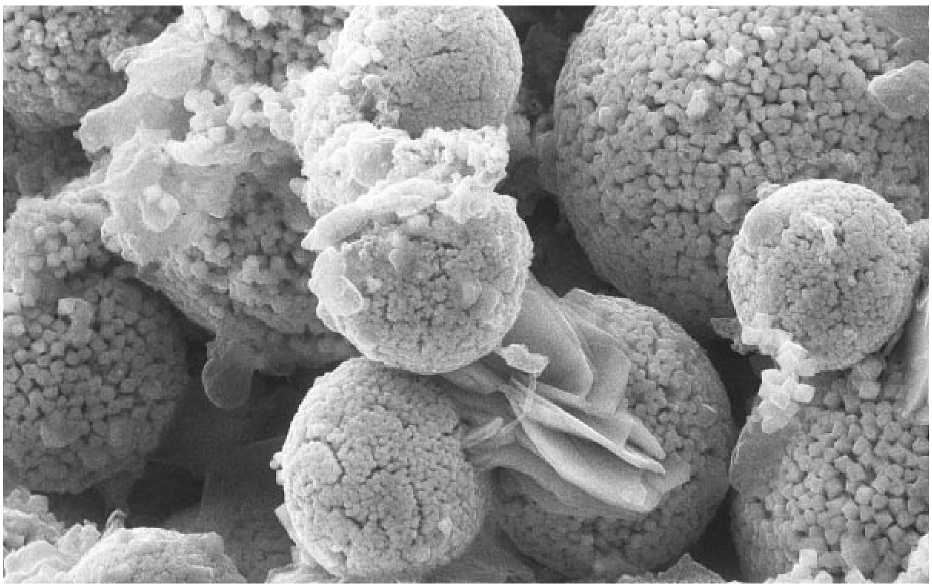
Wendy Pyper

Abstract: Acid sulfate soils in inland areas are a consequence of rising groundwater and a rich geology of iron-sulfate minerals. After a decade of research, CSIRO scientists have identified the processes leading to the formation of acid sulfate soils, which destroy both land and water quality, and have developed manuals for the identification and management of the problem in parts of South Australia and Victoria. Affected areas around the country will eventually be mapped with the help of radar data that identifies areas of soil moisture. Acid sulfate soils may also be used to locate mineral deposits commonly associated with sulfide ore bodies.

Keywords: acid sulfate soils,soil degradation, land management, soil mapping, pyrite, mineral deposits, Mount Lofty Ranges, SA, Tungkillo Landcare Group.



Long, slim sideronatrite crystals appear like wood shavings among spherical aggregates of pyrite crystals called 'framboids'. Sideronatrite forms after the rapid oxidation and dissolution of pyrite crystals in acid sulfate soil. Its presence may help mining companies identify potential deposits of gold, zinc or copper.

Mapping the dangers within

COASTAL acid sulfate soils have been more extensively studied than inland acid sulfate soils because of their tremendous impact on farming, fishing, aquaculture, urban development and engineering works.

It is estimated that more than 40 000 square kilometers of potential and actual coastal acid sulfate soils exist, mainly in mangrove and salt marshes, tidal lakes, swamps and coastal riverbeds.

The reclamation of such land for coastal activities and urban development, however, and subsequent flood mitigation and drainage schemes, has caused the export of acid water into major streams and waterways.

This has led to huge losses of oysters, prawns and fish, the degradation of large areas of land and estuarine habitat, and the corrosion of aluminium, concrete and steel infrastructure such as pylons and pipelines.

For every tonne of pyrite completely oxidised, 1.6 tonnes of sulfuric acid are produced and more than one billion tonnes of pyrite are estimated to exist along the Australian coastline.

Risk maps, which provide information on acid sulfate soil distribution and indicate land uses likely to create an environmental risk, have been constructed for coastal areas in Queensland and New South Wales. These maps assist with land management and environmental planning in coastal areas.

Dr Rob Fitzpatrick says similar maps are needed for inland areas and minesites, where acid sulfate soils are found in waste rock stockpiles and tailing impoundments.

In a 1998 National Land and Water Resources Audit methods paper, Fitzpatrick and other soil scientists suggested ways of assessing the development of acid sulfate soils throughout the country and advocated the construction of a national risk map.