After more than a century of Australian research, why do we still mismanage our soil and water?

Bob Gilkes

School of Earth and Geographical Sciences, The University of Western Australia, 35 Stirling Highway
Crawley WA 6009. Australia. Email: bob.gilkes@uwa.edu.au

Abstract
Australian research into land and water has been active, effective and highly regarded for about a century. We are adept at identifying processes, discovering soil materials and developing theoretical models. We publish prolifically and Australians are major figures in the international soil science club. We seem to be much less capable of using our knowledge and energy to develop sustainable land management practices. Agriculture, urban development, industry and mining continue to desolate our most basic resources: soil and water. This talk will examine several case histories of the development of our profound knowledge of the Australian soil resource while at the same time we failed to recognise the urgent need to preserve this heritage.

Introduction
The twentieth century saw Australia's emergence as a major agricultural nation. State governments released large areas of virgin land to settlers, many of whom were migrants or returned servicemen, with the requirement that clearing of bush should be rapid and virtually total. Major advances in soil science, plant nutrition and animal nutrition at this time lead to the universal adoption of phosphate, trace elements and legumes by farmers. In the second half of the twentieth century the increased use of herbicides, compound fertilizers, and large machinery, together with new and improved plant varieties enabled the agricultural use of much of southern, eastern and Western Australia with annual rainfall in excess of about 300 mm. Throughout the twentieth century major drainage and irrigation schemes were developed across Australia bringing more and sometimes marginal land into production. The farmers and scientists who together built this agricultural revolution had every reason to be proud of their achievements, as they had recognised and overcome major soil constraints. Soil scientists in State Departments of Agriculture, CSIR (later CSIRO) and university faculties of agriculture had collaborated to provide the scientific base enabling diverse soils to be utilised for farming. Many of these individuals deservedly achieved high international distinction for their contributions to soil science and to increasing Australian agricultural production. Notable contributors included JA Prescott (1931) for his recognition of the nature and distribution of Australian soils; CS Piper (1942) who developed appropriate chemical, analytical procedures for Australian soils, and TJ Marshall (1959) who provided a basis for understanding the water retention and transmission characteristics of Australian soils.

The Australian soil science literature of the first half of the twentieth century is limited by modern standards but was primarily focussed on topics that relate to extending and increasing production, albeit that some original fundamental research was also carried out at this time. In the second half of the twentieth century rural industry funding bodies levied cereal, meat, wool and other growers for funds, usually matched by the Commonwealth, to promote research to increase and diversify production. For much of this early period there was relatively little attention from those funding bodies on purely environmental issues relating to agricultural development.

The Australian economy relied heavily on agricultural exports and it is only in quite recent times that minerals, energy, tourism, manufacturing and services have also made large contributions. In the middle of the twentieth century it seemed that agriculture would underpin our economy for ever and that our sophisticated expertise and innovation as soil scientists would overcome all constraints and continues to support increased production and profit. This was certainly the view of the corporations and governments who reaped much of the profit of agricultural development; their focus was to extend and intensify production.

Let us now, with the benefit of 20/20 hindsight, consider the true impact of a century of rapid, horizon-to-horizon, agricultural development on our fragile land. What will be our agricultural future and what will our land look like in the twenty-second century? By the last decades of the twentieth century there was a developing but far from universal consensus that much of our land was under siege from a number of poorly understood degradation processes. Suspicions became certainty followed by alarm and demands for action as land became unproductive. Federal and State reviews of salinity, erosion, water quality and other hazards are now commonplace, but mostly offer little relief to farmers affected by land degradation. Governments who up to very recent times had compelled farmers to clear bush are now urging and assisting farmers to plant trees. Vast amounts of Federal and State funding are now being directed towards reversing the degradation of our land and water, but the solutions are elusive. In some country towns there is a developing siege mentality as salinity inexorably invades and destroys farmland, houses and infrastructure even to the extent of flooding the cellar of the local pub. As farms and districts become unprofitable rural populations diminish and it is the debt adjuster and grief counsellor who visit the farm in place of the fertiliser salesman.

As a nation, we now recognise that agricultural, urban, manufacturing and mining developments have damaged much of our land. The State of the Environment Review (Commonwealth of Australia 1998) identified several soil degradation processes due to agricultural development as being major threats to the environment and to sustainable agriculture. The most disturbing aspect of this review was not the extent of soil degradation that exists in Australia, but our inability to identify and apply effective responses (Table 1). Each one of us could add other threats to this list; in my case I would include extensive loss of land by urbanisation and oxidation of organic and sulphidic soils. Mining of ores, other extractive industries and manufacturing have also left considerable areas of land exposed to chemically and physically unstable wastes. Although the footprint of dumps and their environs is much smaller than the area of degraded agricultural land, the hazards and future costs of remediation are considerable. It is convenient to ascribe these disasters to a lack of knowledge available to developers and their advisers during this period of rapid agricultural, mining and industrial expansion. However, this was certainly not always the case and in several instances soil scientists of the early and mid-twentieth century were warning governments and others of some of the disasters that have now overtaken us. I will illustrate this claim by reference to two Western Australian case studies, parallel histories apply in every state.

Table 1. Soil degradation situation in Australia and the effectiveness of our response (Commonwealth of Australia 1998)

Soil degradation process	Effectiveness of response
Soil structure decline	Problem remains widespread
Soil salinisation	Minor local success, regional responses are inadequate
Soil erosion	Uptake of advice is inadequate
Soil nutrient decline	Some to little effective response
Soil acidification	Very poor uptake of appropriate measures
Soil contamination	Much work needed to identify and rectify problems

(i) Draining pyritic soils causes acidification

The Swan Coastal Plain of south-western Australia is an area of low relief and is occupied by fluvial and estuarine sediments located between ancient coastal dune systems. Sea level changes during the Holocene have resulted in the occurrence of large areas of organic swamps and seasonally flooded soils which contain pyrite in subsoil horizons. Once these soils are drained for agricultural or urban development the pyrite oxidises to create sulphuric acid. This kills plants and animals, and destroys expensive infrastructure (bridges, roads, cables, pipes, etc.). Extensive drainage of these soils for urban development, agriculture and mining took place during the late twentieth century and is ongoing. Consequences have included destruction of terrestrial, fluvial and estuarine ecosystems, greatly increased development costs and large ongoing management costs, together in some instances with contamination of groundwater (previously potable) with arsenic. Yet the existence of this problem had been recognised many years ago, the major hazards had been predicted, the sensitive soils were identified on maps and appropriate management strategies advised. For example Teakle and Southern (1937a, b) investigated acidification of drained organic, pyritic soils used by market gardeners adjacent to Lake Herdsman in Perth and provided a clear explanation of the processes involved..

(ii) Clearing vegetation causes soil salinity

The cause-effect relationship between land clearing and development of soil/stream salinity was known in Western Australia as early as 1907 (Moore 1998) WE Wood was an engineer with responsibility for building dams to provide fresh water to steam trains. He recognised that when the catchment of a dam was cleared the dam water became saline within a few years due to saline groundwater rising under the influence of increased recharge and published his results in the Journal of the Royal Society of Western Australia (Wood 1929). Clearly this hazard was known and publicised well in advance of the massive clearing of land that occurred later in the twentieth century when the State Government's target of a million acres cleared each year was achieved. The presence of subsoil salinity was also well known from the land surveys available at that time and some government soil surveyors cautioned against some land clearing. The inescapable connection between clearing and the salinisation of land and rivers was mostly ignored, clearing proceeded unabated, and the problem of salinity was deferred to future generations. We now estimate that about 30% of agricultural land in WA will eventually become saline and of course reversing this trend and repairing the damage is a more difficult enterprise than prevention.

These two WA cautionary histories exemplify what was happening throughout the country in the twentieth century. Certainly governments and developers are to blame; but so too are soil scientists who were not sufficiently vocal or persuasive to prevent these disasters. It is timely at this meeting of our societies in Sydney early in the twenty-first century to consider if we will do a better job in informing society of the developing soil hazards of this century. Some of the indicators are not encouraging, for example soil scientists seem to be an endangered species. The number of soil scientists in CSIRO, universities and even ASSI has declined during the last decades. There are few soil scientists in senior positions in government and industry who can convince government of the fragile nature of our soil resource. The number of Australian students studying for higher degrees in pure soil science could probably be accommodated in a minibus or two. This decline is at a time when the challenges and opportunities for soil scientists have never been greater.

Many of today's soil research and extension workers have primary degrees in engineering, geography, ecology or environmental science. There are certainly appropriate areas of work and research for these graduates. However, such training may not be the best way to equip graduates with the knowledge, analytical skills and confidence to solve our intractable soil problems or to be assertive to the public, governments or land managers on the need to halt soil decline. Soil degradation processes invariably have pedological, chemical, physical and biological dimensions. Lasting solutions will only be found if the complexity of problems is recognised by appropriately trained researchers and appropriate strategies devised. This is much more likely to occur if soil scientists have received strong training in fundamental sciences, including physics, chemistry, biology and geology. They must also be able to work with agronomists, engineers and other specialists.

We can gain some little comfort from the knowledge that the European and American soil science communities are experiencing the same decline in the size of the traditional soil science community and a growth of soil consultants and researchers with diverse academic training. Indeed the Soil Science Society of America has just released its new mission statement that aims to *inter alia* address this new situation. SSSA identify the following priorities which we should also adopt (SSSA 2004).

Extracts from SSSA Strategic Plan, October 2004.

Mission: "…. to address challenges facing society, in the training and professional development of soil scientists and in the education of, and communication to a diverse citizenry."

Goals: "…. promote interactions with other professional societies, and expand services provided to the increasingly diverse range of soil scientists in public and private sectors."

"… promote outstanding programs, symposia and workshops that address current problems and needs of all scientists studying soils and that involve the breadth of applicable sub-disciplines within soil science as well as other disciplines."

“Participate in relevant public policy issues by providing the scientific basis and relevant timely input for decision-making. Promote relationships, interactions, partnering, and institutionalization of soil science where appropriate.”

There can be little doubt that these directions should also be those of ASSSI. Can we avoid the mistakes of the previous century and anticipate future soil degradation hazards in sufficient time to prevent them from becoming crises? If we are to warn society of these hazards it is essential that we clearly and quickly establish:

- A rank order of the severity of each present and potential hazard and their impacts on production and ecosystems.
- The spatial distribution of potential hazards: much existing soil-landform mapping is ill suited to this purpose as the diagnostic properties of soil profiles and relevant intrinsic properties were not determined.
- The mechanisms generating these hazards: despite huge research expenditure the nature and trajectory of subsoil decline, acidification, nutrient depletion, etc. remain poorly understood.
- Management and amelioration of hazards: farmers may need to introduce quite revolutionary practices including subsoil liming, very deep ripping, tramlines and rotations involving trees and other deep-rooted plants.

At present salinity and acidity are regarded by many workers as (the) major hazards but by year 2100 it may be that the loss of subsoil structure and multiple nutrient deficiencies will be of greater concern to farmers who will have learnt to accept highly salinised landscapes and eutrophic rivers as normal and inevitable. Above all we, the soil science community, have the responsibility of formulating such questions and providing timely advice and comment to the community, whether they request it or not!

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