SOILS OF WESTLAND

H. S. GIBBS
Senior *Pedologist, Soil Bureau, D.S.I.R., Lower Hutt*

Introduction

THE soils of Westland are, in general, a sad-looking lot 'at the present time. Over large areas of the lowlands their native robes of timber trees have been taken away or torn to shreds. Some small areas have acquired a new flimsy garment of pasture or foreign trees, but large areas of flat and undulating terrace lands are a ragged quilt of rushes, ferns, mosses and burnt tree sturnps. Hills previously in tall forests now have a mass of small trees, shrubs and ferns without timber value. If the soils could speak, they would complain that they had been treated like gold or coal (which to a soil is worse than dirt). Gold and coal are inert, diminishing resources of only temporary value to Westland. Soil, on the other hand, has living components that give it powers of recuperation so that it can be used over and over again. It need not be a diminishing asset. With assistance from man, soil can increase its natural productivity and maintain this at a certain level indefinitely. Hence, the soils are potentially a far more important asset to Westland than gold or coal. But this is not apparent either to the resident of Westland nor to the visitor. Along the highways or runways they see derelict farms and wonder if the soils are inherently poor or whether the timber trees took all the "good" out of the soil. On the other hand, the abundant growth of unpalatable plants would indicate a potential source of productivity in the soils.

Factors of Soil Formation in Westland

(1) A VARIETY OF ROCK AND PLANT MATERIALS

The alpine backbone along the eastern side of the district consists of greywacke and argillite grading into schist. Ranges and hills nearer the coast consist of granites, sandstones, siltstones and some limestones. Ultrabasic rocks outcrop in the Cascade Valley. Erosion of these mountains and hills by ice and water has deposited boulders, gravels and sands in morainic heaps or alluvial terraces. After the last glaciation, the older terraces received a coating of silty loess 2 to 3 ft thick, and in recent times a fringe of wind-blown beach sand has accumulated along parts of the coast. These rock materials are almost all siliceous but are only moderately weathered to clays. The surface materials have a high content of gravel, sand and silt which contain many elements not yet in a form available to plants.

The natural vegetation below 3,000 ft is forest — podocarp-broadleaf in central Westland and along the coast, mixed beech and beech-podocarp forest elsewhere. Above 3,000 ft, the vegetation changes from forest through subalpine scrub to alpine grasslands until bare rock, scree and ice begin about 6,000 ft. Lowland swamps carried kahikatea forest, raupo, rushes and sedges.

(2) A MILD HUMID WET CLIMATE AND A RESTRICTED RANGE OF SOIL ORGANISMS

On the lowlands, mean annual temperatures are 52 to 53°F with moderate extremes and are more comparable with those of the southern end of North Island than with those of Canterbury or Otago. Temperatures are likely to be cool to cold above altitudes of 1,000 ft. Relative humidity on coastal regions averages 80 to 90% which is high for New Zealand. Annual rainfalls in the Grey Valley are 80 to 90 in. but increase to 100 in. at Greymouth, 130 in. at Ross and 150 to 200 in. on the coast farther south. Annual precipitations of 200 to 400 in. occur in the mountain districts. This rainfall is well distributed but is commonly intense with dry, clear intervals. For example, Hokitika with an average annual rainfall of 115 in. has an average of 1,900 hours of sunshine per year. These climatic conditions on the lowlands encourage rapid plant growth where plant nutrients are available. But decomposition of plant litter is retarded by the high moisture content of the soils which limits the kinds and numbers of soil organisms. Lee (1959) found few earthworms in the older soils and most of these were in the plant litter. The concentration of organisms in thet litter layer and their restriction to species that can operate in wet conditions means a delay in the circulation of nutrients and their blending into the soil. Organic matter tends to accumulate in a peaty layer above the mineral soil.

The overall effect of the interaction of the climatic and biological factors on surface materials is to encourage (A) acid leaching and (B) waterlogging in the soils.

(A) Acid Leaching

The continual trickling of water through the soil dissolves constituents such as calcium, magnesium, phosphorus, nitrogen, iron and cobalt from the upper layers. Some of these are absorbed by plant roots and taken into the organic cycle, the remainder are either taken away in drainage waters to the rivers or are deposited in lower soil layers together with colloidal particles of clay and humus washed through the soil. Extracts from the surface layer of organic matter increase the decomposition of minerals and the removal of products through the soil. In time, the deposited materials accumulate in distinct layers called pans, some of which show up as black and red seams along the exposed sides of gravel and sand pits. Iron compounds give yellow colours to these soils and the displacement of iron is demonstrated by the development of a pale grey to white horizon above one that is much browner than the material further down. In well-drained soils, the extent of leaching can be assessed from the relative thicknesses of pale grey and brown horizons. The net result of these processes is called a podzol which has the following characteristics :

(a) A surface layer of slowly decomposing organic matter usually called raw humus, duff or mor. It is strongly acid and ranges from 1 to 12 in. in thickness.
(b) A black or dark brown sandy or silty horizon about 1 to 2 in. thick and high in humus.
(c) A pale grey to white sandy or silty horizon from 1 to 6 in. thick. Horizons 2 and 3 are strongly acid and friable.
(d) A dark brown or black silty or clayey horizon 3 to 15 in. thick, moderately acid and cemented.
(e) A yellowish brown to brownish yellow horizon 10 in. and more thick with indistinct boundaries.
(f) All horizons are strongly to extremely acid, and low to very low in exchangeable cations and available phosphorus. Horizon (d) shows small increases in total amounts of many elements (iron, aluminium, manganese, potassium, magnesium, phosphorus and carbon).

(B) Waterlogging in the Soils

Waterlogging is widespread because the soils have to cope with a huge surplus of water after meeting all demands of transpiration and evaporation. Small areas of podzol soil profiles occur on sand dunes (Waita soils) and on rolling ridges or moraines or old alluvium (Waiuta soils) where there is free internal or external drainage. However, as soils become older the subsoils become compact and percolation is impeded. Whilst this delays losses of nutrients, it causes waterlogging of the upper layers of soil and anaerobic conditions eventually prevail. The rates and depths of biological activity (by roots and animals) are decreased so that the surface organic matter becomes peaty and the mineral horizons lose their friability and structure. These characteristics are well developed on high terrace lands formed on 24 to 30 in. of loess over gravels. The humus-iron pans developed in the upper layer of gravels delay percolation and the overlying loess silts become continuously waterlogged. A brief profile of an Okarito soil is:

6 to 9 in.	reddish brown peaty loam ;
6 to 8 in.	dark brown peaty silt loam which is structureless ;
10 to 14 in.	grey silt loam, compact and structureless ;
3 to 6 in.	brownish grey silt loam to sandy loam, also structureless ;
6 to 10 in.	black and reddish brown gravelly sand and sandy gravels which are cemented together ;
on	sandy gravels with a yellowish brown to grey matrix.

Analyses show these soils to be strongly acid (pH 4.7 to 5.0) and to have high organic matter and high carbon/nitrogen ratio in all horizons. Total phosphorus and potassium are high but available values are very low. Clay minerals are mainly illite with lesser proportions of chlorite and clay vermiculite.

Okarito soils are classed as gley podzols and typical of pakihi soils which are very extensive on terrace lands in Westland. The combination of low nutrient fertility and bad drainage makes gley podzols very different from the other classes of soil for pastoral farming and most areas cleared of forest have rapidly become pakihi wastelands of ferns, mosses and rushes. Descriptions of past and present attempts of farming are given in the symposium on pakihi soils elsewhere in these *Proceedings.* Suffice to say here that conventional methods are inadequate to cope with the physical properties of pakihi soils and new methods are needed. For grass and clover pastures, the excessive water, strong tendency to turf development and very soft surface are a severe handicap to grazing. Excellent growth obtained by heavy topdressing has increased transpiration but pastures are commonly spoiled by trampling. High silt and low clay contents make mole drainage unstable and the structureless subsoil does not allow sufficient lateral drainage to make channel drains effective. Until a satisfactory method of draining the surface is devised, the alternative of offsite grazing or of growing edible rushes or ferns could be explored. The soils are not strongly weathered and the clay, silt and sand fractions contain many minerals required for plant growth. Gley podzols occur in many other parts of the world but at present seem to be little used.

Pattern of the Soils

Although acid leaching and waterlogging are the regional processes of soil formation, the extent of their activities is restricted by various local conditions and results in the diverse pattern of soils shown in maps (Gibbs et *al.,* 1950). Local conditions restricting the development of podzols and gley podzols are:

(1) AGE OF SITE

The displacement of materials to form soil horizons requires many years and the podzols of Westland occur on land surfaces exposed for many thousands of years. Soils developed on recently accumulated alluvium or sand dunes have only weakly developed profiles-usually only two horizons on the youngest materials and three on older surfaces. Thus, on free-draining sites the soils on flood plains (Hokitika soils) have a greyish brown topsoil grading into greyish yellow subsoil below 6 to 0 in. Leaching is interrupted by periodic flood deposits which bring fresh minerals into the soil system. Hence, the soils are high in many plant nutrients including nhosphorus. Terraces slightly above flood level and fans bordering hill slopes have soils (Ikamatua soils) in which the topsoil and subsoil are quite distinct. Mahinapua soils on coastal and dunes have-reached a similar stage of development. Some nutrients have been lost and treatment with moderate amount-f lime and fertilizers are needed to get pasture production equal to the Hokitika soils. Terraces 20 to 60 ft above river level in the Grey Valley have soils (Ahaura soils) with three distinct horizons. These soils are more acid and more leached of nutrients than the Ikamatua soils and require large amounts of lime and fertilizers to maintain highlyproductive pastures. The greater degree of leaching is indicated by the brown subsoil and coating to stones together with traces of iron pan development between stones. The next stage is a podzol of the Waiuta type.

(2) LOCATION OF SITE

Leaching and podzolization occur most readily under free drainage and this is not available on land at or below the level of ground water. The continual waterlogging prevents full decomposition of dead organic materials and these accumulate as peat.Soils developed in basins on peat with little addition of mineral materials are named Kini soils, and those developed on mixtures of peat and alluvium are named Karangarua soils. Both require drainage before pastoral use but their low-lying position in regions of more than 100 in. annual rainfall makes drainage by pumping very expensive. In many cases, it would be preferable to use the areas as ponhing basins for flood detention, accumulating more alluvium on the surface to produce Harihari-like soils. The Harihari soils are extensive on low-lying parts of floodplains. They are the same age as Hokitika soils but have grey subsoils with brown and orange mottles. When drained, they maintain excellent pastures for dairying although there is a serious hazard of surface poaching. Heavy liming is necessary to encourage the decomposition of organic matter which otherwise accumulates as a fibrous turf. Liming may also mobilize some of the phosphorus made unavailable through gleying. On swampy terraces above flood level, gleying, combined with podzolization, produces Kumara soils on the intermediate terraces where the silts are shallow (9 to 18 in.) and Okarito soils on the high terraces where silts are deep (18 to 30 in.). Field observations indicate that gleying has been increased by removal of the forest but moisture samples do not show any distinct changes (McDonald, 1955).

(3) PARENT MATERIAL

The degree of leaching, podzolization and waterlogging and their proportions are influenced by the texture and mineral composition of the soil materials. Soils formed from sandy sediments podzolize rapidly, whereas those from silty sediments podzolize slowly but have gleying imposed at an earlier stage. Soils formed from granite podzolize more rapidly than those from greywacke or schist which have more iron bearing minerals. Soils from silty alluvium or loess derived from schist are very susceptible to gleying because the platy particles pack down to leave fewer channels for water. Soils from calcareous marls and siltstones (Runanga soils) podzolize slowly on account of the fine texture and initially high level of calcium and magnesium. They escape severe gleying because they occur on rolling to moderate steep slopes and the surplus water runs Off.

(4) **SLOPE**

The effects of slope in restricting waterlogging on the Runanga soils applies to the hill soils from sandstone (Arahura hill soils) or from conglomerates (Blackball hill soils) and to the steepland soils (Punakaiki, Matiri, Haupiri, Otira and Kanieri steepland soils). The run-off, however, brings on the hazard of accelerated erosion which can be very destructive on the steep slopes. These steeepland soils need the protection given by the surface layer of organic matter provided by forest and consequently are generally best maintained under that cover. This maintenance also requires strict control of noxious animals (Travers, 1964).

(5) **VEGETATION AND ASSOCIATED ORGANISMS**

These influence soil development through their ability to retard the progress of degrading processes by the growth, uptake of nutrients and decomposition of dead vegetation. Where each of these is rapid, leaching, podzolization and gleying are actively opposed and productivity moderate to high; where either one is slow the others are retarded, degrading processes are only slightly opposed and productivity low to very low. However, vegetation and organic life are the soil factors over which man has the greatest control by management practices. Man may:

(a) Replace mineral losses by fertilizers ;
(b) Discourage turfing (raw humus) and encourage incorporation of organic matter through liming, selected fertilizers, plant selection and grazing techniques that increase biological activities both in rate and in depth ;
(c) Stimulate root growth and improve structure;
(d) Remove excessive water by drainage either by moulding the surface or providing channels for percolation :
(e) Encourage some desirable plants and kill weeds and plant pests.

These are the principal methods of management applicable to the improvement of soil productivity in Westland. Which methods and what amounts of each treatment are needed for any area depend on the soils concerned and the intended use of the area. Also, since the soil use is not merely for survival, the costs of management impose limits on the decision. The costs are high for pastoral farming because the soils are forest soils and the climate retards the changes required for grassland production. Large changes are required and half-measures or premature demands on the soils result in failure.

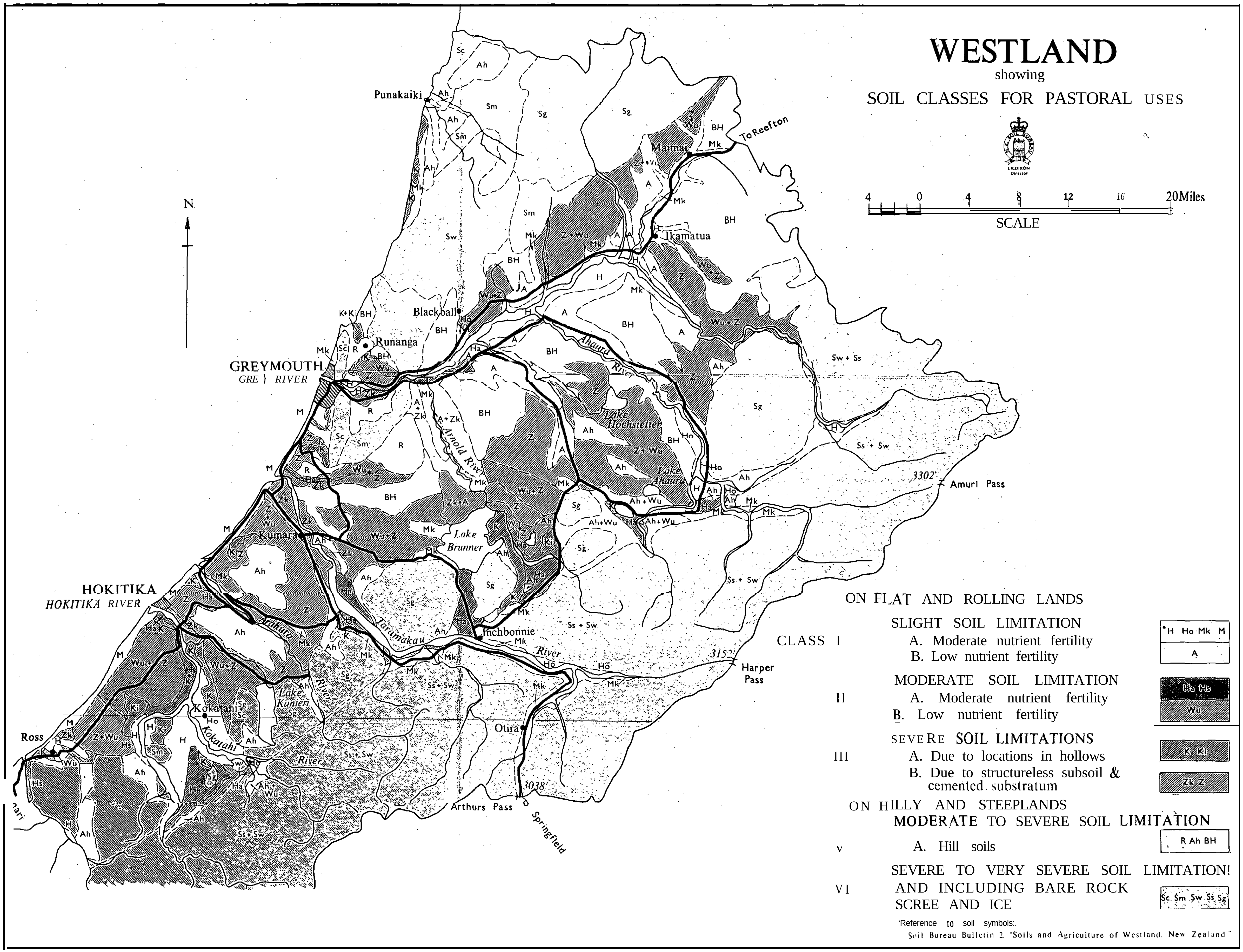
Land Use

Pasture, forestry and cereal cropping have been the chief uses for Westland soils. The regional conditions are really not suitable for ripening and harvesting of cereal crops and production is better obtained in Nelson, Marlborough, Canterbury or Otago. On most soils of usable slope. the present choice lies between pasture and timber growth. While soil is not the only factor concerned in a final decision, its share can be shown by a classification of soil properties. For pastoral purposes the soils of Westland can be grouped into five classes based on degrees of difficulty in converting the individual soils to productive pastoral use. Classes 1, 2 and 3 comprise soils of flat and rolling lands where wheeled machinery may be used, and classes 5 and 6 comprise the soils of hilly and steep lands where aerial methods are the only mechanical aids at present available to management. (Class 4 is omitted in order to maintain conformity with classes used in other New Zealand districts, there being none of this class in Westland.) The distribution of these soil classes in the central portion of Westland is shown on the accompanying map.

SOIL CLASS 1

Class 1 consists of soils with slight soil limitations to pastoral use. Topdressing is needed and drainage, while not essential, can be beneficial, The class may be subdivided into:

(a) Soils of moderate nutrient status — Hokitika, Mahinapua and Ikamatua soils (126,000 acres).
(b) Soils of low nutrient status, requiring larger amounts of fertilizers and lime than 1 (a) — Ahaura and Waita soils (100,000 acres).



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Prepared by H. S. Gibbs from Soil Bureau Data

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SOIL CLASS 2

Class 2 consists of soils with moderate soil limitations to pastoral use. Drainage is essential to obtain adequate benefits from topdressing. This class is subdivided into:

(a) Soils of moderate nutrient status — Harihari soils (158,000 acres).
(b) Soils of low nutrient status and requiring larger amounts of fertilizer and lime than 2 (a) — Waiuta and Cascade soils (96,000 acres).

SOIL CLASS 3

Class 3 consists of soils with severe soil limitations to pastoral use. Drainage is essential but has serious problems in application before the growth obtained from topdressing can be grazed. This class is subdivided into:

(a) Soils located in low-lying sites — Kini, Karangarua soils (90,000 acres).
(b) Soils with severe internal impedance to drainage — Kumara, Okarito soils (300,000 acres).

SOIL CLASS 5

Class 5 consists of soils on hilly to steep lands with moderate to severe soil limitations to pastoral use (310,000 acres). These are the Runanga, Arahura, Blackball and Punakaiki soils which need topdressing to offset their moderate to low nutrient status and careful management to avoid erosion or invasion by weeds. They have the advantage of good drainage without the liability to moisture shortage that restricts production on most hill soils of eastern districts of New Zealand. On Arahura and Blackball hill soils, it would be advisable to aim at deep-rooting mull-forming plants (pastures or forest trees) that will offset the fairly strong leaching tendencies on these soils. For pastoral farming, it would be essential to include areas of Class 1 or 2 soils in the farm unit to assist pasture management on the hill soils. On the other hand, management of pastures on terrace lands could be helped by using the hilly strips along the terrace edges which are now mainly neglected.

SOIL CLASS 6

Class 6 consists of soils on steep lands with severe to very severe soil limitations to pastoral use (2,130,000 acres). The limitations are very low nutrient status, and necessity for a continuous protection of turf or mat-humus vegetation against rapid soil erosion. It may be possible to use the lower slopes of some hills for grazing with soils of Classes 1 'and 2, but the total area so used' would be small. The majority of these soils should be maintaine'd in native forest or subalpine plants for control of water and conservation of lowland resources.

Areas of soils of each class in Grey and Westland counties are given in parentheses in the descriptions' of each class. Bare mountains, riverbeds and lakes are estimated as covering 520,000 acres.

This pastoral classification shows that the total area of soils potentially suited to farming -(Classes 1 to 5) is 1,180,000 acres. Of this total, only 226,000 acres are easily suited to pastoral use. Much more treatment is required on soils of Classes 2 and 5 for pastoral use and the alternative use for forestry must be considered. There is scope for both industries but detailed investigations are needed to clarify the costs of using soils in these classes, so that when the farming'squeeze extends from eastern districts, the more suitable areas for pastoral farming' are not permanently planted in trees. Class 3 soils have problems, for any use and experimental research must be continued to find appropriate methods for practical application. Throughout the region, there is an overall shortage of, free-draining soils for winter and spring grazing when the flat lands are wet. To meet this shortage, every effort should, be made to conserve the soils on the sand dunes and to level, topdress and sow all areas of dredge tailings (15,000 acres, approximately).

For pastoral farming, it is important to remember that Westland soils are. naturally forest soils. The majority. of them are strongly leached of iron and soluble plant nutrients but they have a high proportion of sand and silt particles which contain weather-able reserves of many elements. Soil aggregates are soft and are very weakly developed in most subsoils. The soils are always moist, many being excessively so and requiring drainage to increase the air to water ratio, to improve the condition for biological activity and to reduce the surface poaching under stocking. Although organic matter is high, decomposition is slow and occurs mostly above the mineral soil partly because of strongly acid soil reaction and partly because of excessive moisture. Excepting the free-draining river flats, the soil capital for grassland is small and needs building up by fertilizers, liming, drainage, and grazing management that will provide the conditions for rapid biological activity. Without rapid biological activity in the soil, pastoral fertility will be low. Expansion of soil capital will not be achieved under a mining spirit of maximum benefit from a small outlay. The soils of Westland need the generous spirit of high investment and limitation of demands to the stage of development. If these requirements are met, the soils of many 'parts of Westland can produce acre for acre as much pastoral production as other soils in the South Island. The initial stages could be assisted nationally' by such means as a subsidy on the first half ton of superphosphate that is added per acre in a complete programme. Their improvement will support and be supported by local forestry and industrial expansion. The soils exist for our use and it is our duty to see that they are made into productive resources instead of idle ones. The provincial crest says; "The harvest. is yet to come", and, given the necessary assistance, 'the soils will fulfil this prediction.

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DISCUSSION

Would Mr Gibbs comment on the wisdom of doing detailed research on the difficult pakihi soils until such time as the problems of the easier soils have been solved?

I would favour research on the pakihi soils because the problems are likely to take a long time to solve properly. The situation of these soils close to present settlements and roads makes them a large key to agricultural progress in Westland. Also, the problems on 'the other soils are mainly economic and would be helped by successful use of pakihi soils.

What proportion of the forest areas (coloured blue on the map) can be replanted to forest?

Any areas below 4,000 ft could be replanted but they would have little if any commercial value. If animals are virtually excluded, any areas would revert rapidly to native forest which is adequate for protective purposes.

The limitation to the use of many soils in Westland is their structureless nature. Would Mr Gibbs comment on whether farmers should graze sheep or cattle, or should one fry to improve the structure of the soils?

From field observation, I consider cattle are completely unsatisfactory. Sheep grazing is less damaging but I wish the sheep had bigger feet. However, for any grazing there is an urgent need to improve the structure of both topsoil and subsoil by new methods.

How does Mr Gibbs recommend that West Coast farmers encourage research into the improvement of Westland problem soils?

The directors of research divisions of D.S.I.R., Department of Agriculture, Massey University and Lincoln College might all be consulted. The Research Division of the Department of Agriculture is already doing some research on the West Coast and may be able to undertake more-likewise, Lincoln College. However, they and other departments are very short of research staff.