SOIL SCIENCE AND FORESTRY — PAST AND FUTURE*

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SYNOPSIS

Soil scientists have helped to solve problems which arose during the conversion of native bush to farmland, but, if they had the knowledge available today, they could have prevented many problems from arising by advising on the most suitable land use for a given area. Thus it now appears that some land should be returned to forest cover. Soil scientists must be prepared to better assess the capabilities of soils to grow trees, and to evaluate the potential of land production impartially to compare forest use with farming or any other form of land management. Foresters need to become better acquainted with soil scientists to prevent mistakes, similar to those in the past, from arising again.

Before the settlement of New Zealand by Europeans, the greater part of the country was covered by forests which had a significant effect on the development of the soils on which they grew. Development of egg-cup podzols under kauri in the northern part of New Zealand is well known, but rimu and associated species in central and southern North Island through to Westland in the South Island, kahikatea in valleys and swamps, and beech in Southland, Nelson, Reefton, and mountain lands are all dominant forest species that influenced the development of many of our soils, if less spectacularly than kauri did.

Since the early 1800s there has been a country-wide movement to convert these forest lands to agricultural use with little or no thought given to the long-term suitability of the soils for such use. Old photographs taken at the early agricultural and pastoral shows illustrate how the new form of land use was celebrated amidst burnt tree stumps extending into the distance.

In this one-way conversion of forest lands and soils to agricultural use, serious problems have arisen and soil scientists have played a major part in finding answers to many of them. To name but a few, soil scientists have played key roles in providing answers to:

1. Trace element deficiencies in crops in the Nelson district,
2. Bush sickness on pumice soils, and in
3. The successful establishment of clovers in pastures to provide nitrogen for other species.
The understanding and mapping of the soil types and sequences that exist in New Zealand have gone far towards rationalizing the need for and use of fertilizers throughout the country.

Not every problem encountered in turning former forests into productive farms has been successfully overcome, and I wonder if some of the seeming successes may be only temporary, and in the long run an alternative form of land use will be a better and more economic solution. In retrospect it does seem that, if soil scientists had had the information and had been able to present a more convincing case, some costly mistakes could have been prevented. I do feel that soil scientists should learn from these past mistakes and inadequacies and be prepared to lead in preventing land-use errors in the future. A look at two or three land-use mistakes will show just how costly they can be.

A problem currently attracting public attention has developed in the catchments of the Waipaoa and adjacent rivers near Gisborne. Erosion has reached frightening proportions in this hill country, making large areas of land unproductive and seriously threatening the fertile plains down stream (see figure in Olsen, 1970). Reafforestation and engineering works may be able to prevent the erosion spreading and may even stabilize some areas, but much damage has been done and at the present time, there seems little chance of stabilizing the most actively eroding areas. Could soil scientists have predicted that this erosion problem would develop? I think the answer is “yes”, but I doubt if anyone in a position to act would, in the past, have taken any notice of them.

In Westland some of the most productive native forests grow on flat, poorly drained sites. In the belief that all bush country could be turned into farmland, the early settlers hoped to convert these areas to grassland. The felling and burning of these forests has left “pakihis” on which, to date, pasture establishment has been largely a failure. “Pakihis” are gley podzols which are poorly drained and poorly structured soils; see Fig. 1. They cover 300,000 hectares of easy country. Today selective logging and the continual renewal of the native forests appear to offer a means of productively using the land and preventing the creation of further “pakihis”. Trials in which fertilizers have been used in the establishment of exotic forest plantations on partially drained “pakihis” offer some hope that a productive use can be found for the areas already created. How much do soil scientists really know of the dynamics of our native forest-soil ecosystems? Even though the areas of native forest that are likely to be converted to other forms of land use are rapidly diminishing, I feel New Zealand can profit from a greater understanding in this field.

On the volcanic plateau in the centre of the North Island, erosion problems are increasing, and a return to forest cover in the form of pine plantations is seen as a solution that will ensure the productive use of the land. The Tarawera scoria soils on rolling country to the south of Kawerau are a glaring example of the folly of attempting to establish pastures on
all soils regardless of their physical nature. These coarse-textured soils are very droughty, and the instability of grazed slopes induces erosion and reversion to weed growth (see Fig. 2). On the same type of soil are growing some of the most productive exotic forests in New Zealand. Land users are finding out what they can and cannot do by trial and error. Soil scientists can and should influence land-use decisions, such as this, much more than they do.

In the examples of past mistakes mentioned, it now seems apparent that forests, either native or exotic, are a better form of land use. (This is not to say that forests offer a solution to all land-use problems.) Could soil scientists in the past have successfully advocated the adoption of forests as the best form of land use? I doubt it! In the past, New Zealand has had very much of a one-track mind in its land development. Only if land had proved unsuitable for farming was it considered for growing trees. Thus the Forest Service was (and still is) offered bogs, dredge tailings, eroded lands, etc. Today official and public opinion is becoming more informed and economic factors are highlighting forestry as a profitable alternative form of land use — not just a last resort. I believe it is now more than ever before that soil scientists should be considering forestry as an alternative form of land use and be characterizing soils for it. It will not be easy for soil scientists to be impartial, but it is essential that they be so and be recognized as being so. If land-use decisions are put in the hands of farmers, almost any land which will grow a blade of grass will be classified suitable for farming; if you let foresters have their way, nearly all land should rightly
be in trees. Soil scientists can and should draw up an entirely neutral classification based on the intrinsic capacity of the soil.

For example, two different land uses of the one soil type could be described:

(1) Optimum carrying capacity 7.5 ewe equivalents per hectare, with a maintenance regimen of 250 kg 15% potassic superphosphate per hectare per annum.

(2) Radiata pine site index (height in metres at 20 years)
   29. Deep rooting (wind stability) and no deficiencies.
   Stability for roading — fair.

Foresters need to be more aware of the help they can give to and receive from soil scientists. Agriculturists have realized the advantages of close association with soil scientists, but foresters in general have not developed ties with the chemists, physicists, pedologists, biologists, engineers, and technologists who work in the field of soil science.

How will soil scientists need to adapt their approach and methods to better assess land for forest use? I suggest the following — not as an exhaustive list but as examples.

(1) While soil bulletins contain full profile descriptions, most of the analytical data relate to the top 10 to 15 cm which is the important zone for agricultural plants. However, trees can and do exploit the soil to much greater depths — often more than 3 m where physical conditions allow root penetration. It is encouraging to note that recent Soil Bureau Bulletins do contain analytical data relating to greater depths.

Let us look at an example of the pitfalls of applying to forests information designed for agriculture. Some few years ago, trees growing on Tarawera scoria soils appeared to be suffering from boron deficiency — the dieback was similar to that caused by boron deficiency. When the Single Factor Map for Total Boron in the Topsoil showed that the soil contained very low amounts, there was a temptation to feel that the matter was settled. However, subsequent analyses have showed that the buried soil, lying 30 to 45 cm below the surface and in which tree roots are abundant, contains relatively high amounts of water-soluble boron. Recent experiments have shown that tree uptake of boron is adequate and that the dieback is not in fact a symptom of boron deficiency.

In the central region of the North Island, buried soils are often as important as, if not more important than, the present topsoil. Besides acting as a source of boron (as in the last-mentioned case), it is known that other buried soils can supply magnesium where this is deficient in the present topsoil formed on Taupo Ash. In non-volcanic ash soils too, the lower horizons can be important to trees where they are able to extend their root systems into less weathered zones, and even in the parent material itself.

While tree roots have the ability to penetrate to considerable depths, the physical nature of the B and C horizons in some soils may dictate that roots are confined to the surface
layer. This is very marked on some of the tightly packed gravels on the Canterbury Plains. The coarser gravel-sized pumice ash showers can also constitute a barrier that roots find difficult to penetrate, except where the massive structure is fractured — it is not uncommon to find a sheet of roots at such points. In other soils, the proportions of clay, silt, and fine sand present may result in layers through which roots cannot penetrate.

At present we do not have satisfactory means of assessing a soil’s resistance to root penetration — soil scientists (physicists and engineers) could well get together with foresters (tree physiologists) and characterize more fully the pressure brought to bear by growing roots and the soil’s ability to withstand them.

The mycorrhizal roots of trees enable them to obtain adequate nutrients (particularly P) from soils of low fertility, but to do this and obtain adequate moisture they must be
able to exploit more than the surface layers. There is a need to be able to assess the soil depth to which tree roots can penetrate.

(2) For many years, soil chemists have been developing and refining methods of assessing the "availability" of nutrients to agricultural crops. While no one would suggest that the present chemical extraction techniques perfectly assess the fraction of a nutrient available for plant uptake, it is now possible to obtain reasonable estimates of the quantities of at least P, K, Ca, Mg and some trace elements available to agricultural crops. However, this is not yet true for assessing nutrients available to tree crops. These differ in many features from agricultural crops, notably in their long life span, nutrient recycling, mycorrhizal roots, deep taproots and overall lower nutrient concentrations in photosynthetic and other tissues.

The old "total P" method of assessing the phosphate status of forest soils is not satisfactory in all soils, and recent work has shown that the largely discarded citric-soluble test gives a much better indication of the potential supply to trees. However, the best tests seem to be the Bray No. 2 and Olsen which have also proved successful for agricultural crops.

In a recent study throughout New Zealand, good correlations were found between the uptake of K and exchangeable K in the soil. The position with other nutrients is not as satisfactory. Exchangeable Mg and Ca are apparently completely unrelated to uptake of these nutrients and, in both Australia and New Zealand, hot-water-soluble boron does not give a satisfactory means of assessing boron availability on deficient sites.

There is a need to apply and develop further the "reserve" nutrient tests and find how these correlate with tree uptake.

(3) Just as the nutrient composition of sweet vernal grass (Anthoxanthum odoratum) has been used to estimate nutrient availability in the topsoil — so I suggest more work should be done using the analysis of Pinus radiata foliage to give a measure of the availability of nutrients in the whole of the rooting zone exploited by trees.

Besides these fields of research where the foresters are looking to the soil scientist for help and are in fact completely dependent on him, I would suggest that there are some other fields where the forester can provide soil scientists with some interesting and unique problems to work on. To mention four:

(1) While trees can tap supplies of Mg in buried soils derived from volcanic ash, the allophane-organic matter complex seems to make the N and P in these soils completely unavailable. Can the biologists or physical chemists among our soil scientists develop a means of unlocking this potential source of nutrients?

(2) In Canterbury, stony soils are being ripped in an endeavour to extend the rooting depth, and so give greater
wind stability. Have engineers and technologists any data on the most effective, and efficient way to break up massive gravel layers to give ready root access?

(3) Native forests on hill soils in Westland are being felled, and the land planted in exotic forest. What will be the result on soil biology and chemistry of replacing rimu with radiata pine?

(4) On coastal sands in Northland and Manawatu regions, forests are being established — often on very young soils which show little profile development — but soil development proceeds rapidly once a complete tree cover is established. Is this an opportunity to get in on the ground floor and study the birth of a soil?

It would probably be easier to do so on the coastal sands, than on the gravels and boulders of the dredge tailings in Westland that are being afforested, but there also is a unique chance to study the initial stages of soil development.

There is ample scope for co-operation between soil scientists and foresters, and also between agronomists and foresters. Lest this be thought of as something completely new, I would point out that although early empirical work had shown Mg to be involved in grass staggers, the earliest definitive work on dry matter production responses in pastures on pumice soils was done in forest nurseries after it was found that tree seedlings were seriously affected by Mg deficiency in these soils.

At present the advantages of dual use of some land — both to grow trees and graze animals — are becoming apparent. To date this has been largely restricted to grazing cattle in established forests where results are encouraging. The animals maintain good condition, and access for silvicultural operations is made easier by the control of undergrowth. Thought is now being given not only to grazing animals on forest land, but also to growing trees on farms. Not as woodlots, which have been grown for many years, but as a restricted number of trees in pastures. A profitable return can be obtained from trees grown at stockings of well under 250 trees per hectare if branch development is restricted by pruning. At the same time, good grazing should be obtained — for deer on deer farms, or for sheep and cattle. It may be necessary to turn to unorthodox pasture species, but the growth of trees and pasture in close association raises interesting possibilities.

In New Zealand it has been found that on certain soils other tree species benefit nutritionally from a close proximity to radiata pine. In U.S.A. it has been shown that, on abandoned farmland, there is a greater availability of N and P to herbs and grasses growing within the rooting zone of pines compared with soil of similar total N and P content beyond the influence of the rhizosphere of pine roots. Would the supply of N and P available to pasture plants in New Zealand also be greater under the influence of association with radiata
pine? It is an optimistic thought, perhaps, in a country seemingly dependent on superphosphate and clovers, but one that, evidence suggests, deserves attention.

Another field of co-operation between agriculturists and foresters is perhaps marginally soil science, but it is certainly of importance to soil scientists. It is the improvement in aerial distribution of fertilizer to overcome the present very uneven spread.

When we look back over the history of forestry in New Zealand, some associations between foresters and soil scientists can be seen, but we must admit that most of the success stories of exotic forests have been somewhat fortuitous. The large-scale planting of pines on the pumice soils of the North Island was not done because of their now-known excellent physical nature which ensures good root penetration, high moisture storage, and the exploitation of buried soils. Land was available by default (bush sickness in cattle), there was cheap labour (an economic depression), and men with faith made the most of the situation.

The other great success story of our exotic forests is the use of superphosphate to make highly profitable forests out of the derelict plantations that existed on gumland clays. There were some scientific studies, but it must be admitted that early research was largely hit or miss.

Good fortune and luck must not be allowed to continue as the basis for increasing our forest production into the future. I am certain that success stories just as big will be written in the future if there is a two-way exchange of problems and information between foresters and soil scientists.

REFERENCE