

Soil Quality in New Zealand: Policy and the Science Response

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ABSTRACT

Soil depletion and degradation have been increasingly recognized as important environmental issues in many parts of the world. Over the last decade a number of political and legislative measures have been introduced to encourage and enforce sustainable soil management in New Zealand. Application of the new legislation has highlighted gaps in our knowledge of soil quality and a lack of scientific methods to assess and monitor soil quality. This paper describes the legislative measures and outlines the scientific response to the needs of regulatory agencies responsible for maintaining environmental quality. The research recommended a set of indicators to assess soil quality. Each soil quality attribute has an associated "target range" defining the acceptable value for the attribute. The paper also discusses the communication of results to end-users, including the development of a computerized assessment tool. The legislative measures and scientific response have fostered a closer relationship between the policy and science communities, leading to more well-focused research, but greater collaboration is still required.

farmers to be more efficient, including a lack of farm subsidies, a small domestic market, and the large distance from overseas markets, have all encouraged agricultural intensification, which has increased the risk of soil degradation. New Zealand is now facing a variety of environmental issues, such as hill country erosion, soil compaction, organic matter decline, and soil and water contamination.

Recognizing the strength of the environmentally damaging pressures, the New Zealand government has implemented a number of legislative measures to encourage sustainable use of land resources. In this paper, we describe the new legislative framework employed in New Zealand to promote and enforce sustainable management of natural and physical resources, and the policy-science relationship that has developed as a result of implementing this legislation. We also summarize research developments arising from the refocused science.

ENVIRONMENTAL POLICY AND LEGISLATION

The mid-1980s saw radical economic reforms in New Zealand as the newly elected government moved rapidly to establish a market economy (Bühns and Bartlett, 1993). Prior to this, farm production was encouraged through a range of financial incentives, and soil and water conservation and water quality measures were subsidized. The removal of subsidies had a drastic effect on farm incomes as farmers were exposed to market fluctuations and international competition. Further regulatory reform followed in 1991 with the Resource Management Act (RMA), which brought environmental policy into the forefront of land use activities.

The RMA (New Zealand Government, 1991) was implemented on top of major reforms to government institutions in which policy, provider, and funding functions for government services were separated into independent institutions. For example, the powerful Ministry of Works, which previously controlled city and regional planning and soil conservation at a national level, was disestablished. The RMA defines new responsibilities for "natural and physical resources" in a framework for implementation and policy development at national, regional, and local levels, each with its own funding stream. A new agency, the Ministry for the Environment, has national functions; Regional authorities have regional functions; and City and District coun-

THE NEW ZEALAND landscape is of predominantly hilly to steep topography with a wide diversity of soils (Molloy, 1998). There is generally sufficient moisture available from either surface or ground water resources, or rainfall, to sustain primary production on much of this land. Agricultural and forestry products exported in 1997 accounted for NZ\$13.7 billion, or 67% of the value of New Zealand's merchandise exports (New Zealand Ministry of Agriculture and Forestry, 1998). Therefore, productive land is one of the vital natural resources of New Zealand. It is important that this valuable resource is maintained in good condition to sustain the national economy, and to support New Zealand's "clean and green" image, which is important in international marketing.

The environmentally damaging pressures on soils experienced in many countries are less extensive in New Zealand because of its small population, relatively short history of human settlement, few environmentally damaging heavy industries, and a legume-based pastoral system. However, many years of land use under agricultural production have had their cost (New Zealand Ministry for the Environment, 1997a). Economic pressures on

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Abbreviations: CRI, Crown Research Institute; MDS, minimum data set; RMA, Resource Management Act.

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cils have local functions. Regional authorities gained responsibility for safeguarding environmental quality, including soil and water quality. Local authorities retained control over subdivision of land and waste management. The RMA allows for land management to be regulated through regional and/or district plans and through granting "resource consents." Policies are required to achieve "integrated management" of the resources. Consistency must be maintained between, and within, the national, regional, and district policies. The RMA allows for any inconsistencies to be taken to an Environment Court for resolution.

The stated purpose of the RMA is to "promote sustainable management of natural and physical resources" where "sustainable management" is defined as the use, development, or protection of these resources to provide for the well-being of people now and in the foreseeable future while avoiding, remedying, or mitigating adverse effects on the environment [Part II, Section 5 (1-2)]. Land should be managed to "sustain the potential of natural and physical resources" and to "safeguard the life-supporting capacity of air, water, soil. . . ." Regional authorities have a duty to "control the use of the land for the purpose of (i) soil conservation" (Part II, Section 30c). They must also monitor (a) the state of the environment of their region, and (b) the suitability and effectiveness of its policy statements and plans [Part II, Section 35(2)].

The RMA is extremely prescriptive in legal processes, but is not prescriptive in terms of environmental quality standards. It has been characterized as "enabling legislation" focused on the *effects* of land use activities rather than the activities themselves (Bühns and Bartlett, 1993). The legislation requires effects-based criteria to determine whether a particular activity has a detrimental effect on the environment, but does not specify how this should be done, which properties of the resources should be used to assess environmental quality, nor what the normal limits of these properties are. The RMA requires monitoring of the state of the environment but it does not provide a monitoring protocol or interpretive framework.

Although the scope of the RMA is very broad, this paper will focus on soil quality issues. We follow Doran and Parkin's (1994) working definition of soil quality, that is, "the capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health."

Twelve regional councils are primarily responsible for maintaining and promoting soil quality. Regional authorities have had a long history of monitoring water quality, but monitoring for soil quality is a new requirement arising from the RMA, so associated methodologies and protocols needed to be established. When the RMA was introduced, the soil science community could not provide the technical support or knowledge required for its implementation by the regional councils. Central government acknowledged this in a series of policy documents in the mid-1990s, which identified key soil quality issues and recognized the need for good research into sustainable management (New Zealand Ministry

for the Environment, 1995, 1996; New Zealand Ministry of Research, Science and Technology, 1995).

Soil science in New Zealand is primarily undertaken in the land-focused government-funded Crown Research Institutes (CRIs). Central government now stipulates that CRIs involve stakeholders in research programs, and expects the institutes to operate at a profit. As a consequence, linkages between CRIs, central and local government agencies, and the amount of end-user-funded contract research, have all increased. Since the mid-1990s, CRIs such as Landcare Research, Crop & Food, and AgResearch have been researching (under central government funding) how to measure and monitor soil quality. A sampling methodology has been developed, which includes a rationale for which soil properties should be monitored (Cameron et al., 1997; Schipper and Sparling, 2000). Work is currently being undertaken by the CRIs to interpret or derive acceptable limits for these soil properties.

In 1997 the Ministry for the Environment released a proposal for air, fresh water, and land environmental performance indicators (New Zealand Ministry for the Environment, 1997b). To encourage a unified approach to soil quality monitoring by regional and local government, the ministry offered a 60% subsidy from the Minister of the Environment's Sustainable Management Fund toward soil monitoring costs over a three-year period, on the condition that a standardized methodology was used with a common interpretation. This project, which is coordinated by Landcare Research (which also analyzes and interprets the data), is known as the 500 Soils Project. While this project has enabled the characterization of soils over a large area over many soil orders and land uses, there are also limitations in terms of national reporting (Sparling and Schipper, 2002).

Thus, implementation of the RMA has been the major driver of soil quality research in New Zealand (Fig. 1). The science response to the policy needs is outlined in the next section.

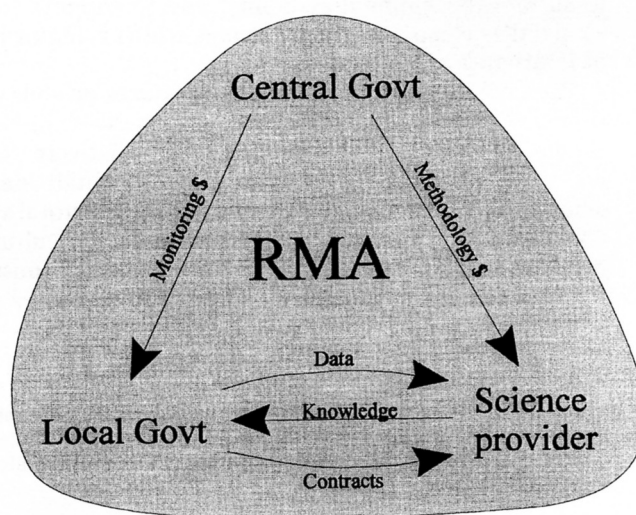


Fig. 1. Soil quality related flows between central and local government and research organizations.

SCIENCE RESPONSE

Soil Quality Indicators

The Ministry for the Environment adopted the OECD pressure–state response model for its environmental indicators program (New Zealand Ministry for the Environment, 1997b). Accordingly, researchers have focused on measuring and interpreting the status of soil quality, and the land use pressures affecting status. Although the policy requirement is for reporting on soil quality at regional and national scales, the initial scientific response was at a field scale. An understanding of how to recognize, measure, and predict soil quality problems needed to be developed at scales where direct relationships between land use pressures and soil response could be determined. This understanding could then be used as a basis for regional- and national-scale prediction of soil quality, and calibration of broadscale surrogate indicators.

Criteria for including particular soil properties in the minimum data set (MDS) were that they should be responsive, affordable, interpretable, internationally accepted, and ecologically significant (Doran et al., 1994). An initial set of 17 soil properties for soil quality assessment were selected from international literature based on their relevance to New Zealand conditions (e.g., Doran et al., 1994; Doran and Jones, 1996; Reganold et al., 1993; Boehm and Anderson, 1997; Robertson et al., 1997). A preliminary study validated the minimum data set and a standardized sampling method (Sparling and Schipper, 1998; Sparling et al., 2000). Further analysis of this soil quality data allowed some properties to be discarded from the suite of indicators on the basis of high variability, high correlation with other properties, or difficulty with interpretation (Schipper and Sparling, 2000). The data set is now reduced to seven indicators (total C, total N, anaerobically mineralizable N, pH, Olsen P, bulk density, and macroporosity). These soil properties have now been measured at 220 sites covering 12 land uses and 10 soil orders (out of 15) and are reported in the accompanying paper by Sparling and Schipper (2002). They represent data collected during the first two years of the three-year project.

Interpretation of Indicators

The interpretation of soil quality is a value judgement based on human demands on soil for a selected land use. Defining justifiable target values has been one of the most contentious areas of soil quality assessment, particularly in the absence of predictable production responses or defined ecological consequences (Sojka and Upchurch, 1999). Nonetheless, there seems little point in proposing any soil property as a soil quality measure if we cannot provide interpretation. Even analysis of trends through time (Larson and Pierce, 1993) requires that, at some point, a value is reached that triggers action to reverse the trend.

In defining useful target ranges for environmental indicators, three issues need to be considered:

1. The ranges need to take account of the natural

variability of soils from different regions and from different soil groups (New Zealand Soil Bureau, 1968). Estimates of the expected (natural) target ranges for each soil are therefore required.

2. They need to be land use-specific, for example, an acid soil that is a suitable pH (good quality) to grow pine trees may well be unsuitable (poor quality) for a productive pasture.
3. They need to strike the right balance between maximizing agronomic production and minimizing environmental impacts.

To date, we have used two approaches to define target values for the items in the MDS. Agronomic production data and expert knowledge, where available, were used to define target values for soil groups and land uses. Examples are the Olsen P and soil pH levels required to achieve 80% of optimum yield (e.g., pastures, horticulture, forestry) on various soil types (e.g., Allophanic, Pumice, Sedimentary¹). These data were taken from standard agronomic recommendations (During, 1984; Cornforth and Sinclair, 1984). Off-site contamination issues were also considered by setting upper target limits for anaerobic nitrogen based on levels exceeding those needed for maximum crop response. Higher levels pose an environmental risk of nitrate leaching. Dose–response information was not available for other items in the data set (e.g., total C and N), so our second approach was to derive these values using information on pasture soils from the National Soils Database. Long-term pasture soils in New Zealand have a high organic matter status, with levels that are comparable with soils under indigenous vegetation (Ross et al., 1999; Schipper and Sparling, 2000; Sparling et al., 2000) and probably represent a maximum standard. Currently, the target value is defined as being above the lower quartile value of a soil under long-term pasture. These values are specific to soil order, although some orders can be clustered. Having set the organic C level, total N values were derived using C to N ratios specific for pasture, cropping, and forestry (11, 14, 20) (New Zealand Soil Bureau, 1968; Sparling and Schipper, 2002). Mineralizable N values were defined from nondegraded soils in the 500 Soils data set (Sparling and Schipper, 2002). Target values for the soil physical properties bulk density and macroporosity were defined from the limits at which plant performance was adversely affected (Drewry and Paton, 2000; Drewry et al., 1999, 2000; Singleton et al., 2000).

A workshop, involving many of the key soil-quality researchers in New Zealand, was held in 2000 to produce estimates of environmental and production dose–response curves for a number of indicators (Sparling and Tarbotton, unpublished data, 2000). Inclusion of this information ensures that the target values are based on a wide range of expertise. We expect our proposed values to be refined as alternative approaches are developed and the justification for setting limits becomes more robust.

¹ Allophanic and Pumice are soil orders (Hewitt, 1998). Sedimentary refers to all other soils derived from sedimentary rock.

Communication of Science Results

Central government has emphasized the importance of end-user uptake of science results. Peer-reviewed publications are no longer viewed as the only, or most effective, channel of communication. Several approaches have been used to communicate results.

1. Summary reports of soil analyses have been produced for each local authority involved in the 500 Soils Project, and to the New Zealand Ministry for the Environment.
2. Reports on the MDS and the sampling methodology (e.g., Sparling and Schipper, 1998) were issued to end-users.
3. Workshops were held to present research results in the context of monitoring issues faced by local authorities.
4. A computer tool called Sindi (Soil indicator assessment tool) was developed to facilitate interpretation of any particular soil sample. This tool encapsulates the data and interpretation of the various soil quality indicators and presents the quality assessment in a graphical format (Lilburne et al., 2000).

The last approach is the most novel and is therefore described in more detail as follows.

Sindi can be used by anyone with measurements of key soil properties (from the MDS) of a site anywhere in New Zealand where the site's soil quality status is of interest. It is envisaged, however, that the main users will be regional council staff rather than landowners. This is because the analyses underlying the graphs focus on long-term trends on broadscale land use and soil categories over the whole country. Easy access is ensured by developing Sindi as a World Wide Web application (<http://sindi.landcareResearch.co.nz> [verified 17 June 2002]).

Two assessment methods are offered in Sindi: (i) a quantitative comparison of the measurements with data from the National Soils Database depicted as statistical box-and-whisker plots, or (ii) a qualitative interpretation based on expert knowledge of likely target ranges. The first approach can currently only be applied to five key indicators (carbon, nitrogen, pH, Olsen P, and bulk density under pasture) as insufficient data are available for other indicators and land uses. By representing the soil data as box plots, it is easy to assess whether the sample measurement falls within the quartiles (normal), in the lower or upper quartiles, or even outside the recorded range of the given soil order-land use.

In the second approach, a stacked bar-graph format (Fig. 2) is used to convey the experts' assessment of the

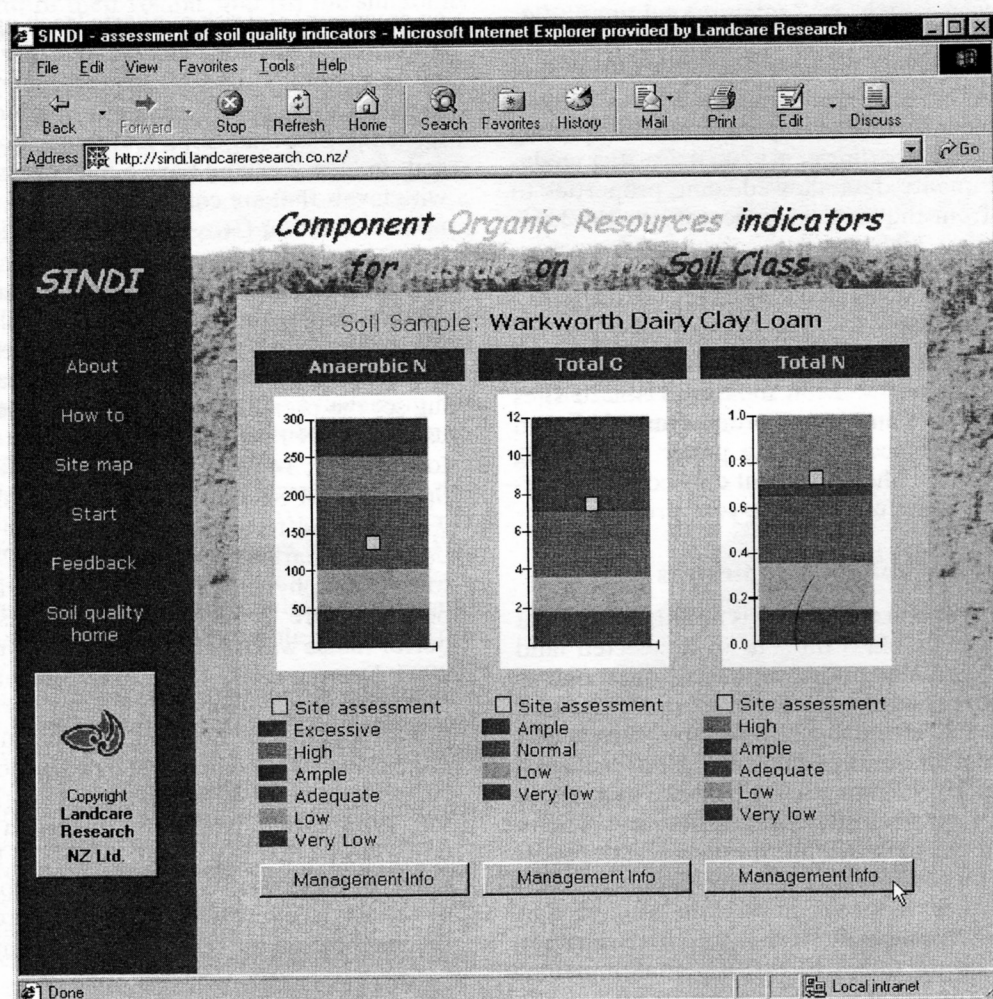


Fig. 2. Sample screen of Sindi (Soil indicator assessment tool) showing interpretative bar graphs.

soil sample's likely quality given its soil order–land use. Each indicator is represented as a bar graph depicting the normal or optimal range plus suboptimal and ample levels. Information on best management practices to maintain or improve soil quality for each soil property can be seen by clicking the "Management Info" buttons. As it is difficult to assimilate seven graphs, indicators are also grouped into four categories (each of which is presented as a bar graph) as determined by the principal components analysis (Schipper and Sparling, 2000). It is planned to represent the four category bar graphs as a four-dimensional star plot, or diamond, allowing a single impression of soil quality.

Initial feedback on Sindi has been very positive. The simple graphics have been easily understood by a variety of end-users. Sindi appears to be an effective way of making the science results and expertise more accessible to the policy analyst. Some modifications have been suggested, which will be implemented along with some further developments. It is also planned to make data from the 500 Soils Project available on the Web, and to aid its interpretation by linking each soil sample directly to Sindi.

DISCUSSION

The "soil quality" perspective of the predecessors of regional councils (i.e., regional catchment boards) was almost exclusively focused on mitigation of soil erosion. With the removal of subsidies for soil conservation, many of these staff have been lost. Thus, nearly a decade later, most regional councils have little in-house soil quality expertise. However, they are now able to access scientific knowledge in the CRIs through the nationally funded projects. While a majority of regional councils have made commitments to the 500 Soils Project, others have undertaken their own soil monitoring projects, and some have done nothing. From these projects, they now have a better understanding of which combinations of land uses and soils in their regions are at risk of low soil quality status. However, there is still debate within many councils as to whether they should regulate land practices affecting soil quality. A common approach to achieve their goals is to use educational programs through landcare groups, and farmer meetings, and to support product registration.

The relationship between policy and science has evolved over the last five years from mutual ignorance of each other's needs and interests, to an increasing interdependence. Implementation by the regional councils of the legislative framework, described above, raised many technical problems requiring collaboration and focused solutions from science. Tools like Sindi can enhance collaboration by making science results more accessible through continual updates in response to user comment, as well as scientific developments. Sindi promoted more interactive two-way communication, giving more direct influence to policy analysts and faster feedback to scientists. This supported more traditional channels of communication, that is, workshops, conferences, newsletters, and journal papers.

However, the collaboration can and should be strength-

ened so that there is more communication both in the scientific planning stage and in the policy implementation phase. Scientists need to focus on the applicability as well as the robustness of their science. As well as insufficient communication, differences in priorities can weaken the collaboration. For example, as autonomous bodies, the regional councils often choose to follow different approaches from each other and prioritize regional issues rather than national environmental auditing needs. Unless regional councils are clear about their respective roles in sustainable management of regional soils, promotion of good soil management practices and monitoring of soil quality will be ad hoc.

CONCLUSION

New Zealand's experience has shown that policy and science can be linked to work in tandem to better understand and manage soil quality issues. This was achieved by the government setting the agenda for environmental research via the RMA, and insisting on policy–science collaboration in research plans. However, there is some way to go before environmental policy and science in New Zealand can be said to be in a truly collaborative partnership in which science results are tailor-made for current and future policy issues.

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