

SOIL AND GRASSLAND: IF GRASS NEEDS SOIL, DOES SOIL NEED GRASS?

H. S. GIBBS

Earth Sciences Department, University of Waikato, Hamilton

¹ **THIS** subject sets a problem of where to begin. As a soil scientist, my choice would be soil and that choice fits into the evolutionary history of the earth which shows soil occurring under forests and existing for millions of years before grasses. It is not known if soil changes assisted the birth of grasslands or followed their expansion, but we do know that soil and grassland* now form a natural partnership over parts of the earth. In New Zealand that partnership has been extensively forced on soils formed under forest or shrublands and my purpose is to review the effects — the benefits or otherwise of this compulsory marriage. In doing so, I would admit that grasses have a higher status than soil. They have been described as “the benediction of nature” whereas soil does not inspire such poetry — perhaps the best being “Soil is mud moistened with love”.

Reading through *Proceedings* of the annual conferences for references to soil I find:

First, a regular interest in chemical properties relating to lime, phosphate and nitrogen — a perpetual concern of members and discussed with fertilizers.

Secondly, an irregular, rather superficial, interest in soil as a complex system of biological, physical and chemical processes. Soil differences tended to be related to the kind of underlying rock—a geological concept inherited from pre-Association era, and reinforced by the discovery that bush sickness in soils was related to particular deposits of volcanic ash. The associated discovery that the cobalt deficiency could also be acquired climatically through intense leaching was

*For purposes of this address, grassland and grass embrace all grass species and legumes commonly associated in pasture lands.

not emphasized and was generally overlooked. The introduction of soil surveys was reported with a caution that the results had to be intelligible to farmers.

Historically it is notable that the 50th anniversaries of the establishment of the N.Z. Soil Bureau and the N.Z. Grassland Association are both celebrated this year, and we trust that the two organizations will continue to flourish and to co-operate in the efficient development of the resources of the land.

In the early addresses to the Association, the major credit for development of grassland farming here was given to "our climate". It was a rain-producing climate particularly adapted to the artificial development of high producing grassland. This theme, essentially "climate grows our grassland", was carried on by scientists and repeated again and again by teachers and politicians. Where dry seasons demonstrated the importance of the moisture component, the artificial climate of irrigation was invoked. Perhaps the theme was a reaction to the crop-farming habit of blaming the weather for poor yields of wheat or turnips.

Whilst not denying the importance of sunshine and rainwater to plant life, their benefit to grassland is indirect and must be qualified. Essentially they are bulk supplies of some essential constituents and without soil, for example, on bare sands or mountain tops, they are destructive of land. Concentration on the climate factor assumes soil to be a mere channel — a pipe to deliver "gifts of the gods" to grassland. This view overlooks essential functions of soil:

- As a battery that stores up solar energy in its reservoir of organic matter.
- As a sponge that absorbs the irregular showers of rainwater and rations them out to various purposes.
- As a source of nutrients for plant life and provided by its own body.
- As a shelter, food supply and toilet for the millions of organisms that operate a recycling system counteracting the degrading effects of climate.

In serving such diverse purposes, soil is no inert substance — its body and its biological, chemical and physical functions combine together as a special factory, special in that constituents of the building itself become a part of the product, and in turn the plant product then assists with reconstruction of the building. Climate also contributes by its renewal of the mineral supplies

through weathering and humification. Under the native vegetation, a reciprocal connection between plant life and soil was formed, but was modified by the subsequent establishment of pastoral grasslands. The obvious landscape effects of this "botanical revolution" have been described by many writers but few have discussed the underground changes (Lee, 1959; Barratt, 1968).

After clearing the forest, the occasional additions of leaves, branches, bark and wood were replaced by frequent additions of fine leaves, plant materials and excreta from grazing animals. For soil organisms this huge change in diet was responsible for

- (1) Replacement of the biological population by new species of consumer organisms (*N.Z. Soil Bur. Bull.* 26 (2), Ch.10)
- (2) New kinds, sizes and distribution of roots
- (3) Wider fluctuation in temperature and moisture levels in the upper soil.

These changes altered the processes of soil formation in favour of:

- more rapid and intensive humification of organic litter into mulloid humus instead of moroid type;
- more rapid release of plant nutrients for recycling;
- thicker organomineral topsoil with a high concentration of roots and lower C/N ratio;
- development of fine granular and crumb aggregates in place of large nutlike or blocky forms and the consequent more suitable spaces for circulation of solutions, gases and rootlets;
- more frequent fluctuations of temperature and moisture in the upper soil;
- less variation in the properties of the soil through more even distribution of rainfall and plant litter; and protection against sheet erosion.

The effects of converting forest soils to pastoral grassland, conveniently described as grassification, is expressed in the upper horizons of soil profiles by the following changes:

- (a) Absence of a distinct organic litter (O horizon)
 - (b) A dark grey to black topsoil (A horizon) of small rounded aggregates with abundant fine roots, evenly distributed and becoming deeper with period in pasture; slight to moderate acidity and high levels of available nutrients
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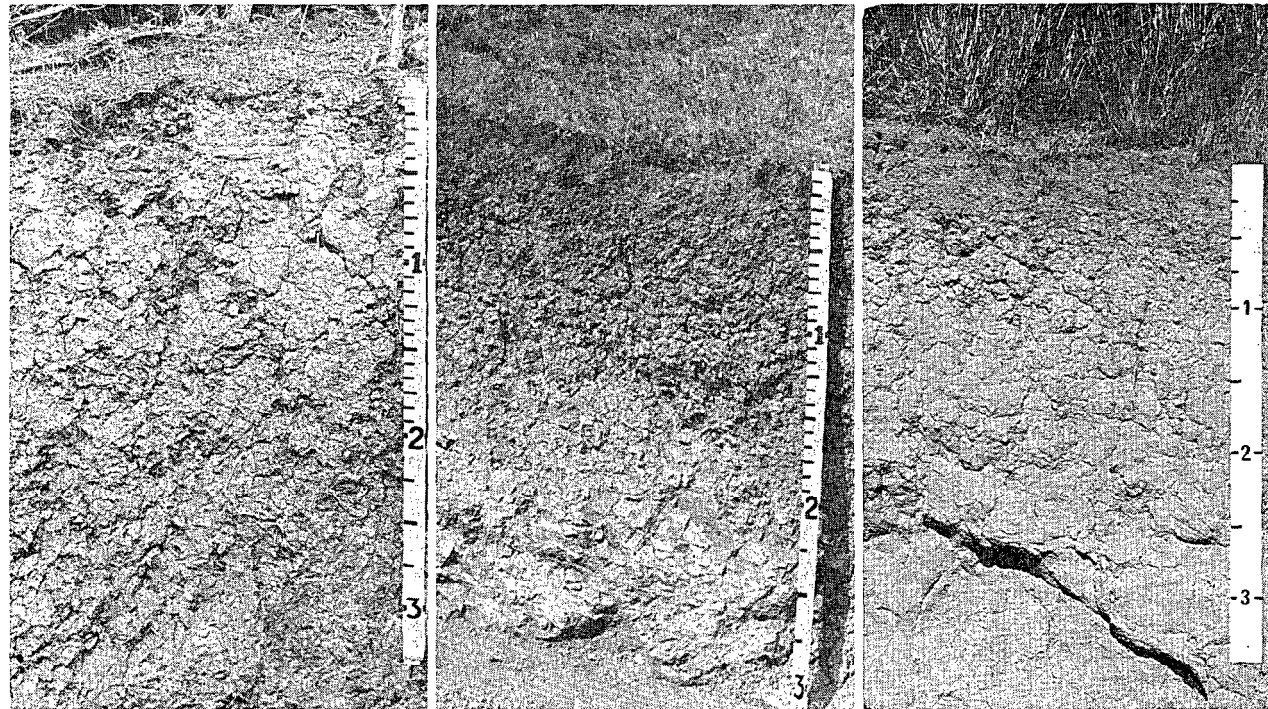
- (c) An irregular lower boundary with numerous worm casts of the topsoil in the upper part of the subsoil
- (d) A large number of small worms and other soil animals,

GRASSIFICATION

In New Zealand soils the rates of grassification differ widely, illustrated by the following estimates of rates according to soil groups. The process occurs rapidly on moderately leached yellow-brown loams and on central recent soils from loamy alluvium. In these soils the initial properties of loam texture, small aggregates, friable consistence and free drainage yet moist conditions provide an excellent physical environment for the establishment of grasses, clovers and associated organic life. Given slight acidity and a high level of nutrients, maintained if necessary by fertilizers, grassification to 5 cm may be seen after two to three years and to between 15 and 25 cm ten years after sowing grassland. On red loams, moderately leached brown loams, yellow-brown sands, and yellow-brown pumice soils under well distributed rainfall and high nutrient levels, the rates of grassification are of a similar order. Slower rates apply where short periods of nutrient deficiency, or waterlogging or wilting point occur to restrict the continuously high level of organic activity in the soil. Inadequate nutrient supplies are particularly applicable to the very strongly leached members of any of the above-named groups of soil.

Moderate rates of grassification (5 cm after five years, 10-15 cm after ten years) occur on areas of central and southern yellow-brown earths (see Fig. 1) brown granular loams and rendzina soils as a consequence of fluctuations of moisture and temperature in the surface soils, of clay content and its resistance to change. A similar moderate level applies in the yellow-grey earths, owing in these soils to the wide fluctuations in organic life resulting from the seasonally wet and dry conditions. Grassification on northern yellow-brown earths, northern podzols and brown granular clays is generally slow owing to their strongly acid reaction, their high content of clay, their low level of nutrients, and the rapid fluctuations of moisture content and associated organic activity under the warm subtropic environment of North Auckland.

On gley podzols, gley soils, organic soils and southern podzols, grassification is seriously limited by the slow drainage and its restriction on humification, on rooting and on granulation of aggregates. Saltiness is a cause of slow grassification on reclaimed tidal marshes. On stepland soils, grassification is generally simi-



No grassification under forest.

6 cm grassification under grassland,
6 years.

18 cm grassification under grassland,
20 years.

FIG. 1: Comparison of grassification on profiles of yellow-brown earths (Photos, Soil Bureau).

lar in rate to the process on their related soil group, but the deepening effects are reduced by the removal of soil from the surface by erosion and also by frequent fluctuations in moisture content. Consequently, progress of the process is very uneven. On the high country yellow-brown earths grassification involves either partial or full replacement of tussock species under which is an organic litter, moderate to low acidity, and a mineral soil with many of the physical conditions for grassland establishment. Restrictions to grassification under introduced grassland are the cool temperatures, the low nutrient level combined with a severe hazard of accelerated soil erosion. A suitable combination of grasses, legumes and management under grazing is required for improved pastoral use of these soils.

Under arable farming most New Zealand soils tend to become disaggregated, more dense and low in organic matter. These effects can be countered by grassification, and to maintain productivity the general practice is to rotate periods of cropping with periods of intensive pastoral grazing. Results have proved very satisfactory.

For hard-wearing playing fields, grassification tends to require frequent mowing, and to encourage vigorous activity of soil organisms and a soft surface when wet. As these are undesirable characteristics, soil management is directed towards surface turf formation, slow humification, restricted activity of soil animals and strong acidification. Slow-growing fine-leaved grasses or prostrate plants are appropriate to these soil conditions.

GRASSLAND POTENTIAL

Descriptions, of soils and interpretations of their suitability for pastoral farming have been given at many conferences and through the rotation of these meetings they have provided a wide range of information to members. However, these district reports do not emphasize differences between regions of New Zealand that are important to national integration of soils and grassland for maximum production. Outlines of the national picture and of regional differences have been given in papers to the N.Z. Institute of Agricultural Science (Gibbs, 1963), to the N.Z. Ecological Society (Cutler, 1966) and to *Soils of New Zealand* (Gibbs, 1968; Walker, 1968), but unfortunately not described in detail to Grassland conferences. This omission has probably been responsible in the past for the slight consideration given to soil in the applications of pasture ecology (Levy, 1970). For many years, ryegrass-

white clover was the major objective of pasture management from one end of New Zealand to the other, and only at recent conferences (well illustrated at this one by the lotus session) has much attention been directed to other species of pasture plants bred for particular regions and soils. Much more needs to be done by closer collaboration between all people concerned with grassland. At present soil, grassland, animal and ecological scientists each have their own subdivisions of the environment and they could demonstrate collaboration by preparing a multidisciplinary framework on which to design research and compare results on a common basis.

In regard to collaboration, may I remind you that, in an address to the third conference in 1934, Lord Bledisloe warned soil and grassland scientists that by working separately they narrowed the outlook on composite problems. He emphasized then that co-operative work was essential to progress, in grassland farming. A similar message is contained in *Land Alone Endures* (Molloy *et al.*, 1980).

Detailed results of grassland research under differing environments are reported from the five substations of Grasslands' Division (DSIR Annual Reports) and from field experiments of MAF (Radcliffe *et al.*, 1974-8).

Similar studies from other environments are needed for regional comparisons and for this purpose a list of benchmark soils compiled by consultation between representatives of the Farm Advisory Division and Soil Bureau should be considered. The experimental work has been partially implemented and with some up-to-date revision could serve as a basis for co-operative investigation as outlined by Lynch (1972). Detailed research is also needed into pastures and pasture management for deer, goats, rabbit; and other mammals under investigation.

Experiments designed to relate stocking rate to fertilizer use are particularly applicable to the detailed consideration of energy balances raised by the increased prices for oil. Energy costs for maintaining soil conditions for high producing grassland are having to be closely examined and soil differences such as the higher total need for fertilizers between northern and central yellow-brown earths, and on yellow-brown pumice soils compared with yellow-brown loams and brown granular loams, deserve serious consideration. These energy studies are also relevant to the controversial expansion of commercial forestry into some areas of pasturelands — e.g., King Country, Northland.

Proposals to use grassland as a source of biomass for fuel production are being evaluated against the conversion of different arable crops and forest growth for a similar purpose. In addition to such use of grasslands lessening the areas for grazing and the supplies of pastoral food, the lowering or absence of the animal return to the soil system must be a part of the evaluation. It must include consideration of the claims that permanent maintenance of grassland depends on grazing and that the benefit of animal effects cannot be fully replaced with fertilizers.

FERTILIZERS

'Fertilizers and associated chemical and field studies of soil have been a continuous source of papers to the *Proceedings*; rightly so, as fertilizers have been a primary means of increasing grassland production from soils to levels higher than the natural vegetation. However, the successes have led many people to assume fertilizers to be the main source of productivity, whereas they are essentially only auxiliary contributors to the total nutrient supply. Applications have tended to become routine rituals as if soil had a fixed appetite that was not altered by the grassification. In addition to the changes described earlier, the increased growth promoted by fertilizers mobilizes elements that were previously idle constituents of the soil. These elements become involved in the interacting processes in humification, leaching and plant cycling, with consequent effects on the properties of the soils and their appetites for fertilizers. Hence the need for close attention to maintenance levels, and for these to be adjusted to changes in the soil system relating to particular elements. For example, evidence regarding the leaching of elements such as nitrogen, calcium or potassium should be examined separately and on a regional basis. Results should not extend to phosphorus, cobalt or molybdenum without supporting evidence of similar needs.

Claims are made that fertilizer treatments on grasslands are partly responsible for nitrate and phosphate content of streams and lakes. Whilst it is possible that some extra nitrogen may reach ground-water through insufficient absorption of nitrate by grass-roots, a direct connection through soil has yet to be proven. The huge capacity of soil microorganisms to use surplus nitrates is likely to prevent large losses.

As regard phosphorus, analysis shows that the rate of leaching of compounds of this element is extremely slow so that very little fertilizer phosphorus can reach streams or lakes through the soil.

On the contrary, moderate to large amounts are retained in very slowly available form combined with clays and humus. Under vigorous pastures a large proportion of applied phosphorus is combined in organic form and becomes available only in small amounts. Biological methods of increasing the rate of decomposition of organic matter are a promising lead to development of a suitable method for accelerating the release of this phosphorus and so reducing the amounts of phosphatic fertilizers needed to maintain adequate nutrient levels. Once adequate levels of phosphorus have been reached, losses from the soil system become small, and continuing to apply phosphates in similar amounts to the building-up stage is a waste of resources. Recent surveys of fertilizer use have shown that costs of excessive applications of phosphorus and potassium amount to \$7.4 per hectare on sheep and beef farms, and to \$25.1 per hectare on dairy farms. From these surveys it was estimated that the national cost of excessive fertilizer was \$48 000 000 which is a waste unless the fertilizer could be transferred (by animals?) to hill country which is not getting enough for high production. Investigations into the maintenance needs for trace elements — cobalt, molybdenum, boron and copper — are in progress in order to avoid waste of these expensive materials (Saunders, 1980) .

Many answers to questions of efficient amounts of fertilizer applications may be obtained through the Soil Testing Service of MAF. National coverage would mean a large and expensive expansion of facilities but a small cost in relation to savings by farmers (or to the costs of another aluminium smelter). If more investment were applied to agricultural production and products New Zealand and the world would benefit.

Another large-scale project, namely, the urea factory, is of more direct concern to grasslanders and deserves their close examination. The benefits of nitrogenous fertilizers to horticulture, to arable cropping, and as a means of extending the season of pasture growth are well-known acceptable methods. But as a substitute for clover in pastures, the benefits are offset by the depression of natural fixation of nitrogen, by the decreased diversity of plant materials and of soil organisms, and by an increased hazard of pollution by leaching. A thorough soil evaluation must be done before a shortage of phosphate and a surplus of urea forces changes to pastoral management. The evaluation should consider different groups of soil, as nitrogen may have a special place on such soils as brown loams or gley podzols. The application of

nitrogen fertilizers on pastures has been raised at previous conferences and in 1934 a very strong advocate, George Holford, quoted a claim by G. B. Shaw that "if you feed dried grass grown from nitrogen treated ground to cows they will produce a much more nutritious sort of butter and a much more vital sort of milk, and if you eat that butter and drink that milk, you will never suffer from disease and you will never die." (Messrs Shaw and Holford were healthy men but are now unable to continue the experiment.)

The soils of Westland have been described and discussed in many publications (Gibbs, *et al.*, 1950; During, 1972; Prickett, and O'Byrne, 1972; Ross *et al.*, 1977). Investigations of particular soils have been made by MAF, DSIR, Lincoln College, Lands and Survey Department, and Water and Soil Conservation Division. Regretfully, despite all the work done, the major limitation to most grassland farms is the weak physical structure of the soils on flat and rolling land as a result of excessive moisture for periods. The waterlogging effects of this moisture are serious limitations to grassification as it favours the moroid process of turf formation instead of deep distribution of roots, rapid humification and release of nutrients, and a vigorous and very numerous population of soil organisms, especially worms. Surface depressions tend to accumulate organic materials to the extent that the soils qualify as organic soils and have all the weaknesses of those soils arising from their very low content of mineral materials.

From a soil point of view, use of the gley podzols arid podzols for pastoral farming requires frequent spelling from grazing obtained by some farmers with access to free-draining soils. If the latter are not available, the hill country soils are a possible alternative. As yet the high costs of fertilizers, the aggressive fern and shrub growth, and the soft surface of the hillsides have proved very serious restrictions to pastoral farming on hillsides. Nevertheless, the co-ordinated use of terrace and hillsides offers the best soil solution to the problems of pastoral farming and justifies a full-scale investigation of methods. Otherwise large-scale use of the podzol and gley podzol soils of Westland should be reviewed against the alternative of forestry for which the hillsides are suited.

Outside Westland, no more land area is likely to become 'available to pastoral farming. In fact, the total area may be less as forestry and arable farming expand their use (Gibbs, 1968). Whether the land is used solely for pastoral purposes or becomes

combined pastoral and cropping or forestry, there is need for more integration of research and information on soils and grassland if productivity per hectare is to increase. As regards particular soils needing research attention for grassland improvement there are extensive areas of high country yellow-brown earths where low temperature seems to be the chief limitation, and the moderately steep to steep land associated with yellow-grey earths where large fluctuations of moisture are environmental conditions for which special strategies for grassland development are needed.

In summary, soils and grassland contribute to life on earth in a reciprocal system;

- Grass needs soil to supply nutrients; to store energy; to ration water; to provide a moist cool home for micro-organisms; and a stable shelter for plant roots.
- Soil needs grass to improve its aggregation and porosity; to accelerate humification, mobilization of elements and cycling of nutrients; to reduce variations in surface soils: to conserve nutrients and the soil surface against erosion and the debilitating effects of climate.
- The progress of the soil-grass system may be assessed by grassification.

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