THE SOILS OF OTAGO AND THEIR PROBLEMS

J. D. RAESIDE and E. J. B. CUTLER, Soil Bureau,
Department of Scientific & Industrial Research, Dunedin

The soil resources of Otago present a challenge to agriculture, for, although much has already been done to promote their development through the efforts of the Department of Agriculture and the imaginative and enterprising work of many farmers, their potentialities are still far from exhausted. Hitherto only the best soils of Otago have been developed to a high productive level, and most of the soils are at a stage of development far below their capacity. As agricultural development expands and becomes more diverse limitations imposed by the nature of the soils will become of overriding importance, and the pattern of agriculture will have to be more carefully adjusted to the soil pattern of the province.

Soil problems, however, are not wholly concerned with immediate economic returns. They concern also the long-term preservation of the soil and the maintenance of soil-plant relationships on the range land of which Otago has more than its share.

The soil pattern of Otago is greatly simplified by the wide distribution of rocks of more or less uniform composition. Most of the soils of the province are formed on schist either on the basement schist itself or on loess or alluvium derived from it. The alluvium covers valley floors and inland basins and the loess, a wind-transported dust, covers most of the coastal downlands and uplands. Rocks of different composition occur in only a few places, as for example in the environs of Dunedin and on Otago Peninsula, where the soils are formed on a complex system of igneous rocks, and on the hills south of Dunedin and in parts of Central Otago, where soils are formed on tertiary mudstones and sandstones.

Differences in the soils from place to place, where the soils are formed on schist, are due principally to differences in the climate to which the soil has been exposed and to differences in the ages of the surfaces on which the soil is formed. A warm wet climate tends to break down the minerals that provide phosphorus, potash, lime, and other plant foods, including minor elements, and wash them away in the drainage water. A cool, dry climate, on the other hand, can accomplish only slight destruction of soil minerals and has little capacity to wash them away. In dry regions, therefore, soils are generally adequately supplied with plant nutrients. Climate, however, is not just a combination of total rainfall and temperature. Its effect on soils is influenced by other considerations as well; the distribution of the rainfall, whether predominantly summer rainfall, or winter rainfall, the amount that is lost in evaporation, and the temperature range. To some extent local climates are determined by local topography. An inland basin, for example, has a different climate from an elevated coastal plateau. Accordingly, soils on a particular kind of landscape tend to have similar characteristics and to belong to the same soil group. In classifying soils it is thus usually convenient to refer soil groups to the landscapes on which they occur. A classification presented in this way is easier to visualise and to remember.

The major soil groups of Otago occur on certain kinds of terrain and in particular geographic regions. They are as follows:

1. **The brown grey earth soils of the dry inland valleys and basins.**
2. **The yellow grey earth soils of the coastal downlands and plains.**
3. **The yellow brown earth soils of the mountains and the wet parts of the province.**
4. **The yellow brown earth/podsol complex of the wet mountains and hills.**

1. The Brown Grey Earth Soils of the Dry Inland Valleys and Basins

The dry inland valleys and basins of the region-broadly described as Central Otago constitute a distinct soil zone, and the dominant soils within it are referred to as the brown grey earths. Textures range from silts to stony gravels and the soils possess a firm subsoil to which the name clay pan is given. Soils without a clay pan occur mainly on low terraces, bottomlands, and steep slopes. With these soils are associated soils containing soluble salts. These are referred to as solonetzic soils. Irrigation, where the terrain permits, is essential if the soils are to be brought to full production. They have, however, some disabilities that are not conspicuous in their unimproved state but which show up when irrigation water is applied. Soluble salts are likely to spread through the soils and the clay pan is likely to hold up the drainage of excess irrigation water and cause waterlogging. Waterlogging and seepage are also likely to be increased by the presence of impermeable strata below. the soils, in the deep subsoil.

2. The Yellow Grey Earth Soils of the Coastal Downlands and Plains

The coastal downlands of Otago are covered with a mantle ‘of loess or wind-blown silt transported from the inland basins and valleys during the last glaciation and derived from the schist mountains. Under rainfalls of from 22 in to 35 in the soils on this loess deposit belong to the yellow grey earth group. These soils are characterised by weakly structured silt loam topsoils and compact silty clay subsoils. The compact subsoil or hard pan is a conspicuous horizon in roadside cuttings where it stands aut as a prominent band with a pronounced prismatic structure, or where this is not conspicuous it is broken by well-define1 fissures into coarse blocks. It generally lies between 12 and 15 in below the surface and is from 10 in to 2 ft thick. The yellow grey earths are low to medium fertility soils. Those under the lowest rainfalls, as for example those near Oamaru, are usually of medium fertility, though some are of high fertility; those under the highest rainfalls, as for example the downs near Tapanui, are of low fertility. The soils in damp regions and on poorly drained sites are characterised also by rusty mottlings in subsoils and in extreme cases they contain ironstone concretions.

All yellow grey earths respond well to lime and phosphates and most appear to respond to molybdenum, but the mechanism of molybdenum response is still not clearly understood. We still do not understand how molybdenum occurs in soils nor what circumstances cause a shortage.

The yellow grey earths are well suited for cereal growing, but their weak structures make them prone to lose their tilth under excessive cultivation or under heavy cropping.

The hard pan in the subsoil can ,be a limiting factor in the utilisation of these soils. In the wetter parts.of the coastal downlands the hard pan acts as a drainage impediment and may keep the soil waterlogged well into the spring in wet seasons. This. may seriously delay spring growth. Fortunately mole drains appear to be stable in the hard pan horizon. Although the pan is compact, moles may be drawn in spring when the topsoil is dry enough to carry machines without compacting and the hard pan is still wet and plastic. It is important to site the moles carefully. Moles do not appear to be stable in the friable horizon immediately above the hard pan nor in the subsoil below the pan.

Mole drainage is most effective in the wetter districts. In wet seasons some of the dry yellow grey earths may waterlog and prompt the thought that they too would benefit from mole drains, but it must be remembered that where seasons are generally dry it is better to conserve as much moisture as possible, and that mole drains may do more harm by increasing droughtiness in average seasons than good by reducing waterlogging in infrequent wet seasons.

3. The Yellow Brown Earth Soils of the Mountains and the Wet Parts of the Province

The yellow brown earths are characteristically friable soils in both topsoil and subsoil. They possess a well-defined crumb structure and subsoils are predominantly yellow brown. By and large the yellow brown earths are of low natural fertility, but they respond well to development if adequately supplied with fertilisers and carefully managed. This does not, however, apply to the yellow brown earths of the high mountains where the stability of the easily erodible soils on the steep slopes depends on the protection afforded by the indigenous snow tussocks. Any large-scale treatment of the soil that could lead to the replacement of the snow tussock and its eventual extinction could have catastrophic consequences if it should be proved in the long run that such introduced grasses were incapable of protecting the soils.

Broadly, the soils of the central and eastern mountains of Otago are of two kinds. The lower slopes of the mountains, where they rise from dry valleys and basins, fall into the brown grey earth group. These extend to about 3,000 ft. Above this altitude the soils belong to the yellow brown earth group and support a snow tussock dominant vegetation. These yellow brown earth soils may be further sub-divided into those formed on the greywackes of the ranges that form the watershed between the Waitaki River on the one hand and the Clutha and Taieri Rivers on the other, and those formed on the schists of the remainder of Otago. These two soils differ in one important respect, Those formed on greywacke contain irregular angular fragments of greywacke and readily form scree when eroded. The soils formed on schist contain flattened fragments of schist and do not form scree so readily when eroded. The process of erosion on these latter soils is thus slower and less spectacular but nonetheless just as destructive.

4. The Yellow Brown Earth-Podsol Complex of the Wet Mountains and Hills

In the wettest parts of Otago yellow brown earth soils form a mosaic with more intensely leached soils called podsols. Podsols are distinguished from yellow brown earths by having a thin and generally discontinuous ash grey band just below the humus topsoil. It develops under vegetation with a very acid litter, in Otago under beech, rimu, and kamahi. Topsoils generally, possess a platy structure and subsoils are dark brown.

These soils are of very low fertility, most of the plant foods having been leached out by the combined action of the high rainfall and the acid litter. They are not suitable for agriculture.

Examples of podsols may be seen at the Haast Pass and in the Tautuku District on the south-east coast of Otago.

5. The Recent and Swampy Soils of the Valley Floors

Recent soils are formed on alluvium only recently deposited and on which soil processes have been proceeding for too short an interval to produce a soil profile. They are characterised, therefore, by topsoils only slightly different in colour and structure from subsoils. They range in texture from silty clays to stony gravels. Except for the stony soils they are of moderate to high natural fertility, but on low-lying sites are liable to flooding. Examples of recent soils may be seen on both sides of the Taieri River between Outram and Momona.

Swampy soils are most extensive near the coast and are predominantly of silt loam texture. Where they can be drained they are of high fertility. With them is included an area of sphagnum peat of high acidity and of little agricultural value. An example of such peat is to be seen in the Otanomomo peat bog south-east of Balclutha.

Problems of Soil Utilisation

The basic aim of sound land use is to obtain from a soil the highest possible sustained yield consistent with maintaining its physical stability-that is, its physical structure or tilth and its freedom from erosion-and at the same time maintaining its fertility level. These objects are easily attained on flat land. On downland erosion becomes an important limiting factor, particularly under intensive cropping, and management must embrace soil and water conservation practices. On steep land conservation practices are of paramount importance, irrespective of whether the hillsides support forests or tussock grassland. Unfortunately, however, soils on steep slopes give a small return per acre, their fertility is generally low, and the steep terrain is quite unsuitable for machines. Conservation practices that can easily be applied on easier land are impossible to apply on steep land, and conservation practices are more or less limited to careful grazing management and stock control and the studious avoidance of all practices that might encourage erosion. By far the most important of these deleterious practices is fire, especially in dry range land and at high altitudes. Fire unfortunately has been and still is to a large extent regarded as an essential feature of range management and is undoubtedly the major factor in the extensive deterioration of high altitude rangeland, in spite of the fact that it has been repeatedly condemned since Buchanan's first critical discussion of its effects in 1868 up till the present. Because these warnings have passed unheeded by farmers and administrators alike, most of our mountain grasslands and soils in Otago are in a poorer state today than when the first pioneers arrived in Otago. Large areas have been seriously eroded and considerable areas have reverted to fern and scrub. Our rangeland management cannot be pronounced a success.

It has been frequently asserted in the past that the damage to the rangeland soils of Otago was primarily due to rabbits. Recent studies have shown that rabbits do not thrive in healthy tussock grassland. It was the opening of the vegetation by fire that prepared the way for the disastrous rabbit infestation of the grasslands.

The following study of the productive capacity of the soils of Otago is based on the physical and chemical properties of the soils. To simplify the approach the soils are arranged in groups, each group being capable of a particular kind of land use. The soils within each group have common properties. Thus all swamp soils are in one group, all fertile alluvial soils in another, and so on. The basic consideration in each group, however, is the nature of the soil and therefore the kind of production of which it is capable.

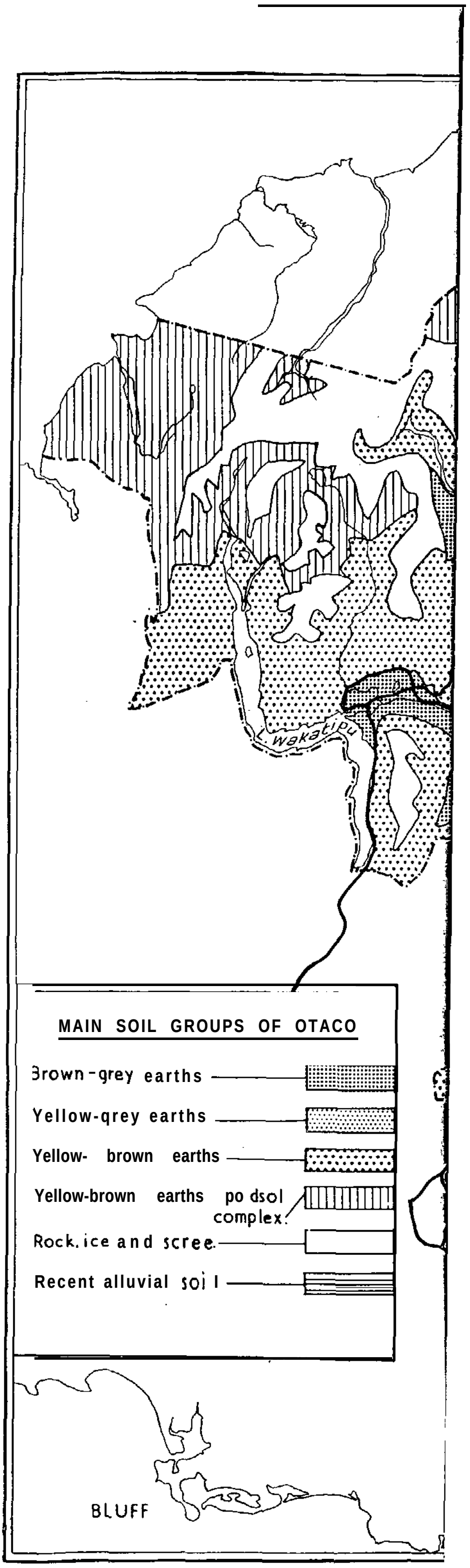
The following table shows the area in each land development group and its percentage of the total area of the province.

Areas in Land Development Classes-Otago Land District

Class	Area in acres (to nearest thousand)	Percentage of total area
1a	65	0.8
1b	569	6.6
1c	44	0.5
2a	446	5.0
2b	592	6.8
2c	298	3.4
3a	16	0.2
3b	687	7.9
3c	516	5.9
3d	900	10.4
4a	1,745	20.1
4b	1,168	13.5
5	856	9.9
6	770	8.9
Total	8,672	99.9

CLASS I-SOILS WITH MINOR LIMITING FACTORS TO INTENSIVE LAND USE

These soils are capable of utilisation to high levels of production because of their optimum texture, high natural fertility, and freedom from such limitations as high water-tables, imperfect drainage, or steep slopes:! With them have been included soils


MAIN SOIL GROUPS OF OTACO
Brown-grey earths
Yellow-grey earths
Yellow-brown earths
Yellow-brown earths podsol complex
Rock, ice and scree
Recent alluvial soil
L. Wakatipu
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capable of high production under irrigation. They have been subdivided into the following sub-classes.

(a) **Soils Suited to Intensive Dairying or Market Gardening**

This sub-class includes the fertile soils of the alluvial plains and a small area of soils of high fertility developed on limestones and basalt tuffs in North Otago. Some of these soils may need drainage, but they are easily managed and with adequate application of fertilisers high sustained yields should be easily obtained. The poorly drained soils are well suited to dairying and the well-drained soils to market gardening and intensive cropping. Although these soils cover only a small area of Otago, they are the most productive soils of the province, but are by no means producing to their fullest capacity. One reason for this is that many of them are within reach of floods. Their ultimate productivity is therefore bound up with the efficiency of flood control and the success of soil conservation measures in the mountain catchments. Another limiting factor to their utilisation is urban growth, an example of which may be seen in the spread of housing schemes over these soils in the environs of Mosgiel.

(b) **Soils Used for Fat Stock Production but also Suitable for Cereal Production**

These soils belong almost entirely to the yellow grey earth group, the soils of the loess-covered downlands of the coast, with rainfalls of from 22 to 35 in. The present position of these soils in the economy of the province can best be understand in the light of their history. When the first settlers arrived the soils had acquired a moderate supply of plant nutrients and a stable structure under a cover of tussock grassland. It is not surprising, therefore, that they were highly regarded as wheat and oat growing soils, and they were accordingly cropped fairly extensively in the latter part of the nineteenth century and the first decade. of the twentieth. Fertilisers were rarely used, however, and the natural reserve of plant nutrients was soon exhausted. Yields fell, the topsoil structure deteriorated, and cereal growing became less popular. Pastures, however, were of poor quality and soon reverted to browntop with erosion a common feature of cultivated slopes. This state of affairs continued until the 1930's when the new strains of grasses produced by grassland research and better management techniques developed by the Department of Agriculture made it possible to maintain better pastures. Soil research showed the importance of regular fertiliser treatment and rising prices did the rest. Soil fertility, organic matter content, and topsoil structure are now greatly improved, and with better management should improve still further. There is little doubt that cereal growing could be reintroduced with a maximum of perhaps two crops every 10 years. This should enable a stable sustained yield type of mixed farming to develop under improved management. It must be remembered, however, that if cropping is reintroduced on these soils, erosion will become a serious risk on rolling land. Cropping should therefore go hand in hand with approved soil and water conservation practices. Mechanical methods of erosion control may have their place in short-term measures, but they do not go to the root of the trouble': Ultimate control of erosion must come from improving the stability of the soil structure and raising the permeability and water-holding capacity of the soil.

(c) Soils Suitable for Intensive Use under Irrigation

These soils lie in the dry intermontane basins and valleys of Central Otago. For the most part they are deep silt loams and sandy loams of the fans, low terraces, and bottomlands. Drainage is free and they do not contain much soluble salts. They cover a small area only and in many places occur as small patches in a mosaic with other soils less suitable for irrigation and intensive utilisation. Most of the fruitgrowing of Central Otago is carried out on soils of this class. Although they are already largely utilised, there is still some scope for further development by the more careful siting of fruit trees with reference to the soil pattern, since fruit trees are sensitive to small variations in soil conditions, and in improved methods of water application to control waterlogging and spread of soluble salts from adjacent soils. Excess irrigation water in early spring may, for example, lower soil temperatures.

CLASS II-SOILS WITH MODERATE LIMITING FACTORS TO DEVELOPMENT

The soils in this class are largely undeveloped, although a good deal of development has taken place in the past decade. The soils of this class offer a greater scope for development than those of any other class. The agricultural future of Otago will therefore depend on the development of these soils. They have been subdivided as follows:

(a) **Downland and Hill Soils of Low Fertility Suitable for Fat Stock Production**

This sub-class is made up of yellow grey earths and yellow brown earths of low fertility under rainfalls of from 30 to 40 in per annum. Some of these soils were cropped in the 90's, but they were invaded by scrub and weeds and some farms were abandoned. The Invermay station is situated on one of the soils of this class. Some of these soils have never been cultivated and are used as rangeland, but the quality of the rangeland pastures appears to be steadily deteriorating, possibly because of falling fertility. The building up and maintenance of soil fertility is thus the key to their successful utilisation. Cereals may be grown successfully, but it is doubtful if they are well suited to these soils.

Soil structures are weak and consequently erosion is a hazard on rolling slopes, particularly when they are cultivated to a fine tilth. Hilly soils are mostly scrub covered and of low productive value, but may respond to aerial topdressing. They are, however, admirably suited for economic forestry and may provide a better return as woodlots than as grazing land.

(b) **Soils of Low Fertility on the Coastal Plateau**

This sub-class embraces the strongly leached yellow brown earth soils of the uplands between Palmerston and Lawrence between 1,000 ft and 2,000 ft above sea level and a small area of similar soils in western Otago and South Otago. Most of the soils are ploughable, but to a large extent the land is intersected by deeply incised valleys. The soils are free-draining and except in particularly dry seasons they are moist throughout the summer. Winters, however, are cold and shelter is necessary against frequent winds. The soils are easily, cultivated and given adequate dressings of lime and fertilisers satisfactory pastures may be developed. It may, however, take several years to build up soil fertility to a desirable level, and maintenance dressings of fefilisers are likely to be higher for pastures than those required for the yellow grey earths of the previous sub-class, chiefly because of the greater loss through leaching.

Although topsoil structures are better than those of the yellow grey earths of the previous sub-class, great care must be taken to avoid erosion through cultivating to too fine a tilth. Because of the high winds' erosion is likely to' be as destructive as sheet erosion.

(c) Hilly and Steep Soils Suitable for Development

This sub-class includes yellow brown earths under rainfalls of from 30 to 40 in per annum, as, for example, in the Kaihiku Hills of South Otago. They receive a well-distributed rainfall, drying out only in exceptionally .dry summers, possess a well-developed topsoil structure, and do not appear to be particularly susceptible to erosion. The soils of this class range in fertility from low to moderate and it is likely that aerial topdressing will be successful. At present they are free of scrub. With careful management, topdressing, and oversowing scrub is not likely, to be a problem in the future. Where water supplies are adequate they would probably carry cattle successfully.

CLASS III-SOILS WITH A SERIOUS IMPEDIMENT TO DEVELOPMENT

The utilisation of soils of this class is strictly limited, in some by a physical limitation, as for example rock outcrops, or it may be partly physical and partly economic as in the swamp soils where the cost of draining may be far in excess of the soils' potential productivity. These soils have been subdivided into four sub-classes.

(a) Swamp Soils

There are several areas of swamp land which if drained could be made into highly productive dairying land. Drainage, however, would require large-scale engineering works to effect the necessary degree of protection, and the cost of this work can scarcely be justified by the area of soils involved. Other swamp land, as for example that around Lake Waihola, is valuable as a ponding area when the Taieri River is in flood. The swamps round both Lakes Waihola and Waipori are also valuable as wildfowl habitats and for this reason should be preserved, as should other small areas of swamp throughout the province that serve as breeding and feeding sites for wild life. It is possible also that Lake Tuakitoto might be better as a wildlife reserve than as farmland.

(b) Soils Suitable for Irrigation but with Limitations

Most of the soils of the valley floors, terraces, and inland plains of Central Otago fall into this sub-class. All these soils occur in a semi-arid region and water is a limiting factor in their utilisation. They belong principally to the brown grey earth group with a small area of yellow grey earths. Limitations to their development are somewhat varied. Some are of low fertility and stony, gravelly texture and high porosity with high water requirements. Others possess an impermeable subsoil horizon which causes waterlogging under extensive irrigation. Others must be irrigated with caution because of impermeable underlying strata that may cause water-logging some distance from the site of water application. Others again contain soluble salts that may accumulate under irrigation in sufficient quantities to reduce plant growth. Some soils may possess all or any combination of these limiting factors. Examples of such soils may be seen in the Ida Valley where waterlogging has taken place and salt has accumulated to the detriment of crops and pastures. These impediments, however, are serious limiting factors only when irrigation methods do not take them into consideration. Where they exist such practices as wild flooding should be avoided. Under this method of irrigation the quantities of water applied cannot be adjusted to the needs of the particular soil. But by the use of more systematic methods of irrigation, such as border dike, contour ditches, or in some cases spray irrigation, the limiting factors can be overcome to a large extent or at least reduced below dangerous proportions.

Irrigation of such soils, however, is more costly than of soils without such disabilities, as for example the soils of parts of the Canterbury Plains, and this requires a careful balancing of costs against production.

Without irrigation, however, these soils are capable of considerably increased production by dry land farming techniques and more extensive use of fertilisers, for many of these soils give a good response to fertilisers in spite of their naturally fairly high fertility.

(c) Soils of the Dry Range Land not Suitable for Irrigation

This sub-class includes the soils of the dry inland downlands, more or less equally distributed between the brown grey earth and yellow grey earth groups. Most of them lie on the margin of the dry basins and are extensively studded with rocky outcrops and tors. The soils are, moreover, shallow and droughty. Rainfalls are less than 25 in per annum and summers are hot and dry. Water is available for the irrigation of small areas only. Although cultivation is greatly impeded by the rocky outcrops and the shallowness of some of the soils, a considerable improvement in their production can be affected. In developing them, however, several considerations have to be kept in mind. Management should give the greatest possible weight to soil and water conservation. The soils have a weak structure and erode readily. Some of them have already been severely eroded. Over many thousands of acres of the soils of this sub-class the loss of only 1/10 in of soil annually would destroy the whole soil in a century. Uncontrolled grazing and the use of fire on these soils are to be deprecated, attention should be given instead to selection of suitable pasture species that will best meet the requirements of the soils, for there is little reason to think that the species that suit the coastal downlands will suit the dry inland soils equally well.

(d) **Soils of the Dry Range Land**

The soils of this sub-class include the semi-arid hilly and steep soils of Central Otago. In the driest localities, as for example near the Cromwell Gorge, the soils are severely eroded and only patches of vegetation remain. In the moister situations, for example-near Roxburgh, the soils are less severely eroded and a good deal of the original tussock still survives. Although the soils are shallow and droughty and of moderate to high fertility, they respond well to topdressing and oversowing in the moister sites. A closed vegetative cover is essential for the protection of what remains of these soils in the interests of soil and water conservation, and this objective is inconsistent with the use of fire. Where possible it will be desirable to establish shelter trees as protection for stock.

CLASS IV-SOILS UNSUITABLE FOR AGRICULTURAL USES

The soils of this group are of low natural fertility and difficult to improve because of steepness of slope and susceptibility to erosion. Their management problems have not yet been solved. Some of the soils, moreover, are developed beyond their capacity and their continued exploitation cannot be reconciled with the interests of soil and water conservation. The economic consequences of continuing the present land use methods-that is, the cost of combating soil erosion and flooding-greatly outweigh the limited production of which they are capable. These soils are subdivided into two sub-classes.

(a) Soils of the High Altitude Tussock Grassland

The soils of the high altitude rangelands are strongly leached soils of low fertility and belong to the yellow brown earth group. They cover the higher slopes of the central mountains of Otago, above an altitude of approximately 3,000 ft. Originally they supported a dense growth of snow and red tussock, but this is now either totally destroyed or greatly reduced. The soils, in addition to their low fertility, possess a weak structure easily destroyed when the soils are exposed to frost and erosion by wind and water. In their natural state they cannot be grazed. The healthy snow tussocks are not grazed by sheep and their dense foliage and overlapping canopies make it impossible for sheep to move through the tussocks. A dense growth of snow tussocks moreover excludes all other vegetation. The healthy snow tussock in equilibrium with its environment and in an ideal state for the protection of the steep aipine and subalpine soils is useless for the pasturage of sheep.

To make it possible for sheep to move over the mountainsides and to provide green shoots for browsing, the tussocks were burnt. This unfortunately exposed the surface of the soil to erosion, which is particularly active in this environment. Practically all the soils in this sub-class have been eroded, most of them severely. Many mountain sides that appear from a distance to be well covered with vegetation are, in fact, eroded to a greater or less degree. On close inspection the snow tussocks prove to be reduced to a fraction of their natural size. Instead of covering at least 50 sq ft with their canopy of leaves they protect less than 5 sq ft and between the tussocks there is much bare ground on which erosion is steadily taking its toll. If the present rate of deterioration is maintained, it will take only a few more generations to destroy most of the alpine and subalpine soils of this sub-class. But to build up a soil mantle again will take many centuries.

Erosion on the soils of this sub-class has a number of important economic consequences. Because the shallow soils are no longer protected by the voluminous foliage and thick mat of litter, which act as a sponge and keep stream flows constant, evaporation from the bare soil surface is greatly increased. The soils dry out completely, stream flows become irregular, run-off increases, and flood peaks become higher. Bigger floods in the lower reaches mean greater costs to the lowland farmer and to the taxpayer in flood protection works and emergency measures. Higher flood peaks and more frequent floods increase the danger to life on the coastal lowlands. Moreover, instead of a steady stream flow, summer river levels fall and less water is available for power stations and for irrigators.

These soils are obviously developed beyond their capacity and the present methods of management will not maintain sustained yields and will not preserve the physical stability of the soil. They have, in fact, been developed beyond their productive capacity. This situation appears to have arisen because no consideration whatsoever has been given to the demands of soil and water conservation in the utilisation of these soils. But when soil and water conservation requirements are taken into account the question arises "Are these soils of more value to the nation for soil and water conservation than as pastoral rangeland?" If the long view is taken there is no doubt that soil and water conservation should be the overriding consideration. For this reason, therefore, the soils have been regarded as unsuitable for agricultural use.

(b) **Soils of the Western Mountains**

The soils of the western mountains lie for the most part in regions of high rainfall, The soils are strongly leached and of very low to low natural fertility. They include a large area of soils under native forests where the stability of the soils depends entirely on maintaining the forests in a stable and healthy state. The western mountains are considerably steeper than the central mountains and the risk of erosion is correspondingly greater. These soils are of little pastoral value, but the forests and the alpine grasslands above the forests are infested with introduced wild animals, mainly deer and chamois, with some goats and wallabies locally. It is likely that pigs, opossums, and possibly thar will also become established in time and their combined grazing could seriously damage the forests. Already some of the Canterbury forests have suffered catastrophic destruction in this way. It may be desirable that all the soils of this sub-class, possibly including also the soils of the tussock rangelands of the previous sub-class, should be administered by the New Zealand Forest Service, the organisation best equipped in terms of experience, facilities, and authority to cope with the problems. If this were done these soils would be administered as a forest park.

CLASS V-SOILS SUITABLE FOR ECONOMIC FORESTRY

Although a case could be made out for treating economic forests as a crop of equal importance to many agricultural crops, in this analysis only those soils which will give a greater economic return in forest crops than of agricultural products are considered. Many of them are in fact not well suited for agriculture. They include the soils of the cut-over native podocarp forests of South Otago and the beech forests of the Blue Mountains as well as some hilly soils of low fertility in eastern Otago.

CLASS VI

Bare soils, ice, and snow of the high mountains. This class includes that part of Otago virtually devoid of a mantle of soil and wholly unproductive.

DISCUSSION

Q. (Dr P. D. Sears): Can structure lost to soils be brought back by management?

A. Yes, We know for example that structure can be improved under pasture. Although the yellow grey earths of the East Coast downlands have been described as suitable for cereal growing we know that such a change will have a detrimental effect on soil structure and pasture unless consideration is given to the need to maintain structure in management.

Q. (Dr P. D. Sears): How many years under pasture? How many years under cropping on soil with weak or destroyed structure?

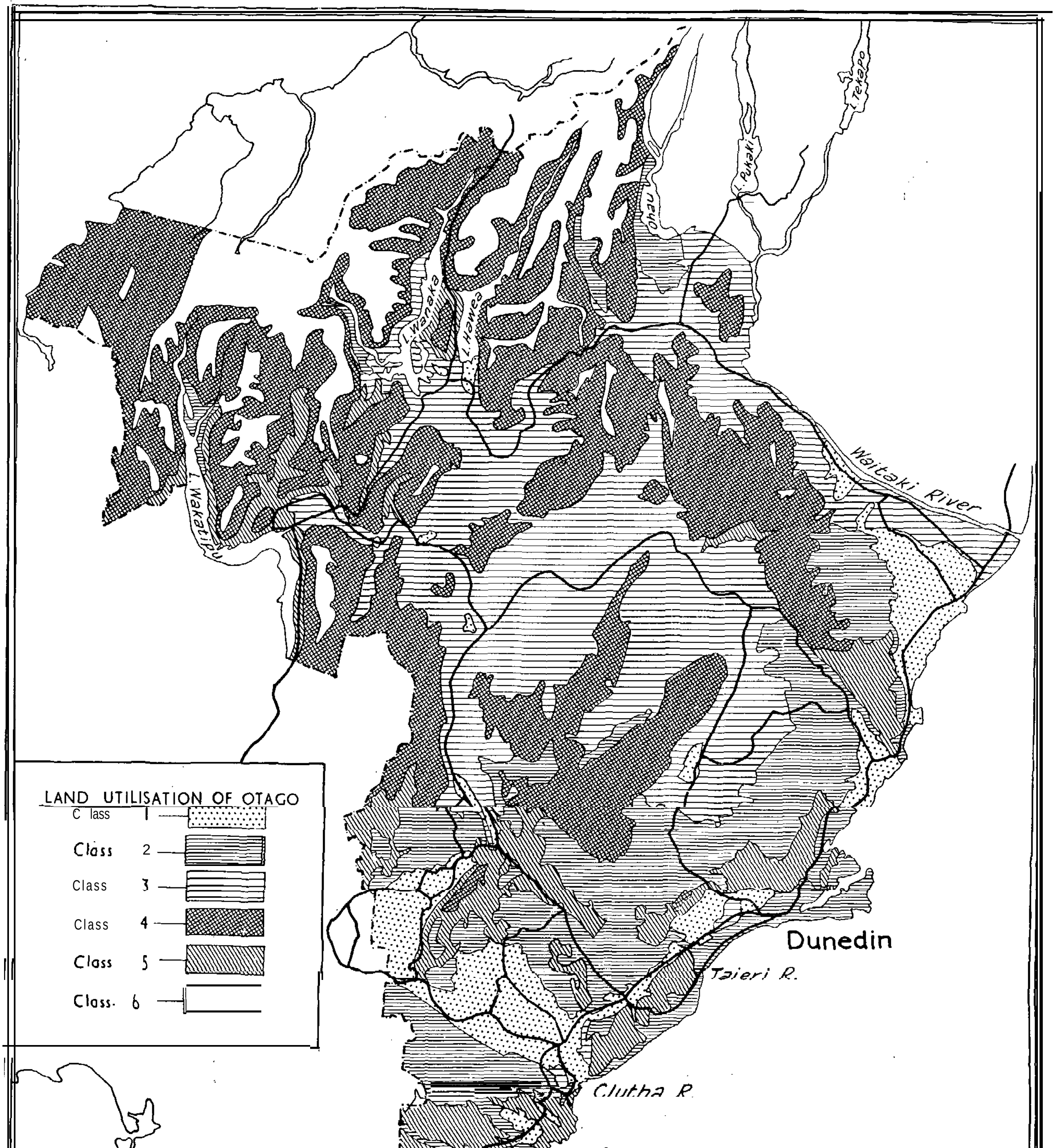
A. I am not prepared to answer that question. We know some of the circumstances under which structure will improve but we can't say how long it may take to achieve a satisfactory structure. It depends on the soil and its condition.

Q. (D. A. Campbell): The limitations of some soils were brought out. Could the importance of water sources and conservation of the regions be discussed?

A. I'm glad Mr Campbell has brought up this matter. Water conservation is a most important consideration on soils of Class IV, the steep mountain soils. Floods on the plains can best be controlled by protecting these soils, Catchments in which these soils predominate supply water for hydro-electricity and irrigation, and water conservation is therefore an over-riding consideration. Water conservation is also important, but to a slightly lesser extent on soils of Class 3.

Q. (Mr Dillon): Could you give acreages above 3,000 ft?

A. Approximately 1,745,000 acres lie above 3,000 feet but this does not include ice and scree.


LAND UTILISATION OF OTAGO
Class 1
Class 2
Class 3
Class 4
Class 5
Class 6
L. Wanaka
L. Hawea
Ohau
L. Pukaki
L. Tekapo
L. Wakatipu
Waitaki River
Dunedin
Taieri R.
Clutha R.
BLUFF
8 0 8 16 24
Scale of Miles