SOUTH AUSTRALIA

# REPORT

OF THE

# SOIL CONSERVATION COMMITTEE

TOGETHER WITH

MAPS AND APPENDICES

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# REPORT OF THE SOIL CONSERVATION COMMITTEE.

To the Hon. Minister of Agriculture.

In pursuance of the instructions issued to us on the 7th April, 1937, we have the honour to present the following report on the question of soil erosion and its correction in South Australia.

## INTRODUCTION.

At a Conference of Commonwealth and State Ministers held in Adelaide in August, 1936, Senator A. J. McLachlan presented a report of the Agricultural Sub-Committee (Development) on the establishment of a national soil erosion bureau :—

> Your Committee recommends that each State establish a committee to study the problems of soil erosion and conservation, and to suggest a means by which correctives might be applied ; the Council for Scientific and Industrial Research to co-operate with such committees.

This report was adopted.

Following on this resolution the South Australian Government appointed the following Committee to report on the question of soil erosion :—

Mr. W. J. Spafford, Director of Agriculture (Chairman),
Dr. A. E. V. Richardson, Director of the Waite Agricultural Research Institute,
Mr. J. N. McGilp, of the Pastoral Board,
Mr. G. J. Rodger, Conservator of Forests,
Mr. C. G. F. Johnson, Engineer for Water Supply.

## METHOD OF INVESTIGATION.

Realizing that it was imperative to see as much as possible of the area of the State which had been seriously affected by soil erosion to enable members to give consideration to suggested recommendations for correction, the Committee visited the north-eastern part of the State, going as far as Broken Hill, in June, 1937 ; the Upper north areas of the State in July, 1937, and the Murray Mallee districts in February, 1938.

## TOUR OF NORTH-EAST OF SOUTH AUSTRALIA.

Investigations into the extent and cause of soil erosion in the Pastoral country to the north-east of the State were conducted in June, 1937, when inquiries were commenced at Burra, and continued throughout the area embracing Dawson, " Melton ", Waukaringa, " Teetulpa ", Yunta, Olary, Mingary, Cockburn and Broken Hill.

At Broken Hill particular attention was given to the soil conservation work being undertaken by the mining companies for the protection of the town, and the transplanting activities of the Zinc Corporation for the protection of the company's works.

Returning from this trip, special attention was given to the problem as it affects " Mutooroo ", " Davenborough Downs ", " Eringa ", " Oulnina ", " Koralta ", " Koomooloo " and " Sturt Vale ".

## TOUR OF THE UPPER-NORTH PASTORAL COUNTRY.

In July, 1937, another tour of investigation was taken into the upper-north pastoral areas, commencing from Peterborough, and proceeding to " Curnamona ", " Wirrealpa ", " Wertaloona ", " Wooltana ", " Moolawatana ", " Mount Hopeless ", " Blanchewater ", " Murnpeowie ", Marree, " Lake Harry ", Farina, Lyndhurst, Copley, Beltana, Blinman and Hawker.

## TOUR OF MURRAY MALLEE FARMING DISTRICTS.

No further tours by the full Committee of Investigation could be arranged until February, 1938, when the sandy areas of the farming district known as the Murray Mallee were visited. During this tour most of the worst drifts in the locality were inspected.

All of the principal cases of soil correction work being undertaken by public bodies or private individuals were investigated, and inquiries were made into the agricultural methods practised by those farmers who have been able to keep down the drift menace although the soils of their farms are of a drifty nature.

## OTHER INVESTIGATIONS IN THE FIELD.

Although it has been impossible for the Committee to make other field investigations as a body, all members, either singly or in company, have made frequent trips into country districts where soil erosion in some form or other is taking place.

District officers of the Engineering, Lands, Agriculture, and Forestry Departments have contributed very extensively to the information gathered in connection with the present-day position of soil erosion in South Australia, and particularly in connection with the collection of the material which permitted the presentation of the affected areas on the accompanying maps.

## CAUSES OF SOIL EROSION.

The carrying capacity of considerable areas of pastoral country in the semi-arid portions of Australia has been reduced substantially in recent years through the destruction of the natural vegetative cover, and the increasing erosion and drift of the soil. All States whose pastoral lands impinge on the arid interior have suffered in this respect, but in South Australia the position is most serious in the north-eastern and northern areas.

Soil erosion and drift on a considerable scale has also taken place in the mallee wheat areas due mainly to the indiscriminate clearing of the vegetative cover during the progress of settlement, and the cultivation of light sandy areas on which the vegetative cover afforded a natural protection. Even in the highest rainfall areas of the State where the forest cover has been removed from hilly country, or where undulating lands have been used for agriculture or horticulture, soil loss in the form of " sheet " and " gully " erosion is a common feature of the landscape.

In all these instances the erosion is fundamentally due to the same cause—the destruction of the natural vegetative cover and the consequent exposure of the bare soil to the erosive action of wind in the pastoral country and mallee areas, and of water in the higher rainfall country.

Perennial vegetation plays a twofold role in protecting the soil from wind erosion—the ramification of the roots assists in binding the soil while the overhead portions of the plants break the force of the wind and reduce its velocity over the surface.

The factor responsible for the destruction of the perennial vegetative cover in the pastoral country is the grazing animal. Over-grazing by stock is therefore the major factor responsible for the destruction of the vegetation and the cause of drift. The effects of over-grazing are accentuated by dry seasons and by the depredations of rabbits, when destruction of the perennial vegetation, especially in the neighbourhood of watering places, takes place on an extensive scale, and perennial bush and shrub within a wide radius from the watering places is killed.

In the semi-arid pastoral country the objective of rational management should be to maintain the natural cover of edible salt bushes, blue bushes, perennial grasses, shrubs and trees, and to utilize for grazing the equivalent of the annual increment produced during the year. This objective, however, is extremely difficult to attain in a region in which the rainfall is so erratic and uncertain as that of the semi-arid pastoral country, and in which dry seasons are so prevalent. By such a method of management the vegetative cover might have been indefinitely preserved for pastoral use. Unfortunately, however, the natural cover over large stretches of pastoral country has deteriorated to such an extent through overgrazing, accentuated by dry seasons and the ravages of rabbits, that the soil has been more or less denuded of perennial vegetation and has become the sport of winds.

In the mallee areas the erosion has been brought about by the same fundamental cause—the destruction of the vegetation—but in this case the destruction was deliberately brought about to make way for the plough and for wheat. On the lighter types of soil which are so widespread in the Murray Mallee regions, the drift has become serious.

The comparatively high prices for wheat which were characteristic of the period immediately following the Great War tempted growers in the mallee areas to raise as much wheat as possible, and frequent cropping, stubble burning and intensive working of the land during this period tended to increase the drift. The drift is most serious on the high sandridges, but is more or less evident on light-textured sandy soils throughout the mallee. The outstanding effects are the removal of the fertile surface soil, which makes the land less productive, the accumulation of sand on fence lines, roadways, channels, railways—thus increasing the difficulties of transport and water supply, and the actual physical damage to growing crops by the destructive action of moving sand.

Water erosion has developed to a serious extent in South Australia, particularly on the slopes of the foothills, and on the deep soil plains near the hills where the run-off water has a high velocity.

Where the original forest cover has been removed from undulating land to make way for cultivation, erosion by water may cause heavy losses of soil as sheet or gully erosion and the erosive power of the water depends on many factors, *e.g.*, the annual rainfall and the intensity of the rainfall, the physical character of the soil, the slope of the surface and, the amount of run-off reaching it from higher ground.

For any given climate, soil, aspect and slope, there is a certain minimum of vegetative cover needed to prevent erosion, and under natural conditions there is a state of balance between the various factors, rainfall, run-off, wind, soil, aspect, slope, but where this natural vegetative cover is removed by the clearing of the forest or the ploughing up of the sward, that natural balance is destroyed and erosion inevitably commences.

## EROSION IN OTHER COUNTRIES.

The problem of soil erosion is as old as civilization itself. As is well known, the Arabian Peninsula, Syria, Irak, Armenia, and parts of Asia Minor contain many architectural remains which prove that these regions were once densely peopled. Regions which prior to the Christian era supported millions of people are now desolate and barren. The forests are gone and the once fertile soil is buried with sand. There can be little doubt that the Middle East was once extremely productive, for Asia Minor alone had more than 250 considerable cities ; and the agriculture of the Middle East, of the Empires of Persia, Babylon, Assyria and of Chaldea rested upon great irrigation works and intensive agriculture. The control of the Euphrates and Tigris enabled the numerous inhabitants to maintain prosperous and extensive civilizations and to hold back the desert, but wars, invasions and desert nomads laid the region waste and destroyed the irrigation works and the agriculture based on it, and the desert sands swirled in.

Antioch was one of the great cities of the Middle East, supporting a population of over three-quarters of a million. The ancient city is now buried some 20ft. in desert sand, and a population of 30,000 lives in poverty amid the ruins of the past.

The countries bordering the Mediterranean were originally well-wooded, but throughout recorded history there has been continuous destruction of the woodland cover. The winter rainfall, characteristic of the region, has washed away much of the fertile soil on these deforested areas.

Travellers in Northern Africa are familiar with the ruins of what were once great cities requiring vast supplies of food in districts that are capable of feeding only a few sheep. A French authority—Loppintot—Chief Administrator of French Colonies—estimated that for the last three centuries the Sahara had advanced into French West African Colonies and Northern Nigeria at the rate of a kilometre a year—approximately three-fifths of a mile per annum.

### CHINA.

Soil erosion has been a striking feature of China throughout recorded history. Eliassen estimates that the Yellow River alone transported annually 2,500 million tons of soil, sufficient to raise an area 400 square miles in extent five feet, every year. Some of the material is deposited as fertile soil, but the gain by deposition is insignificant compared with the losses produced in the densely populated plains by erosion.

In central and south China, both mountainous areas with a high summer rainfall, the upland deforested areas have suffered extensively from erosion, though vast terrace systems for rice culture have developed as an erosion control measure. In many parts of central and southern China whole hillsides have been completely eroded except where the rice fields have been saved by terracing.

North China contains the great delta plains with a mountainous hinterland of loess soil. Wind erosion, which in the past formed the loess from the desert regions and river flood plains, is still active in North China, but is not particularly destructive, in comparison with the erosion by water in central and southern China.

Lowdermilk, who has made detailed studies of erosion in China, states that " it is most important to learn from the experience of the Orient that accelerated erosional processes are like malignant disease, and that it is imperative to reduce the losses by constructive management to their geologic norms to save enormous losses in land values and production, and cost of control works. Fire, man's herds and finally his plough, have all contrived to accelerate the processes of denudation and erosion. It is only by constructive and conservative management of soil resources that these headlong processes of erosion may be arrested and reduced to their norms."

### SOUTH AFRICA.

Soil erosion has been particularly severe in South Africa, as is evidenced by the Drought Investigation Commission's report of 1923, and has transformed some of the richest pasture country into semi-desert. Soil erosion is a feature of every province in the Union, but it is predominantly a pastoral problem. The rainfall, except in the Cape province, is of the summer monsoon type, and the rainfall decreases from east to west. On the eastern highlands tall grass veld predominates, giving place further west to short grass veld and then to the Karroo (desert shrub) and the Kalahari desert. Only on the seaward slopes of the mountainous ranges are limited forests found and these seldom occupy any extensive areas. Erosion occurs extensively on the highland grass veld of the Transvaal and the Orange Free State.

The rapidity with which the country was opened up after the discovery of gold, and the character of the climate, have contributed to the acceleration of soil erosion. These conditions were unfavourable for the gradual adjustment of imported farming conditions to an environment which normally was predominantly pastoral. The Drought Investigation Commission in its report of 1923 pointed out that soil erosion was extending rapidly over many parts of the Union, and that it was caused mainly by the deterioration of the vegetal cover brought about by incorrect veld management such as kraaling, *i.e.*, concentrating stock at fixed places at night, overstocking and indiscriminate baring of the grass.

Other causes of erosion have been deforestation, particularly for timber and firewood, and road and railway construction.

According to Leppan the South African climate and relief are such that less than 15 per cent. of the land area is suitable for, and less than 5 per cent. under cultivation. The country is predominantly pastoral and by far the most important problem confronting pastoralists is how to prevent sheet erosion by maintaining an adequate cover through controlled grazing. Leppan considers that in a policy of land utilization concentrating almost entirely on properly organized animal husbandry and a controlled veld management lies South Africa's hope of controlling erosion.

The South African Government is thoroughly alive to the national importance of the problem. It has provided two kinds of service to deal with the problem—

1. Investigational work in connection with problems of overstocking veld, management, veld burning, pasture establishment, protection of catchment areas, and conservation of the natural vegetal covering of the veld, is being carried out at experiment stations with a view to providing sound information on the prevention of soil erosion.
2. At the same time a gigantic scheme has been instituted for placing at the disposal of individual landowners reasonable facilities for carrying out actual reclamation work in respect to damage already caused by erosion.

The main features of this latter scheme are worthy of note. In Circular 22 of the Department of Agriculture and Forestry, Union of South Africa, the scheme is summarised :—" In view of the rapid and [illegible]stating spread of soil erosion in South Africa, it has become urgently necessary to combat the national [illegible] various measures have therefore been instituted by the Government to assist land-owners in [illegible]ding the evil and to encourage them to erect anti-erosion works ".

Applications may be submitted for assistance under any of the schemes referred to hereunder :—

(1) Scheme A.—Where works are completed at the applicant's expense a bonus of 25 per cent. is paid on the valuation of approved works, if the application was made prior to April, 1936, and a bonus of 33⅓ per cent. on the valuation of works in respect to applications submitted after that date.

(2) Scheme B.—Loans may be granted to cover the construction of approved works, as also a subsidy of 25 per cent. on the final valuation thereof.

(3) Scheme C.—Under which the State meets seven-eighths of the wages of unemployed European labourers employed in the construction of anti-soil erosion works and small dams approved by the Government.

(4) Scheme D.—Provides for loans for purchase of implements and material for the erection of huts required in connection with Scheme C.

(5) Scheme E.—Permits payment of a bonus of 25 per cent. on the valuation of fencing erected for (*a*) the protection of trees and shrubs planted as an anti-erosion measure, and (*b*) of eroded areas.

The Secretary of Agriculture in his annual report for 1937, states that under Schemes A, B, and C, since their inception in 1933, 18,060 dams were approved at an estimated cost of £2,163,260, and anti-soil erosion works (contour banks, gully repairs, etc.) to the value of £385,381 were approved. Similar schemes were instituted in 1936 to assist the reclamation of wind eroded lands, and drifting of coastal sand dunes.

## UNITED STATES OF AMERICA.

Forty-three years ago Professor Shaler of Harvard University spoke in a mood of prophecy :—" Primitive man disturbed the conditions of the soil no more than did the lower animals, but in his first step upward he became a devastator. He became a soil tiller, and with the invention of this art began the greatest revolution in the economics of this earth that has ever been instituted by a living thing. Each extension of civilization has widened the field of devastation until nearly one-half of all the land is subject to its ravages. It is now a question whether human culture which rests upon the use of the soil can devise and enforce ways of dealing with the earth which will preserve this source of life so that it can support the men of the ages to come ".

M. L. Cook, a distinguished American engineer, in an address in 1935 at Cincinatti, urged the men of his profession to take arms in the struggle of the United States against an impending fate of soil erosion. " It is my opinion ", he said, " that as matters now stand and with continuance of the manner in which the soil, the mainstay of individual and collective life, is now being squandered, this country of ours has left to it less than 100 years of virile national existence. And if that represents a reasonably accurate statement it is vastly more significant, if we are to win out against the accelerated progression of this gangrenous growth of soil erosion, that we have probably less than 20 years in which to build up the techniques, to recruit the fighting personnel, and, most difficult of all, to change the attitude of millions of people who hold that ownership of the land carries with it the right to mistreat and even to destroy their land regardless of the effect on the total national estate ".

Dr. O. E. Baker, a leading American authority on economic geography, has estimated that since America was settled an area has been denuded of its surface soil equal to the total area of cultivated land in Germany.

Much attention has been given in recent years to the problem of soil erosion in United States of America, and its relation to industry, national welfare and politics, and soil conservation has now become a political and social question of first importance. In no other country is there such a complete assessment of the erosion damage, and in no other country has there been such complete preparation for the control of erosion as in the United States.

A preliminary reconnaissance erosion survey of the United States was made by the Soil Conservation Service in 1934. A survey was made of 1,907,000,000 acres representing the total area of the country. On 578,167,670 acres the survey indicated little or no erosion of any kind. In an area of 857,386,922 acres sheet erosion was generally prevalent in degrees, from slight damage to complete destruction. Wind erosion had affected an area of 322,961,231 acres, principally in the middle western States. Of this area some 88,000,000 acres were seriously damaged or practically ruined for productive purposes. Gully erosion had caused severe damage on 337,000,000 acres with about 4,000,000 acres so badly cut up as to be unfit for practical cultivation.

Through its Soil Conservation Service, the United States Department of Agriculture is directing a national movement to protect and conserve the land from accelerated erosion. It is developing practical and effective methods of control through research and experiment, and is helping to demonstrate these methods under varying conditions. Erosion experiment stations are maintained in the major agricultural regions, and it operates a network of demonstration areas in practical control in every major agricultural region where erosion is a serious problem. It maintains a series of nurseries for the production and propagation of erosion control plants, and carries out a complete and carefully balanced programme of soil protection in which the various methods of erosion control are applied singly and in combination according to the peculiar needs and adaptability of each type of land requiring treatment. The development of such a co-ordinated programme involves consideration of natural land factors such as climate, land slope, soil formation and vegetation.

Practical control measures generally fall into three main categories :—

(1) Adaptation of thick growing vegetation to practical farm operations :

(2) Use of engineering structures such as terraces and dams :

(3) Retirement of excessively eroded land from cultivation.

It is impossible in dealing with this many-sided problem to rely in large measure on any single unsupported method. All available methods must be welded into a composite whole. Broadly the procedure in demonstration areas involves surveys, co-operative agreements and field work. Each project is mapped from the air and in detail to show the layout of every individual farm, location of fences and physical features. With these maps as a basis the field workers of the service and the farmer draw up practical plans for the stabilisation of all eroded areas. These plans become the basis of five-year contracts between the farmers and the Government.

## THE PROBLEM IN SOUTH AUSTRALIA.

Careful consideration has been given to the problem of assessing the extent of soil erosion in South Australia, and in endeavouring to record the relative seriousness of the problem in the various areas of the State. Maps have been prepared which show graphically the problem as it appears at present in South Australia ; Map 1 showing the drift erosion in the pastoral country, Map 2 the drift in the agricultural districts, and Map 3 the water erosion in the northern agricultural areas.

## EROSION IN THE PASTORAL COUNTRY.

Reference to Map No. 1 shows that the pastoral areas most seriously affected by soil erosion are the north-east and far north. The Pastoral Board of South Australia furnished a statement in which particulars were given of 15 pastoral properties covering an area of 7,381 square miles which at one time carried stock successfully, but which now have no permanent carrying capacity. On a further group of pastoral properties covering over 20,000 square miles of country, the carrying capacity has greatly depreciated during recent years.

The pastoral country in which wind erosion is common is characterized by a low, variable and erratic rainfall and a uniformly high evaporation rate. The average annual rainfall ranges from under 5 inches in the neighbourhood of Lake Eyre to 10 inches where the pastoral land impinges on the cultivated wheat areas. A feature of the climate throughout the area is the irregularity of its distribution of the rainfall with the long periods of dry weather and a high evaporation rate (from 70 to over 100 inches per annum). The erratic nature of the rainfall, combined with a high evaporation rate, the frequency of high winds, and the proportion of the rain which falls in light showers lessen the effectiveness of the rainfall, and lessen the influence it would otherwise have in promoting plant growth.

The variability of the rainfall may be seen from the following table, which sets out the monthly rainfall received at a typical sheep station in the north-east of the State.

MONTHLY RAINFALL AT MUTOOROO STATION IN THE NORTH-EAST OF SOUTH AUSTRALIA.

| Year. | Monthly Rainfall (Inches). | | | | | | | | | | | | Total Rainfall (Inches) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. | |
| 1908 .... | ·06 | ·64 | ·29 | ·08 | ·34 | ·30 | ·00 | 1·93 | ·94 | 1·33 | ·42 | ·40 | 6·73 |
| 1909 .... | ·36 | ·08 | 1·00 | ·14 | 2·43 | 2·21 | ·21 | ·59 | ·13 | ·99 | ·52 | ·00 | 8·66 |
| 1910 .... | ·57 | ·11 | 3·12 | ·05 | 1·16 | 2·67 | ·38 | ·32 | ·78 | ·62 | ·00 | ·22 | 10·00 |
| 1911 .... | 1·67 | 3·71 | 1·33 | ·00 | 1·69 | ·19 | ·75 | ·33 | ·16 | 1·25 | ·50 | 2·51 | 14·09 |
| 1912 .... | ·00 | ·62 | ·49 | ·00 | ·00 | 2·80 | ·70 | ·63 | ·19 | 1·05 | 2·39 | ·00 | 8·87 |
| 1913 .... | ·03 | 1·63 | 2·61 | ·00 | ·42 | ·00 | ·00 | ·00 | ·66 | 1·91 | ·20 | ·25 | 7·71 |
| 1914 .... | ·08 | ·08 | ·29 | ·57 | ·43 | ·00 | ·03 | ·00 | ·17 | ·84 | ·77 | 3·50 | 6·76 |
| 1915 .... | ·23 | ·00 | ·00 | ·33 | ·88 | ·28 | ·39 | ·31 | 1·00 | ·57 | ·00 | ·10 | 4·09 |
| 1916 .... | ·16 | ·00 | ·00 | ·00 | ·28 | 1·01 | 2·66 | ·65 | 1·60 | ·92 | ·30 | ·54 | 8·12 |
| 1917 .... | 3·13 | 1·48 | ·19 | ·06 | ·31 | ·78 | 1·03 | ·41 | 1·02 | ·58 | 2·06 | ·49 | 11·54 |
| 1918 .... | ·44 | ·00 | ·97 | 1·25 | 3·38 | 1·00 | ·26 | ·41 | ·00 | ·66 | ·00 | ·00 | 8·37 |
| 1919 .... | ·18 | 1·29 | ·16 | ·85 | 3·08 | ·06 | ·00 | ·00 | ·00 | ·50 | ·19 | 1·06 | 7·37 |
| 1920 .... | 1·27 | ·00 | ·00 | 1·04 | ·16 | 1·16 | ·21 | 1·55 | 2·88 | 1·62 | 2·19 | ·00 | 12·08 |
| 1921 .... | 1·04 | 3·74 | 3·89 | 1·32 | 1·22 | 1·69 | ·00 | ·54 | ·57 | ·40 | ·64 | ·00 | 15·05 |
| Means 14 years 1908-1921 | ·66 | ·96 | 1·02 | ·41 | 1·13 | 1·01 | ·47 | ·55 | ·72 | ·95 | ·73 | ·65 | 9·25 |
| 1922 .... | ·29 | ·37 | ·00 | ·09 | ·38 | ·57 | ·50 | ·00 | ·60 | ·21 | ·00 | 1·33 | 4·34 |
| 1923 .... | ·00 | ·00 | ·28 | ·00 | ·76 | 2·20 | ·79 | ·35 | ·16 | ·07 | ·00 | 2·06 | 6·67 |
| 1924 .... | ·90 | ·59 | ·14 | ·18 | ·00 | ·62 | ·00 | ·64 | ·63 | ·37 | 1·11 | ·60 | 5·78 |
| 1925 .... | ·29 | ·36 | ·84 | ·80 | 1·19 | ·00 | 1·13 | ·42 | ·48 | ·00 | ·80 | ·00 | 6·31 |
| 1926 .... | ·33 | ·00 | ·55 | ·78 | 1·98 | ·87 | ·00 | ·69 | 1·30 | ·00 | ·00 | ·11 | 6·61 |
| 1927 .... | ·33 | ·29 | ·15 | ·00 | ·05 | ·37 | ·16 | ·00 | ·68 | ·32 | ·71 | ·50 | 3·56 |
| 1928 .... | ·82 | 1·63 | ·66 | ·12 | ·00 | ·82 | 1·14 | ·11 | ·10 | ·07 | ·00 | ·00 | 5·37 |
| 1929 .... | ·00 | ·40 | ·18 | ·36 | ·00 | ·18 | ·04 | ·16 | ·28 | ·00 | ·75 | 2·63 | 4·98 |
| 1930 .... | ·10 | ·08 | ·00 | ·21 | 1·04 | ·00 | ·39 | ·16 | ·69 | 1·51 | ·56 | 1·78 | 6·52 |
| 1931 .... | ·00 | ·00 | ·53 | 2·03 | 1·86 | 1·12 | ·73 | ·31 | ·23 | ·84 | ·00 | ·00 | 10·65 |
| 1932 .... | ·00 | ·63 | ·40 | ·70 | 1·02 | ·44 | ·03 | ·52 | ·51 | ·00 | 1·27 | ·00 | 5·52 |
| 1933 .... | ·00 | ·19 | ·23 | ·38 | ·30 | ·00 | ·67 | ·66 | ·43 | ·16 | 3·27 | ·07 | 6·36 |
| 1934 .... | ·28 | ·00 | ·46 | ·27 | ·00 | ·26 | ·72 | ·17 | ·22 | ·97 | 1·64 | ·00 | 4·99 |
| 1935 .... | ·09 | ·11 | ·32 | 1·13 | ·03 | ·34 | ·00 | ·08 | ·62 | 1·35 | ·11 | ·14 | 4·32 |
| Means 14 years 1922-1935 | ·25 | ·33 | ·34 | ·50 | ·62 | ·56 | ·45 | ·31 | ·50 | ·42 | ·73 | ·66 | 5·64 |
| Means, 28 years 1908-1935 | ·45 | ·64 | ·68 | ·46 | ·87 | ·78 | ·46 | ·43 | ·61 | ·68 | ·73 | ·65 | 7·44 |

The rainfall figures recorded at Mutooroo for the 28-year period 1908 to 1935 show quite clearly how very variable is the rainfall in this pastoral country, not only from year to year, but from month to month. During the period the variation from year to year has been between the very wide limits of 4·09 inches in 1915 to 15·05 inches in 1921. For the six months of January, February, March, May, November and December, the quantity of rain received has varied between nil and over 3 inches, for the months of April, June, July and September from nil to between two and three inches, and for August and October from nil to over 190 points.

The variation in the rainfall received for the individual months, over the period under review, is perhaps more clearly shown in the next table :—

VARIABILITY OF THE RAINFALL AT MUTOOROO—MONTHLY FALLS FOR THE PERIOD 1908 TO 1935.

| Month | Number of the 28 Years receiving Monthly Recordings of— | | | | | | | 28-Year Average. |
|---|---|---|---|---|---|---|---|---|
| | Nil. | 1 to 25 Points. | 26 to 50 Points. | 51 to 100 Points. | 101 to 200 Points. | Over 200 Points. | Highest Recording | |
| | | | | | | | Inches. | Inches. |
| January | 6 | 8 | 7 | 3 | 3 | 1 | 3·13 | 0·45 |
| February | 8 | 6 | 4 | 4 | 4 | 2 | 3·74 | 0·64 |
| March | 5 | 6 | 7 | 5 | 2 | 3 | 3·89 | 0·68 |
| April | 6 | 8 | 4 | 5 | 4 | 1 | 2·03 | 0·46 |
| May | 5 | 3 | 7 | 2 | 8 | 3 | 3·38 | 0·87 |
| June | 5 | 3 | 6 | 5 | 5 | 4 | 2·80 | 0·78 |
| July | 7 | 6 | 5 | 6 | 3 | 1 | 2·66 | 0·46 |
| August | 5 | 5 | 8 | 8 | 2 | — | 1·93 | 0·43 |
| September | 2 | 8 | 2 | 11 | 4 | 1 | 2·88 | 0·61 |
| October | 4 | 4 | 4 | 9 | 7 | — | 1·91 | 0·68 |
| November | 8 | 3 | 3 | 7 | 3 | 4 | 3·27 | 0·73 |
| December | 10 | 6 | 3 | 2 | 3 | 4 | 3·50 | 0·65 |

Besides showing the marked variations in the rainfall received in the individual months, and from month to month, and from year to year, the dividing of the previous table into two periods of 14 years each shows very clearly the great variation in the rainfall recorded as between different periods. This variability of periods is well illustrated in the next table, which gives the yearly rainfall, and the means for the periods 1908 to 1921 and for 1922 to 1935, for six representative stations located around the Flinders Range, three on the east, one of the north, and two on the west of the range. As well as for the two 14-year periods, the average annual rainfall for from 44 to 63 years is also shown.

YEARLY RAINFALL AT SIX REPRESENTATIVE STATIONS IN THE NORTH-EAST AND NORTH OF SOUTH AUSTRALIA.

| Year. | Mutooroo. | Waukaringa. | Curnamona. | Murnpeowie. | Marree. | Beltana. |
|---|---|---|---|---|---|---|
| | Inches. | Inches. | Inches. | Inches. | Inches. | Inches. |
| 1908 | 6·73 | 10·37 | 7·21 | 6·73 | 6·48 | 8·81 |
| 1909 | 8·66 | 9·12 | 5·16 | 2·75 | 5·04 | 9·08 |
| 1910 | 10·00 | 11·62 | 9·13 | 6·11 | 9·06 | 12·65 |
| 1911 | 14·09 | 10·79 | 8·34 | 8·85 | 7·01 | 8·01 |
| 1912 | 8·87 | 11·14 | 8·25 | 4·60 | 4·98 | 8·93 |
| 1913 | 7·71 | 7·81 | 4·54 | 5·58 | 6·18 | 5·58 |
| 1914 | 6·76 | 6·72 | 3·77 | 2·60 | 8·42 | 5·60 |
| 1915 | 4·09 | 4·78 | 4·14 | 3·49 | 3·60 | 4·98 |
| 1916 | 8·12 | 9·66 | 7·39 | 6·92 | 5·83 | 9·97 |
| 1917 | 11·54 | 15·87 | 11·87 | 7·62 | 6·53 | 13·07 |
| 1918 | 8·37 | 8·76 | 6·10 | 4·84 | 5·08 | 5·90 |
| 1919 | 7·37 | 8·82 | 7·45 | 2·67 | 4·85 | 6·75 |
| 1920 | 12·08 | 5·59 | 11·80 | 11·72 | 10·07 | 13·76 |
| 1921 | 15·05 | 14·87 | 10·72 | 2·91 | 7·25 | 11·80 |
| Means— 14 years 1908-1921 | 9·25 | 9·71 | 7·56 | 5·53 | 6·46 | 8·92 |
| 1922 | 4·34 | 5·99 | 2·73 | 3·12 | 3·63 | 5·46 |
| 1923 | 6·67 | 6·05 | 6·46 | 2·87 | 4·78 | 8·62 |
| 1924 | 5·78 | 7·69 | 7·35 | 3·45 | 5·22 | 4·08 |
| 1925 | 6·31 | 5·90 | 5·84 | 4·50 | 4·38 | 5·74 |
| 1926 | 6·61 | 7·48 | 6·55 | 3·27 | 5·66 | 7·64 |
| 1927 | 3·56 | 3·75 | 3·01 | 2·44 | 5·36 | 4·06 |
| 1928 | 5·37 | 4·63 | 5·08 | 1·60 | 4·43 | 5·56 |
| 1929 | 4·98 | 4·77 | 5·54 | 1·93 | 3·67 | 3·44 |
| 1930 | 6·52 | 5·92 | 7·38 | 6·41 | 8·71 | 8·93 |
| 1931 | 7·65 | 7·86 | 7·33 | 4·56 | 4·23 | 5·83 |
| 1932 | 5·52 | 6·94 | 5·92 | 4·43 | 7·61 | 7·54 |
| 1933 | 6·36 | 6·45 | 4·91 | 2·87 | 3·82 | 6·68 |
| 1934 | 4·99 | 6·16 | 5·02 | 2·80 | 3·29 | 8·13 |
| 1935 | 4·32 | 4·79 | 4·48 | 2·58 | 4·30 | 3·02 |
| Means— 14 years 1922-1935 | 5·64 | 6·03 | 5·54 | 3·35 | 4·93 | 6·05 |
| Mean— 28 years 1908-1935 | 7·44 | 7·87 | 6·55 | 4·44 | 5·91 | 7·49 |
| Means to 1936 | 7·60 (50 years) | 7·84 (47 years) | 6·79 (56 years) | 4·51 (44 years) | 5·77 (51 years) | 8·34 (63 years) |

The very great falling off in rainfall for the period 1922 to 1935 as compared to that recorded for the previous 14-year period had a marked influence on the severity of the soil erosion which has occurred over the pastoral areas, which is easily understandable. Following upon a long run of favourable seasons,

accompanied by good wool prices, pastoral properties changed hands at high figures, or money was spent too freely on improvements, or because of the luxuriant growth holdings were stocked up to full capacity, and when the unprecedently long-protracted drought was experienced, pastoralists either chased interest on capital invested, or retained large numbers of livestock in anticipation of a return of the good seasons, and the extreme overstocking led to the complete annihilation of most of the herbage, and even some of the trees. The continuance of droughty conditions for a full 14 years proved most disastrous, for in many places, even where livestock had been removed, sufficient rain was not received to keep the thinned-out shrubs and bushes alive, let alone to give any chance of re-establishing the herbage.

The most important economic pastoral region in the semi-arid areas is the north-eastern country. The areas used for livestock carry a highly specialized type of vegetation in which perennial plants play a dominant role. Broadly, the principal vegetation types are what are known as " salt bush steppe " on the heavier types of soils and limestone areas, the " acacia semi-desert " on the lighter sandy soils and ridges. The salt bush steppe is dominated by Salt Bushes (mainly *Atriplex vesicarium* which reproduces by seeds), and various species of Blue Bushes (*Kochia* spp.) which regenerate mainly from the roots and bases of stems, though many seedling blue bushes were found in our tours of inspection. The acacia semi-desert scrub which is practically identical with Mulga Scrub (*Acacia aneura*) is usually associated with the lighter soil types.

The perennial salt bushes and blue bushes possess highly specialized features in their structure and physiology which enable them to meet the exacting requirements of their arid environment. Professor J. G. Wood has shown that the mean atmospheric humidity in the pastoral areas at certain periods is relatively high, and that the power of absorbing water from a relatively saturated atmosphere is one of the characteristic features of Atriplex and Kochia.

Apart from the perennial salt bushes and blue bushes which form the main plant cover in the salt bush steppe, there are annuals and short-lived perennials in the pasture such as Bindy-i (Bassia), Spear Grass (*Stipa*), Annual Salt Bush (*Atriplex*) and ephemeral plants such as the so-called " Spinach " (*Tetragona*).

The carrying capacity of the salt bush country is determined largely by the annual and ephemeral fodder plants, and therefore cannot and does not remain constant but varies within very wide limits from season to season. The perennial drought-resistant salt bushes and blue bushes make permanent stocking possible in the semi-arid pastoral country, and moreover, constitute the fodder reserve of the stock in dry seasons when the annuals and ephemerals fail for lack of rain.

These perennial plants have been subjected to an exceedingly heavy strain in the long series of dry seasons experienced since 1922, and there is abundant evidence to show that on many pastoral properties the number of stock carried has been in excess of what the perennial vegetation could carry. The salt bush and blue bush have been destroyed by this overstocking and the land has lost the protection of the natural vegetative cover.

F. N. Ratcliffe, in his survey of the soil erosion problem in the north-east of South Australia, has shown that overstocking has been the main cause of the destruction of the perennial vegetation. Rabbits, he contended, were an important accessory factor, mainly because they lived on the annual and ephemeral plants and forced the sheep back on the salt bushes and blue bushes, so intensifying the stress by the stock on the perennial elements of the pasture, and moreover, that the rabbits destroyed young seedlings of perennial shrubs and trees. With the destruction by stock and rabbits, of the perennial protective cover, the soil became the sport of the winds and the process of soil drift began, the erosion extending in ever widening areas so long as the prime causes remain.

## MAP No. 1.—DRIFT EROSION IN THE PASTORAL COUNTRY.

Reference to Map No. 1 shows the position of soil drift in pastoral country in South Australia in 1938.

The land coloured yellow is generally of a very sandy nature, often with ridges of sandhills, though somewhat interspersed with stronger land and gibber tablelands. This type of soil requires very careful handling, for, if overstocked, the sand dunes are liable to drift and spread over the intervening flats.

The areas shown in red comprise what is known as gibber country ; this can be described as land with varied sized stones over a subsoil of fairly firm to extremely loose clayey soil known as " bull " dust. On these areas the over-crowding of stock loosens the light soil under the stony surface, with a result that on one-time purely gibber plains and tablelands there are today many serious sand drifts and sandhills.

The areas shown green were once looked upon as very good pasture or grazing land, but owing to overstocking, drought and rabbits, a great deal of erosion has taken place during the last 50 years. This type of land is generally firm sandy loam and sand over clay. In many cases the top surface has been eroded and blown away, and now forms hillocks of drifting sand, and, in some instances, decided sandridges and hills.

It is this latter type of country that gives the greatest concern, and great care will have to be shown in management of the country to prevent these areas extending, while stringent methods, such as spelling the country, will have to be used if any effort to reclaim these portions is to meet with success. An effort to reclaim this type of land appears worthwhile.

The large area extending north of latitude 30 in the far north-east of the State is of such low value that any suggestion for controlling soil drift here must be confined to those areas which are economically possible. This land has been mostly used for cattle breeding in the past and, except in isolated areas, could not be considered to have been overstocked. Droughts, accentuated by rabbits, probably were the cause of drift here.

The uncoloured portions of the occupied pastoral lands are at present, generally speaking, free of soil drift, but isolated patches appear here and there throughout. Every effort should be made to prevent the spread of these dust centres, which are mostly found near permanent waters.

## DETERIORATION OF PASTORAL LANDS.

Although the problem of soil erosion and deterioration of pastures in pastoral country has only been brought prominently before the public in recent years, an inspection of the affected country clearly indicates that deterioration has been gradually taking place over a long period, the inception probably coinciding with the occupation by white man and the introduction of sheep and cattle.

Generally the pastoral lands consist of sandy soils to sandy loams over clay, gypsum, or limestone subsoils, but there are fairly large areas of firm hilly country, which type of land is only prone to the serious erosion caused by the run-off of water.

Prior to the pastoral lands being stocked with hard-footed animals—sheep, cattle, and horses—the natural fauna consisted of animals which were all soft-footed, and these animals did not harm the light-textured country by wearing tracks or pads to and from the water, as is the case with domesticated livestock. In the course of time, the pads made by livestock, converging as they do on watering places, create dust-centres from which the dust, fanned by the winds, is carried further afield.

Some of the plants of the pastoral areas, particularly the perennial types, depend largely for their existence upon their natural power of absorbing moisture through their leaves, and when the leaf-pores become clogged with dust, the plants are seriously affected, tending to increase the size of the dust centres. The multiplication of water supplies and the consequent concentration of stock at more points, leads to the formation of more dust centres from which the killing of the natural flora may radiate.

The development of swarms of rabbits to the extent of reaching plague dimensions, has been the means of increasing the rate of deterioration of the pastoral country to such an extent that the severe drought of the 14 years prior to 1936 has brought some of the pastoral lands very close to a condition of collapse.

In discussing with the pastoralists of the far north and north-east of the State the causes of deterioration and the corrective steps thought necessary to prevent further soil erosion, or to bring about a recovery of the already denuded pastures, it was found that, generally, they are of opinion that soil erosion and depletion of pastures have been caused by a combination of over-stocking, destruction of trees, droughts, and rabbits, and all who have investigated the position are in agreement with these contentions. Droughts are a normal feature of the natural conditions obtaining, as are also the wonderful rainstorms which unfortunately occur only too infrequently, but before the advent of white man and the introduction of domesticated stock and rabbits, these rains corrected the damage caused by drought, and there was maintained a stable balance of nature.

Destruction of trees, overgrazing by stock, and the destroying of plants by rabbits, leave the country after a drought in such a denuded condition that, even if all the animals had been removed, the soil could not respond to bounteous rains, as did the country when in its natural state. It is always noticeable that the greatest response to rains occurs in places where a good deal of the original perennial growth still survives even when livestock are on the country, and that little definite improvement is apparent on windswept areas which are frequently stocked. The absence of trees and shrubs enables the fierce rays of the sun and drying winds to parch the soil, and the absence of the roots of perennial plants which helped to bind the country, allows the surface of the land to drift. In such conditions, even if seed does germinate, the moving sand, driven by an uninterrupted passage of the wind, quickly kills off the tender seedlings. On the other hand, had the perennial flora been present the new growth would have been protected and it would have probably reached maturity and produced seed, when not overgrazed.

On otherwise badly eroded properties some paddocks contain a fair covering of perennial vegetation, the reason being that there was either a limited or an unreliable water supply, and consequently the area could only be lightly stocked, or it was necessary to spell the country when water was not available. In some almost bare paddocks the only remaining salt bushes and blue bushes are to be found on the tops of rabbit warrens, which places are usually avoided by grazing stock.

While rabbits may not directly cause much damage to the perennial vegetation, they eat up the annual growth and so force domesticated stock on to the permanent fodder plants much sooner than would be the case otherwise.

## OVERSTOCKING.

It is generally recognized that much of the erosion of the pastoral areas has been encouraged by severe overstocking, and whatever the explanation and excuse for the practice might be, the sooner means are taken to prevent the deliberate and unreasonable overstocking which has been so frequently followed in the past the sooner a feeling of hope can be entertained that the pastoral lands will remain in permanent occupation, and be an asset to the State.

In the past considerable latitude has been given to the lessees of pastoral lands in regard to overstocking, but there appears to be no reason why they should have the right to destroy the pastures and soil-holding plants any more than a tenant of a house has freedom to destroy the capital value of that property. It is easy to find instances where lessees, who carry 30-40 sheep to the mile during average seasons, reduce their numbers in poor years, and so keep their country in very good heart, whereas neighbours who attempt to carry 60-80 sheep per mile, denude their country of all perennial fodder plants, and in some cases of all indigenous perennial plants. Because of this wanton carelessness of some pastoralists, control of some kind is required, and restriction in the numbers of stock to be carried seems necessary. The reasonable pastoralists would have no objection to such a restriction being included in the conditions of the leases, for they impose strict limitation of stocking upon themselves, but there are others who should be compelled to give fair treatment to the land placed temporarily in their keeping. Unfortunately, there are no clauses in perpetual leases nor in most of the current pastoral leases restricting the number of livestock to be carried, and until the expiry of these leases, no alteration in the conditions can be made without mutual agreement or by amendment to the Acts. A practice has developed in South Australia, however, in which all new pastoral leases issued contain a condition that the lessee may not at any time overstock the land, and if, in the opinion of the Pastoral Board, the land is being abused by such mismanagement, the leases may be cancelled.

The position has become so serious that it appears necessary to make it compulsory for restrictive stocking conditions to be inserted in all new leases issued. Such conditions should definitely state the maximum number of stock that may be carried, with a provision that this number may be increased when satisfactory evidence has been submitted to the Pastoral Board that the land is capable of carrying more stock because of systematic management on the part of the lessee. It is, however, important that the land should not be overstocked at any time, including good seasons, for it is in such times that the country should be given the opportunity to recover so that reserves can be built up in order to withstand droughts, when they again occur. Sufficient experience has been gained in the country by now to make it practicable to estimate the number of stock that may be depastured on any given area without detrimental effect on the pasture.

In the event of a lessee receiving notice of intention to cancel his lease because of overstocking, he should have the right of appeal to the Tenants Relief Board, in a manner similar to lessees under the Pastoral Act, and when the true interests of the lessee are thus safeguarded, he would have no fear of unjust treatment.

One of the common excuses given for overstocking pastoral country is that the financial position of the lessee demands it. High prices were paid for some stations during the years of high wool prices, and in an endeavour to keep up interest payments on loans and mortgages, the purchasing pastoralists carry too many sheep. Unfortunately the position has been aggravated, because in some cases financial houses insisted on flocks being increased as soon as good rains fell, and almost without exception this proved a mistaken policy, for still greater depletion of pastures and depreciation of capital value followed. Many of the financial houses have realized the mistake of trying to increase flocks before the country has recovered, and some are encouraging lessees to restrict the number of stock carried, in order to protect their security. The results obtained by rigidly controlled understocking are such as to give full assurance of greatly improved pastures in the sheep country. A wider application of this system of reclamation is very desirable, and concessions in rental should be allowed if lessees give a *quid pro quo* in respect to stocking.

Generally the pastoralist is beginning to realize his responsibility, and in many cases has reduced the number of stock carried. The country also gains by this action as the reduced number of livestock have less ill-effects on the country and lessees increase rather than reduce their profits. Several instances are known where a reduced flock has provided more income than was previously obtained. The reason for this is doubtless due to a plentiful supply of feed leading to better and healthier sheep, which are capable of producing more and better wool and of rearing a greater percentage of lambs.

## PREVENTION OF TIMBER-CUTTING.

It is very distressing to find that so much timber has been cut down to feed stock, for fencing and other improvements, and for supplying timber and firewood for mining and other purposes. It is essential that every effort should be made to prevent further decimation of the relatively small number of trees remaining in the pastoral areas for they provide shelter to the ground and prove of the greatest of value as bulwarks against the fierce blasts of wind to which much of the low-rainfall country is liable.

In order to encourage the lessees of pastoral country to refrain from cutting growing trees, it is considered necessary that posts for fencing, either wooden or iron, should be made available at a minimum cost. It might be possible for the Government to purchase posts for lessees at a lower cost than that charged to individuals, and to allow special rates in rail transport. No licences should be issued for the removal of dry timber from lands held under pastoral leases without the consent of the lessees, who should, moreover, have the right to decide upon the locality where the timber is to be cut, and in any case it is considered that no licences for the cutting of green timber, except mallee and commercial sandalwood, should be issued. The exemption as regards mallee and commercial sandalwood has been suggested because the mallee is capable of regeneration from the stump, and the commercial sandalwood has mostly been collected, and the removal of the residue would not materially affect the position, especially as it grows generally in scrub areas.

## NATIVE PLANTS.

It is a matter of common occurrence that where areas of the heavier types of soils in the pastoral districts have been bared of all growth and been windswept for years, native plants of several different kinds appear and become established when rabbits and livestock are excluded from the paddocks, and even when very light stocking is practised. Of recent years several species of sida have appeared and spread to places where they were unknown previously, and besides being very hardy indeed, one of the species at least, has fair feeding value as well, whilst all of them are doing much towards holding and protecting the country so that other types of indigenous plants can establish themselves. In some localities where the more useful bushes, such as salt bush and blue bush, have been eradicated, a strong and fairly dense growth of a large assortment of Bindy-i (Bassia spp.) has developed which is reviving the grazing value of the country, protecting it from further drift and helping in the re-establishment of trees and bushes with some stock-carrying value. On some of the worst of the wind-swept plains of the northern pastoral areas, Nitre Bush (*Nitraria schoberi*) is the first of the indigenous bushes to re-appear, and when given any sort of a reasonable chance, spreads, holds the drifts, and prepares the way for other more useful indigenous plants.

There is no doubt that plants will return to much of the de-vegetated lands of the pastoral areas, except where there are high, moving sandhills, provided that grazing animals are excluded from them altogether, and in most places recovery is certain, but slower, even when very light stocking is practised. When there are no animals, or insufficient to eat out the smaller plants which appear first the soil surface is firmly held by the cover provided by such plants and then it is not long before herbs, then shrubs, and finally trees appear.

There is one introduced plant, known as Teetulpa Weed (*Diplotaxis tenuifolia*), which has established itself in the northern pastoral areas, and which is behaving like a native plant. The seeds of this plant germinate and the young plants quickly establish themselves wherever there is a collection of loose surface soil, such as heaps up against stones, stumps, bushes or furrows. The plants produce a lot of seed and the weed is spreading very rapidly in all localities where it has been introduced. The Teetulpa weed is not particularly palatable, but sheep and cattle do quite well when it is the predominant plant in the paddocks, and because it has some feed value and is not liked sufficiently well by livestock to be eradicated easily, it promises to be a most useful plant for the windswept areas of the northern pastoral country.

## STOCK LIMITATION.

The South Australian Government, on the recommendation of the Pastoral Board, decided to encourage pastoralists to co-operate in an endeavour to repair the damage to country held under pastoral lease. To this end, a reduction of rent was granted to a pastoral lessee who was prepared to reduce the number of stock on the area controlled by him, or to one who would leave certain areas unstocked for a stated period. The effect of introducing such preventive measures, and the progress made towards reclamation of pastoral lands has been pleasing, and give definite indication that regeneration of pastures can be attained in what is known as the " sheep grazing zone ".

To safeguard the pastoral country from soil erosion, every effort should be made to reduce the number of stock carried so that the flock is compatible with the annual growth of vegetation, and it is essential that perennial plants should not be considered when estimating the carrying capacity, other than allowing for a reasonable pruning. Perennial fodder plants should be kept in good condition as reserves against drought. If reasonable permanency of pasture is to be maintained, there is no alternative but to stock the country in such a manner that the grazing is in equilibrium with the expected annual growth.

Favourable seasonable conditions such as apply at present in most of the pastoral areas offer an opportune time to limit stock to reasonable numbers. Nature is trying to re-establish vegetation on much of the country, and with the co-operation of pastoral lessees in assisting nature in this effort, much good should be accomplished.

## DESTRUCTION OF RABBITS.

The successful operations of rabbit trappers close to the railway lines traversing the pastoral areas of the north give proof of an increasing number of rabbits, now that plenty of fodder is available. These rabbits, if left unchecked, will become a menace to the success of any corrective methods adopted to reclaim the pastures. Pastoral leases contain a clause to the effect that lessees must destroy vermin, and many of the pastoralists holding the better class of sheep country have adopted various methods of destroying the pest, the most effective of which has undoubtedly been that of ploughing up the warrens. This method is not economically possible on the lighter carrying country in the far north with a result that the rabbits, after good rains, breed up in vast hordes, and, as the country is "eaten out", they move south, leaving devastation in their wake.

Under existing conditions it would not be wise to attempt to compel the few lessees in the far north cattle stations to destroy rabbits, because if this were insisted upon, the country would probably be abandoned, but every effort should be made to discover a cheaper method of destroying rabbits, for without doubt the far northern country will not recover if the rabbit is to be allowed to breed unchecked. The investigations being made into the possibility of introducing a virus for the extermination of rabbits, are interesting and important, and, if the trials now being carried out on Wardang Island prove successful, it would appear that the destruction of rabbits and the controlling of plagues of these pests by this means will prove of untold value to the country. It appears that the introduction of the virus to any locality will not be costly, and even if it does not mean the extermination of the rabbit, it will probably reduce the number of rabbits to a point where they are so few as to have little influence on pastures. The loss and destruction caused by rabbits is enormous, and there appears to be no doubt that their extermination would prove very beneficial to Australia. If further tests with the virus prove satisfactory it should be introduced into rabbit-infested localities.

In the lower rainfall areas in the interior of Australia, the land is of such low value and the rains so sporadic that little can be done to assist nature to repair the damage caused by man with his flocks and herds, the rabbit and drought. In this country evidence points to the rabbit as being the worst destroyer of the pastures, as it has killed out the canegrass and other indigenous plants which at one time held the sand dunes together. With the disappearance of the soil-binding vegetation, the sand, except in particularly good seasons, began to move to such an extent, until the country is now almost generally devoid of pasture plants. This inferior country is a land of feast or famine, and, beyond the control of rabbits, which is essential, there seems little that can be undertaken economically as a means of restoring the pastures. If this country is gradually becoming drier and drier as some people suppose, it is hopeless to expect any worthwhile results from any action, other than the destruction of rabbits, in so far as re-vegetating the land is concerned.

## PLOUGHING FURROWS.

Some pastoralists are attempting the reclamation of their country by ploughing furrows on bare wind-swept land, and in some cases with very pleasing results. These furrows, which are made across the line of the prevailing winds, are usually spaced from 10 to 20 feet apart, although in some cases where the protection of station buildings is an important aim they are placed much closer together, and these areas might even be cross-ploughed with the furrows only 5 or 6 feet apart. Winds lead to the banking up of drift in the furrows, and as the drift usually contains seeds of local plants which germinate on the advent of rain, these lines of plants, besides holding up further drifts, become nurseries from which further plants spring to eventually cover the country.

## LUCERNE-GROWING.

The cultivation of lucerne in localities where creek floodwaters can be controlled, has been successfully undertaken by some lessees, and the results are so good as to encourage others who have suitable watercourses to grow this fodder as a reserve against bad seasons.

On present appearances it appears that lucerne is well worth trying in the proximity of those watercourses of the Upper North which run at least twice a year. It has been found that it is best to plant the seed early in the winter so that the lucerne will receive the benefit of the cooler weather, and it then develops sufficiently to withstand the heat of summer. When preparing for seeding the soil should be well packed with a cultipacker or roller in order to produce best results.

## FLORA RESERVES.

Several pastoralists have been persuaded to enclose small areas within sheep-proof fences and to retain the areas as flora reserves. These reserves clearly show what have been the effects of stocking the country, for, even where the areas are not protected against rabbits, a splendid growth of natural vegetation both perennial and annual, has been made in two or three years. Almost invariably the areas so reserved have proved nurseries in which much seed has been produced, which carried by natural agencies on to surrounding land, has germinated and resulted in further plant establishment.

These flora reserves are not only valuable as distributing centres for seeds, but they are of distinct educational value, showing what would be the normal condition of the country should stock be kept off it. These reserves are of so much value that they should be encouraged throughout the pastoral areas, and this might be done by the Government subsidising the purchase of fencing materials used in the protecting fences erected around suitable areas approved by the Pastoral Board. As the plants appearing on the country inside of the reserve advance sufficiently in growth, the fencing could be removed to another selected area.

## DRIFT AROUND TOWNSHIPS, ETC.

The country around some inland towns, railway stations and other public utilities is very badly eroded and in some instances (notably Farina and Parachilna, on the North South line to Alice Springs), the towns are being gradually submerged by sand, and will, in course of time, have to be abandoned, unless some action is taken to prevent it. This also applies to many station homesteads and watering places. The success of shutting up areas of country and maintaining them as flora reserves indicates that the protection from grazing animals of areas of land to the windward of the threatened towns, homesteads, etc., will lead to a full correction of the trouble.

So serious is this trouble in some places that immediate action should be taken to proclaim certain areas in the vicinity of towns as flora reserves, and these areas should be placed under the control of some public organization such as the Agricultural Department, which should be responsible for the fencing of the area, and, if thought necessary, some planting of suitable vegetation, such as nitre bush, wattles, sida, etc., should be undertaken. There are some miscellaneous leases adjoining Parachilna and Farina which should be cancelled and all stock should be kept off the areas. At other towns arrangements could probably be made with nearby lessees to surrender portion of their leases for reclamation purposes. Small areas properly treated would prove of inestimable benefit to the towns, and a small local committee could be appointed to see that the reserves were not abused, such committee to be under the control of the Agricultural Department.

## DRIFT ALONG RAILWAY LINES.

Concentration of livestock on small areas does considerable damage so should be avoided wherever possible. Much of the sand-drift trouble experienced along railway lines is due to this close stocking, and the accumulation of sand is costing the State a large sum of money because it has to be removed frequently. The droving of livestock on stock roads parallel to and alongside of railways should not be allowed, except in urgent cases, as the stock cut up the country, and not only cause drift over the railway lines and fences, but set up a dust centre which gradually spreads. Many lessees of northern pastoral lands in proximity to railway lines consider that no hardship would be experienced if, where railways are available, no stockman be allowed to drove livestock along stock-roads running parallel to and alongside of a railway, a greater distance than to the nearest trucking station.

## WATER EROSION.

Although the question of water erosion is being dealt with under a separate heading, it is desired to point out here that in parts of the pastoral country many of the worst drift-soil areas are found to be adjacent to watercourses and creeks. In flood times these creeks and watercourses overflow their banks, and deposit a large quantity of silt over fairly considerable areas. Much of this silt is fine and light and when dry is blown as dust over a wide area, and creates a dust centre. Some of the creeks and watercourses hold water for a time, and overstocking in order to use the water while it lasts, causes the soil to drift.

The actual loss of land through water erosion is not so important in the pastoral country, except in connection with drains into dams, which have been frequently constructed without thought of the consequent water erosion, and much damage has thereby been done.

## TECHNICAL ADVISERS.

There is an urgent need of some system whereby pastoralists can obtain technical advice on many matters pertaining to the sheep industry, as conducted in the low-rainfall areas. Much money has been needlessly expended in the erection of improvements, the sinking of dams, construction of drains and in many other ways, and much of this could have been avoided had the pastoralist been able to obtain reliable advice conveniently and readily. Agricultural advisers go from farm to farm giving advice to the farming community, and a somewhat similar service could with advantage be made available to pastoralists, who appear to be ready and willing to accept such help and put into use practical advice. The advisers should preferably be connected with the Agricultural Department, as it is essential that they must not be looked upon as being inspectors.

It appears that few pastoralists realize that they are overstocking their properties, because the deterioration of their pastures has, until hastened by the recent drought years, been gradual and so unobserved. Lessees should be asked to co-operate with the State in an endeavour to repair the damage caused by the overstocking of the past. Compulsory action in regard to reduction of stock is undesirable if it can be avoided as it is thought that pastoralists are prepared to make stock reductions if the Government is prepared to assist with reduced rents, freights, etc.

One thing, however, is certain, and that is that the number of livestock to be carried on the pastoral country should be greatly reduced for some years to come. A rotational system of spelling paddock by paddock should be undertaken by the pastoralist, and where this is properly carried out it might be possible to make arrangements to have an equivalent reduction in the rent made for the area placed in reserve.

It is in connection with the development of a system of rotational resting of paddocks and the re-vegetation of denuded areas that the advice of a pastoral adviser would be particularly useful.

## MAP No. 2A—DRIFT EROSION IN THE AGRICULTURAL AREAS.

Reference to Map No. 2 shows that the position of soil drift within the farmed areas of South Australia in 1938 was not relatively so serious, and that the only two areas of appreciable extent where the trouble was exaggerated were in the Loxton and Port Pirie districts. In the areas shown of a red colour much of the soil had moved this year to the extent of preventing the growth of sufficient plants to completely cover the surface, and a good deal of it appeared as though it would require a remarkable run of particularly favourable seasons, or its removal from agriculture altogether, if the sand was ever to be held again. In some cases fairly deep " craters " had been blown out in the sand hills, but in most instances the loose sand was in the form of moving sandhills and ridges.

Besides the very serious drifts there is a fairly considerable area which was moderately bad, in so far as drift was concerned, in 1938, with the great bulk of it to be found in the Murray Mallee, and the areas so affected are to be seen on the map coloured blue. These moderately bad drifts had in most cases been rather serious during the years immediately preceding 1937, but with the improved climatic conditions of 1937 and 1938 many of the loose sandy areas had become fairly well covered with growth of some kind or other, and although a few hills and ridges here and there were still bare and on the move, in most cases the movement has ceased, but the sand is so lightly held that the danger of drifting again appears imminent.

Again the great bulk of the area which contains some drift, and which is coloured green on the map, is to be found in the Murray Mallee, although there are also fairly extensive areas so affected to the north of Yorke Peninsula, and in the north-western farming districts of Eyre Peninsula. The areas so shown contain soils of a sandy nature, and scattered throughout them are relatively small patches still quite bare of growth and drifting with every wind, whilst quite an appreciable proportion within the boundaries of the coloured patches have drifted in the past but are now more or less securely held by the growth of crops or weeds holding them together.

The areas shown under the three classes of drift are not so very different in so far as soil type or climatic conditions are concerned, and the severity of the drift damage is in many cases a measure of the mismanagement in the past as much as of the natural liability, and so if greater care is not shown on the areas now grouped as " moderately bad drift ", and even in some parts of the areas showing " some drift ", than has been practised where the land is shown as " serious drift ", somewhat similar results must be expected. Quite a lot of the " serious drift " areas should be removed from agriculture altogether and special measures taken to control the drift, at all events until the trouble is completely subdued, then it, and all of the other areas at all liable to drift, should be farmed in a manner that tends to keep down the drift menace altogether, as is set out in the following pages.

On Map No. 2, no attempt has been made to show the areas liable to drift, but the position as it was in 1938 was attempted to be shown. As a matter of fact, much of the Murray Mallee and Eyre Peninsula is shown uncoloured, as representing non-drifting land, and is so because it is still covered with scrub and is of such a drifty nature that it would probably begin to move as soon as the scrub was burned and cultivation commenced. Some of this uncleared land is so very sandy that it is to be hoped that the Government will never be tempted to open it for selection, but will retain the areas as fauna and flora reserves.

## PREVALENCE OF DRIFT IN THE AGRICULTURAL AREAS OF THE STATE.

Fortunately, soil erosion has not yet reached critical dimensions in the farming areas of South Australia, but it is sufficiently bad to be gradually alarming people into a state of recognizing the fact that unless steps are taken to prevent an extension of the trouble, some of the country now supporting a lot of the people will become a desert waste, and it is even becoming realized that the time has arrived when the relatively small areas of land badly eroded should be tackled so that the trouble does not extend and ruin other uneroded country in the near neighbourhood.

In looking back on the development of land settlement in this State, it is extremely difficult to imagine that any other economic method of preparing land for the production of crops and the maintenance of livestock could have been followed. It is practically inevitable that the natural fertility of virgin lands should be exploited to the full in the early days of settlement, but in several other countries the disastrous effects to fertile lands through over exploitation, is being brought prominently before the world, and very fortunately as far as South Australia is concerned, this publicity has come soon enough to be a warning of what is in store for us if somewhat similar practices of soil exploitation are followed, as have led to the trouble in these other countries.

The farmed areas of South Australia are blessed with Mediterranean climate, and as a consequence, although most of the rains fall during the winter period, torrential rains are of infrequent occurrence, and so relatively little water erosion has yet taken place, except on the slopes of the foothills and on the deep-soil plains near the hills, where the run of water gains fairly high velocity. In these localities, and in the aggregate over a fairly considerable acreage, when all farmed areas of the State are taken into account, serious water erosion has taken place, and is extending year by year, although there are situations where the washing away can be stopped fairly cheaply.

Although water erosion is not so very serious just now inside of the farmed areas, the position is different as regards the loss of soil by wind, for fairly extensive tracts of country with soils of light texture located in districts where the average annual rainfall is relatively low, have been opened up for settlement. In these localities when the natural vegetative cover has been removed, and when after some years of cropping the coarse organic matter keeping the soil together has decomposed and so disappeared, it has become extremely difficult to prevent the surface soil from blowing away. Under the natural conditions which prevail in many of the districts opened up for agriculture in South Australia, the only economic crop which can be produced in the early days of settlement, is wheat, and although the keeping of sheep becomes an essential activity for such holdings when the land is fairly well cleared of scrub, in most cases wheat growing remains the principal agricultural activity. Where the Mediterranean climate is experienced, it is essential to bare fallow the land for a period of 8 to 10 months before seeding it to wheat, and so if light textured soils are cropped frequently, immediately after bare fallow, it is not long before much of the natural fertility is removed and the organic matter dissipated, and then great difficulty is experienced in endeavouring to carry on cropping activities and at the same time to keep the soils from drifting.

The accompanying Map No. 2 shows the type of soil erosion and the districts where it has occurred, as was actually the position in 1938, and from this map it will be seen that wind erosion in the farming areas has already occurred to a serious extent (coloured red) in the Murray Mallee, particularly in that part with Loxton as a centre, near Port Pirie, scattered areas near Port Broughton, and between Dublin, Owen, and Port Wakefield, and a little on the coast near Streaky Bay. Although not so bad, the areas drifted to a fairly serious extent (coloured blue) are found in a large proportion of the Murray Mallee, in the Upper North near Bruce, Hammond, Willowie, east of Johnburgh and Black Rock, near Winninowie, surrounding Wandearah, and smaller areas near Alford, Ninnes, Mount Templeton, and Balaklava. The areas drifted to a slight extent (coloured green) are shown as being in the remainder of the Murray Mallee, on Northern Yorke Peninsula, at Long Plains to Bowmans, Balaklava to Condowie, north of Orroroo, near Port Augusta, Central Eyre Peninsula, near Streaky Bay, and scattered areas from Warramboo right out west to the hundred of Russell.

## WIND EROSION IN THE FARMING AREAS.

So far the only times in our history when really considerable areas of farmed country have drifted throughout their full extent have been after prolonged droughts. On the return of normal seasons a great deal of the trouble has been corrected because of the development of dense stands of weeds of several different kinds which hold the soil together and protect the surface from the damaging action of strong winds. Because of what is known to have happened in other countries, it is inevitable that if the practices which led to the severe drifting in the past are continued, each return of droughty periods will lead to a recurring of the drift trouble, and worse still, it can be confidently expected that in each successive period the intensity of the drift will become greater and greater. At the present time the serious drift that occurs in normal seasons is confined mainly to fairly high sand ridges, and to those places where flatter sandy land has been flagrantly over-cropped, but after each continuous series of dry years the area of bare, moving sand has increased to a considerable extent. Fortunately, the area which does not become properly covered with growth after the specially dry seasons have run their course, is up till now comparatively small in any of our farming areas, and if intelligent farming practices are followed from now onwards, most of the loose sandy areas are not so far gone that the drift cannot be checked fairly soon, and be prevented altogether in the future. In this country, as in all others, in the early days of the drift trouble, the surface soils of really extensive areas do not all move, but certain small areas, such as the tops of hillocks and the ridges of sandy ranges are blown off first, and the trouble gradually extends from these starting points, until whole districts begin to move to an alarming extent. Luckily, we are still in the stage of having these

isolated drifty areas widely scattered about the sandy districts, and if landholders can be brought to realize the seriousness of the drift which will inevitably follow careless and irregular cropping practices, and make adequate efforts to overcome the trouble, the areas can be held, and it will be necessary to remove very few of them from agriculture.

Although most of the farming areas where the soils are sufficiently sandy to be liable to drift, have been opened up for settlement, only for from 60 to 25 years, quite a lot is known about the controlling of drift in these localities, and in all districts where the trouble is likely to occur, there are some careful farmers who have succeeded in supporting themselves without undue loss of soil, and without increasing the risk of drift occurring while they continue their present methods of farming. So successful have some farmers been right through the longest period of dry years yet experienced in the country, that it seems certain that their methods can be followed with perfect safety. Unfortunately, it is often too true that these careful farmers are playing a lone hand and are surrounded by less efficient soil workers, and in some localities the proportion of the less efficient crop growers is so high that the farms of the good men will eventually be overwhelmed by the oncoming streams of drifting soil.

## CONTROL OF DRIFTS IN FARMING DISTRICTS.

If taken in hand in an intelligent manner before the fertility, and so the stability of these light-textured soils has been destroyed, there is every chance of overcoming the trouble before it has gone too far, and after that of preventing its recurrence, and with very little of the affected areas will it be necessary to provide non-edible plants to keep the soil in position. If, on the other hand, the seriousness of the possibilities of trouble being experienced is not recognized soon, and the matter taken in hand in the very near future, a fairly considerable area must go out of cultivation and some of it will become a menace to adjoining country.

The control of drifting soil is wholly dependent upon the provision on the surface of the land of obstructions to wind and cannot be done better than by keeping sufficient vegetable matter, either green or dry, on the soil to protect the surface from soil-disturbing winds. This is not so easy of attainment where the liability to drift is great, because this state of affairs exists as a rule in districts where the rainfall is relatively light, where sandy soils dry out very readily, and in these conditions, unless the soils contain a lot of relatively coarse organic matter, their powers of cohesion are very poor and they move readily.

Under the natural conditions obtaining in those portions of South Australia where the liability to drift is ever present, the only economic crop that can be grown whilst the land is being cleared of its indigenous scrub is wheat, and during the transition period between scrub and thoroughly cleared land, farmers become possessed of a complete wheat-growing equipment, and because of this, and because wheat-growing has been their principal or almost sole activity, they are often inclined to develop a wheat-growing outlook to the exclusion of other forms of production, and this eventually proves disastrous where soils have a natural tendency to drift, and particularly so when these soils are located in Mediterranean climatic conditions. In these conditions it is essential to bare-fallow the land in preparation for wheat, if highly profitable crops are to be produced, and this keeping of the land bare for eight or ten months on end, even if repeated only every three years or so, soon leads to serious drift. Farmers in South Australia who have continued to successfully work drift-liable holdings and who keep down the drift trouble are invariably men who have divided their agricultural activities between wheat and sheep, and in most cases have procured sheep for their farms as soon as they could maintain them with safety, and have gradually increased their livestock activities until wheat-growing has become secondary to sheep husbandry. Besides keeping a lot of sheep, most of these successful sand-farm farmers have developed or adopted systems of soil cultivation which keep coarse organic matter on the surface of the soil instead of overgrazing it or ploughing it right into the soil.

The control of drifting soils in South Australia is dependent upon growing the minimum of crops to be carted off the land as grain or hay, and the maintenance of the maximum number of livestock without overstocking to the extent of exposing the soil surface to the action of violent winds.

## PREVENTING DRIFT WHERE IT IS LIABLE TO OCCUR.

As with every other trouble in the world, prevention is better than cure where soil drift is likely to occur because if not controlled early, drift soon gets out of hand and becomes uncontrollable in itself, and a menace to land in its neighbourhood not likely to drift, by covering it over with poor quality drift sand. The advantages of prevention would be self-evident to farmers could they be convinced in time that their soils would drift if not handled with the utmost care, but it is one of the outstanding difficulties of the position that the owners of sandy land in its natural state appear quite unable to recognize the fact that the land is sandy, and even when this difficulty of realization is overcome, are usually satisfied that their particular block of sandy land is not of a drifty nature. This attitude usually persists until a rude awakening comes with a drift which cannot be held while droughty seasons persist, and unfortunately in many cases the holding of the land by strong weed growth which occurs in the first or second good season after the original drifting took place, re-awakens the false confidence in the stability of the soils of the farm. This false optimism is a most difficult phase of the trouble where newly settled country is involved, and when this can be broken down the problem is simplified to a considerable degree.

In the prevention of drift it is axiomatic that sandy farms should be livestock farms, and wherever it is economically possible, crops should not be carted off the land, but they should all be utilized by livestock maintained on the farm. Still, it is not always possible to do this, and when impossible, the aim should be to keep crops, other than those grown for farm animals, down to the minimum. In South Australia, sandy farms located in districts receiving 18 inches or more of average annual rainfall, should be conducted as livestock farms without growing any annual crops once the land has been properly cleared of the natural scrub. Where the average annual rainfall is below 18 inches some annual crops should be grown, even if all are to be utilized by livestock, and in some localities it will probably be advantageous to grow a few crops for carting off the land.

## PREVENTING DRIFT WHERE AVERAGE ANNUAL RAINFALL IS EIGHTEEN INCHES OR BETTER.

Almost all of the sandy lands in localities in South Australia receiving 18 inches or more of average annual rainfall, with the possible exception of deep white sands, can be farmed by careful, thrifty farmers, if the cropping has been conducted without the growing of annual crops. This can be done by establishing pastures and regularly top-dressing with liberal applications of superphosphate. Soon after the scrub has been killed, no matter by what means, a mixture of about 6lb. Subterranean Clover (*Trifolium subterraneum*), 4lb. Wimmera Rye Grass (*Lolium subulatum*), 2lb. Evening Primrose (*Oenothera odorata*) and ½lb. Yorkshire Fog (*Holcus lanatus*), should be seeded to the acre in the autumn with 2cwt. superphosphate, making certain that the seed is not covered to too great a depth. In the lower rainfall portions of this zone, say where the average rainfall is between 18 and 20 inches, an early strain of subterranean clover should be used, and the Yorkshire fog can be left out of the mixture. These mixed pastures grown in moderate-sized fields, in each of which there is an adequate water supply, and receiving an application of 1½ to 2cwt. superphosphate per acre each autumn, will carry large numbers of livestock, and particularly sheep, and provided that the fields are never grazed so heavily that the land is bared, not only will there be no drift, but the fertility of the land will be rapidly improved. After a few years of grazing such pastures in districts with from 18 to 24 inches average annual rainfall, and if lucerne flea has not made its appearance on the pastures, some of the fields can be cultivated in the early autumn and seeded down with a mixture of 6lb. of Lucerne and 2cwt. superphosphate per acre. The lucerne crops will make excellent growth and provide heavy grazings of succulent feed when most of the other pasture plants have dried out.

When the average annual rainfall is greater than 24 inches there is no need to consider changing the pasture once it is established on sandy land, but in such cases it is advantageous to increase the quantity of superphosphate used in the annual application. Where the rainfall is so heavy, the danger of drift is less, because there is usually fairly good summer growth, including such fodders as Rooted Cats-ear (*Hypochoeris radicata*), and Rib Grass (*Plantago lanceolata*), which appears after the other pasture plants have dried off, but even though it is fairly easy to hold sand where the rainfall is high, drift can be serious if once allowed to take place. Farmed in the above-mentioned manner, drift will never be experienced, provided always that overstocking is not indulged in under any circumstances whatsoever, and that the whole of the pastures receive annual applications of superphosphate.

## PREVENTING DRIFT WHERE THE AVERAGE ANNUAL RAINFALL IS FROM FOURTEEN TO EIGHTEEN INCHES.

The problem of preventing the drifting of sandy lands in districts where the average annual rainfall is between 14 inches and 18 inches is not such an easy matter as in places where the rainfall is heavier; nevertheless, it can be done, provided that the likelihood of drift occurring is realized in time.

Although not absolutely essential in these conditions that crops to be carted off the land should be grown, in many cases it is of monetary advantage to grow such crops occasionally, even after the land has been thoroughly cleared of scrub. Although it is possible to farm some holdings in these conditions with permanent pastures only, in most cases it is necessary to prepare the land and grow some annual crops in regular rotation to be able to get the best out of the land.

Even though it may be found advantageous to cultivate the land occasionally, and this will be mainly because of the necessity of keeping down bad weeds which grow so profusely in such conditions, the safest system of farming to adopt, in so far as preventing the occurrence of drift is concerned, is livestock farming, wherein everything grown on the land is marketed as a livestock product. It must not be forgotten when working out the rotation of crops to adopt, that most of the districts which come within the rainfall range of 14in. to 18in. are liable to experience some fairly marked variations in the seasons, particularly in the lower rainfall districts, and so it is very necessary to conserve fodder in some form or other when undertaking livestock farming. In such conditions there is probably no better form of fodder to conserve for the future of the farm livestock than the grain of one of the cereals, and because it is easily grown, preferably barley.

A system of farming sandy land in these rainfall conditions as a livestock proposition pure and simple, without much fear of the soils ever drifting, would be—(1) lucerne, (2) lucerne, (3) lucerne, (4) lucerne, (5) mixture of rye and oats for grazing, some of which could be cut for hay, (6) barley for grain to conserve, and then return to a four-year stand of lucerne.

If it is desired to grow some wheat, and it is sometimes advantageous to do so, a safe system to follow would be—(1) bare fallow, (2) wheat for grain and some hay, (3) barley for grain to be consumed on the property, (4) lucerne, (5) lucerne, (6) lucerne, (7) lucerne, and then fallow for wheat.

A shorter rotation without lucerne, which should also prove safe insofar as preventing drift is concerned, would be—(1) bare fallow, (2) wheat with which wimmera rye grass seed was shown, (3) mixture of rye, oats and King Island melilot for grazing, (4) pasture, (5) pasture, and then fallowed next year.

In connection with the cropping, there are a few points to be considered. Lucerne would be sown in the barley stubble after grazing it down with sheep to clean up the flag and thin out the straw a bit, using a mixture of 6lb. seed and 1cwt. superphosphate per acre, by seeding it with a disc drill in the autumn. Barley could be sown in June-July at the rate of 50lb. seed with 1cwt. superphosphate. The mixture of cereals should consist of 1bush. oats and 30lb. rye, and where King Island melilot is to be used, 4lb. of this legume can be added to be seeded per acre with 1cwt. superphosphate. About 3lb. of wimmera rye grass per acre is sufficient to seed with the wheat crop.

In preparing the fallow before wheat, fire should not precede the original breaking up, even if there should be a good deal of rubbish on the land, neither should a plough be used, much better results where the control of drift is desired being secured from the use of a rigid-tined cultivator instead of a plough. Very few cultivations should be given to the land during the fallowing period, sheep being used to keep down the weeds, but it is essential that the original cultivation in the winter, and any subsequent workings, should be given as nearly as possible at right angles to the prevailing winds, which come in the main from the west in southern South Australia, and the cultivator should never be worked round and round the fields, as is the usual practice in non-drifty country.

To ensure sufficient growth of plants to hold the soil during the years of pasturage, it is essential that the whole area left out should be dressed with from 90lb. to 1 cwt. superphosphate per acre each year.

## PREVENTING DRIFT WHERE AVERAGE ANNUAL RAINFALL IS BETWEEN TWELVE AND FOURTEEN INCHES.

Very great difficulty indeed is experienced in farming sandy soils where the average annual rainfall is low, and the lower the rainfall the greater the difficulty in preventing drift, but it has been proved possible by careful, thrifty farmers in every locality in the State where these climatic conditions obtain, and because of the success of some it should be possible over whole districts, provided certain practices are strictly adhered to. In low rainfall districts the difficulty is so great because of the extremely high temperatures, low humidity, heavy winds and long periods during which rain does not fall, which are commonly experienced in all of the localities in South Australia receiving less than 14in. of average annual rainfall. Not only do the relatively long dry periods which occur each year increase the difficulty of preventing drift, but in these low-rainfall conditions the seasons are very erratic, and the variations between the yearly falls which go towards making the average rainfall are very great, and quite a high proportion of the seasons are of a droughty character. Because of the great trouble in securing growth of any kind in the droughty seasons, and the difficulty experienced in keeping edible organic matter of any kind on the land during the dry periods which occur each year, it is imperative that sandy lands in low rainfall conditions should be managed as sheep farms, and if any crops are carted off the land they should be very few indeed.

On all farms in these low-rainfall districts high sandhills should be kept out of cultivation, and better still, should be enclosed with vermin-proof fences to keep rabbits and farm livestock off these ridges at all times, so allowing the natural scrub and other bushes to re-establish themselves. High sandhills in low rainfall districts of South Australia are only suitable for agricultural purposes when plenty of irrigation water is available at a reasonable cost, and because of the great difficulty in preventing them from drifting and because of the enormous mass of sand in these hills, which becomes a menace to better land in their neighbourhood, when it appears that these ridges might drift if the natural growth is removed, they should never be cleared with the intention of farming the soils under natural rainfall conditions. If cleared in ignorance, or for the control of vermin, or for any other reason, the sooner these ridges are withdrawn from the ordinary agricultural activities of the farm the better.

Sandy lands other than the high hills should be kept covered with organic matter of some kind, such as grain crops, pasture plants, dry feed or dry weeds, the whole time, even if attempts are made to produce grain for sale, otherwise drift is inevitable in a relatively short time. Because of the frequency with which good pasture plants are replaced by useless weeds in the low rainfall districts when cleared, if sandy land is left out of cultivation for a number of years, and even if regularly topdressed, it becomes necessary to establish grazing plants every now and again which will compete with the valueless plants and provide feed for sheep. A system of management which is workable and will prevent drifting is :—(1) Mixture of rye and oats, for grazing, of which some may be cut for reserves of hay ; (2) barley, with which is sown some wimmera rye grass and evening primrose. The barley to be harvested for grain to be fed to sheep in the periods of feed shortage in the autumn ; (3) pasture ; (4) pasture.

Perhaps, however, the following system of farming the land would be better still in most cases :—(1) Rye and oats ; (2) barley ; (3) lucerne ; (4) lucerne ; (5) lucerne. If it is desired to produce some wheat as well, a longer rotation should be followed by :—(1) Cultivating the land in the winter with a rigid-tined cultivator at right angles to the prevailing winds. Weeds to be kept down by sheep and no further cultivation given during the season unless immediately after soil-soaking rains ; (2) wheat ; (3) rye and oats for grazing ; (4) barley ; (5) lucerne ; (6) lucerne ; (7) lucerne.

## RECLAIMING FAIRLY BAD DRIFTS.

When sandy hillocks and ridges have been cultivated for some years, or have been overgrazed too frequently and have drifted so badly that " craters " have been formed because the sand has blown out to leave big depressions, or the moving sand has formed irregular-shaped knobs of loose and bare sand here and there, the drift must be stopped if the land is ever to become useful again for agricultural purposes. Even if not to be again farmed, the drift must be stopped to remove the menace of the loose, drifting sand tending to ruin good agricultural land in its close neighbourhood, or becoming a nuisance on roads, railways, reservoirs, etc. The reclamation of such drifting sands is by no means easy, no matter where they occur, and is particularly difficult in localities where the average annual rainfall is low, but wherever it is being successfully undertaken, control has invariably consisted in again covering the surface of the land with growth of some kind or other.

To bring these drifts under control quickly, it is essential to break down the edges of " craters " and to level out the knobs and hillocks formed by the wind, so that the seed drills ordinarily used on farms can be run over the loose, sandy areas without missing any of the surface when seeds are being drilled into the sand. Because of the looseness of the sand and the great steepness of the " crater " faces, best results are secured by using a heavy plough drawn by a team of bullocks, and next to this method, a caterpillar tractor drawing the plough gives fairly good results, but is difficult to manipulate where the drift is very bad. This breaking down of the irregularities in the drift cannot be done any length of time previous to the seeding season, otherwise the autumn winds will continue to shift the sands while waiting for sufficiently heavy rains to make certain of a good germination of seeds drilled into the areas, so in ordinary seasons, in most of the agricultural areas of South Australia, the operation would not be commenced until well on in April. As soon as good seeding rains have been received, seed and fertilizer should be drilled in, and better results are generally secured if the seeding is done by cross-drilling in two directions using half of the seed and fertilizer each trip.

In most of the farming districts of the State a mixture consisting of 40lb. rye, 40lb. oats, 2lb. lucerne, 2lb. wimmera rye grass, and 1lb. evening primrose, if drilled in per acre with 2 cwt. superphosphate, will be successful in holding the sand in the year of seeding, provided that a reasonably good job was made of levelling out the irregularities in the drift, and will provide sufficient protection for all time if the areas are regularly top-dressed with superphosphate and the resulting growth is never under any circumstances whatsoever, overgrazed. In localities in South Australia where the average annual rainfall exceeds 22in., the lucerne seed would be left out of the mixture, and be replaced by 2lb. Subterranean Clover, and ½lb. Yorkshire Fog.

As soon after the seeding is completed as is convenient, the drifted area should be surrounded with vermin-proof fences capable of keeping farm livestock and ground vermin, such as rabbits, off the area.

In the year of establishment no animals should be allowed on the area to graze the growth, and it should be left untouched to mature seed, after which, if it is desired, some of the mixture of rye and oats might be harvested, provided particular care is taken to leave as much straw behind as is possible.

If a normal season is experienced when attempting to establish a protective vegetative cover for these drifts, there would be in the second year a good stand of lucerne and Wimmera rye grass and a fair sprinkling of evening primrose, and on the portion not harvested for grain a dense germination of both rye and oats. It would be better in its second year, to top-dress the area with superphosphate in the autumn and again exclude all grazing animals from the growth so that a good bulk of organic matter is assured to protect and hold the surface. After the second year these drift-liable areas should be regularly top-dressed with superphosphate each autumn and only lightly grazed wherever there is thick and strong pasturegro wth, remembering that if the sand is to be prevented from drifting, it must never, under any circumstances whatever, be bared by over-grazing, and in the management of such lands it is essential to aim at the other extreme by understocking to such an extent that there is always a mass of organic matter covering the soil surface.

To ensure protective cover for the surface soil, and at the same time to secure a fair amount of grazing at various times of the year, drifty sand in districts of over 18in. of average annual rainfall should receive an annual dressing of at least 1cwt. superphosphate per acre. When the rainfall is lower the dressing should be from ½ to 1cwt. according to the rainfall. If it is not considered an economic proposition to apply the superphosphate annually, then no fertilizer should be supplied, and the vermin-proof fences should be kept in good order and grazing animals of all kinds should be rigidly excluded from the drift-liable areas.

## RECLAIMING AND HOLDING BAD DRIFTS.

With very deep, loose sands which drift really badly, and where the trouble is liable to recur without much incitement, the drift usually occurs after a very short period of cropping or overgrazing, rapidly becomes serious and soon renders the areas unfit for ordinary agricultural operations. If that was the full extent of the trouble, the problem would not be so very serious, because it would only concern the affected areas by removing them from agriculture, but it is not such a simple matter, for these loose, drifty sands not only become useless for agricultural purposes, but they move so rapidly with each wind that they cover other good agricultural lands in their near neighbourhood, and so become a menace to whole districts as well as lead to much trouble to roads, railways, reservoirs, fences, etc. When occurring in farmed districts, it is essential that sands very liable to drifting be properly controlled so as to eliminate the danger of ruination of the good lands of the particular locality, and to protect near-by public utilities.

Where the drifting areas are of this very serious nature, the movement of the sand can be checked quite readily by covering the principal parts of the areas with coarse organic matter such as straw, cocky-chaff, weeds, stable manure, bushes or tree branches, and provided that the affected areas are protected against grazing livestock by being enclosed within vermin-proof fences, all of the materials mentioned will hold the drift for several years. In so many cases when drifts are held in check by such means, seedlings of different kinds appear, and in some cases so thick are the weeds and bushes that in a few years from the commencement of the control work a full surface soil-cover is obtained, and one which is sufficiently permanent to prevent further drifting, provided, of course, that animals are not allowed on the area. Where the tree branches used as a protecting cover consist of mallees, local acacias or native pines, a good germination of seeds falling from the branches occurs in some instances, and when this fortunate happening takes place, the problem is solved very quickly, provided that animals are kept off the areas until the trees are properly established, and provided, also, that no further efforts are made to again clear these areas of the resulting growth.

To make more certain of promoting sufficient bush and tree growth on these very bad drifts, seeds of certain plants, seedlings of some of the trees, and rooted sections of other good sand-binders should be planted in amongst the layer of protecting coarse organic matter after the vermin-proof fences have been erected. The kind of plants to use for the purpose of permanently holding these bad drifts varies considerably, of course, according to the average annual rainfall received in the particular locality.

In the heavier rainfall districts where the average annual rainfall is 22in. or above, seeds of Evening Primrose (*Oenothera odorata*), Subterranean Clover (*Trifolium subterraneum*), Paspalum (*Paspalum dilatatum*), Golden Wattle (*Acacia pycnantha*), and the Black or Silver Wattle (*Acacia decurrens*), could be broadcast amongst the protecting organic matter; or in the better rainfall portions, seedlings of the Remarkable Pine (*Pinus radiata*) could be planted in rows, or rooted sections of Pyp Grass (*Ehrharta villosa*), Buffalo Grass (*Stenotaphrum dimidiatum*), Kikuyu Grass (*Pennisetum clandestinum*), Giant Lyme Grass (*Elymus giganteus*), Marram Grass (*Ammophila arenaria*) or Couch Grass (*Cynodon dactylon*) could be transplanted to hold the sand after the coarse organic has decomposed. Other sand binding grasses worth a trial in such conditions are *Calamagrostis epigeios* and *Brachypodium phoenicoides*, both of which produce strong, underground stems, and dense, luxuriant growth with good soil-binding qualities, as well as having fair palatability for farm livestock.

In localities where the annual rainfall is from about 14in. to about 20in. on the average, the establishment of sand-binding plants is not quite so easy as in places where the rainfall is higher, but there is a fairly extended choice of plants for the purpose, many of which are indigenous to the country, which could be utilized with some degree of certainty. Seeds for distribution amongst the organic matter spread on the surface which have every chance of germinating well, and which will help considerably in the permanent control of these bad drifts, are Hairy Blue Lupin (*Lupinus hirsutus*), Evening Primrose (*Oenothera odorata*), local sand-binding Wattles (*Acacia* spp), Umbrella Wattle (*Acacia ligulata*), Golden Wattle (*Acacia pycnantha*) African Boxthorn (*Lycium ferocissimum*), Pepper Tree (*Schinus molle*), Giant Salt Bush (*Atriplex nummularium*), Tree Lucerne (*Cytisus prolifer*) and Date Palm (*Phoenix dactilifera*). Trees for transplanting, which will do well in the better rainfall portions of the zone are Black Locust (*Robina pseudo-acacia*), New South Wales Swamp Oak (*Casuarina glauca*), Cork Elm (*Ulmus suberosa*), White Poplar (*Populus alba*), Tree of Heaven (*Ailanthus glandulosa*), Oleander (*Nerium oleander*), Olive (*Olea Europaea*), and any other Mediterranean tree which suckers freely. In the lower rainfall parts of the zone under review, the seedlings of such trees as local Eucalypts (*Eucaluptus* spp.), Lagunaria (*Lagunaria patersoni*), Aleppo Pine (*Pinus halepensis*), Canary Island Pine (*Pinus canariensis*), Stone Pine (*Pinus pinea*), Native Pine (*Callitris* spp.), New South Wales Swamp Oak (*Casuarina glauca*) and Pepper Tree (*Schinus molle*) can be planted out in rows with confidence that they will grow and help in the stabilization of the sands, whilst rooted sections of the Giant Reed (*Arundo donax*), Oleander (*Nerium oleander*), Olive (*Olea Europaea*), and cuttings of Tamarisk (*Tamarix gallica*) would also prove of considerable help in the matter. Of other sand-binding plants, rooted sections of Pyp Grass (*Ehrharta villosa*), Buffalo Grass (*Stenotaphrum dimidiatum*), Couch Grass (*Cynodon dactylon*) and Giant Lyme Grass (*Elymus giganteus*) will all be found to be useful in such natural conditions.

In the very low-rainfall parts of the farmed areas of the State still more difficulty is experienced when endeavouring to replace the natural cover which was removed from the areas now drifting badly, and success is only possible when great persistence is practised. Should the cover of coarse organic matter be spread on the drifts during a series of good seasons, plenty of plants could be established, which will hold the sand, but on the other hand, should the original protective cover be placed during a run of " dry " seasons, it is quite possible that the coarse organic matter will rot right away before sufficient perennial plants have developed, and it will then be necessary to spread another layer of organic rubbish. Of seeds to broadcast amongst the organic matter in these low-rainfall districts, rye, Giant Salt Bush (*Atriplex nummalarium*), Nitre Bush (*Nitraria schoberi*), local sand-loving Wattles (*Acacia*, spp.), Umbrella Wattle (*Acacia ligulata*), and Native Pines (*Callitris* spp.) will germinate in favourable seasons and make permanent protective cover. There can be nothing better in the tree line to plant seedlings of than indigenous kinds of which the local eucalypts, myoporums and eremophilas are all suitable, and rooted sections of the giant reed, olive and oleander will help in the work of this difficult drift control. Sand-binding surface plants which can be transplanted with advantage are pyp grass, buffalo grass, couch grass, giant lyme grass and nitre bush.

### STRIP CROPPING OF DRIFTY SANDS.

In climatic conditions which are favourable to the production of a varied assortment of crops of different types, fairly successful control of drifting sands has resulted from cropping affected fields with several kinds of crops, sown in strips parallel to one another, and so arranged that they run across the line of the prevailing winds. Such a method of control is only possible in countries with a Mediterranean climate in districts where the average annual rainfall is very high, but where these conditions exist in South Australia it is a more economic farming proposition to keep the land under permanent pastures instead of attempting cultivation for crop raising. Where the average annual rainfall is relatively low, in such a climate the annual crops which can be successfully grown are cereals, and a couple of varieties of very early field peas, and with this limitation of wheat, barley, oats, rye and peas as the only crops from which profits can be expected, there is no possibility of conducting strip cropping in a manner which will help to control drifting sands. Not only is there the limitation of types of crops which can be grown, but with the principal one of them, viz., wheat, it is essential that it be grown on bare fallow, and it is also essential in most parts of this country that when light-textured soils are bare-fallowed, no more cultivation than is absolutely necessary is given, and sheep must be used extensively to keep down the weeds. Because of this, it is quite impossible to have strips of fallow and strips of crop in the same field at one and the same time.

## WATER EROSION.

One of the worst forms of soil erosion is caused by the action of water moving over the surface of the soil, and in the process transporting particles of soil which have been loosened from one place and depositing them in another.

As the ability of moving water to scour varies as to the square of the velocity, it follows that anything which tends to retard the velocity of moving water also reduces its erosive power. Vegetative cover is probably the most important factor of all those reducing erosion, and in order that its part in influencing the run-off from any given area may be properly understood, it is necessary to consider this factor, together with all the others exerting such an influence. These are—total annual rainfall, and its distribution, evaporation, the topography of the country, geological structures, soils and vegetation.

### RAINFALL.

Rainfall varies widely from year to year, and for corresponding months of successive years ; indeed, it may be said that in one way or another every year is an exceptional one in this respect.

When rain falls on the earth's surface it either soaks into it, or some of it soaks in and some runs off. The relative amounts that will soak in or run off depend upon the severity of the rain storm, the nature of the soil surface and its physical condition.

The water which soaks into the ground is retained by capillary attraction in the interstices of the soil, or passes down through the soil by gravitation to be retained in subterranean basins, or later to appear as springs. Each class of soil can only retain a certain quantity of capillary water. It follows, therefore, that water soaking into the soil will not pass through it to augment spring flow until the interstices of the soil are fully charged with capillary water, and if once they are so charged all water soaking into the soil will pass through it by gravitation. If the moisture falls slowly this process may continue for some considerable time, but if rain falls more rapidly than it can be absorbed, the surface soil becomes saturated, and the excess remains on the surface as free water.

Water which has penetrated into the soil seldom leads to erosion, therefore, the more water that soil can absorb, and the more rapidly this takes place, the less will be the eroding power of that which remains. In fact if all rain water were absorbed as fast as it falls, there would be no erosion from this source. It is obvious, therefore, that to prevent or reduce erosive action conditions conducive to the absorption of large quantities of rain water are desirable.

## EVAPORATION.

The capillary water is evaporated from the earth's surface by the action of sun and wind, the lower layers of water rising to the surface by capillary attraction to be in their turn evaporated. At the end of a long dry summer the surface of the soil is dry to quite appreciable depths, and the capacity of the soil for capillary water is considerable. Normal winter rains falling upon it when it is in this condition will be absorbed rapidly, and little or no run-off will occur. As the winter rains continue the capacity of the soil for capillary water becomes over-taxed, and in this condition run-off will take place. Evaporation is, however, continuous, though of varying severity, and if dry spells occur during the rainy season a portion of the rain falling at the break of each dry spell will be required to make good the intervening loss of capillary water by evaporation.

The rate at which soils can absorb water varies greatly, coarse sandy soils absorb it very rapidly, and surface run-off from this type of soil only occurs from very heavy rain storms. Heavy clay soils on the other hand can absorb it but slowly, and surface run-off will, therefore, result from much less heavy rains. Furthermore the rate or rise of capillary water, and, therefore, the rate of surface evaporation, are much greater in coarse sandy soils than in heavy clay loams. From the coarser sandy soils, then, run-off may only be expected if the rainfall incidence is such that the rate of evaporation is more than offset, and in such circumstances the yield will usually be by gravity, water passing through the soil to augment spring flow.

## TOPOGRAPHY AND GEOLOGICAL STRUCTURE.

The topography and geological structure of the country exercise considerable influence upon the run-off. Steep rocky hillsides will absorb little or no water, run-off from them will be great in quantity and rate. From gentle slopes the rate of run-off will be less, and the quantity will depend upon the type of rainfall, the soil and the vegetation.

The geological structure will determine whether gravity water passing through the soil will re-appear as spring flow, or be stored in subterranean basins.

## SOIL.

The influence of the nature of the soil upon the evaporation rate by reason of the varying rate of capillary rise has been dealt with above. The surface run-off rate will be greater from less permeable soils, especially from sloping ground. The influence of tillage and mulches to reduce the evaporation loss from the soil is too well known to need elaboration.

## VEGETATION.

For their growth all plants require water, and many species transpire large quantities. The water required by the natural vegetation of the country is supplied by rainfall, and to this extent vegetation may be expected to reduce the run-off. There are, however, other factors to be taken into consideration, such as the shade provided by the growing plants and the mulch of vegetable waste reducing the evaporation from the soil.

In the late autumn and early winter the first rains are generally absorbed in supplying the soil capillary water deficiency due to summer evaporation, and run-off does not, as a rule, occur from these rains. Portion of the capillary water is transpired by the vegetation, and this too must be made good by rainfall before run-off will result.

It should be noted, however, that those grasses which transpire the largest quantities of water provide also the densest surface cover, and what is more important so far as erosion is concerned, retard the velocity of water shed from the country.

Vegetation has a three-fold influence as a protection to the soil against the destructive action of running water. The stems, leaves and branches intercept the rainfall before it touches the soil, thus breaking up the force of its fall, and the resulting pounding action which always takes place on hard bare surfaces. Raindrops, therefore, reach the surface of the soil at greatly reduced velocities. It also tends to minimize the concentration of water on the surface, and its collection into streams. In addition, its roots hold the soil particles together, and both living and decaying roots open up the soil and form small passage ways in the lower layers whereby water is more rapidly absorbed by the soil, and allowed to pass into the subsoil.

Wind erosion has been dealt with in another section, consequently the following remarks have been principally confined to erosion and denudation by the action of water, but as the ill-effects are so often a result of both wind and water, some references have been made to the effects of wind as well as of water.

When small gutters are formed by the passage of water through fallow land, in most cases an endeavour is made to prevent enlargement of these gutters by immediately cultivating over them at right angles to the slope of the ground. If the gutters are too large to be dealt with in this manner, it is the custom to first plough a few furrows up and down the gutter and then to cross-cultivate as before. Sometimes however, the gutters are not level with the adjacent land and a distinct depression remains. The next rain causing run-off deepens this depression, and although the land is again cultivated, this merely has the effect of " feeding " the watercourse with further material for removal. For a time this method retards the deepening of the channels by generalizing instead of localizing the erosion ; that is to say, the same quantity of soil may be removed by the water, but it is obtained from a larger area. Subsequently, a heavy rainstorm causes portion of the depression to scour out to a considerable depth with vertical sides, When parts affected in this manner are abandoned, the erosion soon extends up and down the watercourse. and the watercourse and land adjacent to it can no longer be used for the production of crops. Gutters are often formed in land under crop by heavy spring or summer rains, which cannot be levelled off without severely damaging the crop, or in some cases, cannot be seen until the crop is removed. Generally, when a watercourse reaches the stage when it cannot be dealt with by cultivation, no attempt is made by South Australian landholders to check subsequent erosion, and in a few years it scours to a width and depth, greater than that necessary to discharge the water flowing during periods of maximum run-off. The high velocity causes the banks to undermine and large blocks of earth fall in to be removed by the next flow. Water also commences to flow into these watercourses from the sides, and tributaries or secondary drainage channels are thereby formed. In some cases, stones, straw and manure have been dumped in the watercourses in an endeavour to check erosion ; this merely retards it, but does not stop further erosion.

## DISTRICTS AFFECTED BY WATER EROSION.

No attempt has been made to review the position of water erosion in detail in the State as a whole, but particular attention has been given to the northern agricultural areas where the effects of water erosion are most pronounced.

In dealing with the northern agricultural districts in detail they have been divided into areas consisting of groups of hundreds and part hundreds in which the conditions of rainfall, nature of the soil and surface slopes are similar, as shown coloured and lettered on the accompanying Map No. 3, and to keep the remarks as concise as possible, particular instances are described and illustrated.

## GROUP "A" (MAP No. 3.)

Hundreds of Napperby (south), Howe (south), Booyoolie, Belalie, Crystal Brook, Yangya, Narridy, Bundaleer, Reynolds, Caltowie, Redhill, Koolunga, Yackamoorundie and Andrews.

The first group to be discussed covers an extensive area of valuable agricultural land which has suffered damage by erosion from the action of water and so will be dealt with in greater detail than some of the other grouped areas.

Most of the land within this group lies within the drainage basin of the River Broughton and its tributaries and a large proportion of it is comprised of various ridges running north and south forming the southern extension of the Flinders Range and the slopes adjacent thereto. Some areas are too stony or hilly for cultivation and are used for grazing purposes only, but the greater part of the area is agricultural land. Most of the area has been cleared and cultivated for a long time, and evidence exists to show that damage from water erosion has been proceeding for many years. Remedial measures must, therefore, take the form of correcting and preventing the extension of an existing evil.

## ILLUSTRATING THE TYPES OF WATER EROSION FOUND IN SOUTH AUSTRALIA.

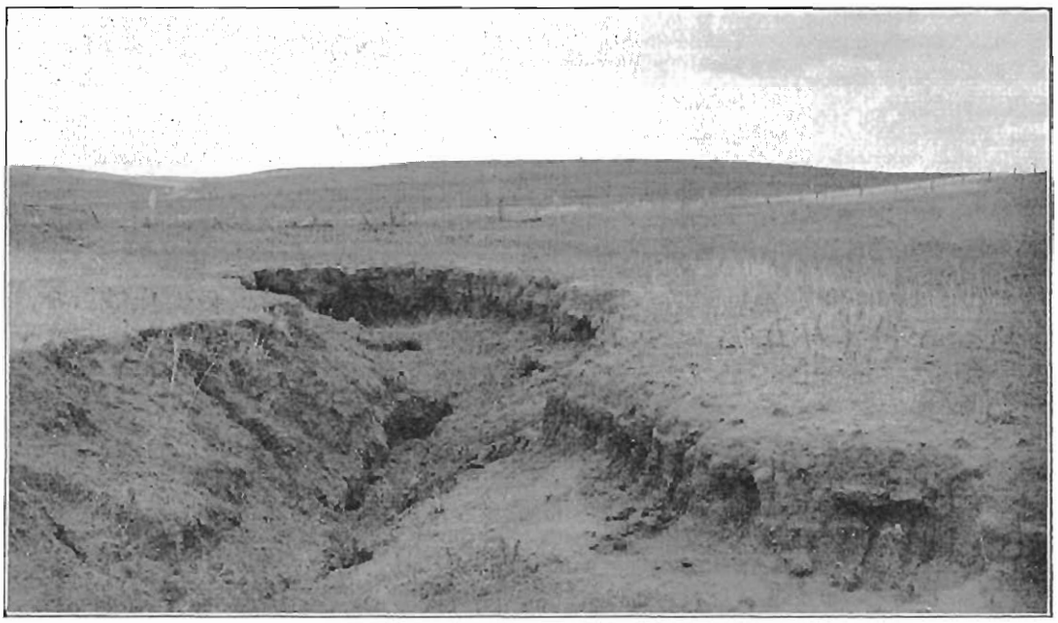


**Plate 1.**—An eroded gully in the Hundred of Reynolds. In the paddocks shown in the background, some erosion has taken place, but it is much more severe in the foreground, as the run-off is augmented by the water discharged rapidly from the macadamized road at this point. The land in the background is under cultivation, but in the foreground it has not been cultivated for many years, probably on account of the number of eroded gullies of the type illustrated. It can be seen that all the natural herbage has been entirely removed from the land drained by this gully.

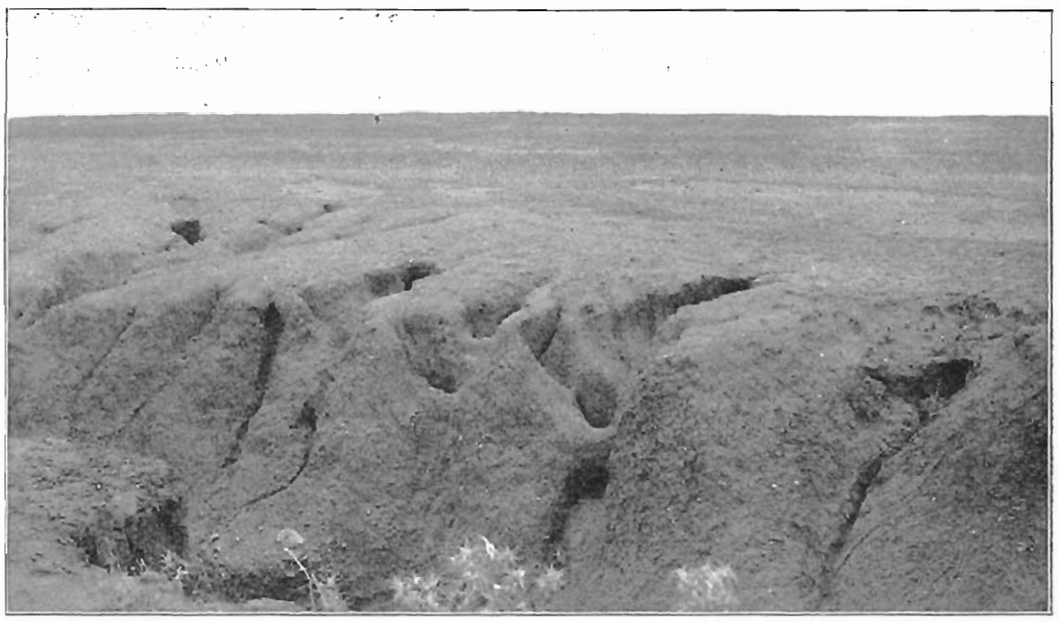


**Plate 2.**—The same gully as in Plate 1 a little lower down indicating the formation of the subsidiary eroded channels leading to the main channel. A complete new drainage system is, therefore, in the process of formation in country which had previously reached comparative stability under the influence of natural vegetation, but has since been rendered unstable by its eradication. This gully is typical of a number in this locality running southerly towards the River Broughton. Because of the large amount of soil suspended in the water flowing in these gullies after rainstorms it is rendered unfit for conservation.

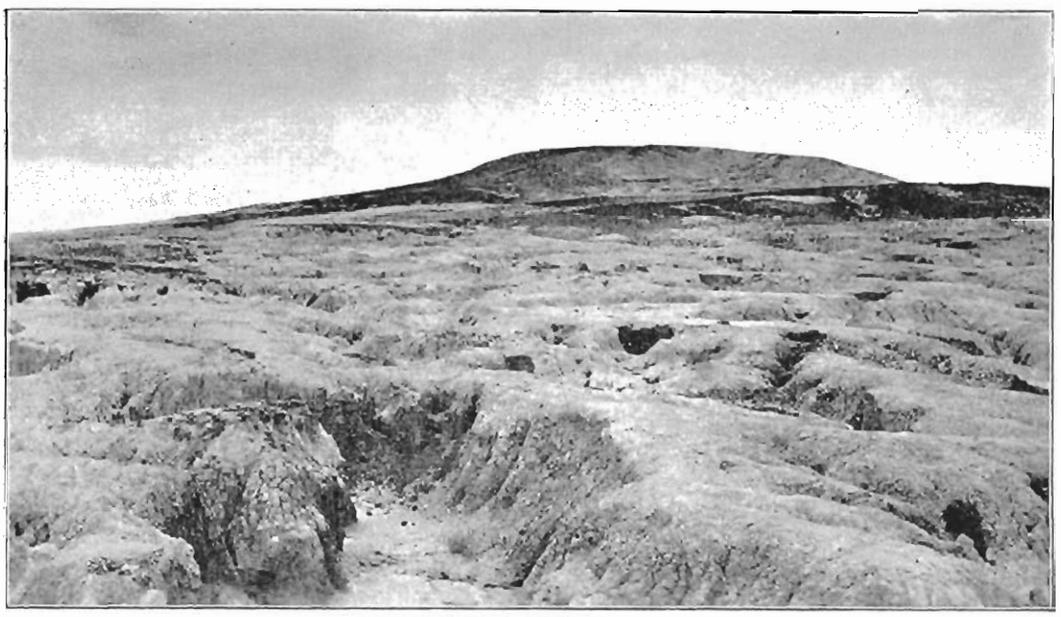


**Plate 3.**—Portion of Section 219w, Hundred of Reynolds, about one mile west of the gully depicted in Plate 2. The conditions in this case, however, cannot be regarded as typical, as the soil at this particular locality has been rendered very friable by mineralization. Laterite and fragments of quartz are present. Nevertheless, it is reasonable to assume that the erosion would not have occurred if the land had not been cleared in the first instance.

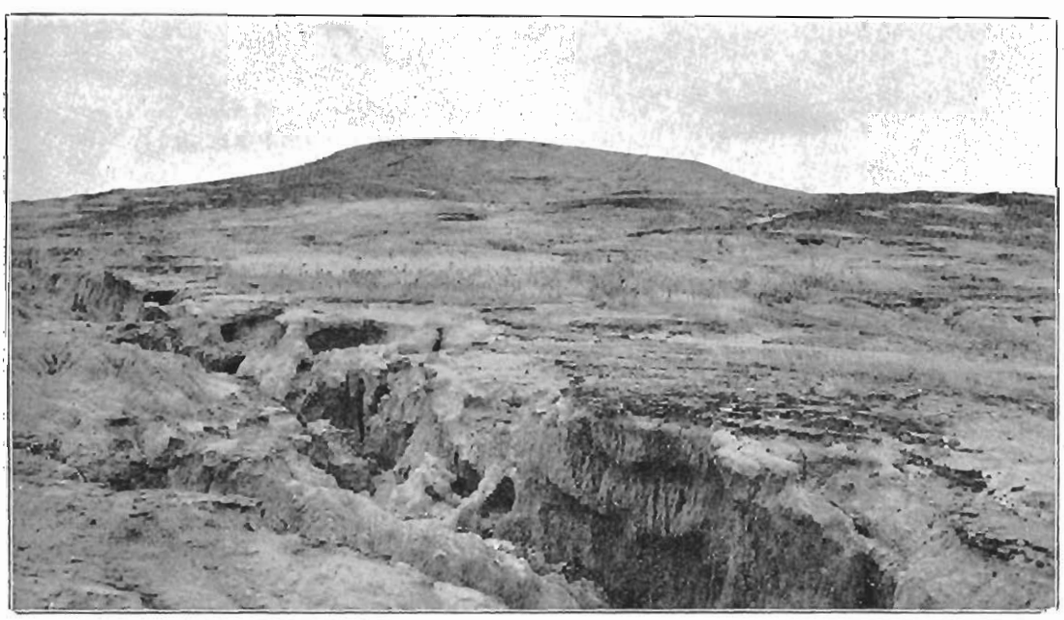


**Plate 4.**—Another portion of Section 219W, Hundred of Reynolds, where the erosion has cut deeper into the plain.

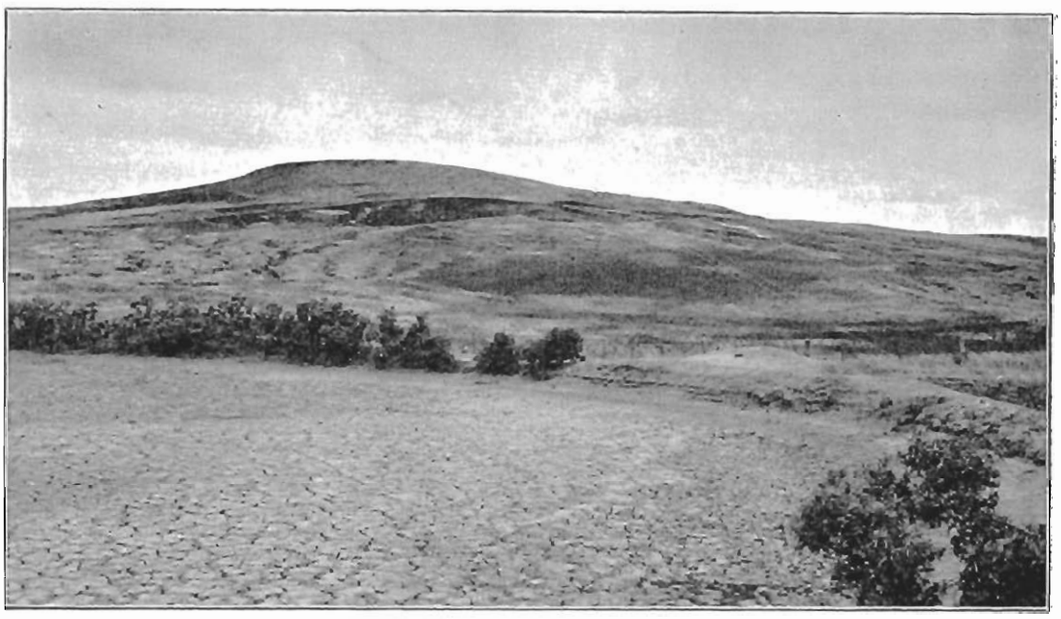


**Plate 5.**—Still another view of Section 219W, Hundred of Reynolds, showing in the foreground where a dam has been completely filled with silt during the last few years.

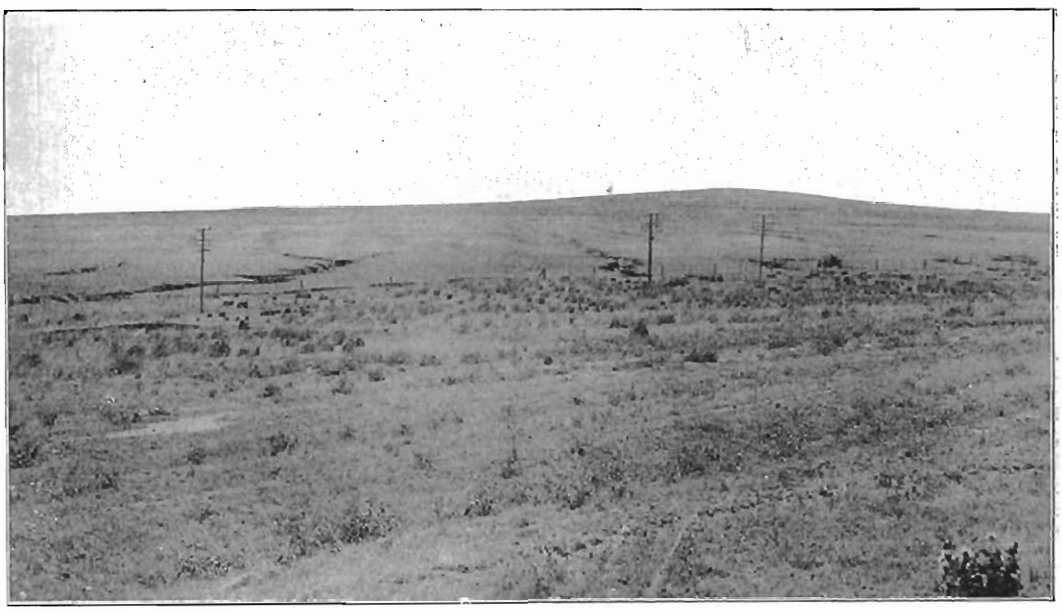


**Plate 6.**—A paddock adjoining the Main North Road in the Hundred of Yackamoorundie, about four miles north of Yacka. This land has been cleared, with the exception of a solitary tree on the ridge. This particular ridge was cropped during the present season, but erosion has rendered about six or seven acres of the slope entirely unfit for cultivation. Because of the damage by water erosion the value of the land has been materially decreased and, what is more, deterioration is still taking place.

**Plate 7.**—A gully in Section 168, Hundred of Yackamoorundie, leading southerly towards the River Broughton. Although a good deal of erosion has taken place, an endeavour has been made to keep it in check by cross-cultivation. In the mid-distance, however, can be seen a section about two chains long which has eroded to a depth of several feet, so rendering cultivation impossible. Unless steps are taken to check the elongation of this eroded section, it will ultimately extend over the entire length of the depression, causing a considerable area of good land to be abandoned for cultivation.

**Plate 8.**—Taken from the same position as for Plate 7, but looking south towards the River Broughton. Both photographs were taken from the road, and it will be seen that the control of erosion has been rendered more difficult by the additional water discharged from the road surface. The average depth of the eroded channel is about 6ft., and both its depth and width will increase considerably after every appreciable run of water following rain. Attention is called to the clearing of the hills at the head of this gully as shown in Plate 7.

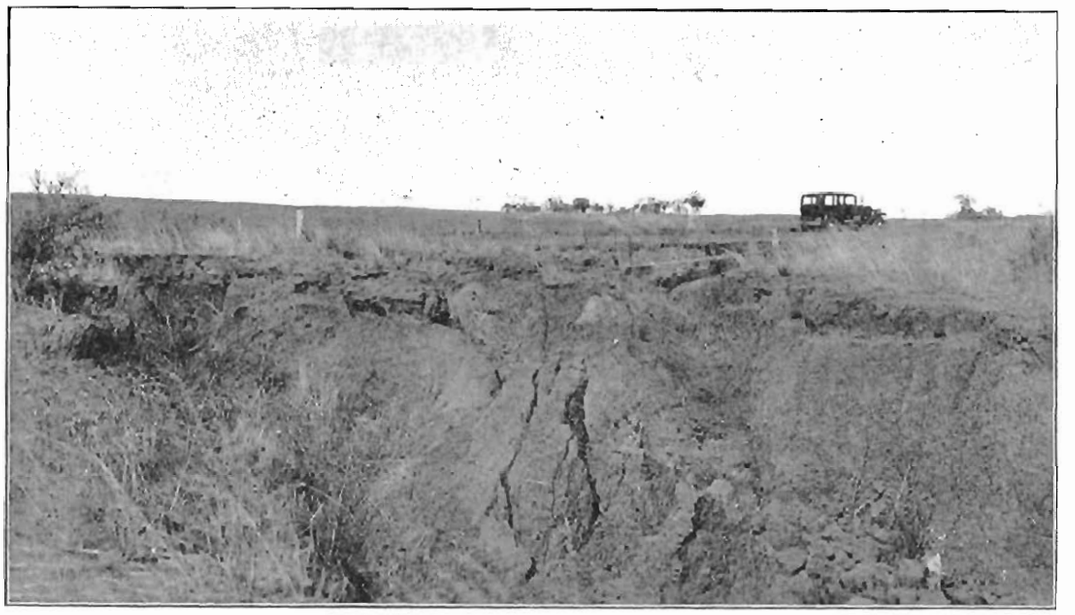


**Plate 9.**—An eroded watercourse on Section 737, Hundred of Crystal Brook. The car in the picture is standing on an earth road, and, although erosion has been kept in check above the road, a channel about 8ft. deep has been scoured out on and below the road, attributable mainly to the extra run-off from the road surface. This deep channel extends halfway across the 1-chain road, and constitutes a danger to traffic.

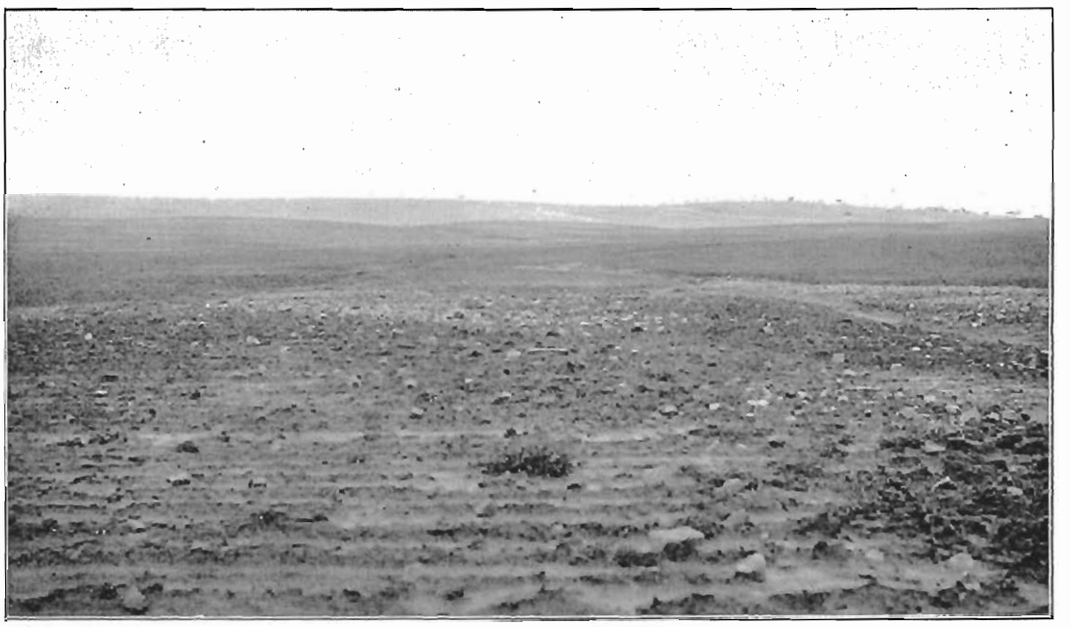


**Plate 10.**—From the road in Clement's Gap looking north in Section 638, Hundred of Redhill. In the background can be seen the cleared hills, in the mid-distance a number of small eroded watercourses, and in the foreground the flat upon which has been deposited some of the coarser eroded soil particles and rock fragments. After each heavy rain, a considerable depth of soil is deposited on the road, making it practically impassable for the time being.

**Plate 11.**—A small gully on Section 16 in the Hundred of Narridy. Cultivation is still possible across this gully, but erosion of the furrows where they steepen has taken place, and it will probably be impossible to check the erosion much longer, in which case cultivation of the gully will then cease and a definite watercourse will form.

The illustrations are typical of very many others and probably 75 per cent. of the holdings in Group A. (Map No. 3) are affected to some degree. It is possible to find erosion in all its stages, including re-erosion of channels in the alluvium of the river and creek valleys, and the commencement and progress of erosion in the subsidiary gullies. Practically all trees have been removed from this area, except where the slopes are too steep or the ground is too stony for grazing and cultivation, and even in the latter instance a large proportion of the timber has been cut down for land development purposes.

The native trees probably consisted mainly of She-oak, occasional patches of mallee on the hills, and gums on the gentler slopes and flats. Porcupine and other grasses also played a big part in the prevention of erosion by water. Prior to the removal of the vegetation referred to, more or less stable conditions prevailed, for the weathering and disintegration of rock on the hills had established slopes flat enough for this flora to establish itself, and thus minimize further erosion. The removal of trees and grasses during the last eighty years has, however, entirely upset the previous stable condition.

It is obvious that most of the damage has been caused by the removal of trees and grasses from the tops of the hills and ridges and from adjacent steep slopes, and it appears that a fair percentage of the land could have been cleared and cultivated without appreciable damage resulting from soil erosion had development of the land for agricultural purposes been confined to the flats and gentler slopes.

Porcupine Grass (*Triodia*) appears to be the main erosion-preventing plant in this area, and in localities where it has been left undisturbed on the hills and steep slopes the damage caused to cultivated land adjacent is very slight. The plant itself is capable of holding a large amount of water suspended in its foliage and the bushiness of its growth causes the water flowing off the slopes to take a devious course and discharge with low velocity on to the cleared area below. In a cultivated paddock on section 395, hundred of Andrews, a large hill exists. A strip of land has been cultivated along this hill, and below this strip, erosion was evident after recent rain, whereas on either side of this strip where the porcupine grass has not been destroyed on or near the hilltop, no erosion has taken place.

Generally, attempts do not appear to have been made to check erosion by re-afforestation or the re-establishment of suitable grasses on the high land, but on one holding in the Hundred of Bundaleer, conditions have been established which should effectively prevent erosion. A high hill exists, sloping fairly steeply down to a flat and creek. Porcupine grass has never been removed from the top of the hill and exists down to a point where the slope flattens to a grade of approximately 1 in 8. From this line down, the remainder of the slope and across the flat of the creek lucerne has been well-established, this plant having excellent soil-binding properties.

## GROUP "B" (MAP No. 3.)

### HUNDREDS OF PIRIE AND WANDEARAH.

The country in this group is very flat and contains a proportion of low-lying salt bush country and saline swamps. Water erosion in this area principally occurs on the banks of the River Broughton, but little damage is in evidence. Portion of the land is subject to inundation by floodwaters from the River Broughton, with consequent building up by successive deposits of silt therefrom. There is evidence of a certain amount of wind erosion and sand drift, but a number of the paddocks previously damaged by sand movement have been planted with lucerne with satisfactory results.

## GROUP "C" (MAP No. 3.)

### HUNDREDS OF MUNDOORA, WILTUNGA, WOKURNA AND TICKERA.

Most of the land within these hundreds consists of a layer of sandy loam varying in thickness from 4in. to 18in. overlying limestone rubble or nodular limestone, with successive low sandy ridges running in an east-west direction

Native timber consists mostly of mallee and she-oak, with some native pine on the higher ridges.

Rain falling is quickly absorbed, and with the exception of road surfaces there is very little run-off. Water from the roads or isolated patches of more compact soil runs to semi-impervious flats where it is removed partly by evaporation and partly by absorption.

Although the Barunga Range is close to the eastern boundary of this area, the absence of watercourses indicates that water shed from the hills is quickly absorbed, consequently there are few indications of erosion by the direct action of water, but there is no doubt that the action of heavy rain on cultivated land, by the separation of the finer particles of soil, makes it more susceptible to erosion by wind action, which is serious in this locality.

Large areas of land and stretches of road have been badly affected by sand drift, particularly in the southern portion of the Hundred of Wokurna.

## GROUP "D" (MAP No. 3.)

### HUNDREDS OF WALLAROO, KADINA, NINNES, KULPARA (WEST) AND TIPARRA (WEST).

The foregoing remarks with regard to Group "C" are, with some modifications, applicable to this group. In the Hundreds of Ninnes and Kulpara, the soil is heavier. Slopes are steeper and in the former hundred large areas drain to low lying ground, forming, in some cases, lakes which are more or less permanent, and little erosion as the result of water action is evident in these hundreds.

In the Hundred of Tiparra limestone carries a very light covering of soil and is exposed in many cases. Evidence of wind erosion is in existence, particularly in the Hundred of Wallaroo.

## GROUP "E" (MAP No. 3.)

### HUNDREDS OF CLINTON, CUNNINGHAM, MAITLAND AND TIPARRA (EAST).

The land within these hundreds was originally thickly covered with mallee, and no erosion has taken place where the mallee is still intact. With the exception of some saline swamps near the coast the soil consists mainly of fairly heavy clay overlying limestone, although in some places the soil is light and in others, particularly in the Hundred of Maitland, a great depth of clay overlies bedrock.

Erosion as the result of water action has taken place, but it appears to be controlled by cultivation. Particular attention is apparently paid to this matter by most of the settlers and no deeply eroded watercourses are apparent in this area. Most of the water running off the land drains on to clay flats, where it is eventually evaporated. In the Hundred of Maitland there is no reticulated water supply and dams have been constructed in most of the drainage channels.

## GROUP "F" (MAP No. 3.)

### HUNDREDS OF KULPARA (EAST), CAMERON AND BARUNGA.

Although the Hummocks Range runs north and south through these hundreds, and the hills and steep slopes have been cleared, damage by water erosion is not great, and the quantity of silt deposited in Bumbunga Lake and the smaller salt lakes on the eastern side of the range is very small.

There are some eroded watercourses particularly on the eastern side of the range, but it is apparent that the soil at the foot of these hills is more resistant to the action of water than it is adjacent to the southern part of the Flinders Range.

## GROUP "G" (MAP No. 3.)

### HUNDREDS OF TELOWIE, BAROOTA AND NAPPERBY (NORTH).

Little damage by water erosion is discernible in this locality, probably due to the fact that a large percentage of the rain falling on the western slopes of the Flinders Range in these hundreds is absorbed, and emerges in the form of springs or flows through pervious strata towards the sea.

When exceptionally heavy rains fall surface flows take place. This is confined mostly to well-defined cracks which are protected by water-worn rock fragments and gum trees. The hills have been partially cleared, but much of the natural timber and bush remains.

Evidence of wind erosion and sand drift exists on the plains between the hills and the sea.

## GROUP "H" (MAP No. 3.)

### HUNDREDS OF WINNINOWIE, DAVENPORT, WOOLUNDUNGA (WEST) AND CROZIER.

The country within these hundreds is situated immediately west of the Flinders Range, and is mostly utilized for grazing purposes. Cereal crops have been cultivated in some parts, particularly in the Hundred of Davenport, but on account of the low rainfall and the prevalence of high winds, have not been a success, and the practice has been abandoned.

Where cultivation has been adopted the blue bush, annual and perennial salt bush, and other herbage have been eradicated. This factor has had a marked effect on the erosion by wind and water.

There are many natural watercourses in this area, arising in or at the foot of the Flinders Range, and on account of the partial clearing of the hills and the removal of herbage from the slopes by overstocking and cultivation, the increased rate of run-off has induced scour. Numerous other small watercourses have also been formed on the slopes and plains. It appears that the most serious damage to the plains is due to the combined effect of both wind and water. The sandy loamy top soil containing the plant roots and seeds has been removed over large areas, and as a result there are many sand dunes which alternately move to and from the coast.

Some of the landholders have effectively minimized drift during the past few years by ploughing long stretches with four or five-furrow ploughs at intervals of from 10ft. to 15ft. over eroded land. Since the good winter of 1937 the extent of the re-establishment of natural herbage over areas so treated is remarkable, bush and herbage growing thickly in the furrows.

There are large tracts of land in the Hundred of Crozier and the northern portion of the Hundred of Davenport, which have not been overstocked or cultivated, and erosion in these areas is negligible. Erosion can best be checked in these hundreds by avoiding overstocking and cultivation, and by conserving the natural herbage.

The country is subject to long periods of drought or a succession of years of low rainfall, and a certain amount of erosion by wind and water will be inevitable after such periods. The winter of 1937 was a wet one, and further useful rains fell in December, 1937, and February, 1938, and as a result the country has materially improved, and many square miles of eroded plains have again been covered with herbage.

In the watercourses and patches of silt which are particularly liable to removal by wind action a thick growth of Tobacco bush is playing an important part. In such cases this appears to be a very valuable plant, and an erosion preventive, for stock will not destroy it, and even when it dies, the dead bushes lie on the ground and assist in holding the soil.

As in Group "G" the percentage run-off from the hills is not high, and much of the rain is absorbed and many springs flow throughout the year.

## GROUP "J" (MAP No. 3.)

### HUNDREDS OF YARRAH (WEST), WYACCA, KANYACKA (WEST), WARRAKIMBO, BARNDIOOTA, WONARKA (WEST), COTABARA, WOOLYANA (WEST), EDEOWIE, BUNYEROO, AND THE LAND WEST OF LAKE TORRENS.

This area lies to the west of the Flinders Range, and is purely grazing land. Flora consists of salt bush, blue bush, tobacco bush, acacia, myall and black-oak with gums on the creeks and flats. Much of this has been adversely affected by over-grazing and consequently the rate of run-off in the hills and slopes has been accelerated, with the result that erosion has been caused on the large creeks running towards Lake Torrens, and also general erosion on the plains.

As in Group "H" the plain erosion is the result of the action of both wind and water. An improvement might be expected by spelling certain areas for a period sufficiently long to allow the re-establishment of the bush, which would only take place after several good years had been experienced, and would be assisted by ploughing furrows on the bare wind-swept land at intervals from 10ft. to 20ft. apart across the line of the prevailing winds.

The plains in many places are bare except for some tobacco bush, and sand drift is bad in patches. Much silt is transported as the result of heavy rain and the silt and drift-sand damage the land and increase the cost of road and railway track maintenance.

## GROUP "K" (MAP No. 3.)

### HUNDREDS OF WOOLYANA (EAST), MORALANA, WARCOWIE, FRENCH, WONOKA (EAST), ARKABA, ADAMS, KANYAKA (EAST), CUDLA MUDLA, WIRREANDA, YEDNALUE, BOOLCUNDA, PALMER, MOOCKRA, UROONDA, EURILPA, YANYARRIE, BENDLEBY, McCULLOCH, PICHI RICHI (EAST), YARRA (EAST).

The natural creeks in this group have been enlarged by scouring, and fairly extensive damage has been done by the combined action of wind and water.

Land has been cleared and cultivated, but the climatic conditions experienced have been such as to adversely affect agriculture. Many of the plains are now bare, as most of the top soil has been removed, and land which, in its virgin state, was suitable for grazing, has depreciated as the result of erosion following cultivation. The good rains of last year have greatly improved the appearance of this country by promoting the growth of bush, but there is yet room for much improvement. Care should be exercised with regard to over-grazing, particularly on the plains, where after soaking rains grass and bush provide good feed.

In many cases, particularly near Hawker, fencing posts originally 18in. in the ground have been completely exposed.

As a result of denudation floodwaters carry a very high percentage of suspended soil causing rapid siltation of dams and reservoirs.

## GROUP "L" (MAP No. 3.)

### HUNDREDS OF PICHI RICHI (WEST), AND WOOLUNDUNGA (EAST).

This country is located in the Flinders Range and damage by water erosion is not extensive. The hills generally are too steep to cultivate, although quite a lot of clearing has been carried out. Erosion is confined chiefly to the gullies, and soil and rock fragments washed down by heavy rain do a certain amount of damage to roads, whilst the slopes at the foot of the hills have suffered damage, particularly below the areas cleared.

## GROUP "M" (MAP No. 3.)

### HUNDREDS OF WILLOCHRA, COONATTA, EURELIA, OLADDIE, YALPARA, PINDA, WILLOWIE, COOMEROO, WALLOWAY, AND ERSKINE.

Damage by water erosion in these hundreds is mainly confined to land adjacent to the eastern arm of the Flinders Range in the Hundreds of Coomooroo, Walloway, Eurelia, and Oladdie, where many deeply scoured watercourses exist, although the actual damage to grazing and agricultural land is not great.

The remaining hundreds in this group are comparatively flat, and water erosion is negligible, except for a certain amount of scouring of creek banks.

## GROUP "N" (MAP No. 3.)

### HUNDREDS OF BOOLEROO, PEKINA, BLACK ROCK PLAIN, MORGAN, APPILA (EAST), TARCOWIE, MANNANARIE, YONGALA, AND WHYTE.

Native flora consist of she-oak, mallee, gums and porcupine and other grasses, and it is noticed that wherever the tops of the hills and fairly steep slopes have been cleared, damage by water erosion is taking place. This is particularly noticeable where the porcupine grass has been removed by cultivation.

Creeks formed under natural conditions were numerous, but these were protected by gravel deposits in creek beds, and the growth of gum trees, bushes and grasses along the banks. As a result of clearing, however, more rapid run-off is induced, and the creeks are not able to cope with the added volume of water, resulting in bank erosion and the washing out of trees.

New drainage channels are also being established by the erosion of additional deep watercourses, and damage to roads and inundation of low-lying areas has thereby resulted. In many cases steps have been taken to minimize erosion by filling the water courses with manure, straw, bushes, etc., and by cultivating small gutters as soon as they are formed. This action, however, is merely exercising control over the effect, and is not removing the cause which is doubtless due to clearing on the steeper slopes.

The result of clearing on three adjoining hills in the Hundred of Pekina is particularly noticeable. The first hill is a very low one, with flat slopes, and although cleared and cultivated, no serious erosion is taking place. The second hill is higher and steeper, but no clearing has been carried out on the top slopes, and in this case also there is no evidence of erosion. The third hill, however, which is very similar to the second one, has been cleared of most of the timber on the top slopes, with the result that numerous small watercourses have been formed.

Erosion of the hills in the Hundreds of Pekina and Black Rock Plain is causing rapid siltation of the Pekina reservoir near Orroroo.

The non-disturbance of natural herbage on the hill tops only is not sufficient to prevent erosion on the slopes, below, and apparently this growth should be allowed to extend down the hillside until the slope flattens to a certain inclination. This is fairly evident after a casual examination of the country, and it should be possible to determine the inclinations applicable to particular areas for the various classes of soil encountered.

It is noticeable that when the top of a hill is uncleared, erosion does not take place immediately below the uncleared portion, but commences at a distance varying from 50yds. to 200yds. from the upper edge of the cleared land. The discharge from the uncleared land is diffused and gentle, but as soon as the water reaches the cleared land it flows towards any slight concavity, and the velocity of the accumulated flow is sufficient to cause erosion, but if timber and grass is allowed to extend to the flatter slopes, scouring velocity is not attained on the cleared land.

## GROUP "P" (MAP No. 3.)

### HUNDREDS OF WINNINOWIE (EAST), GREGORY, WONGYARRA, DARLING, APPILA (WEST) AND HOWE (NORTH).

This country is practically all in the Flinders Range, and although the range in places is high, and the slopes are steep, little damage has been caused by erosion and the formation of new watercourses.

In the slopes of the Hundreds of Gregory, Wongyarra, and Appila, no visible erosion has taken place, although many of the hills are cleared. The heavy red soil apparently has high erosion-resisting properties, for the rainfall in this locality is high. The clearing of some of the hills, particularly on the eastern side of the divide, is, however, having its effect and causing the erosion of alluvial deposits laid down under natural conditions. It is particularly noticeable in the Spring Creek near the Spring Creek Mine, where the soil is being rapidly removed from several flats, causing the destruction of the gum trees growing along the banks of the creek.

The erosion here is a serious matter, as by the more rapid run-off of water the annual flow period is being reduced and springs are being robbed of their source of supply, so that the value of Spring Creek and other creeks as existing and potential sources of water supply is being greatly reduced.

## GROUP "Q" (MAP No. 3.)

### HUNDREDS OF BOUCAUT, HART (WEST), STOWE, EVERARD, BLYTH, HALL AND GOYDER

This area includes many salt swamps, a proportion is also sandy and drifts badly, particularly after several consecutive dry seasons. There are many deeply eroded creeks in and adjacent to the more hilly country, but where the land is fairly level, little erosion has taken place, although a creek approximately 20ft. deep and 100ft. wide has been scoured out between the road and railway embankments adjacent to section 385, hundred of Hart.

In the hundred of Boucaut very little evidence of erosion by water is in existence and sandridges have been stabilized with the growth of bush and grass since the winter of 1937.

There is some erosion in the south-west corner of the hundred of Everard, but otherwise conditions are very similar to those in the hundred of Boucaut.

Many eroded creeks exist in the hundred of Blyth, mostly running in an east-west direction, draining the high land on the eastern side of the hundred, and have been formed as the result of excessive clearing on the adjoining hills and slopes.

The creek running through sections 167, 168, and 156 is approximately 15ft. deep and 30ft. wide, and the banks are falling in badly. This is typical of many watercourses which have scoured out to a depth of from 8ft. to 20ft. and a width of from 12ft. to 40ft.

**Plate 12.**—A wide shallow channel excavated to form a drain through Section 112, Hundred of Blyth, the width being 21ft. with side banks 18in. high. Apparently erosion commenced along the line of the existing channel which was made with the idea of preventing further damage. Recent moderately heavy rains caused a flow, but no damage resulted, although it is not known whether this would be the case after a heavy summer thunderstorm.

Serious erosion has occurred on land abutting the road on the boundary between the hundreds of Hall and Blyth near sections 324 and 166, hundred of Hall. A series of creeks 12ft. to 14ft. deep have scoured out, removing much valuable land. With the exception of the north-east portion, little damage has been done in the hundred of Hall.

In the hundred of Stowe which is farther away from hills, damage from water erosion is slight, although some sand drift is in evidence and salt swamps occur in places.

The country in the hundred of Goyder is very similar, and little damage from erosion by water is in evidence.

## GROUP "R" (MAP No. 3.)

### HUNDREDS OF CLARE, MILNE, AND HART (EAST).

This land forms portion of the catchment area of the River Broughton and its tributaries, the Hutt and Hill Rivers. Native timber consists mostly of gums, the rainfall is good, whilst the land is utilized for pastoral, agricultural and horticultural purposes.

The effect of water erosion is noticeable on the cleared land, although in the hundred of Clare little trouble is experienced where the native timber has been replaced by fruit trees and grape vines. In other parts, however, where the land has been cleared for grazing and cereal growing, defined eroded watercourses have appeared in the gullies, and the consequent acceleration of the rate of run-off has also caused the re-erosion of the alluvium in the river valleys.

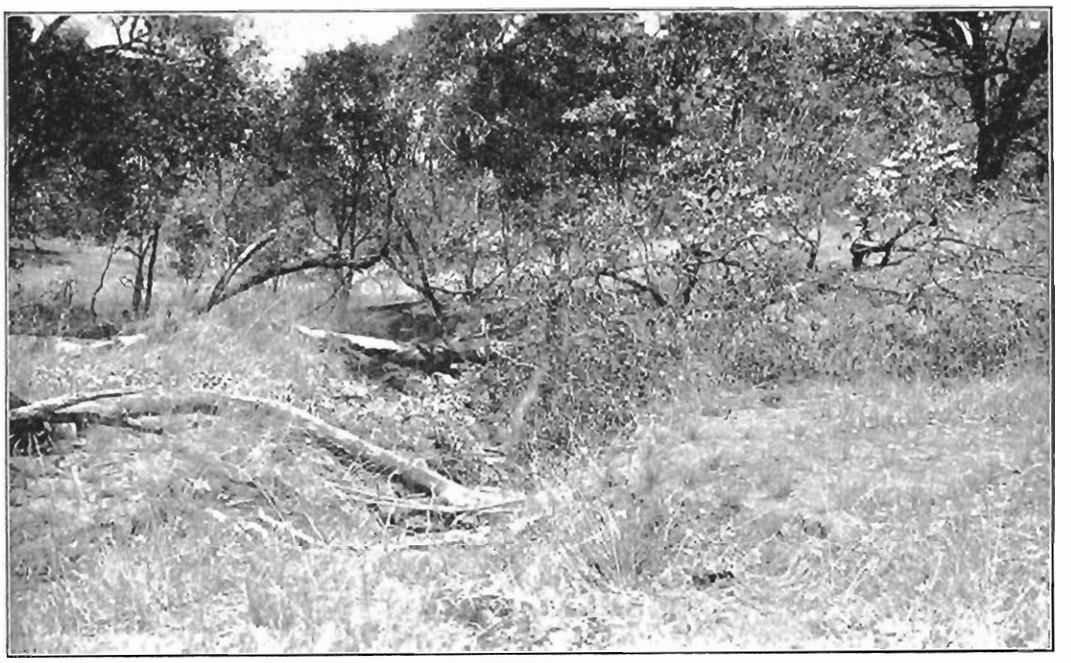


**Plate 13.**—A view near the Main North Road in the south-eastern part of the Hundred of Milne. This gully has not been cleared, and on the western side of the road no erosion has taken place. The water from approximately ¼ mile from bitumen road surface is discharged at this point, and the additional run-off has been sufficient to start the erosion of a defined channel, which can be seen in the clump of trees depicted in the photograph.

**Plate 14.**—Erosion adjacent to the main road in the Hundred of Milne. Above the road the land on one side of the gully has been cleared and cultivated, but this in itself has not been sufficient to upset the stability of this particular soil. The commencement of the eroded channel immediately below the road can be seen in the photograph. Near this locality one landowner has excavated a drainage channel on a flat grade towards the Hutt River. The sides and bottom of this channel are well grassed, and it has proved very effective as no erosion has taken place.

The eastern portion of the hundred of Hart is practically all cleared and under cultivation, and the effect of water erosion is extensive. As a result of clearing in the Hutt River water shed, particularly in the hundred of Milne, the run-off during heavy rains causes erosion of the soil, and consequently the water in this river during flood periods is heavily charged with silt. There is still, however, much uncleared land in the hundreds of Clare and Milne.

## GROUP "S" (MAP No. 3.)

### HUNDREDS OF ANNE, AYRES, HANSON, KOORINGA, AND KINGSTON.

There are some eroded creeks and gullies in this area, but the greater portion of the land is utilized for grazing purposes, and the damage to cleared land is not nearly as extensive as it is in the area immediately to the west.

In this group the greatest damage has been done on the western portions of the hundreds of Anne, Ayres, and Hanson, and on the eastern portion of the hundreds of Kooringa and Kingston.

## GROUP "T" (MAP No. 3.)

### HUNDREDS OF UPPER WAKEFIELD, SADDLEWORTH, ALMA, GILBERT, KAPUNDA, LIGHT, BELVIDERE, MOOROOROO, NURIOOTPA, AND MUDLA WIRRA.

These hundreds comprise for the most part good agricultural land resting upon a clay sub-soil. The surface is undulating and erosion has occurred by the widening and deepening of the natural drainage channels, particularly during fallow periods. In some instances it is noticeable that the direction of ploughing has accelerated erosion.

Portions of Nuriootpa and Moorooroo have more sandy soils, and no erosion has taken place on these.

In the hundred of Light and the higher land of Moorooroo which have not been cultivated, no signs of severe erosion are in evidence.

## GROUP "U" (MAP No. 3.)

### HUNDREDS OF BALAKLAVA, DALKEY, AND GRACE.

In these hundreds the surface soil varies considerably from light sandy loam on ridges running generally east and west to heavy loam on flats and in depressions.

Erosion has occurred in places as in Group "T", but there are few serious cases. The hundred of Grace is less undulating and there is practically no erosion of soil within this hundred.

## GROUP "W" (MAP No. 3).

### HUNDREDS OF MUNNO PARA AND YATALA (EASTERN PORTION).

The surface soil of this area consists of heavy clay loam sloping to the west from the foothills of the Mount Lofty Range. Erosion has occurred on points along the area east of the Main North Road between Pooraka and Gawler, where the surface slope is greatest just below the foothills, but generally speaking the erosion is not serious.

## WATER EROSION IN OTHER DISTRICTS.

Other parts of the State are effected to a lesser degree, and the remarks with regard to the northern areas may be applied in general to other affected portions, particularly with regard to the suggestions for correcting the erosion that is at present in evidence. On Eyre Peninsula, for example, erosion as the result of the action of water has been noticed in at least thirty-two (32) hundreds, the hundreds mostly affected being Koppio, Mortlock, Stokes, Mann, Yadnarie, Solomon, Pascoe, and Rudall. In the first three mentioned erosion is caused by the shedding of water from normal winter rains from the foothill slopes. In the hundreds of Mann and Yadnarie, it is caused by the run-off from the foothill slopes as a result of winter and summer rains, whilst in the hundreds of Solomon, Pascoe, and Rudall, where the slopes of the country are more gradual, damage is caused both from water shed as the result of normal rains, and occasional heavy monsoonal disturbances.

In the northern part of Eyre Peninsula, water erosion is mainly due to heavy summer rains which are of infrequent occurrence.

Evidence of erosion is also in existence in the Mount Lofty Ranges and on the foothill slopes adjacent thereto, being mainly due to run-off resulting from normal winter rains. Occasionally, instances also occur by the shedding of water from some of the higher lands draining into the River Murray. The south-eastern part of the State is not affected to any great extent, as in this area, although rainfall is good, the slopes of the country are comparatively flat.

## GENERAL.

In the area shown on Map No. 3 and reported upon in some detail, the most serious damage by water erosion has occurred on, and adjacent to, the eastern branch of the Flinders Range, extending from Clare to Orroroo. A large proportion of this area is drained by the River Broughton and its tributaries, and it is only necessary to see the turbidity of the water during a flood in this drainage system to realize the large amount of soil lost because of running water. Although some wind erosion takes place in this area of country, particularly after soil which has been washed down from the hills by rain has dried out, most of the damage is directly due to the action of moving water.

In the area west of the Barunga Range between Kadina in the south and Wandearah in the north, much of the damage has been done by wind erosion, as the country is flatter and the soil of a more sandy nature.

In the upper north however, erosion is nearly always the result of the action of both wind and water. The rainfall is less than in the lower north and the Spencer's Gulf coastal area, but the average rate of precipitation is much greater on account of the fact that thunder-storms are the source of a large proportion of the rain. The bareness of the land and the prevalence of strong north winds contribute to the severity of wind erosion. Erosion in which the action of rain and running water play some part, may be divided into the following classes :—

*General Surface Erosion.*—The numerous hard, bare patches in the far north afford an example of this type of erosion. Following heavy rains running water cuts through the surface soil and forms small eroded channels which provide a starting point for wind erosion, the intervening soil being eventually blown away, leaving the hard clay subsoil exposed. This action, of course, is accelerated in many places because of the absence of natural herbage.

Another example of general erosion is that taking place on cultivated land. Strong winds blowing on fallowed land with a surface crust lead to the development of heavy clouds of dust, whereas uncultivated fields in the same locality and fallowed lands which have been roughened up with cultivators after the heavy rains which compacted the surface, do not shift with the wind.

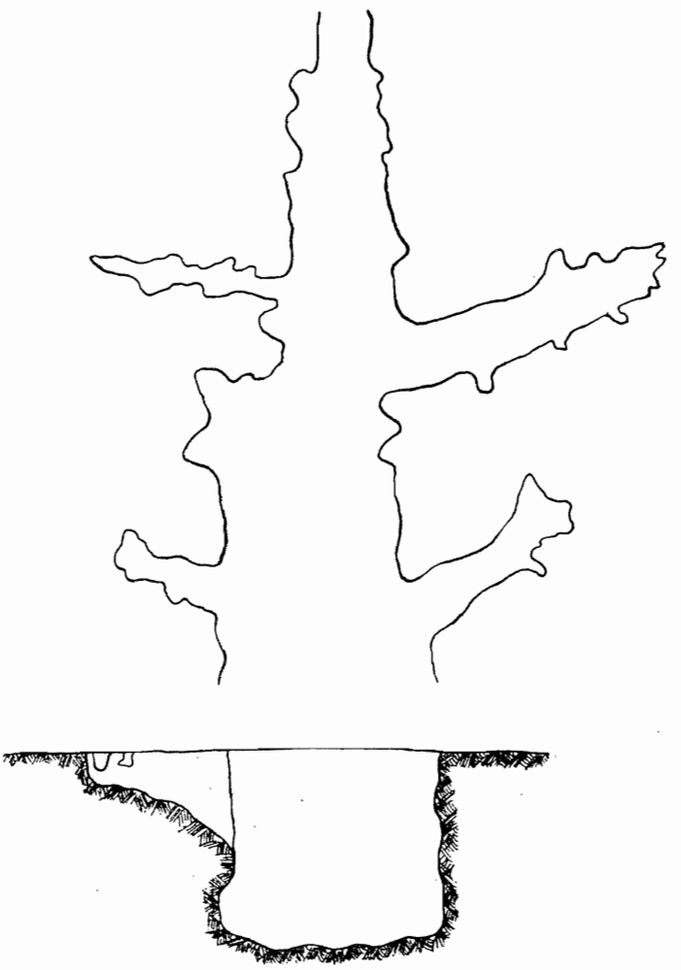
This general erosion is not as impressive as other types, but nevertheless results in fertile soil being lost, and in areas where limestone or bedrock is not far below the natural surface of the ground the depth of soil is ultimately removed altogether.

*Erosion of Defined Channels.*—This type of erosion is at once evident, and much good land in the lower north has been affected thereby.

In most cases the action progresses slowly, and this probably constitutes the chief danger, as rapid deterioration might stimulate action to prevent further loss.

Erosion in the gullies in the first instance, is generally kept under control by cultivation, but eventually a deep channel is scoured out and prevention of the trouble by this means can no longer be undertaken. The channel then extends in length and scours deeper and wider, with steep sides, until eventually water draining into the channel from the sides starts the formation of a secondary system, which is followed later by a tertiary system of eroded channels.

**SKETCH 1. GULLY EROSION.**



No. 40.

Sketch No. 1 shows typical action of this type which is caused mainly by the removal of trees and other herbage from the ridges and the steeper slopes, and by the cultivation of these slopes. Under natural conditions a state of stability existed which has been upset by man but the extent of erosion following his mismanagement varies greatly in different localities where slopes are somewhat similar. For instance, in some parts the removal of a small percentage of the natural herbage will cause erosion, whereas in other cases more liberty can be taken, and most of the herbage can be removed without causing severe trouble. In general, however, it appears necessary, in order to prevent erosion, to leave the trees and bushes intact on the ridges, and for a certain distance down the slopes, the distance depending on the nature of the soil and the steepness of the slopes.

*Erosion in Natural Creeks and Rivers.*—Erosion of creeks and rivers nearly always takes place when natural conditions are upset, and the rate of water run-off is increased. Some creeks and rivers are fairly deep, with steep banks, but trees, grass and roots are capable of preventing undue erosion until the rate of run-off is increased by altering the conditions in the catchment area. Banks are then eroded, and the trees washed out. Other streams pass through wide alluvial flats caused by the normal weathering of the catchment area over a long period, and the deposition of vegetable matter. In such cases where, in the past, there has been a normal flow from springs, there is usually a small defined channel in the alluvium. Acceleration of the rate of run-off, however, causes scouring and a new large channel is cut through the alluvium. An example of this occurs in the Hutt River, hundred of Andrews, where for a distance of about three miles the river bed was originally approximately 10 chains wide, most of which was filled with rich black alluvium. A channel has now been cut through this alluvium to a depth of about 20ft., and a width of 100ft. It is estimated that from this section of the river alone 36 acres of land have been lost, and over 1,000,000 cub. yds. of earth removed.

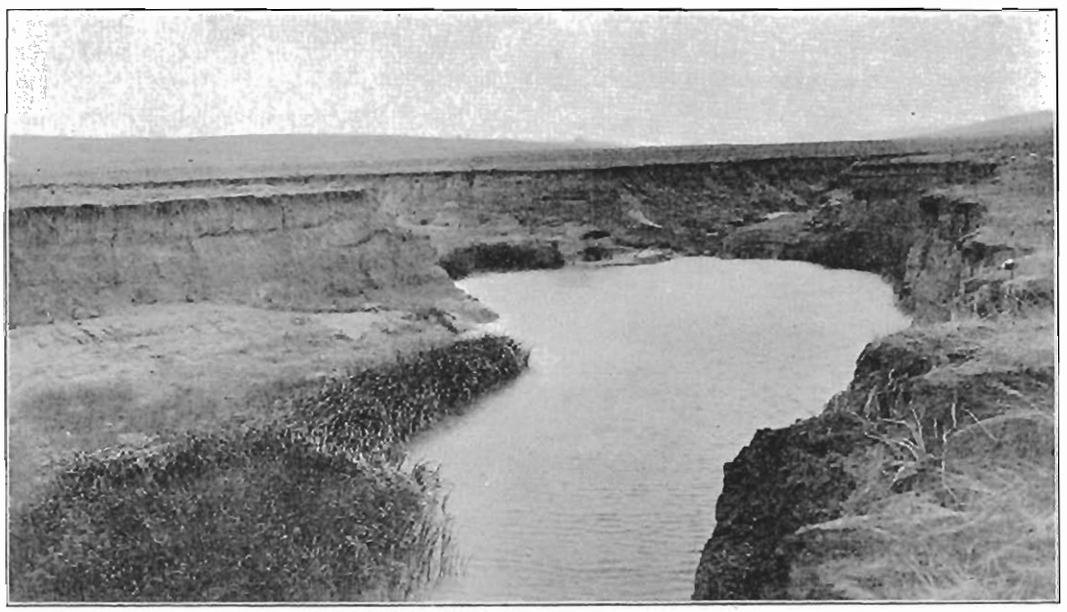


**Plate 15.**—Illustrating an erosion cut made in a wide alluvial flat alongside the Hutt River in the Hundred of Andrews. In some places this new channel is 100ft. wide and 20ft. deep. In the illustration a rapidly-widening side-cut is clearly discernible.

There are a number of similar occurrences on this river, and in addition erosion is noticeable in the various small tributaries.

The average amount of soil removed annually is considerable, but apart from the actual loss of soil, the area of cultivable land is further reduced by reason of the semi-isolation of certain parts due to the formation of deep subsidiary channels, which also result in the lowering of the watertable, and consequent deficiency of moisture in the soil.

## DAMAGE TO PUBLIC UTILITIES.

Details have been given concerning the damage to land by water erosion, but there are also other aspects of the matter. For instance, costly protective works are necessary on roads now that a more impermeable type of road surface is becoming general, and much damage would be done if protective works of this nature were not carried out. Railways also sustain damage, culverts being blocked with silt, and sections of line undermined by the increased rate of run-off. Culverts and bridges of ample size to take the flow under natural conditions have proved incapable of handling the water after clearing has been done, and the enlargement of general openings has been rendered necessary.

Water mains have been exposed in certain sections by erosion, and covered to great depths in others by deposits of silt and drift sand, and unless exposed mains receive early attention there is a danger that sections will be washed out and services interrupted. Occurrences of this nature are becoming more frequent and more difficult to deal with, especially in the Port Augusta water district.

The clearing of catchment areas has, however, more serious consequences so far as water conservation and distribution are concerned, as clearing causes water to run off more quickly, with the result that springs are robbed of their source of supply, and a steady decline in the rate and duration of the flow from many springs is taking place.

In a similar manner the ground water level is steadily falling in some localities, this being noticeable at the Burra, Booborowie, and other places, and consequently valuable crops and lucerne planted over a large area are suffering. A spell of dry seasons is invariably blamed for this, but there appears to be reason to believe that clearing carried out on the adjacent hills over past years is now having some effect in this direction.

Erosion and silt movement on the hills tends to seal the interstices providing ingress to the underground basins, and the consequent increased rate of run-off means that water is not in contact with the soil long enough to provide sufficient absorption in the intake areas for the complete replenishment of underground supplies. This decline in spring flow means that larger storages are necessary to supply requirements, as sufficient water needs to be impounded during the comparatively short period of rapid run-off to meet consumption.

Siltation of reservoirs may also be a serious matter, and evidence of siltation is in existence at the Pekina, Mount Arden, Hawker and Hammond reservoirs, and also at many privately owned dams.

The remarks made concerning the Hutt River indicate to what extent this siltation is taking place, whereas under natural conditions there was probably a more or less continuous flow of fairly clear water.

As a result of the increased run-off, inlet works, where necessary, require to be much larger than would be the case if less clearing had been carried out on the catchment areas.

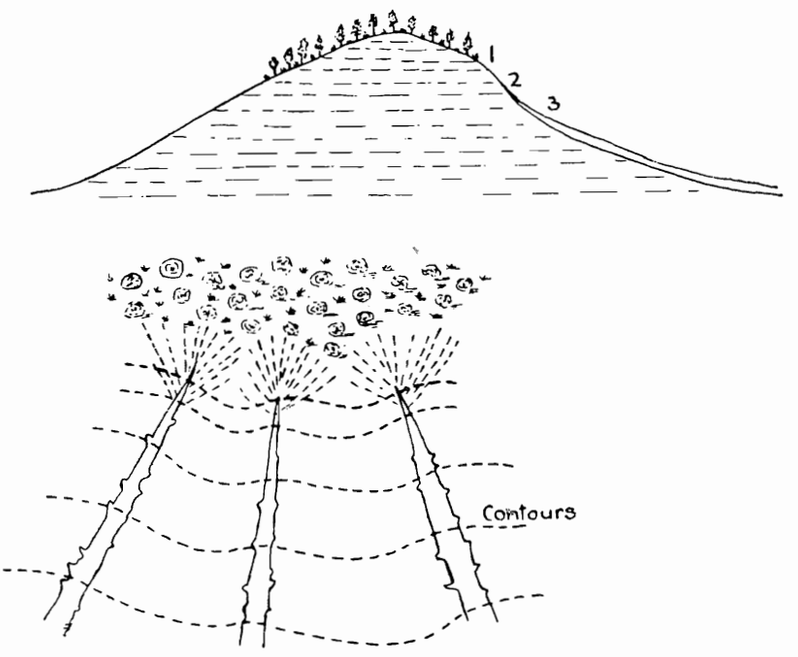
## SUGGESTIONS FOR IMPROVING EXISTING CONDITIONS.

1. *Discouraging further Wholesale Clearing.*—The first and most necessary step appears to be to obtain the co-operation of landholders with a view to discouraging further wholesale clearing, especially on the higher lands, as there appears to be yet time for much good to be done by the judicious conservation of natural vegetation not yet interfered with, particularly in that portion of the lower north adjacent to the Flinders Range.

The part played by various grasses in preventing erosion, particularly porcupine grass, has already been stressed, but as recently as this year cultivation has been extended over hills and slopes, thereby eradicating this plant in the areas concerned.

2. *Re-establishment of Herbage.*—The re-establishment of herbage on hills and slopes already affected by erosion is very desirable as the existence thereon of trees, bushes or grasses likely to be effective for the purpose may be relied upon to check erosion by the action of excess water moving down the slopes. The reproduction of conditions existing prior to the clearing of these parts is desirable if erosion is to be materially arrested, if not by the original herbage, at least by the establishment of kinds likely to have a similar effect. Where the rainfall is sufficiently heavy and the soil suitable it is often possible to plant lucerne on the higher slopes, at all events where the average annual rainfall is not less than 16in. Lucerne thrives on hills in various places in the State, particularly in the lower north.

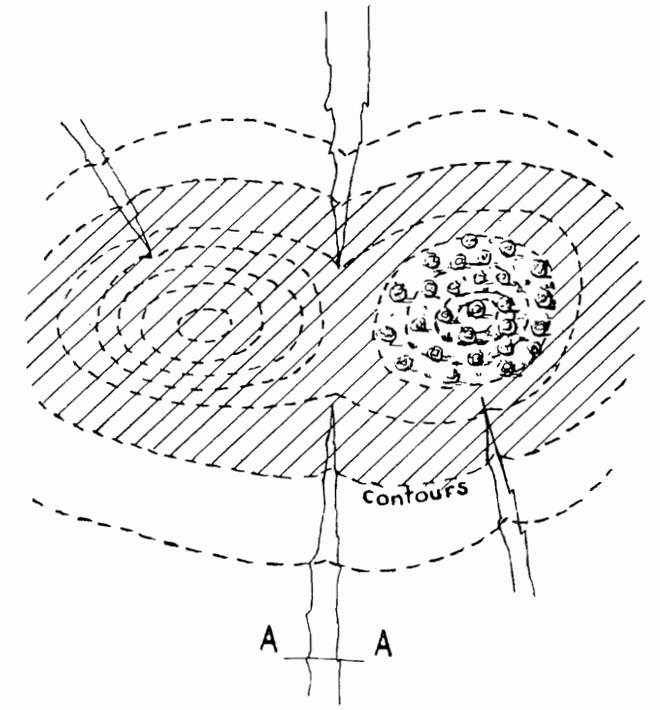
## SKETCH 2. ERODED HILLY COUNTRY.

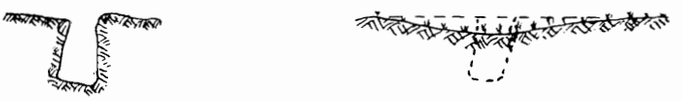



1. Edge of clearing. 2. Commencement of eroded watercourse.

In Sketch 2 the natural herbage has been depicted as having been removed up to Point 1 where the slope of the ground is such that erosion has commenced at Point 2. If the vegetation had been allowed to remain between Points 1 and 3, at which latter point the slope becomes much less, it is highly probable that no erosion would have taken place. Having regard to the various classes of soil likely to be encountered, the determination by investigation of the critical slopes, that is, the slopes at which erosion will commence, is necessary, together with the establishment of suitable plants on those slopes greater than the critical.

## SKETCH 3. REPLACEMENT OF FLORA ON HILLY COUNTRY.



Section A. A.

Area where regeneration of flora is desirable shown thus 

Uncleared area .. .. .. .. " " 

Sketch 3 illustrates the suggestion how the steep sides of water courses should be broken down to a slope sufficiently flat to permit of cultivation, and suitable plants established in the depression so formed. Lucerne would probably be ideal for this purpose where the rainfall and soil conditions are suitable, but otherwise a crop of one of the cereals could be sown to facilitate the establishment of suitable grasses.

After treatment the small depressions so formed should not be cultivated, and care taken to see that the herbage established is not over-grazed. Mechanical means of preventing further erosion, such as stone paving, the construction of small drop weirs, and check dams have their uses, but this type of protection is likely to be expensive in some locations, and furthermore, it is considered that if the steeper slopes were dealt with as suggested under " 2 ", these works would be largely redundant.

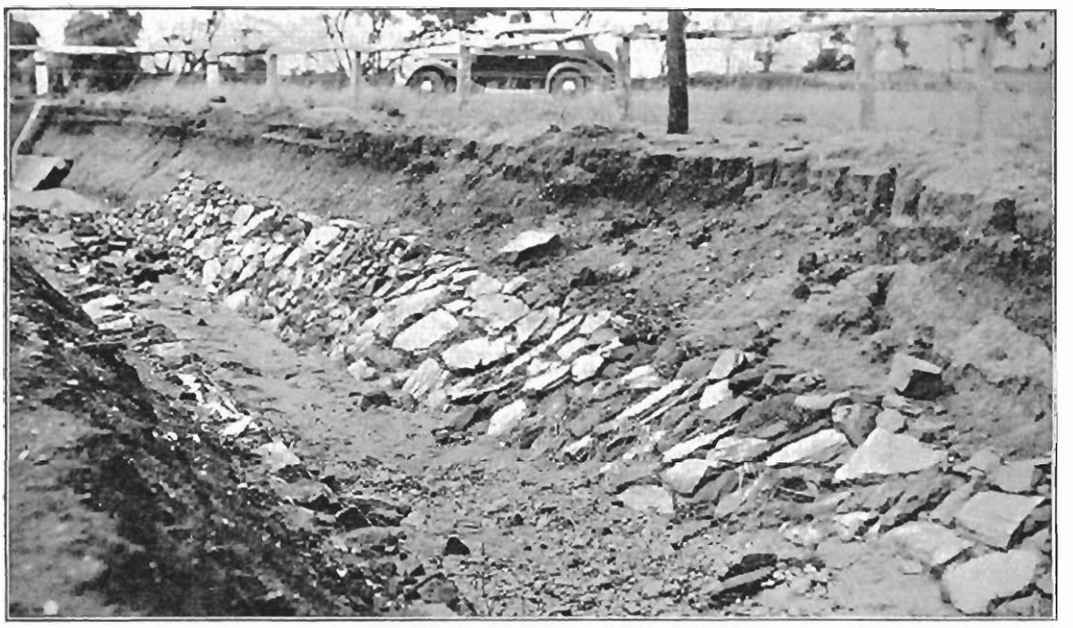


**Plate 16.**—Stone pitching in drain leading to Reservoir at Kimba which withstood the record flood flows of November, 1937.

3. *Planting in Watercourses.*—In some of the watercourses the extension of the trouble can be largely prevented by planting trees and shrubs, as is shown in Plates 17 and 18.

**Plate 17.**—A case of water erosion about four miles from Kapunda towards Greenock.

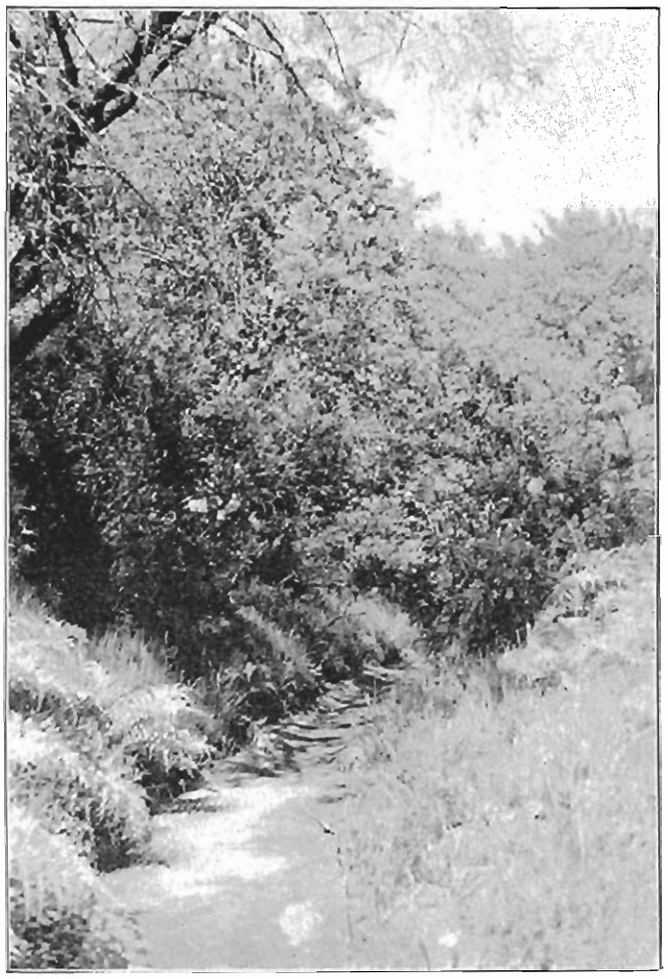


**Plate 18.**—Eighty yards downstream on the creek illustrated in Plate 17, and here only about 2ft. in depth and securely held by Almonds, Furze, and Wild Artichokes.

It is felt that action by individuals along these lines would result in material benefits.

**Plate 19.**—A relatively small watercourse in the Hundred of Davenport now safely held by native vegetation.

4. *Contour Cultivation.*—Much has been said regarding the importance of cover as a protection against erosion, but the maintenance of cover is not the only remedy. It is obvious that native vegetation cannot be left intact on fields which are to be cultivated and the land must be tilled in order to produce the maximum yield of sown crops. Moreover, there are occasions when growing crops are as great a protection to the soil against erosion as native vegetation, but at many times these are not at a growth stage which will provide the much needed relief. Nevertheless, damage to cleared land can be materially lessened if cultivation methods are carefully and intelligently undertaken.

One of the simplest methods of prevention where the country is not too steep is by cultivating along the contours. Cultivation at right angles to the slope, although a move in the right direction, is not sufficient because there are very few slopes so uniform that there will be no places unprotected if cultivation is done in this way.

It has been noticed that many comparatively steep slopes have been ploughed and cultivated with the fall of the country. When this is done a series of defined channels are provided for water, and the danger of the removal of the top soil by erosion is considerably increased.

**Plate 20.**—Erosion on fallowed land in the Hundred of Narridy, on a gentle slope of about 1 in 20. There is no creek or gully leading on to this land, but a narrow strip about 20yds. only in width was cultivated down the slope, immediately prior to a heavy rain. The previous cultivation given to the field was across the slope.

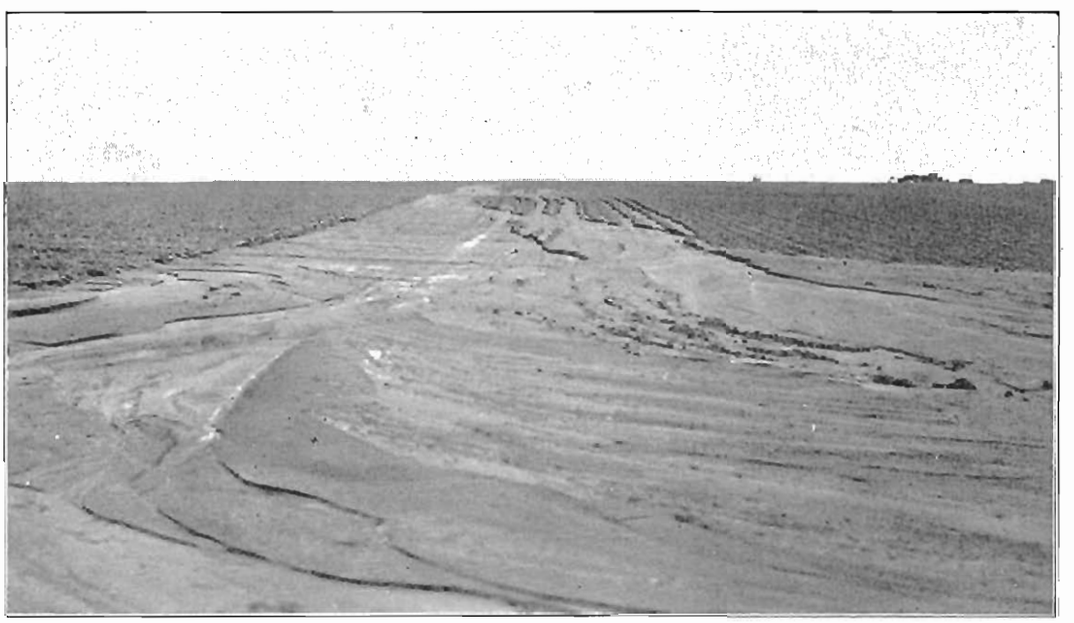


**Plate 21.**—Another view of the eroded fallow in the Hundred of Narridy depicted in Plate 20, showing that much of the loose soil of the strip cultivated down the slope has been removed and deposited at the bottom end of the field. As a matter of fact a good deal of the silt passed right over or lodged on the road.

To sum up the subject of water erosion very briefly, it may be stated that the key to the solution when considering methods of treatment of water-eroded soils, whether for prevention or correction, is fundamentally the same, viz., the maintenance of proper balance between cover, slopes, soil, and water.

## FORESTRY AND SOIL CONSERVATION.

### GENERAL PRINCIPLES.

All soil erosion is the ultimate result of removing the natural vegetative cover, and of the various vegetation types evolved by nature, forests are one of the most effective means provided for the protection of the soil against erosion. In the extent and permanency of the side and overhead cover provided by the foliage, the soil cover of fallen leaves and twigs and the binding effect of the strong, deep, spreading and interlaced root systems they possess a combination of advantages superior to those of any other form of plant life.

Tree growth minimizes soil losses most directly by (1) lessening surface wind velocity, thus reducing the blowing away of soil, and (2) retarding rainfall run-off, thus reducing the washing away of the soil.

Interference with the natural vegetation of a locality almost invariably results in some loss of the soil stability or fertility, or both, and the nearer the natural vegetation type approached forest, the greater is likely to be the loss.

Certain damage resulting from the destruction of native vegetation can be countered by engineering and other mechanical operations but no such works can provide the general protection to the locality that is provided by forests.

The benefit to be derived from tree growth depends largely upon the extent and density of the growth, but the area which any country can devote to this form of vegetation must of course be governed by economic factors.

What is required is a wise use of land so that apart from providing for the timber needs of the inhabitants, trees will be grown in those localities and situations where they are needed to permit the greatest permanent advantage to be obtained from the land.

### STATE FORESTS AND EROSION CONTROL.

The proper allocation of land for tree growth can be achieved to a large extent by the authorities responsible for land settlement retaining the necessary areas as national reserves. To some extent this has been done in South Australia, but the total area so reserved does not exceed 500,000 acres (including forest reserves, national parks and other pleasure resorts, catchment areas, etc.). It only represents a little over 2 per cent. of the total area of the portions of the State receiving 15in. or over of average annual rainfall, while the bulk of it is in the south-east where, from the point of view of soil protection, it is probably least needed.

The forest growth on all Crown lands not required for a particular public purpose or contracted to be granted in fee simple might with advantage be placed under the control of the forest authority as is the practice generally adopted in some of the other States of the Commonwealth. Moreover, before any Crown lands are subdivided, allocated, or alienated, the advice of competent authorities should be obtained in order that the proper use of the land may be planned, especially with regard to the reservation of areas for tree growth and the preservation of native vegetation under lease conditions to ensure that the requirements of the district in vegetative protection are provided.

It is not, however, practicable by these methods to make all the provision required, and in any case in South Australia there is now comparatively little land left unalienated in the better portions of the State. It is therefore incumbent upon the landholder himself in most cases to make reservations for tree growth upon his own property and to hasten to repair any damage resulting from inattention to this requirement in the past.

### THE PROTECTION OF PRIVATE HOLDINGS WITH TREES.

As the income of the landowner is affected by alterations in the use of his land, it is necessary to satisfy him that the benefits to be gained by devoting portion of his land to tree growth will not entail too great a sacrifice. He often contends that it is impossible to have grass and trees too, but he loses sight of the fact that the removal of tree growth in certain situations will often result in the ultimate inability to grow not only grass, but indeed any form of herbage because of the severity of soil erosion.

There is ample evidence to show that the clearing of the steeper slopes and the cultivating of even moderate slopes, permits the rainfall to flow from those areas with such velocity that not only is the surface soil removed from the slopes themselves by sheet erosion and land slides, but gullies develop in the better and more gently sloping land on the lower levels to such an extent as to rapidly render them valueless,

while floods, destruction of creek and river banks and the silting of reservoirs are further resultant catastrophies. In the drier areas unrestricted wind effect may result in the total loss of the surface soil off extensive tracts of country and in addition will often cause appreciable loss in production from crop, pasture and stock.

Where the forests, besides providing protection against erosion can be managed for the production of sawmilling logs, there is no doubt that they will yield very satisfactory returns, but even where the climate and soil restrict the species to those of minor utility, farm forestry can often be made to yield a return sufficient to justify its practice, even apart from the value provided in protection, for practically any type of tree growth in forest, if properly managed, will produce timber suitable for use as shed poles and rafters, local telephone poles, fence posts and rails, tool handles, repairs to implements, fuel and other farm requirements. Because of its bulk, wood is an expensive item to transport and where timber and fuel are produced in sufficient proximity to enable the farmer to do his own cutting and carting, the saving made will usually more than pay any costs of production and land rentals.

Another benefit of forest growth under proper management to be remembered is the improvement of the soil. Trees draw sustenance from the soil, but their general effect is to improve rather than to exhaust. By the shedding of leaves and twigs, large quantities of plant food and organic matter are being constantly added to the surface soil beneath the trees. The decaying litter and roots also assist to keep the soil porous and retentive of moisture and air. Except on steep slopes or in regions climatically unsuited to cultivated crops, the forest need not be the permanent crop of the site, and in certain situations where trees have been established for erosion correction purposes they may, after they have effected their object, be followed by other forms of agriculture.

In areas devoted to tree growth for soil protection purposes, fires must be prevented and grazing animals excluded.

Fire destroys the beneficial ground litter which assists in preventing soil erosion, while the trees suffer injuries in the destruction of young growth, the deformation of saplings and injury to the timber and growth rates of even the largest trees. However much forest burning may be temporarily justified on economic grounds in the pioneering years of a country, there can be no question that continued burning of the forest must result in its deterioration and ultimate destruction.

Areas planted with trees should not be regarded as permanent pasture. In fact, they should not be used for grazing unless absolutely necessary and then the grazing should be as light as possible. Apart from the browsing of the animals on the leaves and bark of the younger growth, the trampling causes compacting of the soil resulting in injury to the roots and prevention of regeneration, while when the slope is steep, the earth is loosened and erosion is likely to commence. Rabbits must be kept under control, and if possible exterminated.

If shade for stock is desired, special shade trees should be provided.

The benefits to the State of intensive tree planting to assist in the control of erosion is such that the Government might help in regard to the cost of trees and freight, those people who satisfy the Woods and Forest Department that they have made proper preparations for the planting, protection and care of large quantities of trees for the control or prevention of erosion.

At one time trees were distributed free at the various forest nurseries, and, although this may not be the best practice to follow, it was noted in the northern areas that tree planting on farms appears to have been much more general during the period of free distribution than at the present day.

The possibility of permitting discarded or unused roads to be planted by the adjoining landholders is also brought under notice. In this connection some of the old stock routes would specially lend themselves for the purpose. It would be necessary, of course, to apply conditions ensuring proper care of such plantations.

In view of the importance of encouraging the establishment of trees in all localities where soil erosion can best be controlled by trees. it would be of great advantage if landholders desiring to plant large areas for soil protection purposes could obtain the services of officers of the Woods and Forests Department to examine their properties and advise them on the most suitable species to employ and the establishment, cultural, protective and utilization methods to adopt in order to secure the object desired with as low a cost and high a return as possible. The department might also be of great assistance in the control of soil erosion by trees if it could conduct trial and demonstration plots on eroded areas throughout the State.

## TREE GROWTH AND SITES.

In the provision of tree growth for soil protection purposes the type of trees, methods of establishment and management will vary according to the natural conditions obtaining in each locality but can be separated generally as follows :—

1. Hilltops and slopes where the rainfall run-off is likely to obtain sufficient velocity to cause water erosion.

2. Rivers, creeks and gullies where flooding is likely to cause excessive bank cutting.
3. Areas where soil erosion is likely to result from wind action.
4. Drifting sands.

Although the average annual rainfall has been largely used in recommending species for planting and methods to be adopted in various situations, it is desired to point out that in view of the inter-action of the many factors affecting tree growth, any prescription requires a very careful survey of the actual site. The most important factor in deciding the growth of trees in South Australia is usually the available soil moisture rather than the rainfall, so that in dry regions a depth of sand which protects the soil moisture from evaporation may present a site capable of supporting tree life where the exposed impermeable subsoil or a shallow soil over such a subsoil or rock may not do so.

It may be taken that the species given for a particular region will usually succeed in the higher rainfall regions and the choice of an exposed site may necessitate the use of species suggested for regions of lower rainfall.

Many more species than those mentioned are available, but those given are usually the most useful from the point of view of adaptability to a variety of situations.

## TREES ON HILLTOPS AND SLOPES.

As has been shown already, up to a certain degree and length of slope varying with the extent and nature of the rainfall and the soil type, cultivation carried out on proper lines is practicable without involving the risk of excessive erosion. Up to a further degree and length of slope, grass and other low herbage are sufficient for the purpose, but beyond this tree growth is necessary to reduce erosion to the safe minimum.

It is sometimes stated that slopes over 10 per cent. should never be cultivated, that only very light clearing should take place on slopes over 15 per cent., none at all on slopes over 25 per cent., and that gradients over 40 per cent. should not even be grazed, but however useful such figures may be considered for general purposes, they should not be accepted as the guide for all localities. Just where the boundary lines come can usually only be defined by close study and observation, but unfortunately it is only too frequently sufficiently obvious from the present marks of erosion.

On moderate slopes there is often no objection to clearing or thinning the timber to permit grass growth, but on long slopes of even moderately steep grade, belts of timber should be left at intervals at right angles to the slope in order to prevent undue acceleration of the run-off as it gathers volume. In any case trees containing useful timber should not be destroyed if it is possible to avoid doing so unless the timber is required for use.

Clearing of the steeper slopes may provide grass for a few years, but no matter how close the cover of grass, it will not be as effective in retarding soil erosion as trees, and eventually the soil will disappear while much damage will be done to grass, crops and streams lower down.

Apart from the red gum forests of the Murray River, the high rainfall regions of the south-east and the higher parts of the Mount Lofty and Flinders Ranges carry the only natural timber forests of any value in South Australia, although, as a result of logging, fires and clearing, the present stands are only the derelict remnants of the original forests mixed with second growth which is usually badly damaged and deformed as a result of fire and maltreatment. In these particular localities it is generally unnecessary to take any special action to encourage the landowners to plant trees. It is considered, however, that even here it would be an advantage if the advice of the State Forest Service could be placed at the disposal of land-holders to ensure a continuance of appreciation of the value of trees and care in the management of existing tree growth.

Outside of the south-east of the State, the high rainfall country is generally hilly and the slopes are often so steep that the retention of a large proportion under forest is most desirable if serious soil erosion, land slides, floods, destruction of creek and river banks and the silting of reservoirs are to be avoided.

In realization of the fact that so little unalienated Crown land remains in the good rainfall regions no further land suitable for forestry should be alienated from the Crown without a thorough investigation into the liability of serious soil erosion occurring if the area is cleared. In these regions efforts should be made to obtain further suitable areas on catchments for purposes of afforestation and all available Crown lands on steep slopes not required for a special public purpose should be placed under forest management.

In the region of 15in. to 25in. average annual rainfall which includes the bulk of the good agricultural districts of the State, there is considerable evidence of water erosion resulting from the clearing of native vegetation off the slopes and continued cultivation of the land and although such erosion is not so striking as the wind erosion of the Far North, from a national viewpoint it is certainly serious.

On denuded steep slopes in low rainfall areas and even in high rainfall areas where the soil is shallow or excessively drained, tree planting will often not be practicable and all that can be done will be to fence the areas against stock and rabbits until, by continual protection and seeding, sufficient regeneration is induced of such hardy native tree species as she-oaks and other Native Oaks (*Casuarina* spp.), Mulga, Wattles, etc. (*acacia* spp.) Cypress Pine (*Callitris*), and Mallees (*Eucalyptus* spp.) which will provide some return of minor produce in the form of fuel, shed poles, etc., as well as hold the soil.

In the 15in. to 20in. average annual rainfall regions, plantings can be made in suitable spots of such other species as Pepper Trees (*Schinus*) and Carob Trees (*Ceratonia*). The main advantage would be an increase in protection from wind, although the bean of the carob possesses a fodder value.

In an average annual rainfall of 20in. to 25in. and on fair soils, useful forests of Sugar Gum (*Eucalyptus cladocalyx*), Blue Gum (*E. leucoxylon*), Red Ironbark (*E. sideroxylon*), Aleppo Pine (*Pinus halepensis*), Maritime Pine (*P. pinaster*), Stone Pine (*P. pinea*), Coulter's Pine (*P. Coulteri*), Canary Island Pine (*P. canariensis*), Digger Pine (*P. sabiniana*), Arizona Cypress (*Cupressus Arizonica*), Mediterranean Cypress (*Cupressus macrocarpa*), Kurrajong (*Brachychiton populneus*), White Cedar (*Melia azedarach*), and Olive (*Olea Europea*) can be grown.

Establishment can be considerably assisted by furrows ploughed along the contours so that the maximum benefit is obtained from any rain which falls.

Where the annual rainfall is over 25in. on the average with reasonably deep and retentive soils or subsoils, commercial forests can be grown of such species as Red Gum (*E. rostrata*) and Stringybark (*Eucalyptus Blaxlandi and obliqua*), or exotic conifers such as Radiata Pine (*Pinus radiata*), and where the average rainfall reaches 35in. or over per annum, the more exacting Yellow Pine (*P. ponderosa*), Oregon (*Pseudotsuga douglasii*), Spruce (*Picea* spp.) and Firs (*Abies* spp.) will succeed.

## TREES ON GULLIES, CREEKS, AND RIVERS.

Throughout the State the losses due to recent gully erosion and the cutting away of stream banks is evident. In the northern areas this often results in a layer of silt being deposited over the country which buries vegetation and in the dry weather breaks up and drifts before even light winds.

In a 15in. to 25in. average annual rainfall gullies are forming and extending rapidly as the result of excessive run-off from cleared slopes and hard roadways, the greatest damage occurring upon cultivated land where it has as a background long fairly steep slopes. In the Torrens River which arises in the higher rainfall regions, the damage to the river banks and the consequent siltation is a matter of deep concern.

Apart from afforestation of the denuded slopes from which the floods obtain the increased velocity which causes sheet erosion and ultimately gully erosion, it is necessary that action should be taken to prevent further extension of the gullying. In these cases, especially where impoverishment of the surface soil has occurred, trees can be established more readily and will often give greater success and permanency of protection than either grass or crops.

To prevent gully erosion extending, the area should be fenced off and planted over from half to one chain on either side of the banks as well as across the bed and for some distance ahead of the gullies.

To successfully establish trees along gullies it is first necessary to stabilize the site by making check dams and setting brush or other silt traps to check the flow, while the banks should be sloped off to prevent further caving in and to supply cultivated sites on which to plant the trees.

Trees should be set closely in planting, from 4ft. to 8ft. apart, but, once established, may be thinned out to permit the best development.

Suitable species for the planting of eroded gullies of recent origin are Wattles (*Acacias* spp.), False Acacia (*Robinia pseudo-acacia*), which, being legumes are of special benefit to other non-leguminous species with which they may be planted owing to their ability to fix nitrogen in these often raw soils. Another, although more exacting leguminous species is the Judas Tree (*Cercis siliquastrum*). The Tamarisk (*Tamarix gallica*), Pepper Tree (*Schinus molle*), White Cedar (*Melia azedarach*) and Tree of Heaven (*Ailanthus glandulosa*), although not legumes, are also useful.

Where climatic conditions permit, these species may later, when the site is stabilized, be gradually replaced with more useful timber trees.

In the case of stream banks, when sufficient footage above the permanent water level exists, trees, by their roots and trunks will protect the banks against the force of the flowing water and will often cause backwaters to form in which silt is deposited during floods to build up further protection.

Most trees will not grow standing continuously in water but do not mind temporary flooding. In such situations grass and other vegetation can be grown to assist in preventing the force of the water from making direct contact with the soil.

Where no footage exists at the bottom of banks, and the banks are low, trees planted on the bank will still assist to bind the soil by their roots, but they will be of no value in the case of high vertical cliffs.

On sloping high banks trees can be planted with advantage and various methods have been adopted to use them to prevent damage to such banks as a result of floods. One device, known as inclined tree planting, is to lay limbs of Willow (*Salix alba*) 4in. to 6in. in diameter up the slope of the bank with their butts in the water, the limbs spaced about 4ft. apart, wired together, anchored at intervals and covered lightly with earth. With the butts in moist ground, these limbs will develop both roots and shoots all along their length and after a short time will become a mat of living growth, providing splendid protection against flood damage.

On permanent water courses both in this region and in the dry north, there is no more useful species for bank planting than the native red gum, the coolibah, in the far north, and the Murray Box (*Eucalypti*) in the Murray Mallee could also be utilized.

On such water courses in the 15in. to 25in. annual average rainfall, as well as in the higher rainfall regions, Willows (*Salix* spp.), Poplars (*Populus* spp.) will succeed and develop root systems with special soil-holding properties, while Pepper Trees (*Schinus molle*), False Acacia (*Robinia pseudo-acacia*), Oaks (*Casuarina* spp.), Aleppo and Maritime Pines (*Pinus halepensis* and *pinaster*), and Blue Gum (*Eucalyptus leucoxylon*) are useful species for the higher slopes. The Ash (*Fraxinus* spp.) and the Elm (*Ulmus* spp.) are also useful along stream banks in regions of 20in. average annual rainfall and over.

When a free flow of water down the bed of the stream is required to prevent damage to banks, species must not be chosen which are liable to regenerate on the temporary banks in the bed of the stream and cause further obstructions.

It is to be emphasized however, that the primary cause of gullying and excessive flooding in streams is the denudation of the upper slopes, and the planting of gullies and stream banks will not eliminate the necessity for attention also being given to afforestation measures on these slopes.

## TREES IN SURFACE WIND EROSION AREAS.

In the region of less than 20in. average annual rainfall there is ample evidence of very serious wind erosion of the fine soils. The cause is obviously the destruction of the vegetation through grazing and the loosening of the soil by trampling of stock in the pastoral districts and of cultivation, especially fallowing, in the agricultural areas.

Apart from the question of costs, engineering methods cannot be applied to the prevention of wind erosion as they can to water erosion, and the most obvious remedy is the reduction of the surface wind velocity by the provision of a protective vegetative cover, especially trees.

In regions of less than 15in. average annual rainfall, it is unlikely that close wind breaks will be grown, even in narrow strips, except in positions such as the seepage areas from dams, tanks and bores, or along creek beds where the available water supply is much greater than would be indicated by the local rainfall.

Elsewhere scattered trees and scrub may be grown in such formations as to give a considerable degree of protection. This can be achieved by fencing off areas in close proximity to existing seed trees and keeping rabbits and stock permanently out and by providing protection for natural regeneration wherever it is found occurring elsewhere. It will probably be impracticable to fence off large areas in this manner, but small areas of an acre or two and even smaller could be fenced off from time to time until quite a belt is obtained. In fact the work could be planned to amount in the aggregate to considerable areas in the course of years, but in any case planning will be necessary to obtain the maximum benefits in the form of protection. The regeneration that takes place on such areas is surprising, and the main essential, the maintenance of protection of the growth, will be found to be the greatest burden in connection with this work.

For homesteads and sheds, considerable improvement and protection may be provided and the appearance of the property enhanced by planting out seedlings in jam tins, or kerosene tins, in positions where they can be protected, cultivated, and watered for the first few years.

In addition to the Mallee (*Eucalyptus* spp.), Oaks (*Casuarina* spp.) Native Pine (*Callitris* spp.), Native Willow or Apricot (*Pittosporum phillyreoides*), Bullock Bush (*Heterodendron oleifolium*), Sugar-Wood (*Myoporum platycarpum*), Native Orange (*Capparis Mitchellii*), *Hakeas* (*Hakea* spp.), Pepper Tree (*Schinus molle*) Olive (*Olea Europea*), Oleander (*Nerium oleander*), and Bamboo (*Arundo donax*), should not be overlooked.

A mixture of non-edible species is an advantage but it will, in all circumstances, be necessary to prevent stock from having access to such areas for grazing or camping over any lengthy period of time.

It is exceedingly doubtful if crop-growing, especially where fallowing is required, should be practised in regions particularly liable to serious soil erosion where dense shelter belts cannot be grown.

In the 15in. to 25in. average annual rainfall regions of South Australia, the growth of trees in shelter belts sufficiently dense to provide protection for cultivated fields will generally be possible.

In most districts of the State, except the South-East, and the surroundings of the Adelaide Hills, there is a lamentable lack of provision for shelter upon farms. Where any action whatever has been taken reliance appears to have been placed almost entirely upon the sugar gum, and in later years, the Tuart gum.

In the drier regions both these trees are very susceptible to drought and borer attack after a certain age and ultimate results are often most depressing. The planting usually consists of a single row of trees along the edge of a paddock in the form of a hedge. They are open to trampling and damage to the roots from stock, and afford very little protection from wind, especially close to the ground surface where it is primarily needed, the final effect being that of a row of huge scarecrows.

In the lower rainfall regions, narrow dense shelter belts are the natural means of protection but it is important that the location of shelter belts should be given proper consideration and that they should not be relegated to lands useless for any other purpose without consideration of the probable value of the site for the growth of trees and protective purposes.

Shelter belts should not be too narrow. They need to be at least wide enough and of such a design as to present an absolute barrier to wind. As a rough figure, they should be 1 chain to 3 chains wide and anything from 20 chains to 80 chains apart, being closer on agricultural land than on grazing areas and should be set out with their length across the direction of the prevailing winds.

The agriculturist and grazier very often object to the provision of such shelter belts upon the score of the loss in growth to grass and crops adjoining such windbreaks. It is believed, however, that such loss is more than compensated for by the increased production resulting from the protection afforded. Experiments have shown that the effect of a properly designed windbreak is felt over distances roughly equal to 20 times the height of the shelter belt. Actually the stronger the wind the farther the effect of the windbreak is felt. With a properly designed shelter belt, not more than $\frac{1}{4}$ chain on either side should be seriously affected by the roots of the trees, and this can be kept cultivated to act as a firebreak. With shelter belts 2 chains wide and 80 chains apart, this would mean, with the unproductive area on either side, a little over 3 per cent. of the area under tree growth, or, with 2 chain strips, 20 chains apart, 10 per cent. of the area, and even this should not be considered too much.

Shelter belts should consist of evergreen, rather than deciduous trees. If deciduous trees are used, they should be mixed with wide spreading, compact-crowned evergreen trees. The outer rows should in most cases be evergreen, but actually the composition will depend upon the locality and requirements.

A mixture of species is desirable to minimize failures and the possibility of extensive damage from insect attack, etc.

Shelter belts need to be designed to lift the wind over them rather than to present an immovable obstacle and should consist of on the outside a line of hedge dimensions, such as giant salt bush, nitre bush, boobialla, pittosporum and wattles, then a line of low shrubs such as the olive or carob, then a formal type of tree such as the Arizona cypress, and in the centre, tall and wide compact-headed trees such as eucalypts or pines. A low hedge on the outside is important to prevent ground litter blowing away and the drying winds from the outside reaching the soil surface under the trees.

In preparation for planting, the ground should be ploughed, and, if possible, fallowed for one year. It should be fenced against stock and if necessary against rodents such as rabbits and hares. In planting, the rows should be spaced from 8ft. to 12ft. apart, the hedges 4ft. to 8ft. apart in the rows, with the trees 6ft. to 10ft. apart in the rows, depending upon species.

If possible the plants should be cultivated for a few years after planting ; in fact for as long as the growth of limbs permits the use of a cultivating implement. A harrow type of cultivator is to be preferred for this work to the single disc type of cultivator which tends to throw the soil up against the trees.

Besides protecting the soil from drifting, these windbreaks provide shelter for livestock but as the areas are of necessity fenced such shelter must be secured from outside, and not within, the shelter belt. If shade is required for stock, trees should be specially planted for this purpose.

A shelter belt will need protection from fire and this should be provided by ploughing or cultivating each year about 12ft. on the outside of the belt. Such cultivation will assist the growth of the plants and also discourage their spread beyond the area of cultivation. Thinning will be required as time goes on to keep the stands healthy. Wood requirements should, as far as possible, be obtained from such trees as need removing.

Renewals in the shelter belts will be required from time to time if they are to be kept in good order .

In the 15in. to 20in. average annual rainfall districts in the more favourable soils and situations, it should be found possible to grow the following species on forestry lines for shelter and timber production in narrow belts of dense formation provided every effort is made to induce forest conditions as suggested above :—

Timber species—

Canary Island Pine (*P. canariensis*).
Aleppo Pine (*P. halepensis*).
Stone Pine (*P. pinea*).
Maritime Pine (*P. pinaster*)
Coulter's Pine (*P. Coulteri*)
Digger Pine (*P. Sabiniana*)
Torrey's Pine (*P. Torreyana*)
Arizona Cypress (*Cupressus Arizonica*)
Erect Cypress (*C. sempervirens*)
Native Pine (*Callitris* spp.)
Red Ironbark (*E. sideroxylon*)
Blue Gum (*E. leucoxylon*)
Yate Gum (*E. cornuta*)
W.A. Red Gum (*E. calophylla*)
Salmon Gum (*E. Salmonophloia*)
White Poplar (*populus alba*)
Elms (*Ulmus* spp.)
False Acacia (*Robinia pseudo-acacia*)

Wood and shelter species—

Mallees (*Eucalyptus* spp.)
Swamp Oak (*Casuarina glauca*)
Pepper Tree (*Schinus molle*)
White Cedar (*Melia azedarach*)
Olive (*Olea Europea*)
Carob (*Ceratonia siliqua*)
Lagunaria (*Lagunaria Patersonii*)
Tree of Heaven (*Ailanthus glandulosa*)
Tamarisk (*Tamarix gallica*)
Kurrajong (*Brachychiton populneus*)
Moreton Bay, and small-leafed figs (*Ficus* spp.)

Shelter only species—

Camphor Laurel (*Cinnamomum camphora*)
Bullock Bush (*Heterodendron oleifolium*)
Pittosporum (*P. undulatum*)
Wattles (*Acacia* spp.)
Boobialla (*Myoporum insulare*)
Oleander (*Nerium oleander*)
Bamboo (*Arundo donax*)
Giant Salt Bush (*Atriplex nummularium*)
Nitre Bush (*Nitraria schoberi*)

In regions of 20in. to 25in. average annual rainfall, most of the commercial timber producing species found growing in this State can be grown under the conditions provided by such shelter belts.

## DRIFT SANDS.

Along the coast, especially in the region from the mouth of the Murray south-eastwards, in the Murray Mallee, on Eyre Peninsula and in the far north, there are considerable areas of moving sandhills. Even inland in the south-east, sandhills are inclined to form and drift if the country is disturbed by cultivation.

The fixation of drift sands in farming practice has already been dealt with and it is only necessary to refer specifically to the use of trees for this purpose.

It is not usually practicable to fix sand drifts with trees alone. A swirling action of the wind takes place around the stems of the small scattered trees and ends in their being uprooted. Sand-fixing grasses and herbs must be used, but some of these will not persist once the sand stops moving and it is therefore necessary to add more permanent shrubs and trees to the vegetation as quickly as possible.

Once the trees and shrubs are firmly established they afford themselves all the protection required.

The system of attacking of such areas is essentially the same :—

1. Fence the area off from man and beast and protect it from fire.

2. Commence the attack from the windward side.

3. Plant a sand-fixing grass such as marram grass, pyp grass, lyme grass or spinifex.

4. Cover the area with brush, laid with butts and tops reversed in alternate rows with the pieces laid so that the side branches touch and the ends overlap to prevent the formation of wind funnels.

5. Plant shrubs and trees, especially those that will grow quickly, such as nitre bush, leucopogon, olearia, boobialla, Californian Tree Lupin (*Lupinus arvoreus*), Wattles, Ti-Tree (*Melaleuca and Leptospermum* spp.), oaks, tamarisk, mallees, native pine and maritime pine.

6. Do not stop the work until the whole area of the drift is covered.

7. Later the less useful species used in the fixation work may be replaced by more valuable species, thus, in a 30in. average annual rainfall region, radiata pine can be grown where the sands are not deep.

## MISTLETOE.

The frequency of the occurrence of the Mistletoe (*Loranthus* spp.) on practically all tree species in the drier areas and also upon the smooth-barked gums elsewhere cannot be ignored.

The general opinion of local people is to the effect that infection of native trees by mistletoe has been increasing at an alarming rate in recent years. If such statements are correct, it is not definitely known to what the spread may be due. By some it is suggested to be the destruction of the opossum which is stated to feed upon the leaves.

Experience abroad is that certain species of mistletoe are most commonly found upon the borders of forests or upon trees in areas where the density of the forest cover has been reduced. Perhaps in such cases the birds largely responsible for the spread do not inhabit the denser portions of the forest. Destruction of tree growth may, then, be another reason for any spread of mistletoe in South Australia. Still more likely is it that in the absence of regeneration of our trees due to the grazing of stock and rabbits the older trees which carry the mistletoe are more obvious than would be the case in the natural forest with the trees of various ages.

Mistletoe produces seed covered with a viscous coating and can be spread either by the dropping of this seed on to branches from plants above or by being carried by birds, especially the Mistletoe Bird (*Dicaceum hirundinaceum*). When the seed germinates its roots push down through the bark into the wood of the tree and fuse with the growing layers below.

The mistletoe most commonly found in South Australia (*Loranthus*) is a semi-parasite in that while it draws water, nitrogen and mineral matter from the sap of its host, it obtains carbon from the carbon-dioxide of the air, and like all green plants, is able to convert these substances into carbohydrates.

The mistletoe causes considerable damage to the trees on which it makes its home. Its attachment to the host is usually accompanied by an abnormal swelling and part of the branch beyond the mistletoe frequently dies. The limbs may be broken by the extra weight, the rate of growth of the tree is reduced, and, if the infection is sufficiently heavy, the tree will be killed.

From the point of view of damage to the timber, the mistletoe is relatively unimportant as it is found chiefly upon the branches where the more tender bark permits its access.

The only method of control known at present is to lop off the bunches of mistletoe, including that part of the limb to which it is actually attached.

As mistletoe is a stock fodder of some value, this fact should be taken advantage of by pastoralists in the northern areas during dry seasons when the branches of mistletoe could be removed from the trees for the purpose of providing feed for livestock.

## RESEARCH.

### PASTURE REGENERATION IN SEMI-ARID AREAS.

The Waite Agricultural Research Institute, through the establishment of the Ranson Mortlock Laboratory, has become interested in the problems associated with soil erosion and pasture regeneration in semi-arid localities. That the problems of pasture regeneration in semi-arid localities are by no means easy of solution needs to be emphasized.

Much of the country in which these problems have to be investigated is of very low carrying capacity, and consequently of low capital value. Only a comparatively small expenditure per acre for improvement would therefore be justified from an economic point of view. Moreover, the rate of natural regeneration, as measured by the only index at present available—the Koonamore Vegetation Reserve—is extraordinarily slow even when stock are withheld from the regenerating areas. Furthermore, the outstanding feature of these regions is the erratic and variable character of the rainfall.

Finally, if the hypothesis is accepted that the fundamental cause of erosion in the pastoral country is the destruction of the perennial vegetative cover—whether the agency of destruction be maladjustment of stocking, depredation of rabbits, or dry seasons, singly or combined—then it is clear that nothing that the botanist or agronomist is likely to discover would bring results comparable with the benefits that would be achieved by a general reduction of the level of stocking throughout the arid country.

The problem of pasture regeneration on arid pastoral country may be approached from many aspects, but the following appear to be essential as a preliminary study. The requirements of two major areas may be considered.

(1) The problem of pasture regeneration in the marginal wheat areas where the main cause of erosion is the complete clearing of the vegetative cover, and the excessive cultivation of land for wheatgrowing.

(2) The problem of soil erosion and pasture regeneration in purely pastoral country in which erosion has been brought about mainly by overstocking, accentuated by dry seasons and depredations of rabbits.

The former problem is of importance to South Australia since the permanent and profitable settlement of much of the land in the marginal wheat areas is dependent upon a combination of pasturage for sheep with a limited amount of cultivation of cereals.

In the semi-arid pastoral country the problems are more difficult, partly because of the increased severity of the climatic conditions and partly because of the practical difficulty of land of low capital value bearing any considerable expenditure for improvement.

It would appear that economic methods of attack must be sought along lines of the modifications of existing grazing practice, frequent spelling of land, and strict limitation of stock numbers to encourage regeneration, and the development of methods whereby hardy aggressive plants of high colonizing power may be spread from such foci as *e.g.*, small protected seed areas, or from widely spaced plough furrows through eroded country.

The modification of existing practice is a matter of administration for those departments associated with the control of pastoral lands. Investigations need to be made, however, to determine the precise influence of the biotic factor on the native vegetation, and to determine precisely what happens when a climax ecological association such as shrub-steppe (typical salt bush country) is subjected to various intensities of grazing by sheep.

A fundamental phase of the vegetational studies is the study of the process of natural regeneration on representative ecological association in the pastoral country. Such investigations could be made by establishing fenced pasture reserves at a limited number of representative areas or by taking advantage of such fenced reserves as have already been made by pastoralists in the arid country.

An important vegetational problem in the soil eroded areas is the attempt to establish an association of plants of a stable character on eroded soil, or alternatively, the development of methods whereby hardy and aggressive plants of high colonizing power may be spread from such foci, *e.g.*, small protected seed areas, or from widely spaced plough furrows through eroded country, to speed up the establishment of a suitable plant cover.

The deliberate introduction of appropriate aggressive pasture plants into the sward offers possibilities from a scientific point of view, both in the pastoral areas and certainly in the marginal wheat lands. The Plant Introduction Section of the Council for Scientific and Industrial Research might co-operate with South Australian research organizations in testing out promising introductions of possible value either for the marginal wheat areas or for the semi-arid pastoral belt.

The committee inspected the experimental area at Pallamana conducted by the Waite Institute for the testing out of promising indigenous and exotic species for such areas as are indicated above. When the status of the various species of pasture plants at Pallamana has been determined from the point of view of persistence and capacity to spread by natural means, the next step would be to determine the best methods of introducing such species into the eroded areas by the technique of establishment in plough furrows, establishment of small seed furrows, etc.

Two biotic factors have been imposed on the vegetation of semi-arid lands—domesticated livestock and the rabbit. One of these biotic factors—the livestock—may be controlled by withholding the animals from the areas for specified periods (by spelling), by rotational grazing, and by modifying the intensity of grazing by alteration of the grazing numbers. The other biotic factor may, under the conditions of semi-arid pastoral occupancy, be largely uncontrollable, and it may therefore be necessary to regard the rabbit as a permanent occupant of the country, the influence of which will vary from season to season.

If, as is believed to be the case, the grazing animal is the major factor, and indeed the only factor, that has caused the deterioration of the vegetal cover, then the study of the grazing animal and it effects on the sward must yield valuable results which will ultimately provide a sound basis for regulating the stocking of these areas. The shrub-steppe of the north and north-eastern pastoral areas of South Australia represents a climax association, and an interesting scientific problem would be to determine the intensity of grazing that would (1) maintain the shrub-steppe in normal vigour, (2) stabilize the cover at the Stipa-Bassia stage, or (3) destroy the saltbush and produce erosion.

The climatic aspects of the pastoral regions of Australia afford opportunities for intensive statistical study. Considerable progress has been made by the staff of the Waite Institute in the study of the climatic indices in relation to agricultural and pastoral pursuits, the ratios of rainfall to evaporation, and the relation of rainfall to saturation deficit of the air. These measures have been found to be a useful guide to climatic conditions throughout the year, and have enabled the calculation of such quantities as the length of growing season and the amount of influential rainfall to be made with some degree of precision.

The study of climate is mainly a statistical one, and exact methods of analysis have yet to be developed. The variability index facilitates the comparison of drought tendencies and may be employed to define with a comparatively high degree of precision the extreme of variation in rainfall which may be expected to arise by chance in any given period of years. Investigations of this character are in progress at the Waite Institute, and form a valuable supplementary study to the vegetational investigations described above.

## SUMMARY.

1. The problem of soil erosion is as old as civilization itself.

2. All cases of soil erosion are fundamentally due to the destruction of the natural vegetative cover and the consequent exposure of the bare soil to the erosive action of wind or water.

3. The factor responsible for the destruction of the perennial vegetative cover in the pastoral country of South Australia is the grazing animal. The effects of over-grazing are accentuated by dry seasons and by the depredation of rabbits.

4. In the mallee areas the destruction of the vegetation was deliberately brought about to make way for the plough, and with the lighter types of soil which are so widespread in these districts the drift is becoming serious.

5. Where the original forest cover has been removed from undulating land in South Australia to make way for cultivation, erosion by water may cause heavy loss of soil.

6. The rainfall recording stations in the northern pastoral areas show a very great falling off in rainfall for the years 1922 to 1935, as is disclosed in the figures presented in the body of this report.

7. The 14-year period of severe drought prior to 1936, and plagues of rabbits, have brought some of the pastoral lands close to a condition of collapse.

8. While rabbits may not directly cause much damage to the perennial vegetation they compel livestock to eat the permanent fodder plants sooner than would be the case otherwise.

9. Every effort should be made to discover a cheap method of destroying rabbits, for the far-northern country will never recover if the rabbit is to be allowed to breed unchecked.

10. If further tests with the rabbit virus now being experimented with prove satisfactory it should be introduced into rabbit-infested localities.

11. Even when livestock have been removed from country denuded of vegetative cover the soils will not respond to bounteous rains as do those of country in its natural state or where they are well protected by growth of some kind or other.

12. The sooner means are taken to prevent deliberate and unreasonable overstocking, the sooner a feeling of hope can be entertained that the pastoral lands will remain in permanent occupation.

13. Reasonable pastoralists impose strict limitation of stocking upon themselves, so would have no objection to restriction in the number of livestock to be carried being included in the conditions of the lease.

14. Native plants will return to much of the de-vegetated lands of the pastoral areas except where there are high moving sandhills, providing that grazing animals are excluded from them altogether.

15. There is one introduced plant known as Teetulpa weed, which has established itself in the northern pastoral areas, and which is behaving like a native plant, and is spreading rapidly in all localities where it has been introduced.

16. The surrounding of blocks of bared lands by sheep-proof fences, and retaining them as flora reserves, has almost invariably led to a splendid growth of natural vegetation both perennial and annual, and in most cases these reserves have proved nurseries for the establishment by natural agencies of plants outside of the protecting fences.

17. Immediate action should be taken to proclaim as flora reserves certain areas in proximity to towns threatened by drift.

18. The ploughing of furrows on bare wind-swept land in a direction across the line of the prevailing winds is helping in the re-establishment of protected growth in many cases.

19. No licences for the cutting of green timber, except mallee and sandalwood, from pastoral lands should be issued.

20. When estimating the carrying capacity of pastoral lands, it is essential that the perennial plants should only be considered by allowing for a reasonable pruning not exceeding the annual growth.

21. The droving of livestock along stock routes parallel and alongside of railway lines should not be allowed except in special cases.

22. There is an urgent need of some system whereby pastoralists can obtain technical advice, and the services of pastoral advisers could, with advantage, be made available to pastoralists for the purpose.

23. Wind erosion in the farming areas has occurred in 1938 to a *serious extent* in the Murray Mallee, particularly in that part with Loxton as a centre, near Port Pirie, scattered areas near Port Broughton, and between Dulbin, Owen and Port Wakefield, and a little on the coast near Streaky Bay.

24. To a *fairly serious extent* wind erosion has occurred in 1938 in a large proportion of the Murray Mallee, in the upper north near Bruce, Hammond, Willowie, east of Johnburg and Black Rock, near Winninowie, surrounding Wandearah, and smaller areas near Alford, Ninnes, Mount Templeton, and Balaklava.

25. Sand drift to a *slight extent* existed in 1938 in most of the Murray Mallee not already referred to, on northern Yorke Peninsula, at Long Plains to Bowmans, Balaklava, and Condowie, north of Orroroo, near Port Augusta, central Eyre Peninsula, near Streaky Bay, and scattered areas from Warramboo right out west to the hundred of Russell.

26. At present the serious drift that occurs in normal seasons in the agricultural areas is confined mainly to fairly high sandridges, and to those places where flatter sandy land has been flagrantly overcropped, but it is inevitable that if the practices which led to the severe drifting in the past are continued, each return of droughty periods will lead to intensified drifting.

27. If taken in hand before the stability of these light-textured soils has been destroyed, there is every chance of overcoming the trouble without the necessity of providing non-edible plants to keep the soil in position.

28. There are some careful farmers in every drift-liable district of the agricultural areas who have succeeded in supporting themselves without undue loss of soil and without becoming menaces to their neighbours. So successful are such men that it seems certain that their methods can be followed with perfect safety.

29. The control of drifting sand in South Australia is dependent upon growing the minimum of crops to be carted off the land as grain or hay and the maintenance of the maximum number of livestock without overstocking.

30. South Australian farmers on drift-liable holdings who have successfully kept down the drift trouble divide their agricultural activities between wheat and sheep, and have gradually increased their livestock production until wheat-growing has become secondary to sheep husbandry.

31. Most sandy soils in districts receiving 18in. or more of average annual rainfall can be safely farmed by establishing pastures and regularly topdressing them.

32. Although it is possible to farm sandy holdings in zones receiving from 14in. to 18in. of average annual rainfall with permanent pastures only, in most cases it is necessary to prepare the land and grow some annual crops in regular rotation to get the best out of the land.

33. If wheat is to be grown on sandy land in districts receiving from 14in. to 18in. average annual rainfall, fire should not precede the original breaking of the fallow and a rigid-tined cultivator should be used for the purpose instead of a plough ; the work should be done as nearly as possible at right angles to the prevailing winds. Very few cultivations should be given during the fallowing period, sheep being used to keep down the weeds.

34. In low-rainfall districts the difficulties of preventing drift are great because of the extremely high temperatures, low humidity, heavy winds and long rainless periods which are commonly experienced in localities in South Australia receiving less than 14in. of average annual rainfall.

35. High sandhills in low-rainfall districts are only suitable for agricultural purposes when plenty of irrigation water is available at reasonable cost, and where this does not apply they should be kept out of cultivation.

36. The control of bad sand drifts invariably consists in again covering the surface of the land with growth of some kind or other.

37. Where drifting areas are of a very serious nature the movement of the sand can be checked by covering with coarse organic matter such as straw, cocky-chaff, weeds, stable manure, bushes or tree branches. The drifts can be permanently held by broadcasting seeds or transplanting seedlings or suckers of sand-binding plants into the sand below the protecting organic matter.

38. In connection with water erosion it is well known that anything which tends to retard the velocity of the moving water reduces its erosive power, and vegetative cover is probably the most important means of doing this.

39. If all rainwater were absorbed as fast as it falls there would be no erosion from this source, and to reduce erosive action conditions conducive to the absorption of large quantities of rainwater are desirable.

40. Generally, when a watercourse reaches the stage when it cannot be dealt with by cultivation, no attempt is made by South Australian landholders to check subsequent erosion.

41. The most serious damage by water erosion in South Australia has occurred on and adjacent to the eastern branch of the Flinders Range, extending from Clare to Orroroo. A large proportion of this area is drained by the River Broughton and its tributaries.

42. Erosion in gullies in the first instance is generally kept under control by cultivation, but eventually a deep channel is scoured out and the channel extends in length and scours deeper and deeper.

43. Erosion of creeks and rivers nearly always takes place when the natural conditions are upset and the rate of water run-off is increased.

44. Costly public utilities, such as roads, railways, water mains, reservoirs and dams are severely damaged because of water erosion.

45. Landholders should be discouraged from the wholesale clearing of timber and other perennial plants from the higher lands in districts liable to water erosion.

46. The re-establishment of herbage, such as trees, bushes and grasses on hills and slopes already affected by erosion is very desirable.

47. The treatment of water eroded soils consists of maintaining a proper balance between cover, slopes, soil and water.

48. Forests are one of the most effective means provided for the protection of the soil against erosion.

49. Farm forestry, besides protecting the holding from erosion, can often be made to yield sufficient to justify its practice in the production of shed poles and rafters, local telephone poles, posts, rails, tool handles, implement parts, fuel, and other farm requirements.

50. Fires should never be permitted near to trees grown for soil protection, for not only are the trees injured, but the green litter which does so much to hold the surface soil together is destroyed.

51. Areas planted with trees should not be grazed by livestock unless circumstances demand it, and rabbits must be kept under full control.

52. Landholders who satisfy the Woods and Forests Department that they will plant trees for soil protection, after proper preparation for the planting, should be assisted in regard to the cost of trees and freight.

53. On long hill-slopes of even moderately steep grade belts of timber should be left at intervals at right angles to the slopes to prevent undue acceleration of the run-off as it gathers volume.

54. Clearing of the steepest slopes may provide grass for a few years but this will not be as effective in retarding soil erosion as trees.

55. To successfully establish trees along gullies the flow should be steadied by check-dams, and the banks sloped to prevent further caving in.

56. The primary cause of gullying is the denudation of the upper slopes, and the planting of gullies and stream banks will not eliminate the necessity for attention to the afforestation of these slopes.

57. In the lower rainfall regions narrow dense shelter belts are the only means of protection, but it is important that the location of such belts should be given proper consideration.

58. Shelter belts of trees should not be too narrow, but should be from one to three chains in width.

59. Shelter belts should consist of evergreen rather than deciduous trees.

60. It is not usually practicable to fix sand-drifts with trees alone, as the swirling action of the wind finally uproots some of the trees.

61. Mistletoe growing on native trees appears to have increased to an alarming extent in recent years, and there is no doubt that the pest does great damage retarding the growth of the affected trees, and finally leading to their premature death, and so preparing the way for soil erosion.

62. For any given climate, soil, aspect and slope, there is a certain minimum of vegetative cover needed to prevent erosion, and under natural conditions there is a state of balance between the various factors, rainfall, run-off, wind, soil, aspect and slope, and if this natural vegetative cover is removed, the balance is destroyed and erosion inevitably commences.

63. The investigations on soil erosion and pasture regeneration at the Waite Agricultural Research Institute, under the provisions of the Ranson Mortlock Trust, should provide most valuable data on the extent to which natural regeneration of eroded country is possible, the value of indigenous and exotic pasture species for eroded areas, and the extent to which such species may be utilized in promoting pasture improvement.

The knowledge acquired through these investigations should, in course of time, have a most valuable bearing on the soil erosion problem, and will be of especial value to the pastoral and agricultural advisers (referred to in Main Recommendation) in the carrying out of their advisory work.

## RECOMMENDATIONS.

The Committee has given consideration to the nature of the services that are needed to deal with the problem of soil erosion.

It is recommended that the State should adopt a policy of soil conservation which would have as its aim the protection of the agricultural and grazing country from the effects of water and wind erosion, so that the productivity of these lands will remain unimpaired for the use of future generations.

A soil conservation service, under the control of a competent director, working in close co-operation with the Departments of Lands, Agriculture, Forests and Engineering and Water Supply, and charged with the responsibility of preserving the soil resources by the control and prevention of erosion, and by intelligent land use, would be the most effective method of implementing this policy.

While the Committee believes that eventually such a soil conservation service will be essential in the interests of the State, it considers that as a first step a less ambitious and less costly type of organization could provide a useful service for South Australia.

## MAIN RECOMMENDATION.

The Committee recommends as a first step the establishment, within the Department of Agriculture, of a nucleus of a staff, under the control of the Director of Agriculture, for dealing with soil erosion problems. Such a staff should consist of two technical advisers on drift erosion (one of whom would be engaged on soil erosion problems in the pastoral country, and one on soil erosion problems on agricultural lands), and in addition one officer to specialize on water erosion control throughout the State. The fullest advantage should be taken to co-operate with the existing State departments directly and indirectly concerned with soil erosion, namely, the Lands Department, the Engineering and Water Supply Department, and the Woods and Forests Department.

## SECONDARY RECOMMENDATIONS.

The following recommendations, mainly concerned with administrative matters, are submitted by the Committee :—

1. All new leases issued for pastoral purposes should be issued on the basis that leases may be cancelled if land is abused by mismanagement, particularly by overstocking.

2. Restrictive stocking conditions should be inserted into leases of pastoral lands prescribing the maximum number of stock to be grazed. A provision, however, should be inserted providing that the number of stock may be increased if satisfactory evidence is submitted to the Pastoral Board that the land is capable of carrying more stock.

3. No licences for cutting of green timber other than mallee and sandalwood should be granted. Mallee is readily capable of regeneration, and the removal of sandalwood has proceeded to such an extent on pastoral properties that the removal of the remainder could not seriously affect the erosion problem.

To encourage lessees to refrain from cutting growing trees it is considered necessary to make available posts for fencing, wooden or iron, at a minimum cost, and allow special rates for transport.

4. The Pastoral Board has decided to encourage pastoralists to repair damage done to the country under pastoral lease and to reduce the rent where the pastoral lessee would reduce the number of stock or leave specific areas unstocked for a stated period.

This policy should be continued and extended to all pastoral lands.

5. All leases contain a clause that lessees must destroy vermin. The ploughing up of warrens is an effective method of control on the better class of country, but is not economically possible in the lighter carrying country.

If the experiments with rabbit virus now being conducted on Wardang Island prove successful, it would be of great value to the country.

6. Sheep-proofed flora reserves have resulted in a substantial growth of natural vegetation and have acted as distributing centres for seeds.

Pastoralists should be encouraged to establish flora reserves. Such encouragement might take the form of assistance by the Government towards the fencing of areas approved by the Pastoral Board.

7. Flora reserves should be retained around threatened towns, *e.g.*, Parachilna, Farina. Such reserves should be placed under the control of an organization which would be responsible to the Department of Agriculture for the fencing and control of the area and if thought necessary would plant suitable vegetation on the areas.

Stock should be kept off miscellaneous leases adjoining Parachilna and Farina.

8. Provisions should be made to prevent the droving of stock along stock roads running parallel to and alongside railway lines past the first trucking station on the route being taken.

9. The appointment of technical advisers is urgently needed for the pastoral areas. Much expenditure has been needlessly incurred in the erection of improvements, sinking of dams, construction of drains, and much of this could have been avoided had the pastoralist been able to obtain reliable technical advice. In connection with the development of a system of rotational resting of paddocks, and the revegetation of denuded areas, the services of a pastoral adviser would be particularly useful.

This procedure is referred to in the main recommendation.

10. The prevention of further drift in agricultural areas rests largely on the dissemination of information on the lines indicated in the report through the medium of advisers appointed specifically for the purpose, in accordance with the main recommendation.

11. The Committee strongly recommends :—

(1) That lands liable to serious erosion and surrendered to the Crown should not be reallotted for agricultural purposes but should be locked up as reserves.

(2) Lands liable (through erosion) to injure other properties should be resumed by the Crown and be removed from agriculture.

12. That before any Crown lands are subdivided, allocated or alienated, the advice of competent authorities should be obtained to enable the proper use of land to be planned, especially in the matter of reservation of areas for tree growth and the provision of lease conditions to provide for adequate preservation of the native vegetation required for the general protection of the district.

13. That native forest growth should be retained on all steep slopes particularly liable to serious erosion, and, as far as possible, placed under sound forest management, and that afforestation should be extended wherever possible on the watersheds of the catchment areas of the heavy rainfall regions.

14. That experiments be carried out by the forest authority to ascertain the possibility of the growth of species suitable for soil protective purposes in various divisions of the State.

15. That assistance be given landholders in the purchase and freight of any large quantities of trees required for soil protection purposes.

16. Facilities should be provided for reclamation work in the form of—

(*a*) assistance towards fencing for the protection of trees and shrubs as an anti-erosion measure ;

(*b*) nurseries for the propagation and distribution of soil erosion plants, shrubs and trees by the Department of Agriculture and/or the Department of Forests ;

(*c*) assistance for construction of contour banks, gully repairs and dams where erosion is serious.

W. J. SPAFFORD, Chairman.
J. NEIL McGILP, Member.
A. E. V. RICHARDSON, Member.
G. J. RODGER, Member.
C. G. F. JOHNSON, Member.

L. S. SMITH, Secretary.
30th September, 1938.

**Plate 22.**—Farina is being inundated with sand blown from the western side from where all of the natural vegetation has been removed.

**Plate 23.**—Farina need not be destroyed by drift, for much of the windward side would again be covered with vegetation if adequately protected from grazing animals. Couch grass, Giant Saltbush, and Red gums grow in profusion on the north-eastern side of the township.

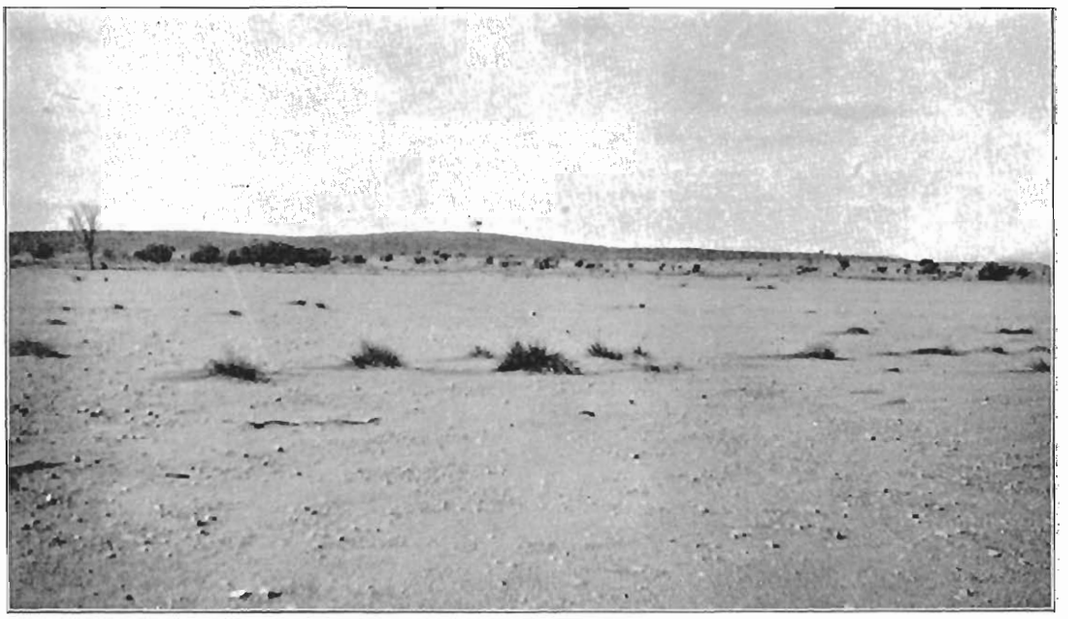


**Plate 24.**—A windswept plain in the north-eastern pastoral country on which only a few Spear-grass plants have appeared, despite the particularly favourable season of 1937.

**Plate 25.**—A plain on a pastoral holding in the North-East bared by the combined action of water and wind.

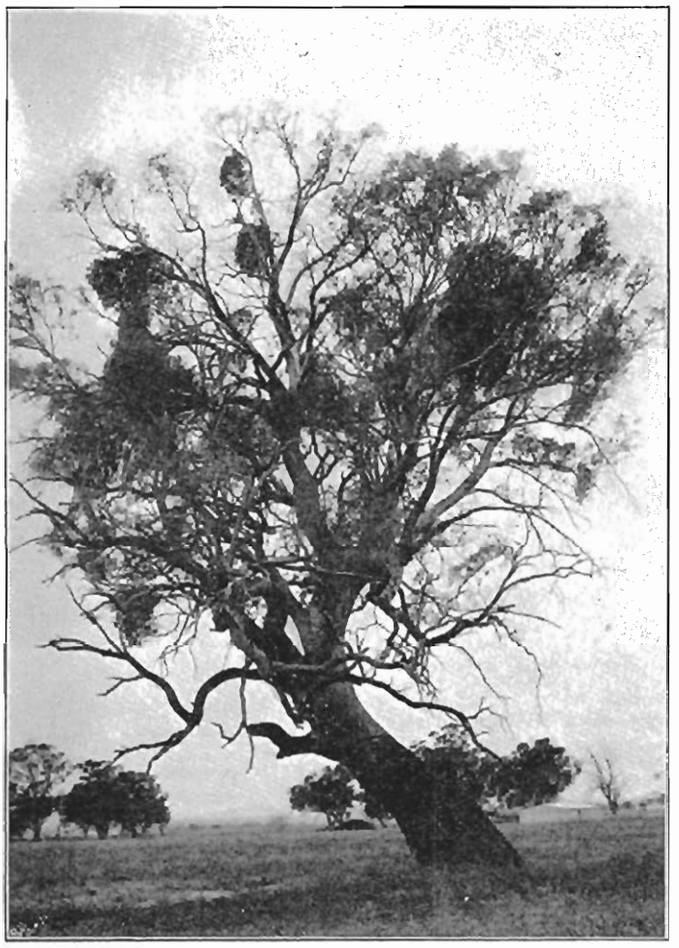


**Plate 26.**—Mistletoe killing native trees. Although the Red gum (Eucalyptus rostrata) is not particularly liable to damage by Mistletoe, when the forests are thinned the pest becomes active.

**Plate 27.**—Native plants return to bare windswept land of the pastoral areas when protected by sheep-proof fences. Five years ago this area was quite bare.

**Plate 28.**—Mistletoe killing native trees. Havoc is being wrought with one of the best of the fodder trees of the pastoral country, the Mulga (Acacia aneura).

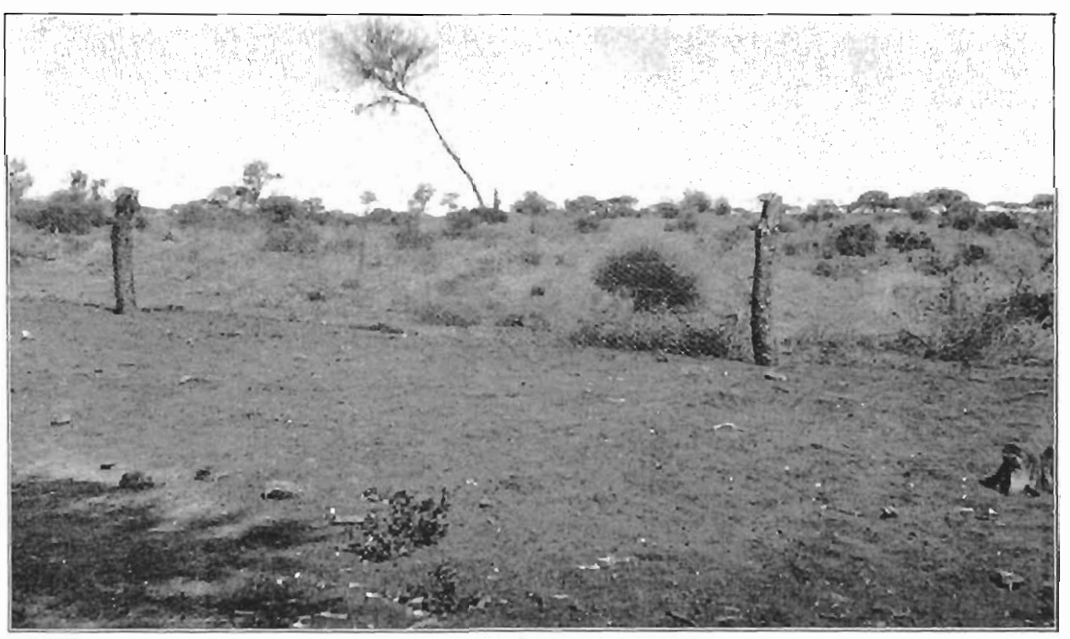


**Plate 29.**—A striking illustration of the recovery of bare pastoral country in the North-West when protected from grazing animals.

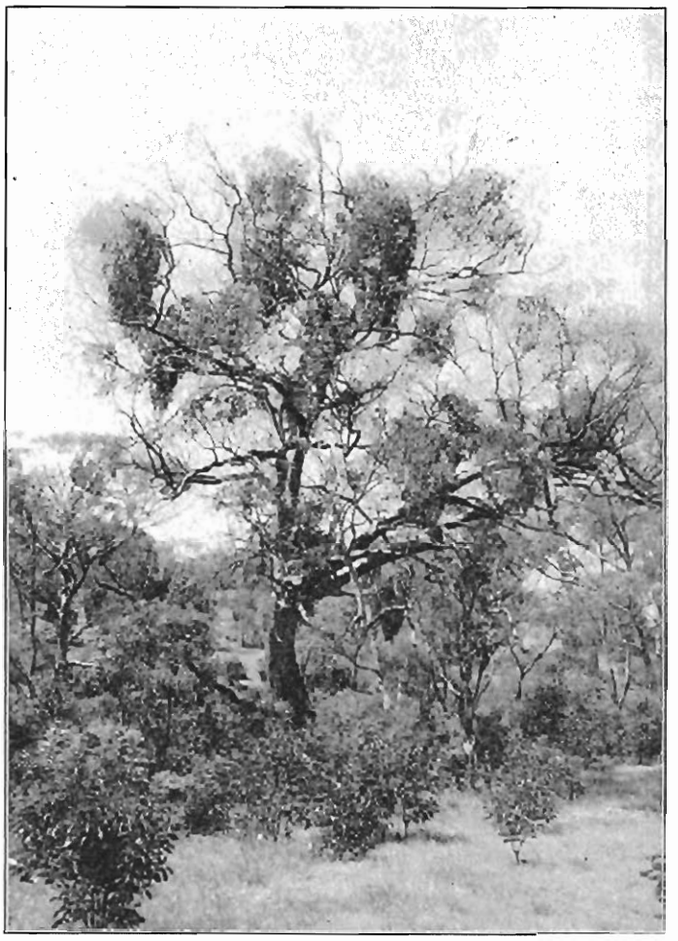


**Plate 30.**—Mistletoe killing native trees. The Blue Gum (Eucalyptus leucoxylon) is being annihilated by the Mistletoe in many districts in the State.

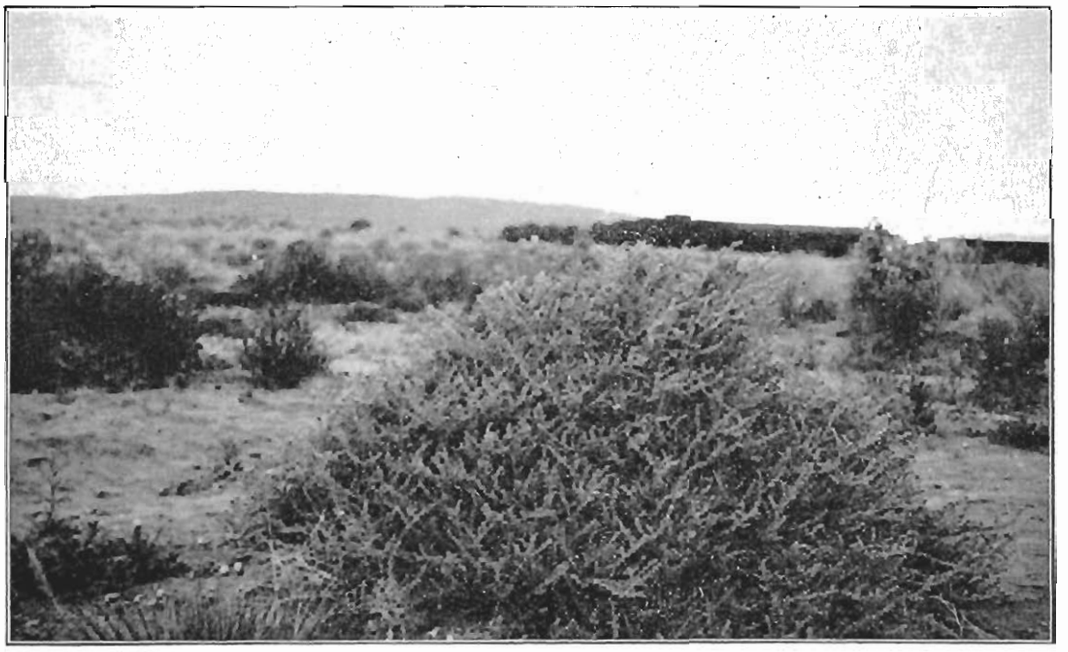


**Plate 31.**—A remarkable recovery of vegetation on an area on a pastoral holding in the North-East which had been bare and windswept for about 20 years, after ploughing furrows and protecting from grazing animals.

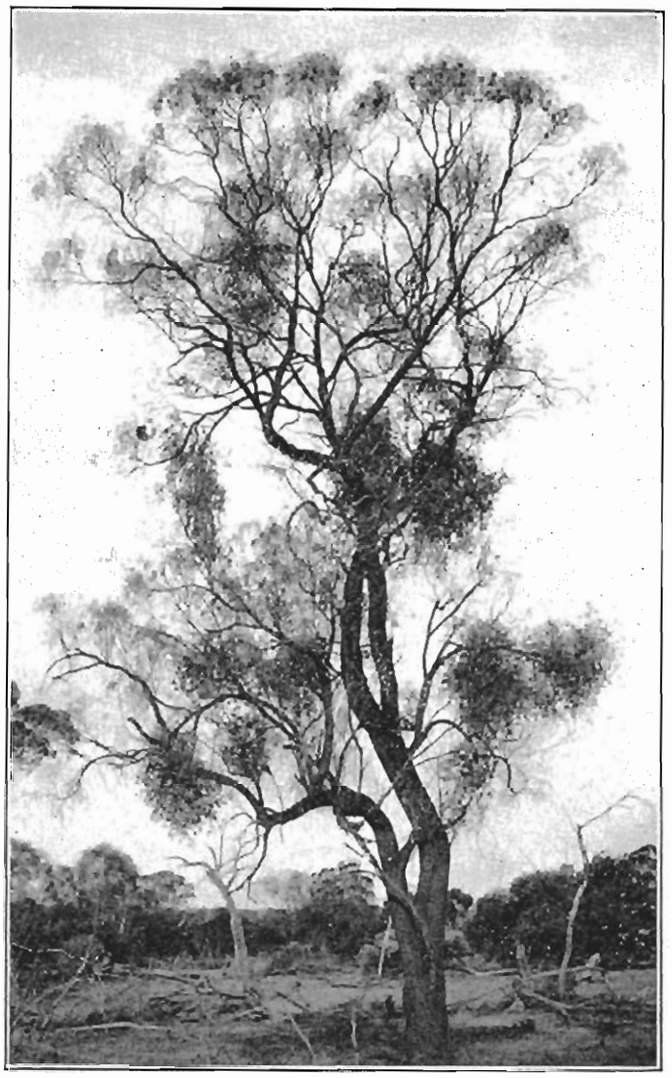


**Plate 32.**—Mistletoe killing native trees. The widely distributed tree of the low-rainfall areas of South Australia, the Sugar-wood (Myoporum platycarpum), is also being decimated by Mistletoe.

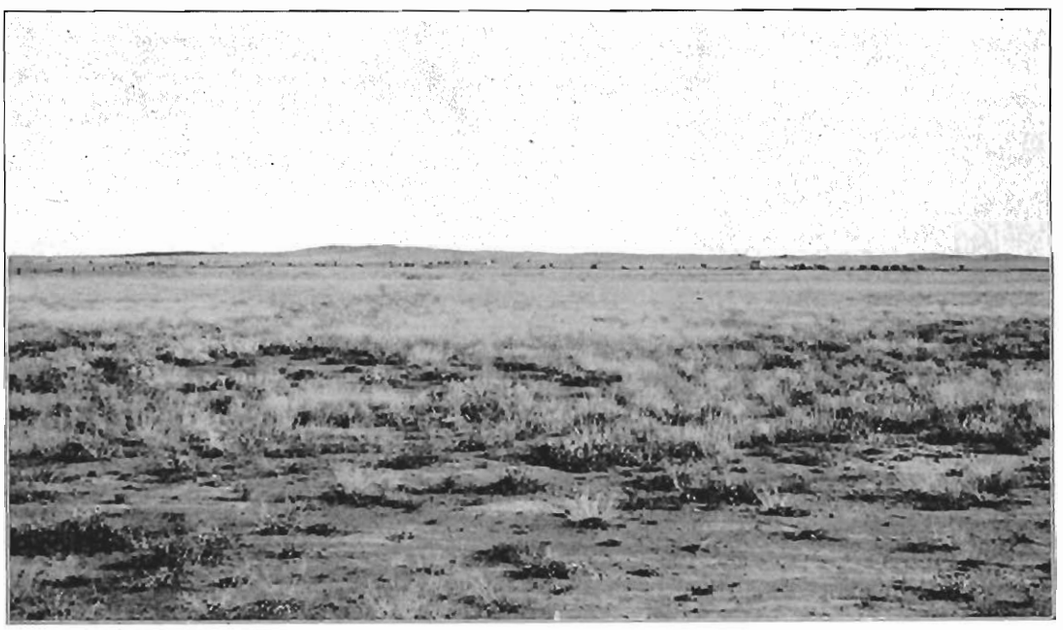


**Plate 33.**—By diverting water from a nearby watercourse over a bare windswept plain in the North-East, a fairly complete recovery was made in one season.

**Plate 34.**—Mistletoe killing native trees. Even the extremely hardy Sheoak (Casuarina stricta) is liable to attack.

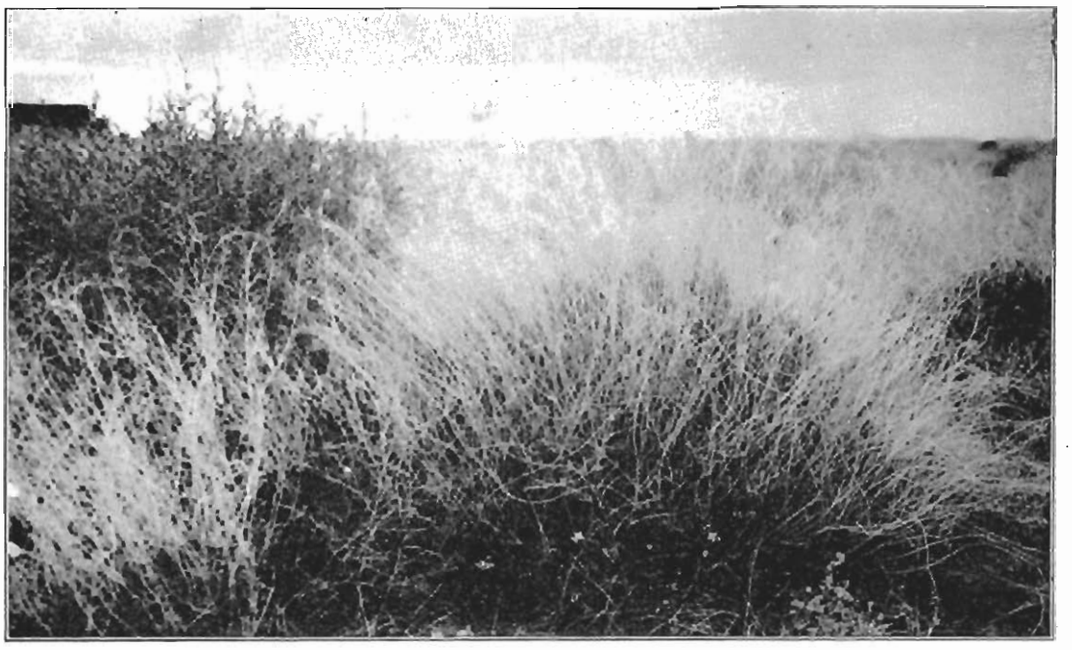


**Plate 35.**—Teetulpa Weed (Diplotaxis tenuifolia) has established itself in the pastoral areas, is behaving somewhat like a native, and is proving very useful in helping towards the recovery of eroded country.

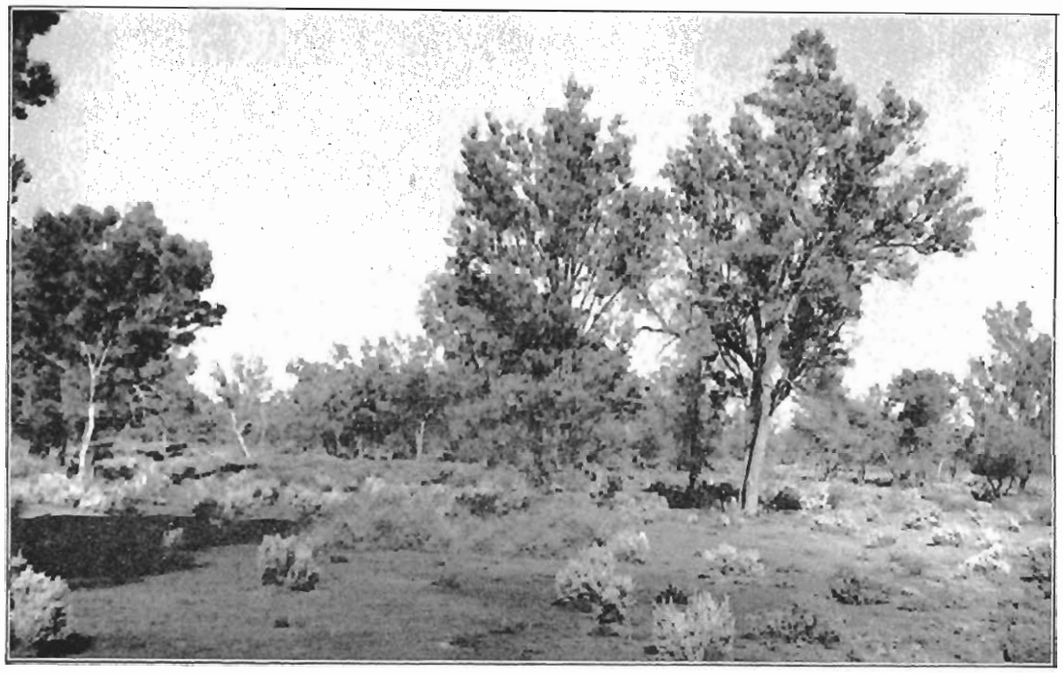


**Plate 36.**—There is no need to destroy the natural vegetative cover, as is shown in this illustration of North-Eastern pastoral country which has carried just as many, or more, livestock over the past 70 years as other similar country which has been bared.

**Plate 37.**—The result of clearing sandy ridges, with fire and plough, in the agricultural areas.

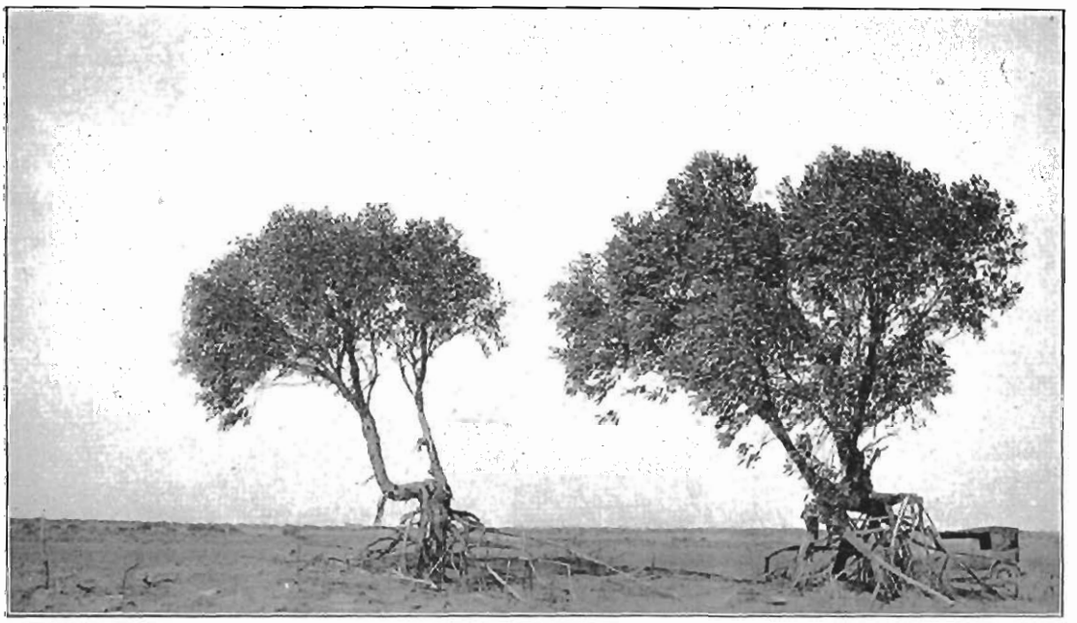


**Plate 38.**—Even old live Mallees (Eucalyptus spp.) can have the sandy soil blown away from them when the remainder of the protective cover has been removed.

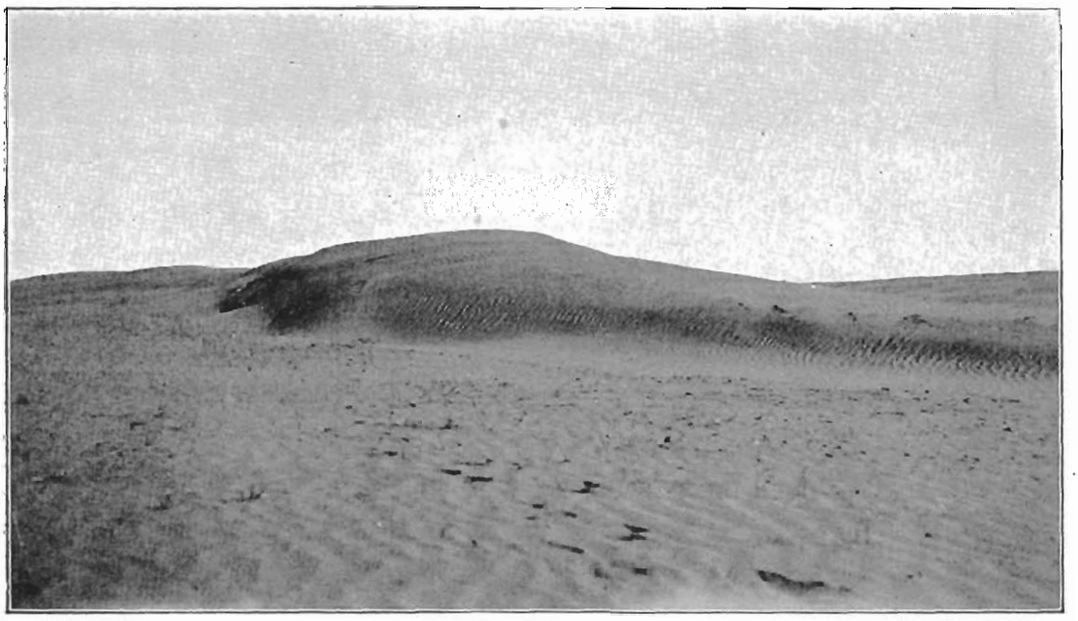


**Plate 39.**—Fallowing sandy land in windy seasons not only leads to loss of soil but becomes a menace to better land alongside.

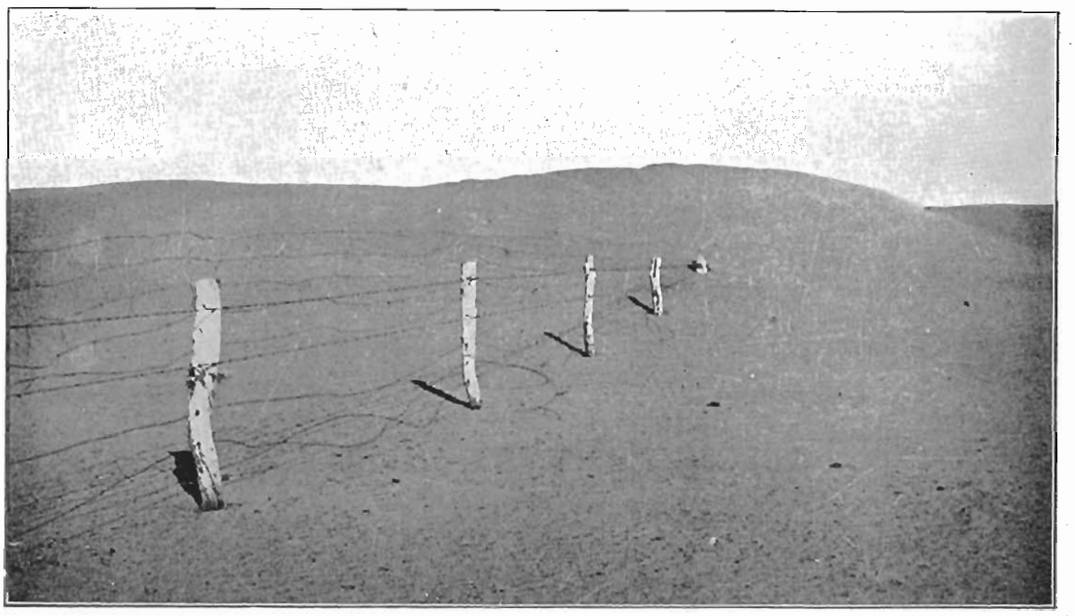


**Plate 40.**—Fences and public utilities such as roads, railways, reservoirs, etc., are liable to damage when sand drifts.

**Plate 41.**—The mere throwing of brush on to drifting sand ridges will temporarily hold the sand in position.

**Plate 42.**—On steep faces of drifting sandhills the laying and fixing of brush in a careful manner will hold the sand for some years. In the meantime sand-binding plants can be established in amongst the brush.

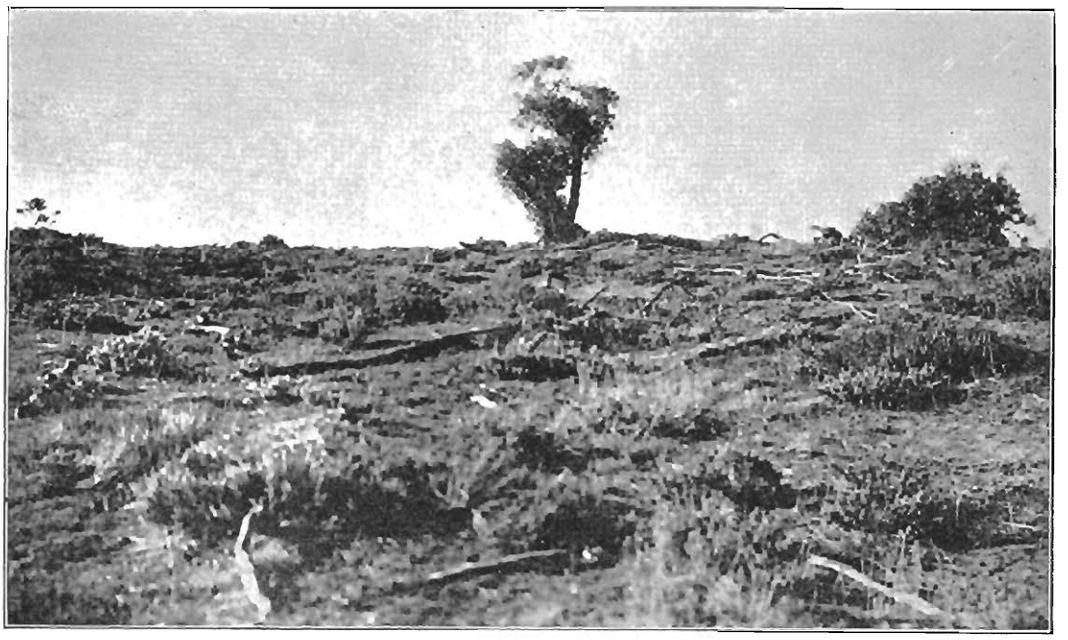


**Plate 43.**—A bad drift reclaimed by covering with brush and protecting from grazing animals. There has been sufficient re-establishment of native plants to hold the sand, provided the land is not again bared by fire or animals.

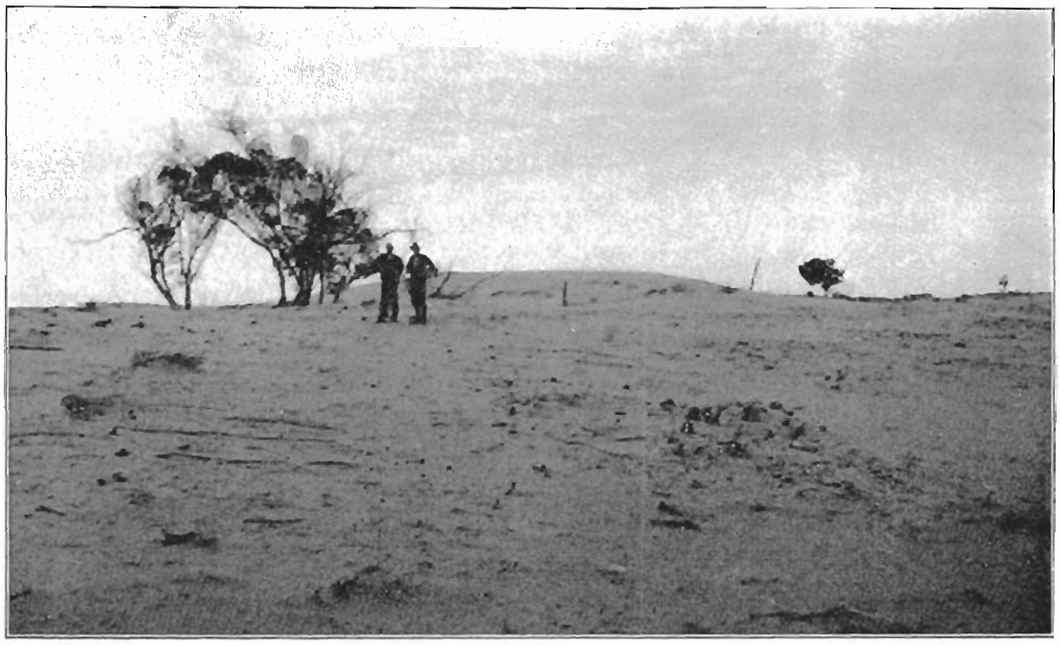


**Plate 44.**—A wide sand ridge which has been windswept for some years. Before attempting the establishment of cover, the mounds, and banks of hollows, should be broken down so that a seed drill can function everywhere.

**Plate 45.**—A sand ridge quite similar to that in Illustration 44, held in one year with Rye, Lucerne, Wimmera Rye Grass, and Evening Primrose.

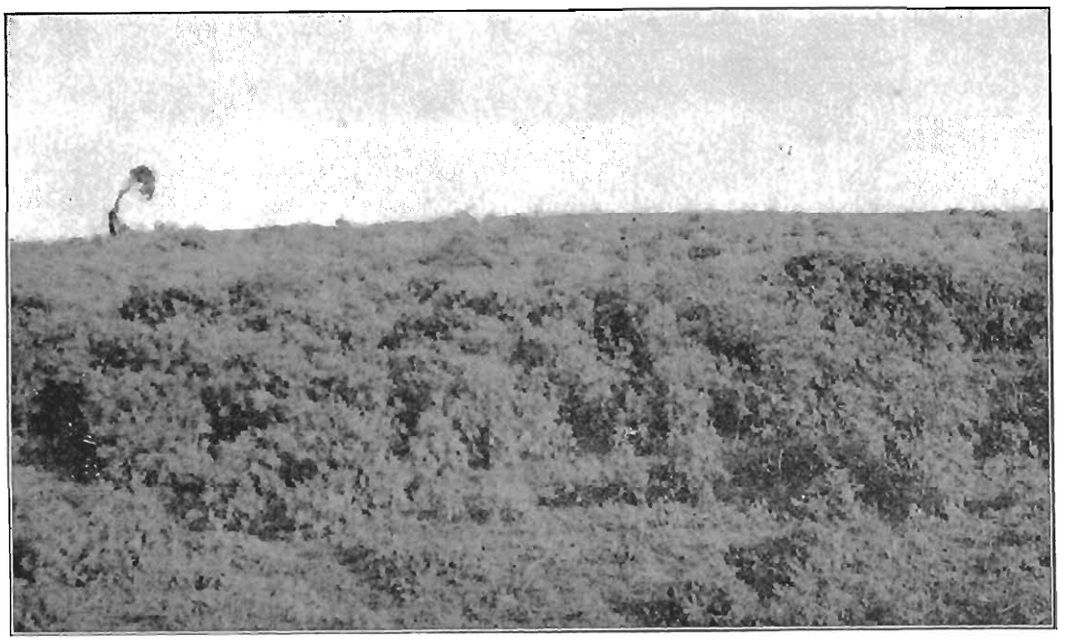


**Plate 46.**—Blue Lupins are useful sand binders. The illustration shows a bad sand drift near Murray Bridge held with Lupins.

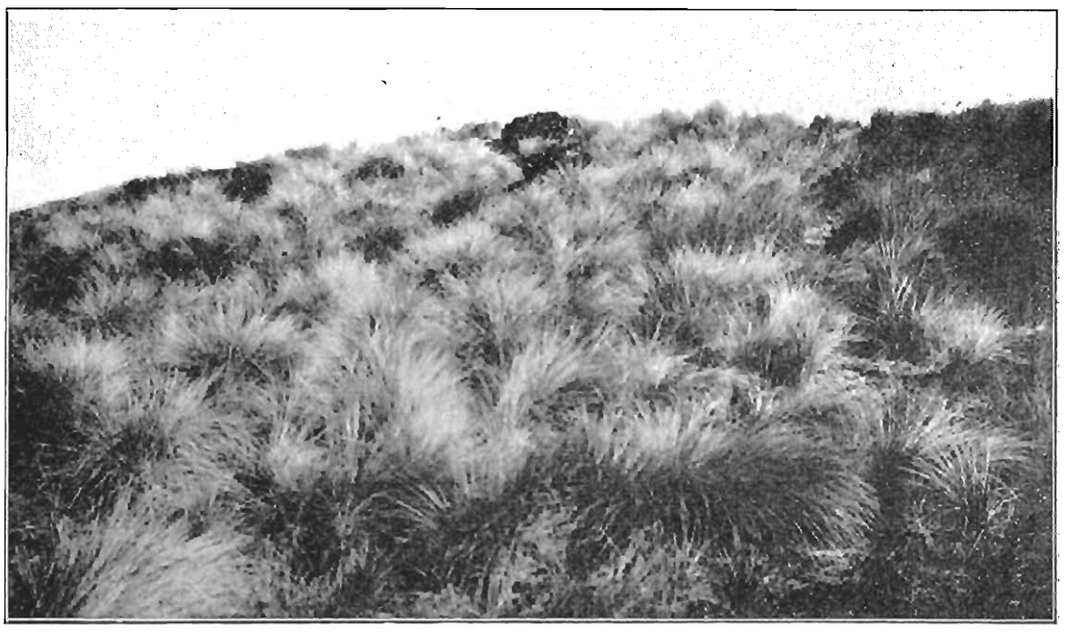


**Plate 47.**—Near the coast, and in those other portions of South Australia where the average annual rainfall is 18in. or more, Marram Grass (Ammophila arenaria,) is an extremely good sand-binder.

**Plate 48.**—Pyp Grass (Ehrharta villosa) is an excellent sand-binder and does really well where the average annual rainfall is even less than 14in.

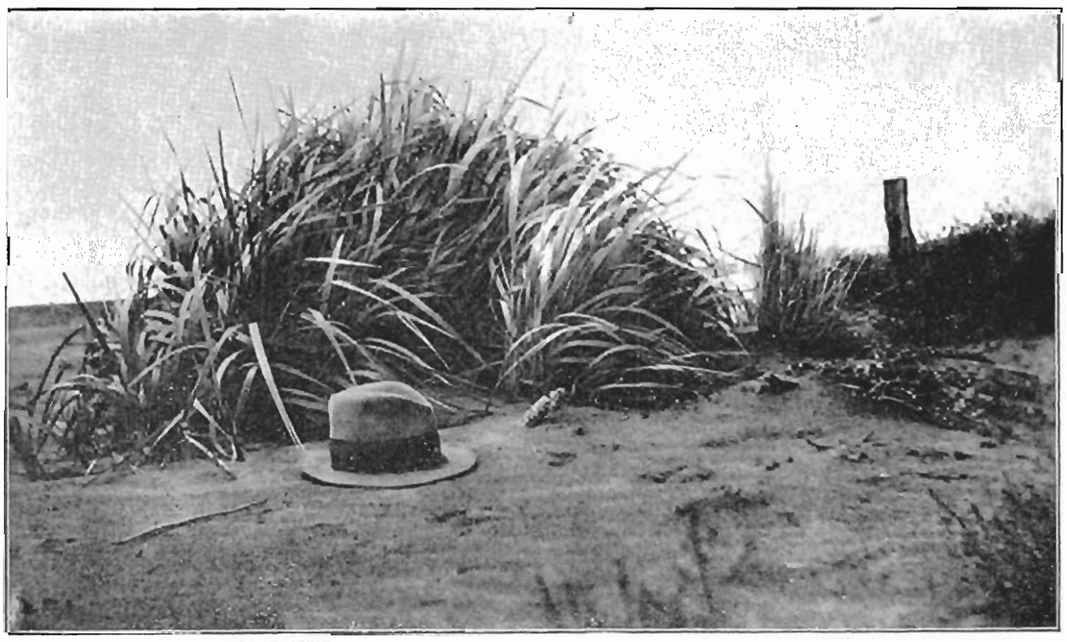


**Plate 49.**—Relatively new to Australia, sand-binding grass, Elymus giganteus (Giant Lyme Grass), is very promising indeed, even in low rainfall districts. The above illustration is of a clump less than one year since transplanting.

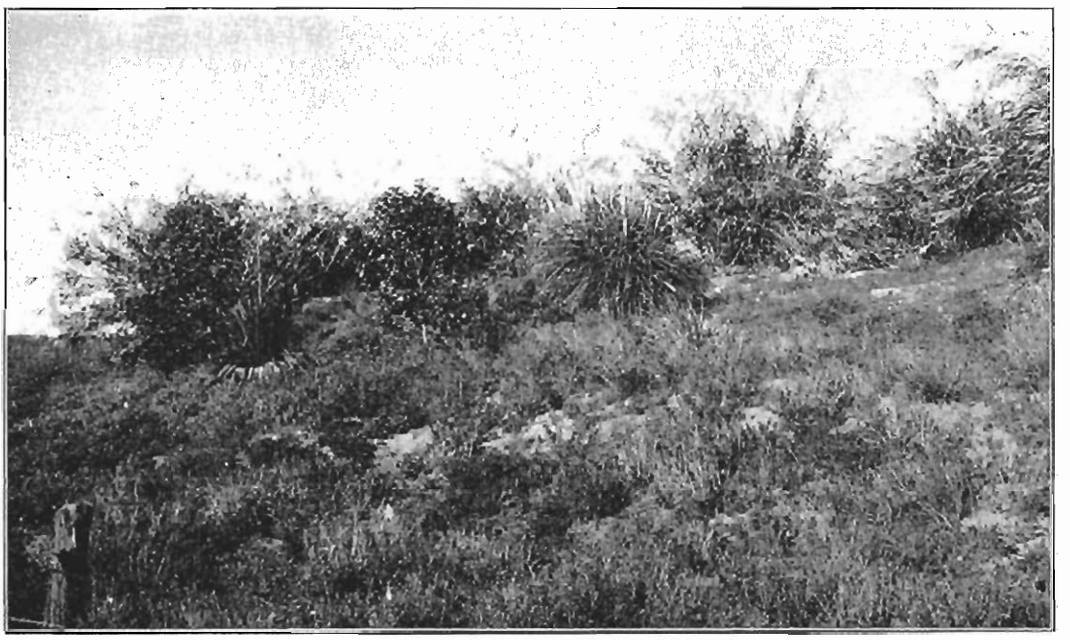


**Plate 50.**—A very bad sand drift permanently held with Giant Reed (Arundo donax) and Pampas Grass (Gynerium argentum).

**Plate 51.**—Showing the edges of a deep "blow-out" securely held with Giant Reed, Pepper Trees (Schinus molle) and Eucalypts.

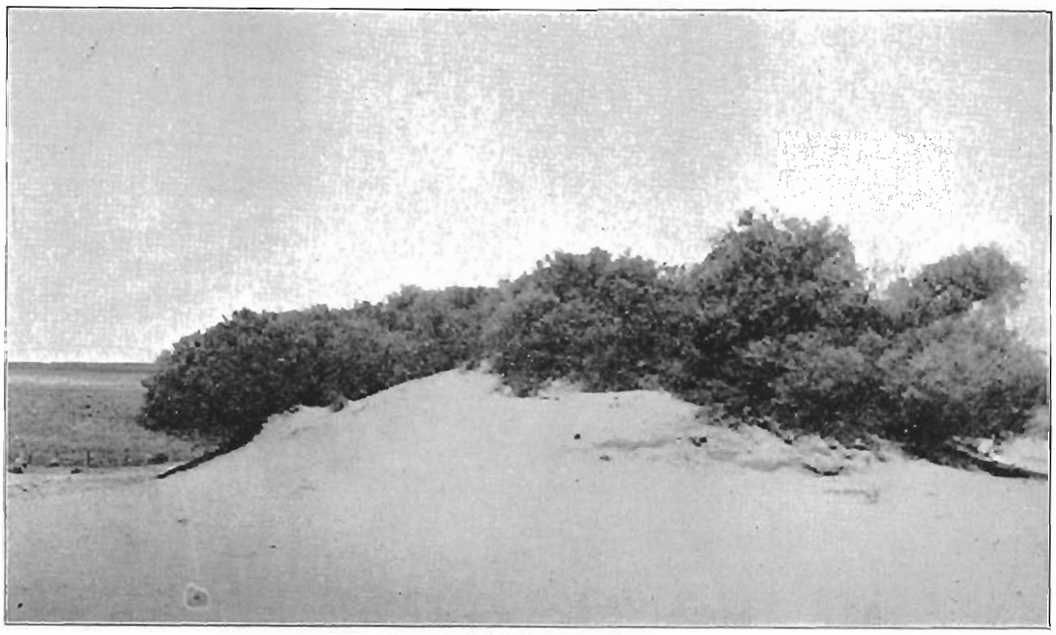


**Plate 52.**—Of native plants, the Umbrella Wattle (Acacia ligulata) is very useful for holding sand in the agricultural areas of the State.

**Plate 53.**—The introduced plant Watsonia meriana is spreading in the better rainfall parts of the State and is helping to prevent water erosion. The illustration shows a narrow creek being reclaimed by Watsonia, Briars, and Eucalypts.

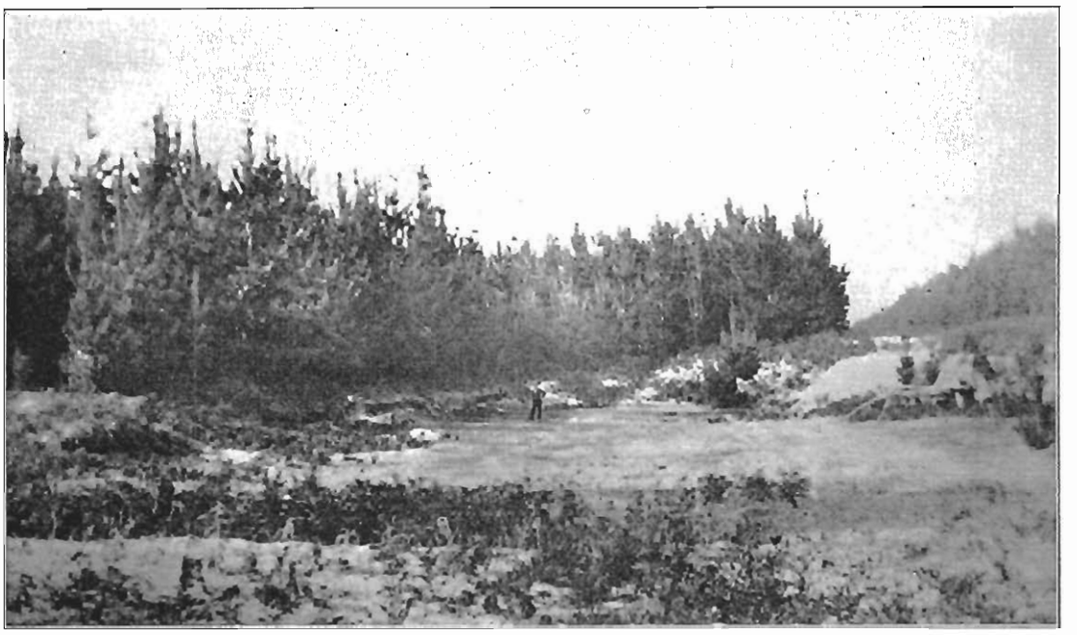


**Plate 54.**—Eight-year old trees of Remarkable Pine (Pinus radiata) planted across a very drifty area in the South-East. After the trees were established Bracken Fern and other sand-loving plants extended all over what was before a loose drifty area.

**Plate 55.**—Remarkable Pine (Pinus radiata) planted over 20 years ago on the outside of a deep "blow-out" in the South-East, while the loose sand in the "crater" was held by Black Wattle (Acacia decurrens).