Focus on the land

The Year of Land Care — 1990 — ushers in the decade of the same name. They mark a matter of urgent importance for Australia. Currently, about 55% of our arid area requires treatment for some form of land degradation, and 45% of the non-arid part of the country is similarly afflicted.

This widespread damage to the land upon which we ultimately depend has all occurred in the 200 years since the first European settlement. It is hurting us economically and even threatens our future food supply.

Acidification, dryland salinisation, and structural decline of our soils together cost at least $600 million every year in lost production.

Major causes of land degradation have included clearing for crops and pastures, overgrazing, and the introduction of animals and plants that have become pests. Results, apart from massive soil damage, include the extinction or placing at risk of many species of our unique flora and fauna.

It's no use blaming previous generations for this bad news. They didn't know that most of Australia's soils developed on very ancient landscapes and did not benefit from the 'rejuvenating' effects of glaciation as did those of Europe and North America. Consequently, our soils are inherently less fertile than those in the countries where our agricultural practices originated. The rate of formation of soil in most parts of Australia is very low, and cannot keep pace with the loss caused by erosion on cleared or overstocked land.

And the early settlers had no inkling that introduced animals like rabbits, and plants like prickly pear, would thrive so destructively.

Agriculture inevitably removes nutrients from our already infertile soil. Eaten by people and animals, they end up in sewage outfalls around the world. For example, for every one million tonnes of wheat we produce the soil loses 20 000 tonnes of nitrogen and about 3000 tonnes of phosphorus, as well as large amounts of potassium, sulfur, and other nutrients.

Unfortunately, the means by which much of the nitrogen and phosphorus is replaced — growing sub clover, which fixes atmospheric nitrogen, and topdressing with superphosphate — has caused the soil to become acid, or more acid, over large areas. This damages plants by changing the availability of many elements. Replacing nitrogen directly, via fertiliser, is expensive, uses up fossil fuels for manufacture and transport, and can produce damaging levels of nitrogen where we don't want it — in rivers or on areas of native woodland.

Analysis of our wheat has shown that its protein levels are falling, as the nitrogen in our soils is not being fully replaced. (Nitrogen is an important constituent of protein.) Less protein makes the wheat less valuable. Our major customers set a standard of 10·5% protein in the grain. There is a danger that in the future our wheat could fall below this value, jeopardising large export earnings.

The soil is our most important natural resource. But it is old, infertile, and fragile. We depend on it, but our use damages it. There is no easy solution to this dilemma. Stricter control of land use and better management practices will help; clearly we must find ways to ensure that the land maintains its capacity to sustain us in the future.

The next ten pages look at research on a range of land-care problems — erosion in catchments, destruction of native animal habitats in the arid zone, and the damaging spread of an introduced tree. Later issues will focus on other research related to the state of the land, including work on strategies for tree-planting as a way of reversing some of the damage.

Sediments — revealing past and future

Old beer bottles, pollen grains, bits of charcoal, and caesium-137 may not be the stuff of every fossicker's dreams, but when researchers find them in reservoir sediments they become a rich source of information about environmental changes and land management practices upstream.

Taking advantage of low water level in Burrinjuck Reservoir, Dr Bob Wasson prepares a sediment sample for removal and later analysis.

Dr Bob Wasson and Dr Robin Clark, of CSIRO's Division of Water Resources, are among scientists who have been using the analysis of reservoir sediments to reconstruct catchment histories. Their 'pictures of the past' help land- and water-resource managers answer some important questions about reservoir catchments. For example, how quickly is the sediment in the water storage accumulating? What is the major source of sediment? How are land-use changes affecting soil erosion and water quality? And what are the impacts of past urban, industrial, mining, and agricultural pollution?

Sediment sources

Sediments are mainly eroded rock fragments and clay minerals washed into the reservoir by run-off, but they can also include airborne particles, decomposing organic fragments of plants and animals, and inorganic siliceous and calcareous 'skeletons' produced by organisms such as diatoms and molluscs. Some of the sediments' biological component comes from plants and animals that actually live in the water storage.

For scientists seeking to unlock a catchment's environmental history, identifying all of a sediment's components is only part of the process. Other steps include the accurate dating of the detritus. As long as sediments have not been disturbed — by wading or burrowing animals, for example — they provide a vertically layered record with the oldest layers at the base. Once researchers know the age and quantity of the sediment, they can estimate the rate of sedimentation — valuable knowledge for the managers of town water supplies!

On one occasion a dated beer bottle lodged in a cross-section through a sediment provided Dr Wasson with the age of the material deposited above it.

Normally, the scientists date the sediments from core samples using a range of techniques determined by the characteristics of the catchment. For example, as part of a large-scale research project in the Burrinjuck Reservoir catchment in New South Wales, involving many scientists and organisations, Dr Clark and her colleagues established a chronology of the sediment by correlating charcoal layers with bushfire history, noting the first appearance of caesium-137 (a radioactive element produced by atmospheric nuclear-weapons testing), and identifying seasonal pollen peaks.

Using these techniques the researchers calculated the rate at which the sediment had built up — a reflection of the rate of erosion in the catchment. They found that sedimentation, and hence erosion, in the Burrinjuck catchment has decreased since the mid 1940s, probably as a result of changes in land use and management such as the introduction of improved pastures and the control of rabbits.

Tracing sediment

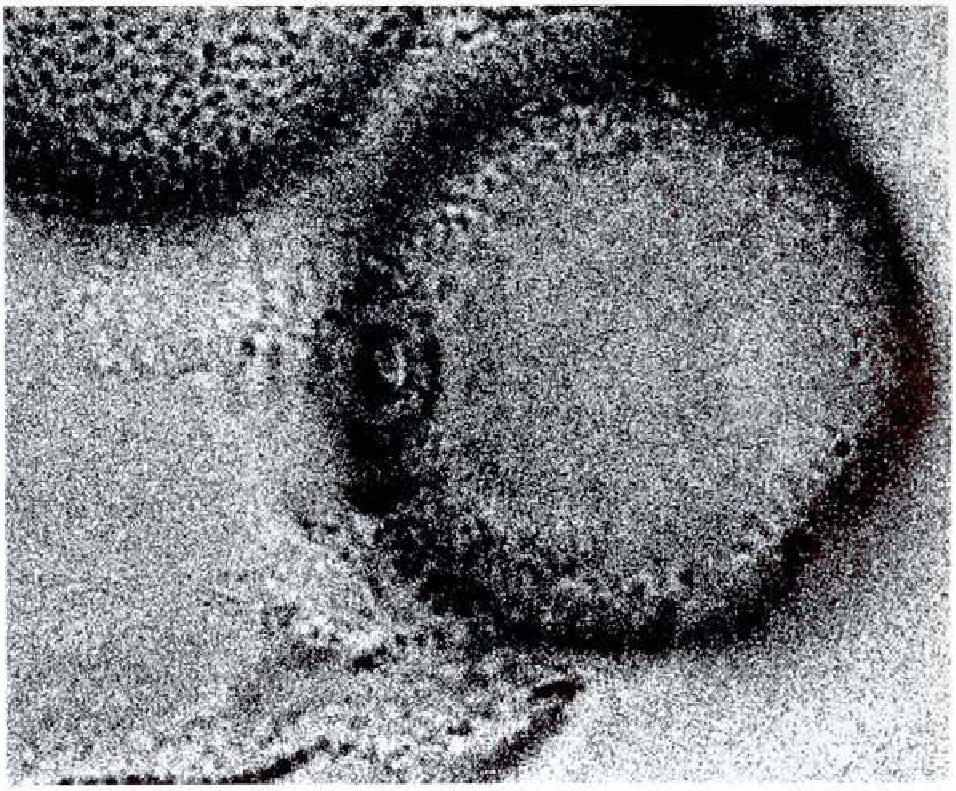
Reservoir sediments can tell scientists a lot more than the rate of erosion. Careful analysis can also reveal where in the catchment the sediment originated. As mentioned earlier, seasonal layers of pollen in the sediment serve as a useful chronometer, but pollen grains can also be a sediment tracer. From her analysis of pollen deposited over the last 40 years in the Burrinjuck sediment, Dr Clark has identified where most erosion has occurred at different times in the reservoir's history.

Using the reasonable assumption that most pollen of the Myrtaceae family (that includes the eucalypts) comes from native forests, most pollen of the Poaceae (grasses) from pastures, and almost all *Pinus* pollen from pine plantations, she has found that serious floods eroded the soils of pastures and pine plantations more than those in the native forests.

By contrast, although variable rainfall across the catchment would have influenced the outcome to some extent, pollen records show that drought years appeared to produce more topsoil eroded from pastures and native forests than from pine plantations. Dr Clark distinguishes between top- and sub-soil sources by comparing the numbers of damaged pollen grains — unlike pollen grains further down the soil horizon, pollen in topsoil tends to be degraded by physical and chemical decay and microbiological destruction.

Analysing pollen grains is not the only way to trace the origins of sediment. Recently, Dr Wasson teamed with Mr Gary Caitcheon, a colleague in the Division of Water Resources, and Dr Ian Willet of the Division of Soils, along with Mr Richard Hammond of the Australian Capital Territory Parks and Conservation Service, and Mr Brian Wild of the New South Wales Soil Conservation Service. This team used natural tracers — magnetic minerals and radionuclides — to determine the source of the sediments in Lake Burley Griffin, A.C.T.

Magnetic minerals (such as magnetite) are commonly found in weathered soil profiles and have unique magnetic characteristics — linked to their geographical origin — that can be readily measured. By comparing samples in sediment cores with soil samples in the Lake's catchment, the scientists pinpointed the origin of the sediment.



When linked to the age of a sediment layer, the number and type of pollen grains provide valuable clues about the catchment's vegetation at specific dates in its history. Shown here is pollen from the grass family.

Further analysis, using the ratio between the naturally occurring radionuclides lead-210 and radium-226, indicated whether the sediment came predominantly from upper or lower soil horizons. It seems that, to date, most of Lake Burley Griffin's sediment has come from eroding gullies within the Molonglo River catchment. Clearly, analysis like this is valuable for land managers seeking to identify the parts of a catchment where soil conservation programs should be given priority. Dr Andrew Murray of the Division of Water Resources is refining this work by analysing radionuclides found in the sediment of rivers.

Future from the past

As well as showing sedimentation rates and the sources of worst erosion, sediments also provide a record of other changes in a catchment. For example, chemical analysis can track pollution following industrial, agricultural, or urban development. (Canberra's population growth, and its keen amateur gardeners, can be correlated with a commensurate increase in phosphorus found in Burrinjuck Reservoir sediments.)

But the supply of information to be gleaned from sediments doesn't cease there. Although reservoirs are effective

Sediment cores — records of the past with a message for the future?

sediment traps that offer a convenient source of stored and layered material, scientists can use the same analytical methods to track the movement of mineral and biological fractions deposited downstream in natural lakes, swamps, estuaries, and floodplains. With techniques such as radiocarbon dating, researchers can build up pictures of a catchment's environmental history going back hundreds, even thousands, of years.

For example, working with Dr Bob Galloway of the Division of Water Resources, Dr Wasson has estimated the sediment yield for the catchment of Umberumberka Creek, just west of Broken Hill, N.S.W., for two periods before European settlement and for three periods after settlement. Their studies reveal a dramatic change in the catchment following the arrival of Europeans and domestic stock. Although the last 30 years has shown some decline in the extent of post-settlement erosion, the scientists conclude that the current average yield of 2 cubic metres per hectare per year is about 60 times greater than the average yield for the 3000 years preceding settlement.

This dramatic indictment of European treatment of Australia's fragile soils is supported by Dr Wasson's other studies in the Southern Tablelands of New South Wales and the Australian Capital Territory. He has found that, before settlement, a catchment near Canberra yielded less than 1 cu. m of sediment per sq. km per year. By the mid to late 19th century this rate had risen to 200 cu. m. It has now declined to about 50–60 cu. m.

Dr Clark and Dr Wasson are keen to emphasise that because sediments represent a long-term record of the past they can also be useful predictors of the future.

Soil on its way to becoming sediment.

Knowledge about the incidence of flooding, fire, and vegetation succession over several thousand years can help managers predict the probabilities of future changes and tailor management programs that reinforce or retard the natural sequence of events.

Managers can also use the sediment's historical record of past events to improve the precision of models that attempt to predict the future and to provide answers to environmental questions. For example, how often can we expect major cyclones at the proposed space centre at Cape York? And if the Ranger uranium mine tailings dam should fail in the next thousand years, where will the low-level radioactive waste end up?

David Brett

More about the topic

Sediment yield in the Barrier Range before and after European settlement. R.J. Wasson and R.W. Galloway. *Australian Rangeland Journal*, 1986, **8**, 79–90.

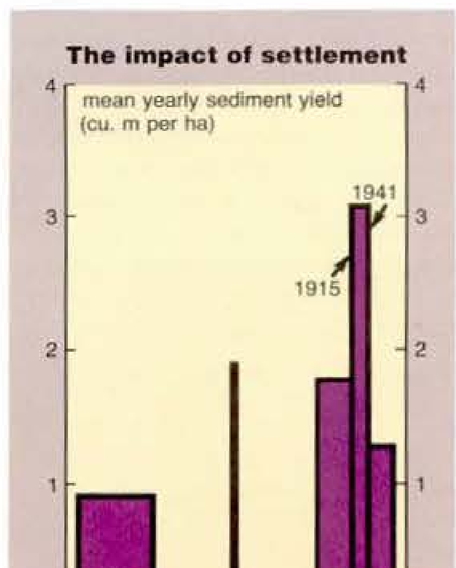
The Lake Burley Griffin study: its implications for catchment management. G.G. Caitcheon, R.P. Hammond, R.J. Wasson, B.A. Wild, and I.R Willet. *Conference on Agricultural Engineering, Hawkesbury Agricultural College, N.S.W., 25–29 September 1988.*

Pollen as a chronometer and sediment tracer, Burrinjuck Reservoir, Australia. R.L. Clark. *Hydrobiologia*, 1986, **143**, 63–9.

^{210}Pb as a chronometer and tracer, Burrinjuck Reservoir, Australia. R.J. Wasson, R.L. Clark, P.M. Nanninga, and J. Waters. *Earth Surface Processes and Landforms*, 1987, **12**, 399–414.

Removing a core of sediment from Burrinjuck Reservoir.

Reservoir sediments. R.J. Clark and R.J. Wasson. In 'Limnology in Australia', ed. P. DeDecker and W.D. Williams. (CSIRO and Dr W. Junk: Melbourne 1986.)



The arrival of Europeans with domestic stock, and a need for timber for nearby mines, dramatically increased the sediment yield from the catchment of Umberumberka Creek, far western New South Wales.