A NOTE ON THE PRODUCTION OF CREOSOTED FENCE POSTS BY THE STATE FOREST SERVICE.

A new and important development in the utilization of the State exotic forests is the establishment of non-pressure creosoting plants.

As shown in the illustration on the opposite page, creosoted posts are already being produced; similar results are being obtained at Conical Hills (Otago) and a third creosoting plant will shortly be in operation at Hanmer Springs.

Briefly, the process is as follows:—

Posts (either European larch, eucalypts, Austrian or Corsican pine) are cut to standard length (6 ft. 6 in. in the North and 5 ft. 9 in. in the South), and the bark is either removed in the forest or square-sawn: the posts are then stacked in a seasoning yard for several months until sufficiently dry for creosoting.

The treating process consists of immersing the seasoned posts in creosote at a temperature of 180°-200° F., for a period varying with the timber species, then discharging the hot creosote and refilling the tanks with cool creosote; by this “hot and cold” process, degrees of penetration and absorption of creosote similar to that obtained by the pressure process are obtained. A minimum average service life of 20 years is anticipated, well treated posts creosoted between 1922 and 1925 still being sound and in use in various districts.

The treating tanks are 37 feet long, 4 feet wide and 4 feet deep and steam heating is supplied through coils at the bottom of the tanks.

A normal charge is approximately 250 posts, and with two tanks operating simultaneously as at Rotorua, it is possible to treat at least 2,000 posts per week.

The treated posts are required to conform to certain specifications, and at least half a gallon of creosote per cubic foot of timber is retained.

The price of creosoted posts varies from £8 to £12 according to their dimensions and the locality of the plant; a standard grade of creosoted post produced at Rotorua measures 6 feet 6 inches × 4 inches to 5½ inches minimum diameter.

Telephone and the smaller transmission poles are being similarly treated to meet orders placed by Electric Power Boards and Government Departments.

T.C.B.
EXTRACTS FROM
Maintenance of Vegetative Cover in New Zealand with Special Reference to Land Erosion.
(Report of Committee of Enquiry).
Bulletin No. 77—Dept. of Scientific and Industrial Research, May, 1939.

(The problem of erosion is of such primary interest to foresters that no apology is needed for the reprinting in the Journal of lengthy extracts from this valuable Report. Of particular significance are the conclusions, published for the first time, regarding the physical limits of altitude and rainfall for forest growth in New Zealand.

INTRODUCTION.

ORDER OF REFERENCE.

To enquire into and report on measures necessary for the preservation of vegetation in New Zealand, with special reference to the incidence, control, and prevention of land erosion.

The committee's interpretation was that it was concerned with the problem of maintaining a cover of vegetation adequate for the control of erosion, and not with the relatively insignificant matter of the preservation of individual species.

* * * * * *

New Zealand under Primitive Conditions.

The Primitive Vegetative Cover.

The vegetation of New Zealand developed during a long period of isolation from other lands, in the absence of man and of all grazing and browsing animals except the moa. Climatic, topographical, and soil factors thus had free play, and a closed, stable vegetative cover resulted. Only on coastal sands and in the upper subalpine areas occurred an open type of vegetation. The critical rainfall determining whether forest or grassland prevailed was approximately 30 inches to 35 inches per annum. Thus practically the whole of North Island and the northern, western, and southern parts of South Island were in forest, while only on the eastern side of South Island were grasslands extensively developed.

Broadly the communities could be grouped as coastal, lowland, and lower montane (up to, say, 2,500 feet), higher montane (up to 3,500 feet), subalpine, and alpine. No detailed studies have been made of the altitudinal range of the different belts of vegetation, but the forest line may be taken as at from 3,000 feet to 3,500 feet and the scrub line at 4,000 feet. A close cover of vegetation seldom reached above 4,500 feet, and 5,000 feet may be taken as the upper limit of a vegetative cover significant as an erosion controller.

The main types of vegetation may be grouped as follows:

1. Forest and Shrubland.

i. Coastal Shrub and Forest:

These communities were fairly extensively established in many areas along the coastal lands of both islands. The shrub contained numerous species of shrubs growing together in dense masses and often bound together by climbing plants, especially lawyer, pohuehue, climbing rata, and kiekie. Important trees of coastal forest were karaka, ngaio, and kokekohe.
(ii) Lowland and Montane Forest, and Shrubland:

Forest was by far the more important type, the different classes being determined by climatic, topographic, edaphic, and historical conditions. The two major classes of forest were—

(a) Mixed Broadleaf-conifer Forest: This included the kauri-taraire forests of the northern part of North Island and the podocarp-broadleaf forest, which was generally distributed in both islands. The prominent trees were kahikatea, especially on the wetter lowland soils, totara, rimu, matai, tawa, kamahi, and species of rata.

(b) Beech Forest: This was generally distributed, especially in montane areas, and in South Island formed an almost continuous belt along the slopes east of the divide. Wet-beech and dry-beech forest were differentiated by the subordinate species and were distributed according to climatic conditions. The dominant species in mixed or pure communities were black beech, hard beech, red beech, silver beech, and mountain beech.

Though occupying important areas, shrubland and fernlands were less extensive under primitive conditions than now. The major dominant species were manuka and bracken. The primitive extent of tawhinu shrublands is not known. It is certain that they were much less in evidence than they are now.

(iii) Subalpine Forest and Shrubland:

No hard-and-fast line of demarcation existed between the lower and higher montane forests, but at the higher elevations beech forest was by far the most important and extensive, with silver beech and especially mountain beech (often as a pure dominant) playing the leading role. Of the podocarp-broadleaf species previously mentioned, totara, kamahi, and southern rata extended to higher altitudes than the others, and were joined by species of Dacrydium and Phyllocladus.

Shrubland, especially in the dense communities known as “subalpine scrub,” existed as a more or less continuous belt above the forest line and was composed of numerous species.

(2) Tussock-Grassland

(i) Lowland and Lower Montane Tussock-grassland:

After forest by far the most important and extensive community was tussock-grassland, occupying some 16,000,000 acres.

This was divided into two chief classes:—

(a) Low-tussock grassland with hard-tussock and to a lesser extent silver-tussock as dominants, and blue-tussock and blue-grass as especially important members. Low-tussock grassland was chiefly developed on the plains and lower montane areas in South Island east of the divide below the belt of beech forest.

(b) Tall-tussock grassland, with one or other of the forms of snow-grass, occurred mainly at somewhat higher altitudes. There were considerable areas on the volcanic plateau in North Island, and in South Island above the level of the low-tussock belt. A special type was the red-tussock grassland, best developed over the Southland Plain.

(ii) Subalpine Tussock-grassland:

Above the shrub belt, or sometimes replacing it, in many mountains, especially in South Island, was a closed community dominated by the snow-grass, with a floor covering of numerous herbaceous species, small grasses, sedges, and herbs. This community shaded into herbfield by the lessening amounts of tussock-grass. These communities reached to about 4,500 feet.
(3) **Open Subalpine and Alpine Vegetation.**

Above the tall-tussock areas, or replacing them in the more exposed situations the vegetation was more open, with much bare ground between the plants. Many of the non-dominant species of the tussock-grassland and herbfield persisted, and were joined by other species confined to this open country or to the rocky outcrops. Above 5,000 feet the vegetation became sparse, and at the highest elevations plant life was confined to rock-inhabiting lichens.

(4) **Coastal Dune Vegetation.**

This occupied approximately 290,000 acres in North Island and 24,000 in South Island. Three chief classes may be distinguished:—

(i) Sand-grass dunes dominated by silvery sand-grass and pingao.
(ii) Shrub dunes, dominated by species of taunhia, mingimangi, and *Pimelea*.
(iii) Heath dunes on the inner, more stabilised, areas, dominated by manuka.

**Erosion under Primitive Vegetative Cover.**

In the heavier-rainfall areas where forest was the natural cover the run-off was reduced and so impeded that it had little power to erode, hence the hillsides tended to be smooth and on the easier slopes to become covered with a deep mantle of chemically weathered rock waste. Streams, by down-cutting, over-steepened the valley sides, and adjustments took place by soil creep and by mass movement such as slips.

Under these conditions erosion proceeded slowly; ground bared by slips had time to be invaded by vegetation before other slips appeared—bare rock had time to weather. Only in the most precipitous situations was erosion able to outpace the soil-forming processes and the growth of a vegetative cover. A modification of these conditions occurred in areas subject to earthquake shocks, when, during periods of seismic activity, mass movements took place rapidly.

In the lighter-rainfall areas under the primitive tussock cover soil creep was more active and slopes became smooth and graded at a less steep angle. Rock decay was slower and outcrops of bare rock persisted longer than in more humid regions. As there was not the same tendency for a thick mantle of rock waste to accumulate on steep slopes, slipping was far less common than under forest.

In areas covered or partially covered by subalpine and alpine vegetation normal erosion was more active. The great daily range of temperature, the exposed position, and the steepness of the slopes made for rapid physical disintegration of the rocks and active streaming of rock waste down the mountain sides. The native plants of this region, adapted as they were to live strenuous lives in the exposed positions, some even on moving rock waste, assisted in regulating the supply of rock waste to streams and glaciers. Much of the waste from this area was in the form of fine rock dust which, carried down by the rivers and blown over the surrounding country, was caught by the tussock and other vegetation to form the loess soils so well developed in Canterbury.

**Normal Flooding of Rivers.**

Periodic flooding is a condition normal to all streams and rivers, especially in those areas subject to violent downpours of rain or quick melting of snow on the mountain tops. The high natural levees bordering many of our streams and rivers show to what heights floods have attained under the primitive cover. The floods, however, were probably less frequent than at present, and the flooded rivers were not charged with such abnormal amounts of debris and alluvium.

**New Zealand under Present Conditions.**

**Present Vegetative Cover.**

In very few localities indeed has the primitive vegetation remained undisturbed; most has been modified to a greater or less extent, and much completely replaced. In the more settled parts a new vegetation has arisen, dominated by alien plants purposely or unintentionally sown or planted. Some five hundred exotic species...
have become completely naturalized, several, e.g., blackberry, gorse, lupin—now forming in many places distinct communities. Many more exotics are in process of becoming established. In spite of this, indigenous species have shown the power to return when conditions at all favour them. Some have proved aggressive under the new conditions—e.g., Danthonia, piri-piri, and manuka.

The effect of man’s occupation on the main types of primitive vegetation is briefly as follows:

(1) **Forest.**

The forest area has been greatly reduced. In both Isands extensive areas of all classes of forest have been felled and burnt, followed by more or less successful attempts at grazing or cultivation. The greater part of this felled area has been sown down in exotic grasses, and on most of the flatter and easier rolling country this new grassland shows every evidence of stability. On the lighter and poorer land, however, a thoroughly satisfactory turf has not always been achieved, with resultant bare spaces and weed invasion.

Still more difficulty has been met with in the hill country, especially in the higher-rainfall areas over steep slopes, and on country carrying a poorer class of forest. On much of this country the grassland, as sown, has not persisted, but has gone to danthonia or brown-top. The small danthonias—*D. pilosa, D. semi-annularis*—and their allies were probably much less in evidence in primitive grassland, but owing for their powers of vegetative spread, high seeding (the seed well adapted for animal carriage), and tolerance to burning they now dominate many hill pastures.

In addition, especially in the heavier-rainfall areas, much of the sown grass lands has reverted to bracken fern, piri-piri, shrubs, and other types of second-growth. In certain parts of South Island areas originally forested have become tussock-grassland of doubtful stability.

(2) **Tussock-grassland.**

The tussock-grassland of the plains has very largely been converted into arable land with cultivated crops, or to pastures of exotic grasses. A small amount of afforestation has also been carried out. Nearly all the remaining tussock-grassland below the lower limits of the forest has been much degraded by continuous stocking with sheep and rabbits, and by burning repeated for many years. Efforts at improvement by surface-sowing and other means have gained some success in places, but these are comparatively few. There has been great deterioration of the vegetative cover. The tussocks have been much reduced in number and vigour and many of the associated species, especially the more palatable ones, have also been greatly reduced in numbers. On the other hand, certain unpalatable species, such as Celmisias and Bulbinella, have become aggressive. Much bare ground has been exposed, and in certain exotic species have become prominent—e.g., Yorkshire fog, sweet vernal, brown-top, sorrel. In some places, as in parts of the drier areas of Central Otago, the tussocks with their accompanying indigenous grasses have been almost completely replaced by scabweed and bare ground. Tussock above the scrub belt has also been degraded by burning and the grazing of sheep, deer, and other animals. Deterioration in this vegetation has, however, seldom reached the extreme stage shown in the lowland tussock areas.

(3) **Open Subalpine and Alpine Vegetation.**

Grazing by deer, chamois, and other animals, and the summer depasturing of sheep, have also affected this vegetation, but little exact information is available for the comparison of primitive and present conditions.

(4) **Coastal Dune Vegetation.**

Much of the more stabilized sand country, including especially the inner heath dunes, has been successfully sown to permanent grassland. While the original
species have persisted, a number of alien exotic annual grasses and weeds have come in. Damage by stock and burning have destroyed the protective plant cover in many places, with resultant sand-blows and renewal of sand movement. On the other hand, protective planting of marram-grass has largely and increasingly been carried out, while lupins have proved successful on areas of less actively moving sand.

The changes in plant cover from primitive to present times is roughly of the following order:

<table>
<thead>
<tr>
<th></th>
<th>Primitive</th>
<th>Present</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forest-and Shrubland, etc.</td>
<td>41,000,000 ac.</td>
<td>23,000,000 ac.</td>
</tr>
<tr>
<td>Exotic plantations</td>
<td>—</td>
<td>800,000</td>
</tr>
<tr>
<td>Tussock grassland</td>
<td>17,000,000</td>
<td>14,000,000</td>
</tr>
<tr>
<td>Open Subalpine vegetation</td>
<td>900,000</td>
<td>900,000</td>
</tr>
<tr>
<td>Alpine vegetation and boro rock, etc.</td>
<td>6,000,000</td>
<td>6,000,000</td>
</tr>
<tr>
<td>Coastal dune vegetation</td>
<td>300,000</td>
<td>150,000</td>
</tr>
<tr>
<td>Sown grassland</td>
<td>—</td>
<td>18,000,000</td>
</tr>
<tr>
<td>Cultivated land, orchards, etc.</td>
<td>—</td>
<td>1,500,000</td>
</tr>
<tr>
<td>Lakes and rivers</td>
<td>800,000</td>
<td>800,000</td>
</tr>
<tr>
<td>Boroughs, roads, and railways</td>
<td>—</td>
<td>850,000</td>
</tr>
<tr>
<td></td>
<td>66,000,000 ac.</td>
<td>66,000,000 ac.</td>
</tr>
</tbody>
</table>

The greatest changes in vegetative cover have been:

1. The replacing of a large part of our forest with grass, some of which has reverted to fern and scrubland.

2. The degrading of the greater part of the native tussock cover to a cover of very inferior type and the converting of the remainder to arable and exotic grassland.

3. The planting of 800,000 acres to exotic forest.

**Erosion under the Present Vegetative Cover.**

**Areas previously forested.**

In the heavier-rainfall areas where the former forest cover has been cleared and pasture laid down there has been but little noticeable acceleration of erosion on the flat and easy land. On the steeper country, however, there has been a speeding-up of the processes of slipping and soil creep, and where the pasture cover is poor and open there is considerable sheet erosion of the topsoil. Gullying is not everywhere in evidence, but in some places the previously smooth graded slopes are being destroyed in this way. Lateral cutting of streams and river banks, which was formerly controlled, has with the removal of the fringing forest become more active.

When forests are felled and burnt and the hillsides sown in grass many important changes take place. The litter layer of the forest disappears and a grass humus layer forms below the surface of the mineral soil. The strong roots of the forest are replaced by the finer and generally shallower roots of the grasses. The surface soil becomes more compact. By far the greatest change, however, is the change in the soil moisture status. Under the grass cover less rainfall is absorbed (especially where the cover is incomplete), causing increased run-off and wider fluctuations in the moisture content of the soil. In dry periods the soil becomes more parched and cracking of the ground becomes more pronounced. With more water passing over the surface of the soil sheet erosion becomes important wherever the soil is unprotected by vegetation, and the alternate wetting and drying of the soil, with its seasonal cracking and swelling, weakens the soil mantle and tends to speed up the processes of soil creep and slipping.
A hillside in balance under forest is not necessarily in balance when clothed in grass. The soil tends to move into the valleys more quickly, forming easier slopes that can be grass controlled, and causing the upper slopes of the hills to become steeper. On these steep upper slopes more bare rock is exposed and the run-off further increased. The scars now disfiguring many steeper hillside are thus seen to be due to the acceleration of the processes normally taking place as part of the erosion cycle under forest.

Where the soil is underlain by rocks that weather slowly and are low in plant foods, the steeper and more unbalanced slopes tend to become more and more infertile. Each time a slip occurs some bare rock is exposed and much of the surrounding soil is left in a shallow and infertile condition. Where, however, the underlying rock weathers rapidly to produce a fertile soil this does not apply. The slips grass over more rapidly and there may be little or no permanent loss of fertility on the hillside.

The continued use of fire to control roughage and second growth, by baring the ground and weakening the vegetative cover, causes widespread sheet erosion of hill soils.

The general experience in New Zealand is that good turf protects slopes very well, though not so well as the forest it replaced. There is, however, a critical slope above which it is dangerous to clear forest. This varies widely with the nature of the underlying rocks and with the climate.

* * * * * * *

**Restoration and Maintenance of a Stable Vegetative Cover.**

The foregoing brief summary of vegetative changes and their relation to accelerated erosion shows how necessary it is that an effort be made to restore and maintain a stable plant cover. By this means not only will erosion be largely controlled, but also a greater measure of permanence will be given to the source of our primary production. The problem is, in essence, one of correct land use—a just compromise between the requirements for erosion control and the fullest economic use of the land. The factors governing the type of plant covering that can be established and the useful function that it can perform, must be clearly recognized if funds and effort are not to be wasted. In the discussion that follows, our incomplete knowledge of many subjects will be frequently stressed. In certain areas there is call for immediate action, but together with this should go research, so that future action may be based on more complete knowledge.

**Forest and Shrubland.**

Forests are needed not only to supply the timber requirements and to conserve the water-supplies of the Dominion, but also because they are the only type of vegetation that can effectively control erosion on certain classes of land. Forests are needed also for flood control, since both run-off and the supply of rock waste to rivers is relatively low under a forest covering. The distribution of forests is limited by climate. In primitive times forests did not grow where the average yearly rainfall was below 30 inches to 35 inches, and consequently afforestation will be governed by rainfall conditions. Forest rarely grows above 3,500 feet, and 2,500 feet may be taken as the upper limit of forests suited to timber production. Between 3,500 feet and 4,000 feet subalpine scrub acts as a protective cover in most mountain district.

**Forest Area and Erosion Control.**

Primitive forest and shrub land covered approximately 41,000,000 acres, above 62 per cent., of the land area; and, considering the topography, probably from a third to a half of it could have been converted to good grassland without significant acceleration of the erosional rate. This indicates that a minimum of 20,000,000 forest-clad acres is required for erosion control provided it is correctly distributed.
Forest Area and Timber Economics.

It is usually considered that a modern civilized country, not concerned particularly with timber exports, and of moderate relief requires for its timber demands some 25 per cent. of its area in forest land (see Appendix A). This percentage is, moreover, accepted as the "average for Europe" in the 1938 report of the Conference Internationale d'Utilisation du Bois. For New Zealand this would mean 16,500,000 acres of productive forest. From the immediate economic viewpoint this area may be reduced because the population density is below normal, but, on the other hand, there is an existing softwood export market in Australia which is capable of considerable expansion. The low population density is further offset by the fact that our per capita wood consumption is extremely high even on recorded statistics alone, and it is admitted that full statistics have never been obtainable for such items as fencing-posts, mining timber, and firewood. Approximately 16,500,000 acres of timber forest may therefore be accepted as needful, plus areas of purely protective forests necessitated by the large amount of broken and erodible terrain.

Existing Area of Forest and Shrubland.

Accurate figures showing the existing areas of forest and shrubland are difficult to obtain, chiefly owing to different interpretations of the term "forest" and to the numerous types of ownership involved. Under the heading "Present Vegetative Cover" it was estimated that 23,000,000 acres are covered with forest and shrubland, but particulars could be obtained for 20,000,000 acres only (see Appendix B). This area would appear to satisfy the minimum requirements of forest and shrubland for erosion control, but it does not function effectively because of improperly distributed in space and in time; in space, because many areas especially liable to erosion are inadequately protected; in time, because of the great gap in age classes between the young recently established forests of one year to twenty years age class, and the primitive forests of maximum and unknown age class. The younger age classes have not yet had time to build up a genuine forest soil, water-retentive to the maximum potential capacity for the various localities.

Unless remedial measures are applied, the effectiveness of the forest and shrubland cover is likely to be further reduced because of—

1. Inadequate statutory protection of the status quo as forest. (Only 12,000,000 acres out of the existing 20,000,000 must by statute be retained as forest land).

2. Improper use and occasional destruction by fires, etc.

3. The attritional effect of browsing animals.

Measures necessary.

Steps should therefore be taken both to redistribute the forest and shrubland area and to protect it adequately against degradation. The present heavily burdened financial structure of the State Forest Service should not be expected to bear the whole cost. Forestry not required by the timber industry, but necessary to maintain agricultural production and the general national assets and welfare of the country, should be regarded as a social service.

* * * * * *

Subalpine Vegetation.

In the subalpine belt the only practicable way to improve the plant cover is to protect it as far as possible from grazing and browsing animals and from fires. Summer grazing of sheep should be strictly controlled, and wild animals of the subalpine belt (such as thar and chamois) and the migratory red deer should be severely reduced in numbers. The reduction of the deer population is already being undertaken by the Department of Internal Affairs.
## Relation of Erosion Control to Vegetative Cover.

<table>
<thead>
<tr>
<th>Rainfall over 30 inches to 35 inches</th>
<th>Rainfall under 30 inches to 35 inches</th>
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</thead>
<tbody>
<tr>
<td><strong>Chief Types of Vegetation and Land Utilization</strong></td>
<td><strong>Erosion Control</strong></td>
</tr>
<tr>
<td>5,000 ft.</td>
<td>Alpine vegetation, bare rock, etc.</td>
</tr>
<tr>
<td>4,000 ft.</td>
<td>Open subalpine vegetation</td>
</tr>
<tr>
<td>Subalpine tussock and herb-field. Summer grazing</td>
<td></td>
</tr>
<tr>
<td>Subalpine scrub</td>
<td></td>
</tr>
<tr>
<td>3,000 ft.</td>
<td>Protection forest and pasturage</td>
</tr>
<tr>
<td>Pasturage and commercial forest with protective forests in special areas.</td>
<td></td>
</tr>
<tr>
<td>2,000 ft.</td>
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<tr>
<td>1,000 ft.</td>
<td></td>
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<tr>
<td>Sea level</td>
<td>Largely arable land</td>
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</tbody>
</table>
Sand Dune Vegetation.

The stabilizing of the sand-dune country by the planting of sand-binding plants, is already being actively effected by the Public Works Department and others (See article on "Sand Dune Reclamation" elsewhere in this Journal.—Ed.), and this work should be extended. On sand country which has been fixed and grassed there is need for constant vigilance to assure that the vegetative cover is never allowed to deteriorate, for even the smallest opening in the cover may lead to extensive wind erosion.

Flood Control.

Floods cannot be completely prevented by restoring the stability of the vegetative cover, but they can be materially controlled so that they become more nearly of the order existing under primitive conditions. The retaining of the original native cover (in many places forest) at the headwaters of the rivers, where rainfall is highest and slopes are more steep, will do much in controlling both the run-off of surface water and the supply of rock waste feed to the rivers.

It must be remembered, however, that the greater part of the drainage basins of many rivers must remain as farmed grassland, and the condition of this grassland is likely to affect river flooding to no little extent. There is often a greater difference between the run-off from good and poor pasture than there is between the run-off from forest and from good pasture. This is also true of the amount of silt fed to the rivers. On properly grass-controlled slopes the erosion loss is very slight. It is obvious then that both reforestation and grassland management play important parts in flood control.

EROSION CONTROL; SUMMARY OF CHIEF POINTS INVOLVED.

The chief points involved in the control of erosion are summarized in the following items and the accompanying table:

General.

(1) Accelerated erosion is largely due to the instability of the vegetative cover of the land under man's regime.

(2) The restoration and maintenance of a stable vegetation cover is mainly a problem of correct land use, especially as concerns forest and grassland management.

Forest.

(3) The minimum forest and shrubland area required for erosion control in New Zealand is a properly distributed 26,000,000 acres. A large part of this can be timber producing.

(4) The natural distribution of forest is limited by climate. Native forests do not grow, nor should forestry be attempted, in areas with a rainfall less than 30 inches per annum. Attempts at commercial forestry on such areas have always failed in the past and occasioned great losses, as well as inducing widely spread tree diseases.

(5) New Zealand already has the required minimum acreage of forest and shrubland for erosion control, but the distribution is faulty, and as a whole, it is inadequately protected.

(6) If soil erosion is to be controlled a proper distribution of protective forest must be secured and the forest area (whether State or privately owned) maintained as forest by statute. Proper and adequate finance is needed to effect this.

Tussock-grassland.

(7) The natural tussock-grasslands have deteriorated over large areas and no longer function adequately in controlling erosion.

(8) The chief agents of deterioration are burning, overgrazing, and rabbit infestation, and, at higher levels, red deer.

(9) Remedial measures consist in controlling the agents of deterioration and re-establishing an effective grass cover and a balanced grazing in equilibrium with it.
Sown Grassland.

(10) On flat and easy country, which can be cultivated and sown down, erosion control presents few difficulties, but on much surface sown hill land conditions have become far from stable. Over large areas the carrying capacity has fallen; other areas have been invaded by second growth and abandoned.

(11) The immediate causes of deterioration of these hill grasslands have been the closely related factors of falling fertility, invasion of second growth, and soil erosion; the basic reasons are the difficulty of maintaining a non-arable pasture, coupled with the low economic return therefrom.

(12) The present situation has arisen because (a) farming has been attempted on land unsuited to permanent pasture; (b) the establishment and maintenance of many pastures has, in the light of present knowledge, been faulty. The maintenance of hillside pastures has proved more costly than was originally anticipated.

(13) If the situation is to be remedied, (a) farming should be restricted to areas that can be permanently grass controlled; (b) the management of land that can be converted to permanent grassland should be improved; this calls for the consideration of such questions as the greater use of cattle, closer subdivision, spelling of pastures, top-dressing, and resowing.

Grassland Economics.

(14) Conditions of land tenure and the economics of the aspects of farm management affecting erosion control are subjects of prime importance and should be specially investigated. Knowledge of these matters is imperfect.

(15) The problem of erosion control is largely connected with the development of marginal lands, and it is doubtful whether there can be developed efficiently by private enterprise alone.

Cultivated Land.

(16) There is some evidence of erosion on sloping cultivated land, and appropriate known methods of control should be further practised.

Subalpine Vegetation.

(17) In the subalpine belt the only practicable way of improving the plant cover is to protect it as far as possible from grazing and browsing animals and from fires.

Sand Dune Vegetation.

(18) Methods of controlling sand drifts are well known and are being successfully practised in many areas. Insufficient attention is being paid to apparently minor breaks in established pasture.

Flood Control.

(19) Re-afforestation and grassland management both play important parts in flood control.

Research.

(20) From the survey made further research work is desirable . . . .

General Recommendation.

Reviewing the whole body of evidence before it this Committee is convinced that soil erosion in many areas has reached a serious stage, and if uncontrolled will accelerate rapidly.

The Committee, however, deprecates an alarmist attitude. As was inevitable in the development of a young country, mistakes have been made, but in few places is the damage wholly beyond repair.

Permanent production must ultimately be based on a more stable vegetative cover, combining in due proportion forest, shrubland, and grassland. Only so can the forces of erosion be adequately controlled and water-supplies necessary for the closer development of the country fully protected.
For these reasons this Committee recommends that—
Statutory and administrative measures should be taken at the earliest opportunity to inaugurate a programme to handle the serious soil-erosion, soil-conservation, and land-utilization problems that now face us. In such a programme the most effective factor will be the preservation and establishment of a stable vegetative cover in which forest land, shrubland, and grassland have most important parts. Further, such a programme should include the active collaboration and co-operation of foresters, agrostologists, botanists, agriculturists, engineers, and soil technologists.

APPENDIX (A).

Percentages of Forest Areas, Etc., in Various Countries.

<table>
<thead>
<tr>
<th>Country</th>
<th>Percentage land area under Forest</th>
<th>Acres of Forest per head of Population</th>
<th>Authority and Date (chiefly for Column 2 only)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Britain*</td>
<td>5.0</td>
<td>0.07</td>
<td>Heske, 1938</td>
</tr>
<tr>
<td>Australia*</td>
<td>5.8</td>
<td>1.76</td>
<td>Zon and Sparhawk, 1923; &quot;Forest Resources of the World.&quot;</td>
</tr>
<tr>
<td>Denmark*</td>
<td>7.5</td>
<td>0.23</td>
<td>Heske, 1938</td>
</tr>
<tr>
<td>Holland*</td>
<td>7.76</td>
<td>0.07</td>
<td>C.I.U.B., 1938 Report</td>
</tr>
<tr>
<td>Turkey*</td>
<td>10.0</td>
<td>—</td>
<td>C.I.U.B., 1938 Report</td>
</tr>
<tr>
<td>China*</td>
<td>12.2</td>
<td>0.04</td>
<td>Zon and Sparhawk, 1923</td>
</tr>
<tr>
<td>British Africa*</td>
<td>15.7</td>
<td>0.67</td>
<td>&quot;Ibid.&quot;</td>
</tr>
<tr>
<td>Italy*</td>
<td>15.9</td>
<td>0.31</td>
<td>&quot;Ibid.&quot;</td>
</tr>
<tr>
<td>France*</td>
<td>18.4</td>
<td>0.63</td>
<td>&quot;Ibid.&quot;</td>
</tr>
<tr>
<td>Switzerland*</td>
<td>23.0</td>
<td>0.62</td>
<td>&quot;Ibid.&quot;</td>
</tr>
<tr>
<td>Norway</td>
<td>23.5</td>
<td>6.00</td>
<td>(As Sweden and Finland, 1938).</td>
</tr>
<tr>
<td>Germany</td>
<td>(a) 23.8</td>
<td>0.49</td>
<td>Zon and Sparhawk, 1923</td>
</tr>
<tr>
<td></td>
<td>(b) 27.0</td>
<td>—</td>
<td>C.I.U.B., 1938 Report</td>
</tr>
<tr>
<td>Canada</td>
<td>25.9</td>
<td>8.23</td>
<td>&quot;Ibid.&quot;</td>
</tr>
<tr>
<td>Union of Soviet Socialist Republics</td>
<td>28.0</td>
<td>10.1</td>
<td>Boutzykus, 1931, in B.C. Lumberman.</td>
</tr>
<tr>
<td>Japan</td>
<td>(a) 53.3</td>
<td>1.2</td>
<td>Zon and Sparhawk, 1923</td>
</tr>
<tr>
<td>Japan (including Manchukuo)</td>
<td>(b) 72.0</td>
<td>1.1</td>
<td>Elchibegoff, June 1938, in &quot;Paper Trades Journal.&quot;</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>&quot;Northern Countries in World Economy.&quot; (Semi-official publication of northern countries delegations, 1937).</td>
</tr>
<tr>
<td>Sweden</td>
<td>56.5</td>
<td>9.16</td>
<td></td>
</tr>
<tr>
<td>Finland</td>
<td>67.2</td>
<td>15.4</td>
<td></td>
</tr>
</tbody>
</table>

*Timber imports exceed exports.

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(APPENDIX B.)

The Existing Area of Forest in New Zealand.

The following are, in the main, Year-book figures, with marginal notes to assist in their interpretation (or to warn against implicit acceptance of them).

<table>
<thead>
<tr>
<th>Ownership or Control</th>
<th>Acreage</th>
<th>Source and Date</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. National parks, • scenic reserves, domains.</td>
<td>3,802,741</td>
<td>1938. Year-book, 1938, page 463.</td>
<td>Includes much open country, bare mountain-top, etc.</td>
</tr>
<tr>
<td>3. Afforestation companies</td>
<td>414,569</td>
<td>Year-book, 1938, page 347.</td>
<td>297,000 acres only in forest and of young age classes only.</td>
</tr>
<tr>
<td>5. Native-owned virgin forest</td>
<td>250,000</td>
<td>Departmental estimate only</td>
<td>There is no survey or tally of such land. Year book shows there are in all 4,000,000 acres of Native Land, and the figure shown is merely an estimate of the proportion of it in saleable forest. A good deal of that is already under long term lease to saw-millers.</td>
</tr>
<tr>
<td>6. Plantations other than Crown or private companies</td>
<td>112,000*</td>
<td>Year-book, 1938, page 347.</td>
<td>Open to grave doubt. The Year-book gives 815,000 acres of &quot;Plantations on occupied land.&quot; This should not include any Crown area, but there is a suspicion that collectors have included such areas (see Year-Book, 1938, p. 398.)</td>
</tr>
<tr>
<td>7. Local body and other forests of different types not elsewhere included</td>
<td>×</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Total ...</strong></td>
<td><strong>20,202,000</strong></td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

* y deducting State forest exotic acres and afforestation companies' Year-book figure (see remarks column). × No figures available.