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25437

INDEX TO VOLUME 8, 1952

SUBJECT INDEX

INDEX—*continued.*

AUTHOR INDEX

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FOREWORD

BY

E. S. CLAYTON, H.D.A., Commissioner.

IN recent years the State of New South Wales has suffered a succession of the most disastrous and widespread floods in its history. During the floods public attention is focussed on the tragic loss of stock, property and human distress, but the greatest loss, and the one which cannot be replaced, occurs when acres of the rich alluvial lands themselves are lost, as they have been, particularly on many of our coastal river valleys.

The rivers themselves are of the greatest possible importance to this country, and the lands bordering them are irreplaceable. Some bitter losses have been suffered in recent years in the river valleys. Very severe floods have been experienced, and doubtless will be again. In fact, the indications are that if deterioration of the Catchments continues, the floods will inevitably become more destructive.

No doubt there are lessons to be learnt by all those concerned with the immediate effect on towns and homes built in low-lying portions of coastal river valleys, and the effect of floods on rail and road transport and on industry generally. The obvious erosion occurring on the alluvial lands is very serious indeed. These flats are the most fertile lands in the State. Where they border coastal rivers and favoured portions of the inland streams, the rainfall and climate meet the exacting requirements of a high class of agriculture, and the combination of rich, deep and well-drained soil, in abundant and fairly reliable rainfall areas, renders these lands the most productive and most valuable in the State. They carry a relatively high proportion of our rural population, and they make possible a more advantageous use of the generally rougher, poorer lands between the river valleys. Nationally, we cannot afford to lose an acre of these alluvial lands. Yet they are going, and in recent years the rate of loss has been very rapid.

To correct this position, the outstanding requirements are:—

(1) Stabilisation of the whole watersheds of the rivers by the avoidance of inappropriate land use, the full utilisation of vegetative protection to the soil, and the application of other supplementary soil conservation measures where appropriate.

(2) River control for the protection of the banks against erosion with provision of storage dams where required.

To stop the worst effects of a river running wild in flood periods, both these broad requirements must be met. The first will reduce both the amount of water which immediately reaches the river in flood rains and the amount of silt and erosional debris. More of the rain will be taken into the soil, and both the immediate and the total run-off will be reduced. If these measures are supported by carefully located earthworks for holding water, the total run-off can be still further reduced. Nevertheless, in those periods of extensive, prolonged flood rains on coastal rivers, they will need the support of river control measures.

The application of soil conserving measures throughout the valley generally is required, including effective protection of the eroding stream banks.

There is need to take full stock of the whole position on all the coastal watersheds in order that a properly balanced approach can be made to the problem as it exists on each river.

Conservation measures, which will include land usage, applied to the watersheds are, in my opinion, the only practical means of ensuring that water run-off will not become increasingly greater and that protective structures on the lower reaches of rivers will not be called upon to withstand ever-increasing flood heights.

Steep watersheds must be kept protected by an effective cover either of forest or grass or other vegetation. Overclearing and lack of forest management on what forest does remain, burning and overgrazing are the worst evils on watersheds. The area cultivated on these catchments is usually small, but if steep lands are cleared and cultivated, great damage can result. Some tragic examples of this soil exploitation can be seen on the northern rivers, where slopes much too steep for intensive cultivation have been cleared, with consequent loss of soil.

The value of forests as a means of protection from erosion and floods and as producers and protectors of water supplies has been universally acknowledged. This recognition came after disastrous experiences following upon the excessive removal of forest cover in many parts of the world. In a watershed the role played not only by the commercial forests but by those which could be called protective forests is very important.

The achievement of effective watershed management is a big task, but it is by no means impossible. Much has been learnt by observation of the effects of the unplanned exploitation of forest and grazing lands. Field research is now commencing to indicate effective management procedures to meet the different environmental conditions. Both experience and research show that effective watershed management requires the best possible treatment of both forest and grazing areas. Good forests, good pastures, good soils and good water are generally associated.

HYDROLOGICAL STUDIES IN THE UPPER SNOWY CATCHMENT AREA WITH SPECIAL REFERENCE TO THE EFFECTS OF LAND UTILISATION.

BY

A. B. Costin, B.Sc.Agr.*

INTRODUCTION.

THE Snowy Mountains of New South Wales form that portion of the Great Dividing Range between Forest Hill on the Victorian border and Bullock Hill near Kiandra. Forming the watersheds of the Snowy Catchment Area in the east and the Hume Catchment Area in the west, the Snowy Mountains are probably the most valuable natural water resource in Australia.

The most important part of the Snowy Catchment is the relatively small portion situated above Jindabyne, near the confluence of the Upper Snowy River and its two major northern and southern tributaries, the Eucumbene and Thredbo Rivers. In this paper, these three rivers, collectively, are termed the Upper Snowy River System and their combined catchments the Upper Snowy River Area (Fig. 1). This catchment may be sub-divided into four well defined environmental tracts: alpine, sub-alpine, montane and tableland.

The alpine tract extends from the tree line at approximately 6,000 feet to a maximum elevation of 7,328 feet at Mount Kosciusko. The average annual precipitation varies between approximately 70 and 90 inches, and the ground is snow covered for at least four months of the year continuously. Semi-permanent snow patches occur above 7,000 feet, which sometimes persist throughout the year. The climatic climax vegetation is tall alpine herbfield, and the associated soils are alpine humus soils and humified peats. Important physiographic and primary edaphic vegetation climaxes and soils also occur interspersed with the tall alpine herbfields. These include sod tussock grassland with silty bog soils, grey podsols, and alpine humus soils; short alpine herbfield (snow patch vegetation) with snow patch meadow soils; fen with fen peat and silty bog soils; valley bog and raised bog with valley bog peats and raised bog peats; fjældmark with lithosols and alpine humus soils; and heath with lithosols, grey podsols, and alpine humus soils. Of greatest significance in catchment area studies are those plant communities and soils determined primarily by ground water influences. The most important of these in the alpine tract of the Upper Snowy Catchment Area are certain of the sod tussock grasslands with silty bog soils and grey podsols; short alpine herbfield with snow patch meadow soils; fen with fen peat and silty bog soils; and valley bog and raised bog with valley bog peats and raised bog peats.

The sub-alpine tract, situated between approximately 5,000 and 6,000 feet, receives average annual precipitations from about 50 to 80 inches. This tract is snow covered continuously for one to four months of the year. The climatic climax vegetation is sub-alpine woodland and the associated soils are alpine humus soils and humified peats.

*Formerly Soil Conservationist, Soil Conservation Service, now Thomas Pawlett Scholar, Sydney University.

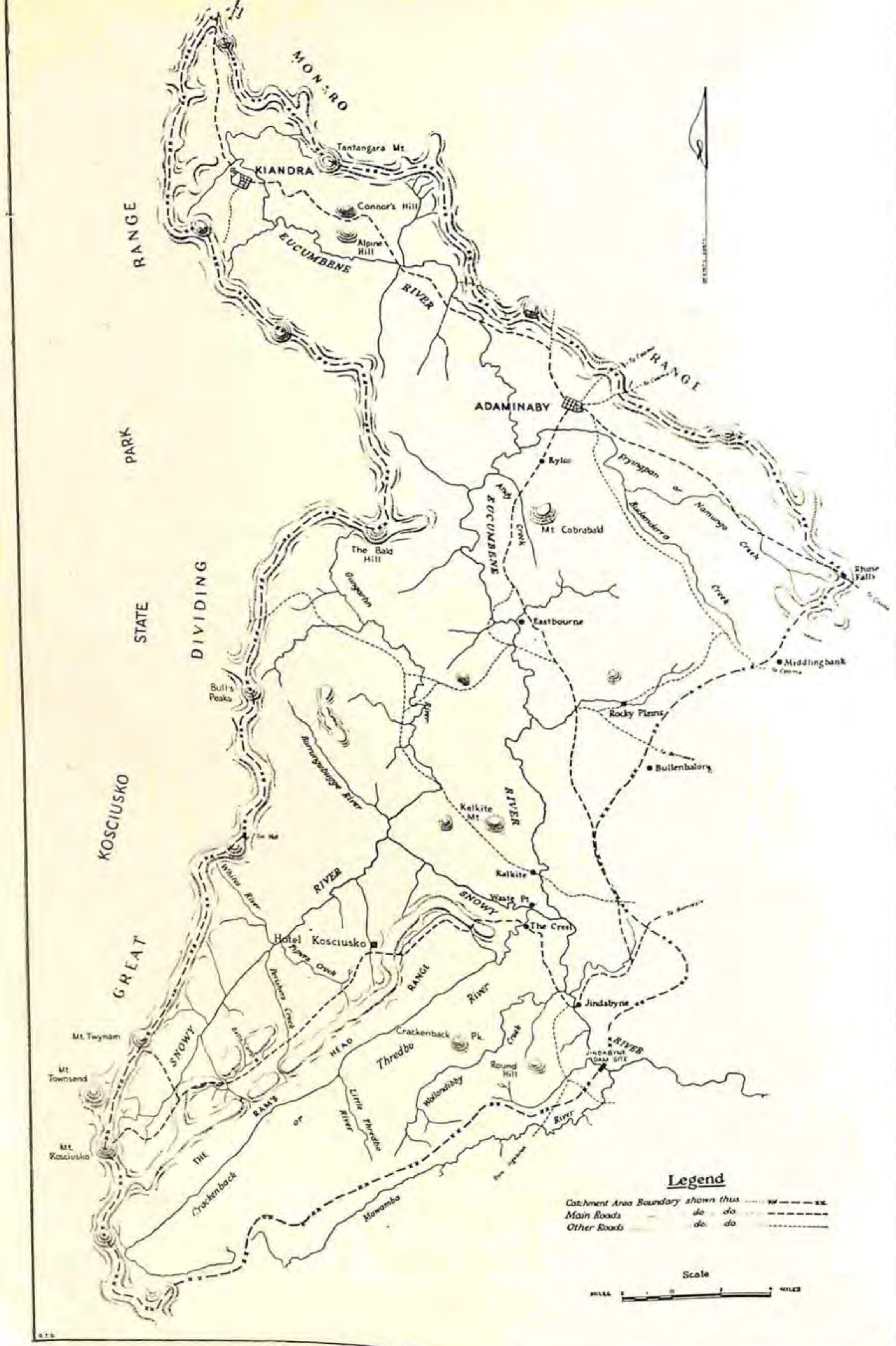

Fig. 1.—The Upper Snowy Catchment Area.

Except for fjældmark, and short alpine herbfield with snow patch meadow soils, the sub-alpine tract contains the same physiographic and primary edaphic vegetation and soil climaxes as the alpine tract.

The montane tract extends from about 3,000 to 5,000 feet. Average annual precipitations are relatively low, ranging from approximately 20 to 50 inches, and winter snowfalls do not usually persist for more than two to three weeks continuously. The climatic climax vegetation consists of wet and dry sclerophyll forests associated respectively with transitional alpine humus soils, brown podsolics, iron podsols, red loams, and lithosols; and with brown and grey-brown podsolics, brown earths, and lithosols. Associated physiographic and primary edaphic climaxes include wet tussock (meadow) grassland with meadow soils, silty bog soils, grey podsols, and brown earths; wet scrub with lithosols; wet mallee with lithosols, brown podsolics, and transitional alpine humus soils; and savannah woodland with brown and grey-brown podsolics, iron podsols, meadow soils, grey podsols, brown earths, and transitional alpine humus soils. The most important ground water plant communities and soils are wet tussock grassland with meadow soils, silty bog soils, and grey podsols. Localised fen and raised bog communities are occasionally encountered.

The tableland tract constitutes the least important portion of the Upper Snowy Catchment Area, fringing the montane tract below elevations of approximately 3,000 feet. Average annual precipitations vary from 20 to 30 inches, and winter snowfalls are usually light and non-persistent. The climatic climax vegetation is mainly savannah woodland with brown and grey-brown podsolics, iron podsols, meadow soils, grey podsols, and brown earths; but in areas of locally higher rainfall wet sclerophyll forest with brown podsolics and iron podsols may occur. Physiographic and primary edaphic climaxes include wet tussock grassland with meadow soils, silty bog soils, grey podsols, brown earths, and alluvial soils; wet scrub with lithosols; and dry sclerophyll forest with brown and grey-brown podsolics, brown earths, and lithosols. The most important ground water communities and soils are wet tussock grassland with meadow soils, silty bog soils, and grey podsols. Localised fen communities are occasionally encountered.

From the preceding discussion it is apparent that the alpine and sub-alpine tracts not only contribute most to the total flow of the Upper Snowy River System by virtue of their heavy precipitations and persistent snows, but also contain a larger proportion of ground water plant communities and soils which act as natural reservoirs for the storage and gradual discharge of water. For these reasons the alpine and sub-alpine tracts are the most important in relation to questions of catchment area efficiency and conservation. Comparatively small areas of the montane and tableland tracts are occupied by ground water soils and vegetation, and consequently the catchment area problems in these tracts are largely those of accelerated erosion and siltation.

The investigations outlined in this paper were undertaken to ascertain, firstly, the nature of the precipitation-riverflow relationships in the Upper Snowy Catchment Area, and, secondly, to what extent, if any, these relationships may have been modified by practices of land utilisation.

METHODS AND RESULTS.

1.—*Selection of River Flow and Precipitation Recording Stations.*

In studying the relationships between precipitation and river flow in a catchment area, the selection of representative recording stations is the first essential. In the Upper Snowy Catchment the only stations for which reliable data are available for a sufficiently long period of time are Kiandra in the sub-alpine tract for precipitation, and Jindabyne in the tableland tract for river flow. The distance by river between these stations is approximately 50 miles.

The paucity of recording stations is partly counter-balanced by the respective situations of Kiandra and Jindabyne. Detailed examination of precipitation data available for all stations in the Upper Snowy Catchment shows that not only is there a good correlation between precipitation at Kiandra and in the alpine, sub-alpine, and upper montane tracts as a whole, but that the lower montane and tableland tracts contribute comparatively so little to the total river flow of the Catchment that lack of precipitation recording stations in the latter tracts does not introduce serious sampling errors. The steepness of the precipitation gradient between the alpine and tableland tracts is illustrated in Fig. 2, in which the average annual precipitation

channel over a period of years may lead to erroneous conclusions concerning alterations in the volume of flow. Such changes in the shape of the river channel may occur quite rapidly if the river passes through unconsolidated sediments; but if it flows between well stabilised banks and over a stony or gravelly bed the rate of change, except, perhaps, over long periods, is not appreciable. Since the latter conditions obtain at the

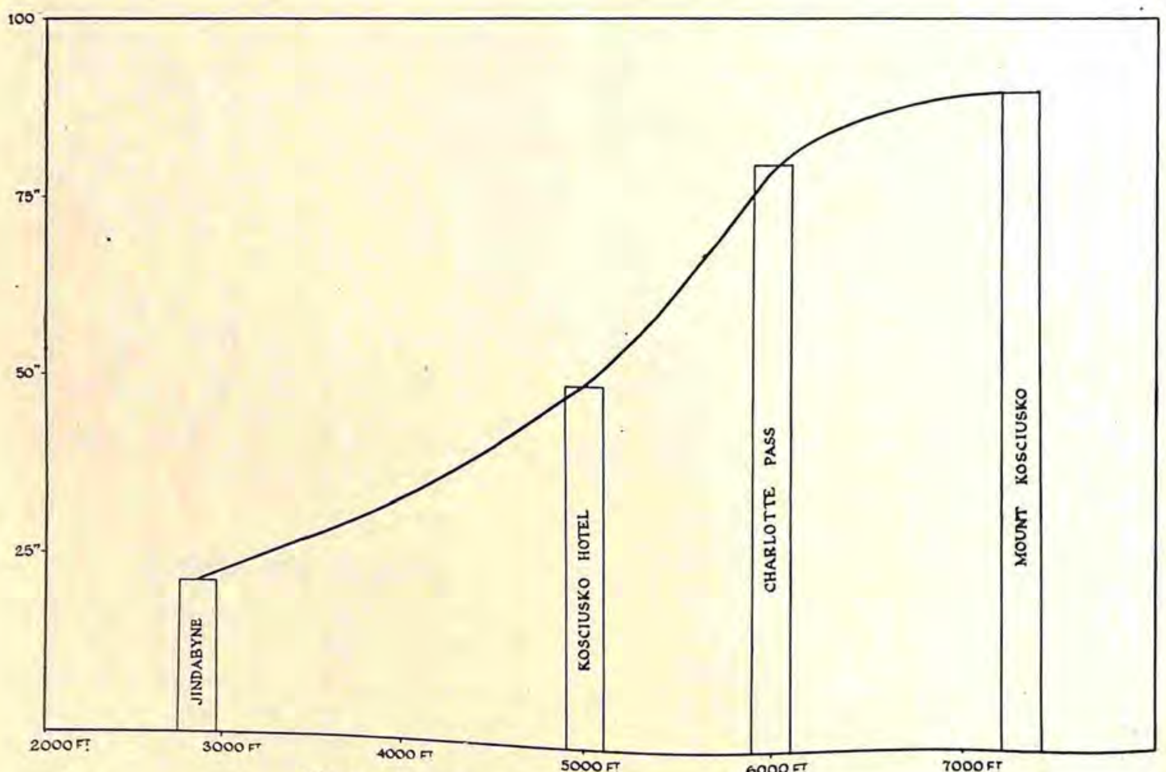

Fig. 2.—Precipitation Gradient, Snowy Mounttins.

decreases from approximately 90 inches at Mt. Kosciusko to less than 22 inches at Jindabyne within a distance of about 20 miles.

In view of the situation of Jindabyne just below the confluence of the Upper Snowy, Eucumbene, and Thredbo Rivers, the river flow data at this station also represents the resultant of conditions for the Upper Snowy River System. Where flow estimates are based on river height readings at a given point, changes in the shape of the river

Snowy River at Jindabyne, alterations in the shape of the river channels do not constitute a significantly complicating factor in the present hydrological investigations.

2.—*Selection of Data.*

The nature of the relationships between river flow and precipitation in the Upper Snowy Catchment Area is complicated by the heavy winter snowfalls in the alpine and sub-alpine tracts, and by the consequently large volume of water suddenly released

from melting snow during the spring thaw. The months of the year during which the effects of snowfall are least are November to April, inclusive, and only these months were considered in the present investigations.

Inspection of the data also revealed that small precipitations produced no appreciable variation in river flow, so that daily precipitations less than 20 points and their corresponding river flows were ignored. The elmination of data in this manner does not bias the statistical results.

The earliest and latest five-year periods for which complete daily precipitation and river flow data are available—1903-1907, and 1943-1947—were selected for analysis. Preliminary examination of Kiandra weather reports showed that during and prior to these two five-year periods, similar meteorological conditions were experienced.

Any changes in the river flow regime since 1907 might, therefore, be examined as evidence of changes in the Catchment Area itself.

At Kiandra and Jindabyne, respectively, 9.00 am. precipitation and river flow readings are taken. These daily readings provided the basis for the following statistical analyses.

3.—*Statistical Procedure and Results.*

Pilot analyses showed that river flow at Jindabyne on a given day was not affected significantly by precipitation measured at Kiandra more than four days previously. The following multiple regression equation was therefore adequate to study the precipitation-riverflow relationships for each period 1903-1907 and 1943-1947.

$$Y = a + b_1R_1 + b_2R_2 + b_3R_3 + b_4R_4,$$

where Y = change in river flow (as cubic feet per second) during a particular 24 hour period compared with river flow during the preceding 24–48 hours.

R_1 = precipitation (points of rain) during the same period of 24 hours.

R_2 = precipitation during the preceding 24–28 hours.

R_3 = precipitation during the preceding 48–72 hours.

R_4 = precipitation during the preceding 72–96 hours.

An Analysis of Variance was used to test the significance of total regression for each period (Table 1). In both periods the total regressions were highly significant $P < 0{\cdot}01$)

TABLE 1.

Analyses of Variance for Periods 1903–1907 *and* 1943–1947.

Period.	Source of Variation.	Degrees of Freedom.	Sums of Squares.	Mean Square.	$F_{4,00}$
1903–1907	Regression ...	4	156,873,548	39,218,287	33.913*
	Residual ...	384	444,075,860	0,156,448	......
	Total ...	388	600,949,408	......	......
1943–1947	Regression ...	4	65,272,496	16,318,124	18.748*
	Residual ...	399	347,287,027	870,394	......
	Total ...	403	412,559,523	......	......

* Highly significant — $P < 0{\cdot}01$.

Having thus demonstrated the significance of total regression, the individual regression coefficients were then examined for significance by means of "t" tests with the following results. (Table 2.)

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statistical results of the river flow-precipitation analyses for the Upper Snowy Catchment Area indicate the importance of ground water both in relation to the general hydrology of the Catchment and to the changes which have occurred between 1903-1907 and 1943-1947.

Under completely natural conditions, the ground water plant communities and soils of the Upper Snowy Catchment Area would probably be almost completely saturated, and the ground cover of the more extensive non-ground water communities and soils dense and unbroken. Under these conditions, a given precipitation on reaching the ground would probably be discharged rapidly into the river system mainly as surface run-off. Little of this precipitation would be retained as ground water unless the same quantity of water already stored in the ground water soils and plant communities were released. That this river flow-precipitation regime probably obtained during 1903-1907 is indicated by the statistical results for this period. The highly significant positive relationship ($+b_1$) between change in river flow on a particular day (with regard to the previous day) and precipitation recorded during the same 24-hour period, indicates that most of the precipitation rapidly entered the rivers as surface run-off within 24 hours. The highly significant negative relationship ($-b_2$) between change in river flow and precipitation recorded 24-48 hours previously also shows that most of this precipitation had entered the river within the first 24 hours and that by 48 hours river flow was returning to normal. That river flow rose to a maximum within 24 hours after a given precipitation and fell to its base level within the next 24-48 hours is also shown by the lack of significant relationships ($-b_3$ and $-b_4$) between change in river flow and precipitations recorded 48-72 and 72-96 hours previously. (See Fig. 3.)

The statistical results for 1943-1947, however, indicate a different river flow-precipitation regime for this later period.

There is still a highly significant positive relationship ($+b_1$) between change in river flow on a particular day and precipitation during the same 24 hours, indicating that most of the precipitation still enters the rivers as surface run-off within 24 hours. The highly significant negative relationship ($-b_2$) between change in river flow and precipitation recorded 24-48 hours previously still obtains as in 1903-1907, but in addition the negative relationship ($-b_3$) between change in river flow and precipitation during the previous 48-72 hours is now highly significant. This shows that the effect of a given precipitation now persists for a longer time since the river flow no longer returns to normal within 48 hours as in 1903-1907, but is still decreasing significantly up to 72 hours. The non-significant negative relationship ($-b_4$) between change in river flow and precipitation 72-96 hours previously shows that after 72 hours no appreciable decrease in river flow occurs. (See Fig. 3.)

The tests of significance of the differences between corresponding regression coefficients in 1903-1907 and 1943-1947 also indicate that different hydrological conditions obtained in the Catchment during these periods. The significant differences between the regression coefficients (b_{1_A} and b_{1_B}) for change in river flow on precipitation during the same 24 hours, indicates that a given precipitation now causes river flow to increase less rapidly in 24 hours than in 1903-1907, presumably because less of this precipitation is now being discharged immediately as surface run-off. That a substantially greater part of this precipitation now enters the rivers after 24-48 hours than in 1903-1907, is shown by the significant difference between the regression coefficients (b_{2_A} and b_{2_B}) for change in river flow on precipitation during the preceding 24-48 hours. The differences between the corresponding regression coefficients in 1903-1907 and 1943-1947 (b_{3_A}; b_{4_A} and b_{4_B}) in respect of the 48-72-hour periods are not significant. (See Fig. 3.)

These differences between the river flow-precipitation relationships in 1903-1907 and 1943-1947 might be due either to changes in the condition of the Upper Snowy Catchment itself during the present century, or to the possibility that for one of the periods Kiandra may have been a much better estimator of average precipitation over the total Catchment than for the other period. While the latter alternative would seem to

be supported by the smaller proportion of the variance accounted for by regression in the later period as compared with the earlier, and cannot be ruled out until further analyses for intervening periods have been undertaken; field evidence more strongly supports the former alternative that changes have occurred in the condition of the Catchment itself as suggested below.

The above-mentioned differences between the river flow-precipitation regimes of the two periods may be explained adequately in terms of the ratio of immediate surface run-off to ground water discharge, on the assumption that the effects of a given precipitation in increasing surface run-off will be virtually complete within 24 hours, while the effects on ground water discharge will be less rapid and persist for a longer period. That the ratio of immediate surface run-off to ground water discharge, with regard to a given precipitation, is now less than in 1903-1907, may be attributed to anthropeic changes in the ground water soils and plant communities of the Catchment. Field evidence is quite definite that these soils and communities have undergone widespread desiccation and humification during quite recent years (particularly since the severe fires of 1939) with the result that they are not only less water-saturated than previously, but also considerably lower in potential storage capacity. Whereas in 1903-1907 precipitations on undamaged and saturated ground water areas do not appear to have been absorbed appreciably but to have been discharged as surface run-off into the rivers within 24 hours, precipitations at the present time are now arrested temporarily, apparently because the partly desiccated ground water areas are no longer fully saturated. Furthermore, since their storage potential is also less because of accelerated peat humification, this arrested water cannot all be retained, and part of it discharges from the ground water soils or displaces some of the ground waters which have accumulated there previously. It would appear that the discharge of this temporarily arrested water is not complete within the 24 hours after a given precipitation, and the effects of the latter on river flow therefore persist longer at the present time than in 1903-1907. From the standpoint of the hydrological engineer, the greater lag between precipitation and run-off evident in the hydrograph for 1943-1947 would, at first sight, be preferable to the more immediate run-off in 1903-1907. This impression may be erroneous, however, for the following reasons. The hydrograph for 1943-1947 probably corresponds to an early transitional stage of damage to the ground water plant communities and soils. If this transitional stage were relatively stable—that is, if the hydrological changes in the Catchment Area occurred relatively early during the present century and little additional change occurred in more recent years—the long-term catchment efficiency of the Area would not be expected to undergo much additional deterioration. On the other hand, if this transitional stage represents a more recent condition of instability, there is a real danger that the present trend might continue to the stage where most of these soils and communities may be destroyed and accelerated erosion in non-ground water areas may also occur; finally resulting in the reduction of the water holding capacity of the Catchment Area to the extent that the hydrograph may become even steeper than in 1903-1907, with virtually no lag between precipitation and run-off. Although additional statistical analyses for intervening periods are needed to answer this question with certainty, the field evidence strongly suggests that the latter condition of instability is the one which now obtains in the Upper Snowy Catchment Area. A comparison of the areas under the two hydrographs, moreover, shows that approximately 10 per cent. less of a given precipitation reached the river in 1943-1947 than in 1903-1907. This loss of precipitation in 1943-1947 may be attributable mainly to the greater evaporation which would have occurred during the longer period of its temporary arrest by damaged ground water areas.

Since the incidence of the factors influencing the Upper Snowy Catchment Area in 1903-1907 and 1943-1947 appears to have been the same in most respects except the length of time under land use, a consideration of the nature and extent of the anthropeic changes in ground water areas of the Catchment is obviously necessary to an adequate understanding of the changes in hydrological conditions which appear to have occurred. These matters are discussed in the following section.

SIGNIFICANCE OF STATISTICAL RESULTS IN RELATION TO LAND USE.

Much of the Upper Snowy Catchment Area has been used for summer grazing of sheep and cattle for periods approaching 100 years; at first quite indiscriminately and during more recent years under the snow lease system.

Notwithstanding the undoubted value of the Upper Snowy Catchment Area for summer grazing, its importance as a watershed is so great that its future management to preserve its catchment efficiency appears a vital consideration for Australia.

As early as 1893, Helms (1893) predicted the disastrous consequences of fire in the Upper Snowy Catchment. More recently, Costin (1949, 1950), and the Joint Scientific Committee of the Linnean Society of N.S.W. and the Royal Zoological Society of N.S.W. (1946), have drawn attention to various aspects of catchment area deterioration. Detailed ecological work since 1946 has substantiated these findings and revealed more precisely the nature, extent and recentness of the damage. The ground water vegetation and soils have suffered most, particularly the short alpine herbfields (snow patch communities) and snow patch meadow soils, the fens and fen peats, and the valley bogs and raised bogs and corresponding bog peats.

The short alpine herbfields and associated snow patch meadow soils are normally soft underfoot due to permanent saturation with snow water, and are thus most susceptible to the effects of trampling. This position is aggravated by the fact that certain palatable snow patch plants are eagerly sought after and selectively grazed by livestock. Excessive trampling has broken the naturally continuous herbaceous carpet of many snow patch areas resulting in accelerated nivation, water erosion, and desiccation.

The fens and fen peats have also suffered from grazing and burning. The dominant sedge, *Carex Gaudichaudiana* Kunth, is extremely palatable, with the result that the fens are overgrazed, irrespective of the overall stocking rate. This overgrazing has caused serious peat desiccation and humification accompanied at a later stage by the rapid removal of the desiccated peat by wind erosion. Once desiccated, peat becomes very light and difficult to re-wet, and is thus highly vulnerable to wind action. These conditions have been aggravated further by burning, and in extreme cases ignited fen peats have continued to smoulder throughout the summer months.

The bogs and bog peats of the Upper Snowy Catchment Area are characterised by the moss *Sphagnum cymbigolium* Ehrh. The present Australian environment in alpine and sub-alpine areas appears barely suitable for the active development of *Sphagnum* bogs and peats, which on the Australian continent may be considered relics of an earlier, moister climatic period. For this reason the bogs are most susceptible to any type of unfavourable human interference, and once damaged are in danger of progressive deterioration. Like the fens, the bogs are selectively grazed by livestock, and, owing to the soft character of the *Sphagnum* moss and underlying half-formed peat, are even more susceptible to damage by trampling. The bog surface is readily broken in this way, leading to accelerated drainage which, in turn, is followed by desiccation, humification and erosion of the peat. Severe fire damage of the same type as described for the fens has also occurred. Examination of many bog peat profiles throughout the Catchment has shown that a regional fall of several inches in the level of the water table has probably occurred since human occupation. Evidence for this conclusion is furnished by the presence of a podsolised horizon *within* the peat, and by the invasion of the bog communities by non-hygrophilous species. Neither of these processes operates in an undamaged fully saturated bog.

The deterioration of ground water soils and vegetation by accelerated desiccation, humification, and erosion is now widespread in the Upper Snowy Catchment Area, and if allowed to continue at the present rate, will probably lead to its pronounced drying out and a permanent reduction in its storage capacity. In relatively few areas, however, has this deterioration reached the stage of complete destruction, so that if remedial action is taken without delay, at least the present efficiency of the Catchment could be maintained.

Fire control throughout the catchment appears essential, and although restricted grazing is compatible with catchment area stabilisation in relatively dry areas not containing susceptible ground water soils and vegetation, these latter areas are especially liable to destruction by fire or stock or both.

The Upper Snowy Catchment Area is now being developed on a grand scale for water conservation and hydro-electric purposes. Constructional work in certain localities is being carried out at some cost to catchment area stability. In particular, road making operations have already destroyed numerous ground water plant communities and soils and initiated accelerated erosion in non-ground water areas. There is need for particular care in so locating these operations that the minimum reduction of catchment area efficiency results and this can be achieved by giving due consideration to the soils and vegetation of the areas concerned.

In a country such as Australia, where lack of adequate water resources is the most important natural limiting factor to production, the conservation of existing resources is a vital matter. This applies particularly to our limited alpine and sub-alpine catchments which, because of high average annual precipitations, persistent winter snowfields, and steep physiography, provide abundant and dependable supplies of water suitable for irrigation and also potentially valuable for hydro-electric purposes.

From the evidence which has so far been obtained, it is tentatively concluded that significant changes have occurred during comparatively recent years in the river flow-precipitation regime of the Upper Snowy Catchment Area, which may be attributable to anthropeic damage to the alpine and sub-alpine ground water communities and soils.

SUMMARY.

The river flow-precipitation relationships of the Upper Snowy Catchment Area during the six snow-free months November to April were examined statistically for two five-year periods 1903-1907 and 1943-1947.

The statistical results demonstrated for both periods a highly significant relationship between increased flow of the Snowy River at Jindabyne on a given day (relative to river flow during the previous day) and precipitation at Kiandra during the same 24 hours. This rapid increase in river flow is attributed to surface run-off. The increase in river flow after a given precipitation was followed by a sudden decline and return towards normal. This normal flow was re-attained within 24-48 hours in 1903-1907, and within 24-72 hours in 1943-1947.

There were significant differences between corresponding river flow-precipitation relationships in 1903-1907 and 1943-1947. Immediate surface run-off was significantly greater in 1903-1907, and virtually none of a given precipitation was arrested temporarily as ground water. By contrast, immediate surface run-off was significantly less in 1943-1947, probably due to the temporary arrest of part of the precipitation as ground water. This temporary arrest led to increased evaporation, with the result that approximately 10 per cent. less of a given precipitation reached the river in 1943-1947 than in 1903-1907.

These differences are associated with anthropeic changes in the ground water plant communities and soils during the last 50 years. It is suggested that in 1903-1907 these communities and soils were more nearly in their natural, undamaged, water-saturated condition, and consequently did not arrest or retain precipitations appreciably but discharged them immediately as surface run-off. By 1943-1947, however, the practices of grazing and burning had so damaged and desiccated these communities and soils, that precipitations were probably no longer discharged completely as immediate surface run-off but were partly arrested for a short time before being released as ground water.

The greater lag in 1943-1947 may be interpreted as a transitional stage associated with early damage to the ground water areas, which, if continued, may ultimately lead to a more rapid rate of run-off than in 1903-1907 and to reduction in the efficiency and storage capacity of the Upper Snowy Catchment Area.

ACKNOWLEDGEMENTS.

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SOIL EROSION AND SOIL CONSERVATION IN THE PARKVILLE DISTRICT.

BY

C. M. BLANDFORD, H.D.A., District Soil Conservationist.

THE Parkville district, five miles north of Scone, is located in the Kingdon Ponds valley; this stream is a principal tributary of the Hunter Valley, and its catchment includes the Scone, Parkville and Wingen districts.

LOCATION AND TOPOGRAPHY.

The area under discussion in this article lies within the Parish of Park, County of Brisbane, in the land District of Scone. It lies on the eastern side of Kingdon Ponds and is bounded on the east by the Scone Mountain Range and the mountains north of this range which run up to the Black Top Trigonometrical Station at an elevation of 3,297 feet. Plan of the area is given in Fig. 1. The Parkville Railway Station has an elevation of 798 feet above sea level, and travelling north-easterly to Black Top Trig, a distance of four miles airline is covered. Approximately half this distance covers the lower area of up to approximately 17 per cent. slope. It is at Parkville that the valley begins to narrow with the lower slope areas becoming merely pockets of flats along the stream when Wingen is reached.

The lower slope areas are frequently cut by drainage lines from the higher lands on either side of the main stream. Figs. 2 and 3 show plainly the pattern of the tributary drainage lines and their ultimate disposal in the main stream (Kingdon Ponds).

EARLY SETTLEMENT.

Prior to the year 1908, the lands shown in Fig. 1 were owned by St. Aubins Estate. With the exception of small areas, the Parkville lands were not used for cultivation but for fattening stock.

In 1908, two sub-divisions of the Estate were made embracing an area of 15,000 acres mostly within the Parish of Park, covering the whole of the area shown in Fig. 1.

After 1908, the practice of cultivation, principally for wheat, replaced that of fattening stock on the grassland areas of the lower slopes. Wheat growing has been the principal activity for quite a number of landowners in the Parkville area. However, in later years a more balanced type of farming has taken place, with grazing playing a more important part in the land utilisation of the area.

EROSION.

With the advent of greater areas of cultivation and the use of sloping lands beneath steep hills for this purpose, erosion became more prevalent. A deterioration in the subsidiary drainage lines took place as a result of increased run-off. Some men on the area now can recall when wheat was grown across watercourses which are now gullies up to 14 feet deep. Sheet erosion became more prevalent because of the more intensive usage of the land after sub-division. Figs. 2 and 3 show the condition of subsidiary drainage lines in 1938, 30 years after the change in land utilisation.

SOIL CONSERVATION AND LAND USE.

In 1947 the first major demonstration of soil conservation work was commenced. Now, a coverage of the area is developing which will ultimately mean the application of soil conservation measures to all the farms in the area. Fig. 1 shows the areas whose owners are already undertaking comprehensive soil conservation work. On these farms the land use factor has been stressed, with

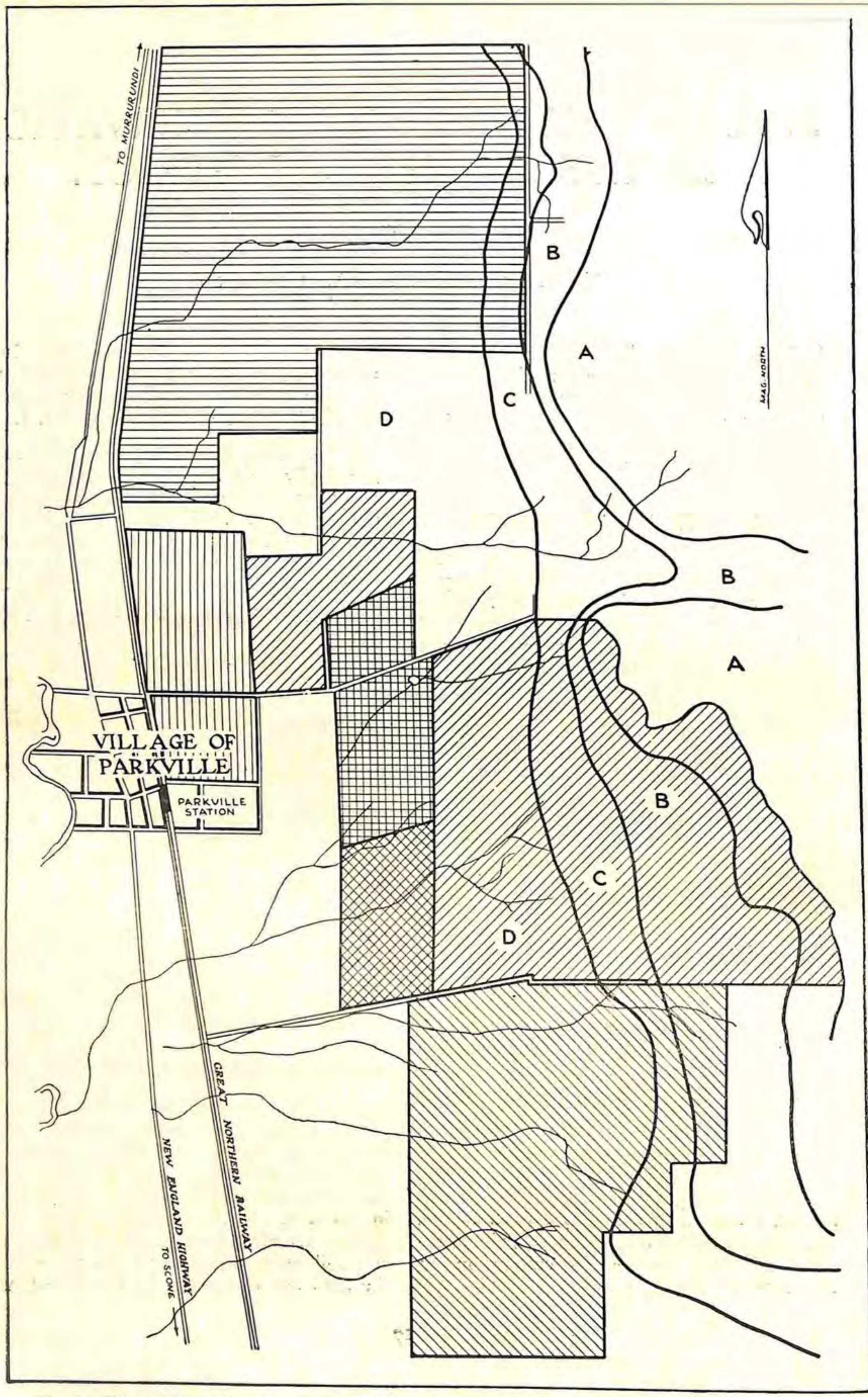

Fig. 1.—Plan of Parkville Area showing land classes and boundaries of landholders co-operating with the service in this vicinity.

particular reference to management of higher lands; on the lower lands, also, land use has been altered where one-crop farming has resulted in soil compaction, loss of structure, loss of surface soil by sheet erosion, and then eventual gullying of the area.

Mechanical means of erosion control have been used on the lower slope areas to prevent further soil loss and these methods have been incorporated in the reorganised land usage.

The land class and control measures adopted are:—

Class A.—High Mountainous Timber Country. 30-40 per cent. slopes. Maintenance of timber cover. prevention of fire, grazing only at opportune times and extermination of rabbits—very restricted usage.

Class B.—Steep slopes 17-30 per cent. Light grazing only with strict control over stock and rabbits. On certain areas pasture improvement can be carried out by non-cultivation methods such as re-seeding and top dressing. Restricted usage in accordance with seasonal and pasture conditions.

Class C.—Medium Slopes 7-17 per cent. slopes. Heavier grazing land—Mechanical measures for erosion control can be applied and also incorporated into the pasture improvement programmes. Mechanical measures have included diversion of run-off from higher lands into stable disposal lines and dams, pasture furrowing, ripping and gully reclamation. For the

Fig. 2.—Extensive mechanical soil conservation measures are necessary at Parkville because of removal of timber from steep slopes.

pasture improvement work Rhodes grass (*Chloris gayana*), Lucerne (*Medicago sativa*) and rye grass (*Lolium spp.*) have been used.

Class D.—Cultivation lands 0-7 per cent. These lands are suitable for cultivation, but should be protected from run-off from higher lands by mechanical means where necessary. In the 3-7 per cent. grouping, protection of the cultivation land by mechanical means is generally advisable for prevention of further soil loss and for the introduction of conservation farming. Some of the lands used for wheat growing have been so consistently cropped that they are considered to be "wornout," and the laying down of pasture mixtures, principally Rhodes grass and lucerne, is being undertaken for the rehabilitation of fertility for future arable land usage.

MECHANICAL CONTROL MEASURES.

Mechanical control works have been carried out as demonstrations, minor demonstrations, plant hire, individual and co-operative works by farmers and Shire Authorities with their own or hired equipment. Co-operation between farmers and Shire Authorities has been very readily given, so that effectiveness of the programme has been high.

CONCLUSION.

Land utilisation in the Parkville area was changed from a pastoral to an agricultural basis some 42 years ago; an erosion factor was set up which reduced the productivity of the area. Now that conservation farming and conservative land usage are being adopted in this area, loss from erosion is being prevented, and the present productivity of these lands is being maintained and steadily improved.

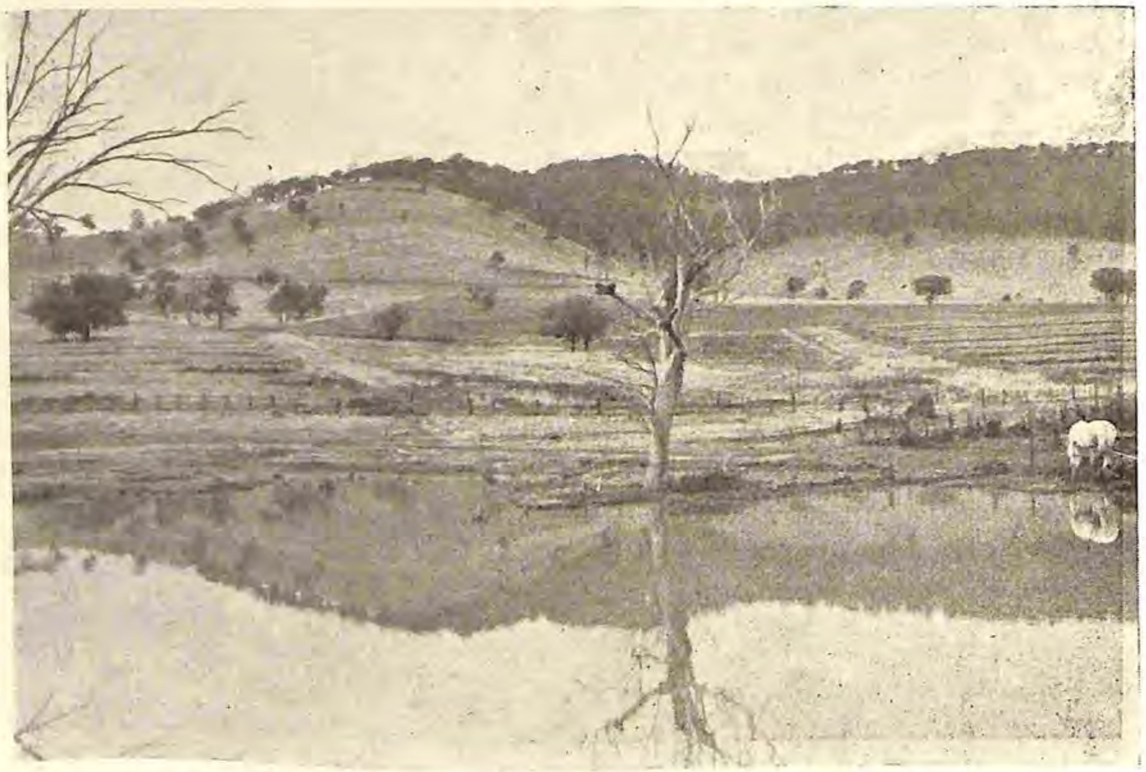

Fig. 3.—Water safely disposed by grassed waterways into a farm dam.

SOIL CONSERVATION IN THE WESTERN DIVISION.

BY

R. W. Condon, B.Sc.Agr., Research Officer and Botanist.

INTRODUCTION.

THE problem of soil erosion in the arid portion of this continent is one of considerable importance and one which will have considerable bearing on Australia's future. Equally important is the serious degeneration of pasture which has been taking place, leading to a reduction in the productive capacity of the country, and leaving the soil more susceptible to erosion.

This article is intended as a brief review of the work of the Soil Conservation Service in Western New South Wales in dealing with the problems of erosion and its many detrimental effects. It will bring before the landholder a summary of the work executed in recent years. Research work on soils and vegetation, even under good climatic conditions, resulting in regular germination and rapid growth, may take several years. In the arid climate of Western New South Wales, the low and irregular rainfall lengthens this period. However, previous investigations over a period of years have brought us to a point where methods of solution of many problems are now in sight. The application of these methods is a matter for the landholder.

EROSION IN WESTERN NEW SOUTH WALES.

Soil erosion has been a serious problem in the Western Division of New South Wales and the nearer western plains since early settlement. It was first brought to public notice by the Royal Commission on the Western Division in 1901, when erosion and the many factors causing erosion were listed as the principal causes of the depression in the Western Division at that time. Periodically, during the long and severe droughts which visit the west from time to time, the occurrence of frequent dust storms with their origin in the west, creates renewed interest from the public.

Wind erosion in its many forms is probably the greatest problem the western landholder has to face. Blowflies, grasshoppers, rabbits, floods, drought and other troubles come and go, but erosion is an ever-present and ever-increasing menace. Erosion itself is not a "disease" but merely a "symptom," the disease being the misuse or abuse of the land, to which all erosion problems can be directly attributed. The primary cause of erosion is the removal of the protective plant cover, enabling the wind to play on the surface of the soil and so become a destructive agent. The roots of plants help to bind the soil together while the above-ground parts break the force of the wind and reduce its velocity over the surface. Agents responsible for the removal or reduction of the plant cover are therefore directly responsible for the occurrence of wind erosion. The grazing animal, therefore, is the prime factor in the widespread destruction of much of our valuable dry pastoral country.

Once erosion is initiated its progress can be likened to that of a cancer growing and spreading to an alarming degree, destroying country by the removal of soil here and the deposition of soil there. The bare scalded surfaces left behind present a very poor habitat for the re-establishment of vegetation, and are rarely recolonised. If colonisation does take place, it is rarely of a permanent or stable nature. Likewise, dunes, caused by the accumulation of wind-blown sand, are a poor habitat for plant growth and recolonisation is slow and very unstable.

The detrimental effects of wind erosion are many, even apart from the actual loss of productive land from the affected area, and the very important matter of reduction in productive capacity. The silting up of fences, tanks, yards and, even homesteads, tells its own story. Dusty and inferior wool from underfed sheep brings lower prices. Dust storms create unpleasant conditions around the homestead, particularly for the housewife. Less penetration or rapid run-off of water reduces the effective rainfall, making droughts longer and more frequent.

The landholder and the community, therefore, will readily appreciate the necessity for finding solutions to this all-important problem and bringing it under control.

It must not be thought that wind erosion is the sole erosion problem in the western parts of the State. Nor must it be thought that because the rainfall is infrequent and low that water erosion does not occur. The occurrence of erosion by water is widespread where the country is undulating or hilly. Extensive sheet erosion has materially reduced the productive capacity of the gently undulating country surrounding Cobar, and extending from Condobolin to Bourke. The reclamation of severely sheet eroded country is considered to be an economical proposition, and landholders who have undertaken pasture furrowing of such country have been pleased with the results. Pasture furrowing not only prevents further erosion, but brings about considerable improvement in the native pastures, both in amount and type of pasture. Research into this phase of soil conservation has been confined to regular study of regeneration resulting from furrowing in various localities. Investigations are being carried out into such matters as

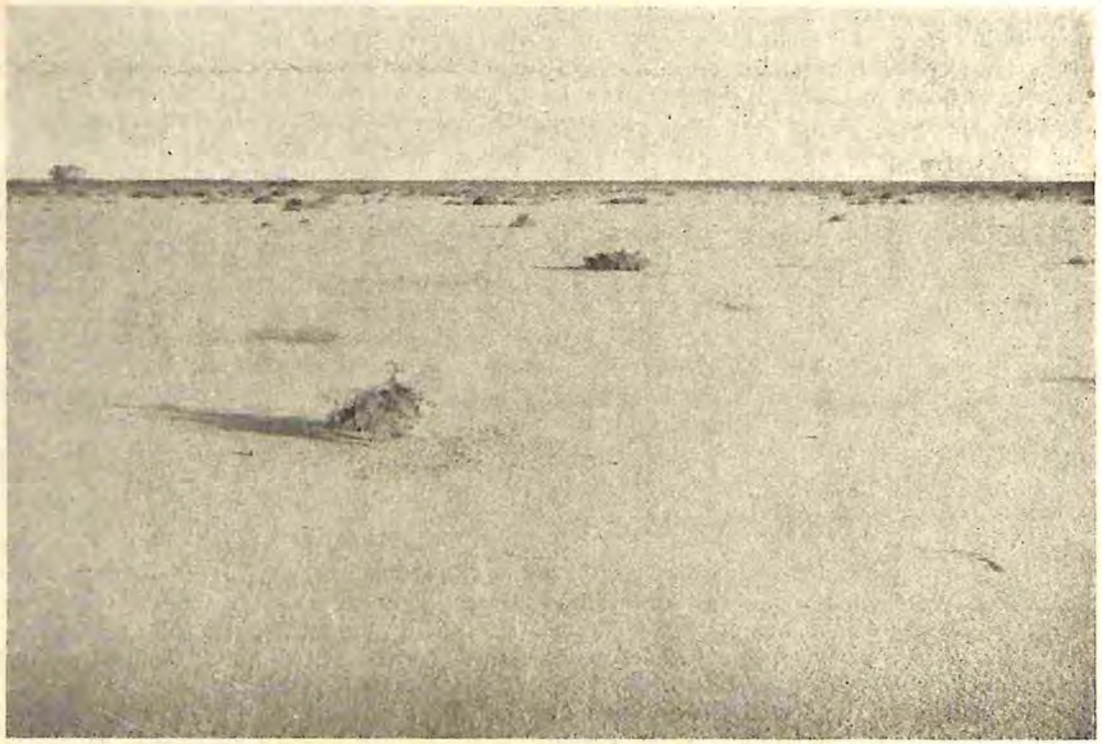

Fig. 1.—Severe and extensive scalding on bluebush country near Arumpo.

most suitable machinery units, improving techniques, introduction of improved pasture species and regeneration of edible scrub species. It has been demonstrated that even land not showing active sheet erosion can be considerably improved by pasture furrowing.

Combination of sheeet and wind erosion on slight rises in open plain country probably presents the most difficult soil conservation problem, due to the most uneven surface resulting from rilling and gullying, and the extremely high rate of run-off from the scalded soil surface. This type of erosion, common around old lake beds, is receiving attention.

Gully erosion is of widespread occurrence throughout the Western Division. Although its consequences are not as serious as on the more valuable arable land of the Western slopes, it can prove an expensive problem, in the destruction of roads and tracks, in the silting up of tanks, fences and valuable "flooded" country.

The occurrence of water erosion results from the same causes as those responsible for wind erosion. The destruction of vegetative cover and the change in soil surface conditions from the padding of stock reduces absorption of water into the soil, causing increased and more rapid run-off. Control and prevention of water erosion in the more arid parts of the State is based on the same principles as those applying to those areas blessed with a more liberal rainfall.

SOIL CONSERVATION SERVICE ACTIVITIES.

When the Soil Conservation Service of New South Wales was set up in 1938, the seriousness of the problem in Western New South Wales was well realised. It was a problem which from time to time had received a lot of temporary publicity, but about which little information of a usefui nature had been gained. It was realised that the problem was a very complex one,

Fig. 2—Reclamation of completely scalded land on the Condobolin Regeneration Area. On the left, cultivated, cereal cropped and salt bush then established; on the right untreated.

that there was no simple overall solution and that before any attempt could be made to bring the problem under control a detailed knowledge of the soil and vegetation of the area was necessary.

The stability of the soil in the arid and semi-arid western districts of the State is dependent principally upon the vegetation and its preservation. A vegetative survey of the whole of the Western Division, and certain contiguous areas of the Central Division, was carried out by Beadle[2]. Eighteen major vegetation associations were classified and a description of the soils, pastures and erosion of each given. Also included are precise accounts of the topography, geology, climate, soils, erosion and pastoral history of the west. Beadle's research has provided a very sound basis for future detailed study and solution of specific erosion problems in arid and semi-arid country. In addition, Beadle[3] carried out considerable fundamental research into the nature of scalded surfaces which have clarified this problem greatly.

In 1938, one scald reclamation area was set up at Condobolin, followed by several others in 1945; mechanical and vegetative regeneration of scalded surfaces has been studied continuously since that date. Research into methods of scald reclamation on these areas shows considerable promise for the reclamation of scalded country in the Central-West and South-West where rainfall is approximately 14 inches or better. The results and implications of this work will be published in subsequent issues of this Journal.

The success of the work in the Condobolin district has led to the establishment of similar experimental areas in districts further west where research work is being conducted on similar lines to that at Condobolin, with modifications to suit climatic conditions. Experimental work conducted at Booligal over the last three years, in an area of 11 inches average rainfall, has given

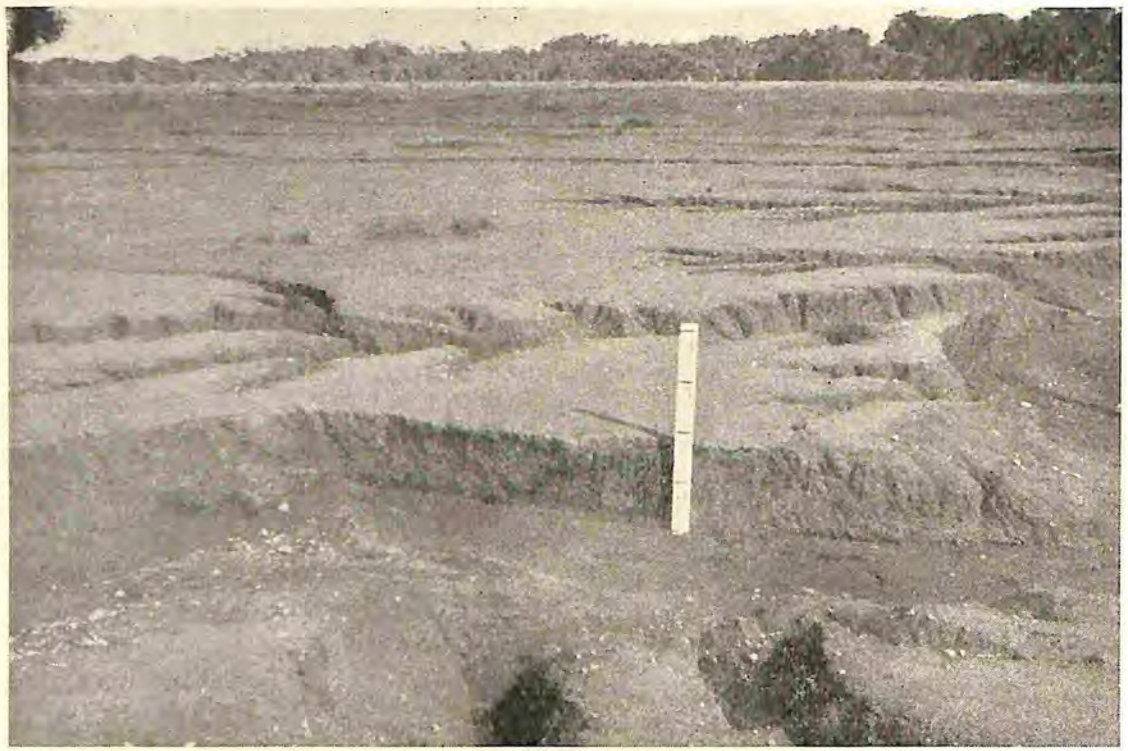

Fig. 3.—Severe sheet and gully erosion on gently sloping country north of Lake Cargellico.

indication of similar promise to the Condobolin work, and four experimental demonstration areas are now being set up in the Hay-Balranald district.

The broad but, nevertheless, painstaking survey carried out by Beadle has emphasised the need for detailed investigations of soil and pasture types on some of the major vegetation associations. This need has also been emphasised by other scientific investigators working on this problem. Accordingly, six experimental regeneration areas, ranging from 200 acres upwards, have been selected along and adjacent to the Condobolin-Broken Hill railway line. Three of these areas, Kiacatoo, Booberoi and Trida, have already been established and detailed studies initiated. Each of these areas was selected as being typical of the class of country it represents, including as many degrees of erosion as possible, as well as a proportion of non-eroded land. The lines of research on each of these areas comprise studies of natural regeneration, on each of the various classes of erosion, a study of the soils and natural pastures, and their relation to each other and to erosion, and at a later date a study of reclamation measures. Detailed studies such as those being initiated will provide a great deal of information on the fundamental aspects of wind erosion under a wide variety of western conditions; this will enable a greater understanding of the factors concerned in the initiation and spread of erosion.

The administrative headquarters of the activities of the Service in the West are located at Condobolin, where the Service has laboratory and nursery facilities in addition to the experimental areas. Officers have been stationed at Hay, Bourke, and Coonamble. It is intended to locate officers at additional centres at a later date. Detailed erosion surveys are carried out from each sub-district headquarters, related to the soils and vegetation of the sub-district. All landholders in the area are contacted, and their local knowledge of the

Fig. 4.—Regeneration, firstly along the furrows, following pasture furrowing of scalded country in the Cobar district.

area fully availed of. On completion of the basic detailed surveys, experimentation is set up to deal with the particular problems of local areas. There is much information that the Soil Conservationist can convey to landholders at an early stage, based on data previously obtained in other areas, and, in some cases, adaptable to different districts.

CONCLUSION.

The efforts of the Soil Conservation Service have been directed to basic studies of the soils, climate and vegetation of the West, broadly over the whole area and in detail in particular areas. Scald reclamation in representative areas is receiving particular attention and techniques are being developed for the stabilisation of other forms of eroding country. Erosion is the "symptom" of a disease, and unless steps are taken to remedy the disease itself, the trouble will continue indefinitely. Grave warnings have been given by many authorities in the past. Ratcliffe[1], after his extensive survey of the problem in South Australia, has given an excellent review of the situation in that State, and we may conclude by quoting one of his observations:—

"The immediate and essential need is to adjust the stocking of the country to the vegetation in its present state. The varying and uncertain rainfall results in wide variations in the carrying capacity, and renders the country essentially unsuited to stocking at a constant level. Unless the level is determined on a 'poor season' basis, periodic overstocking is unavoidable, resulting in progressive destruction of the most important plants, the longer lived species which alone can provide a permanent protective cover of the soil. On the other hand, the alternative is an extension and intensification of the present trouble with every recurrent period of drought until in the end the country as a whole will be incapable of supporting permanent pastoral settlement at an economic level."

Fig. 5.—Severe gullying following depletion of vegetation on a bluebush ridge near Oxley.

At this stage of our work in the West, it appears clear, therefore, that many eroded areas can be regenerated, but that if the permanent vegetation in any area is destroyed or depleted by excessive stock numbers then erosion must inevitably occur or recur.

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THE CLOVER - LEYLAND - WHEAT ROTATION.

Its Value in Soil Conservation.

BY

D. G. CAMERON, B.Sc. Agr., Soil Conservationist.

ON glancing through literature on soil conservation one often obtains the impression that the main means of arresting the erosion that is rapidly reducing much of the best and originally fertile agricultural land of Australia to unproductivity is by the use of mechanical controls, such as the graded bank; but as knowledge of the forces and factors behind this decline has increased of recent years it has been more widely realised that soil conservation involves much more than attempts to control the flow of run-off water.

We are now beginning to realise how important a part general soil fertility plays in the prevention of soil wastage, while work such as that of Ellison[1] has shown the need for protection of the soil surface itself from the erosive agents such as the beating action of falling rain.

As a result, increasing emphasis is now being laid on the land use factor in soil conservation, and on the use of rotations on arable areas that will maintain soil fertility, where it is still satisfactory, or will, where it has been depleted, build it to a safe level as rapidly, but economically, as possible.

It should not be thought that mechanical measures can be dispensed with completely, for they have, if nothing else, one important function, and that, the reclamation of areas already suffering from serious erosion. But *alone* they are insufficient to restore such areas to complete, permanent production, as also *alone* they only postpone the time when areas relatively stable at present, may pass into unproductivity, unless some consideration is given to the condition of the soil itself, both physical and chemical. In other words some attempt must be made to adjust the management, in such a way as to place the system of agriculture practised on a permanent basis.

SOIL FERTILITY AND CONSERVATION.

How then can the state of soil fertility affect the physical removal of the soil by erosive agents such as running water? Briefly, the main effects are twofold.

1. The effect on vegetative cover, and so straight out protection of the soil. It will readily be seen that a more fertile soil will, with similar rainfall, grow a more vigorous and so more effective vegetative cover than a soil with depleted fertility.

2. The effect on the inherent stability or cohesion of the soil. Any soil has a certain inherent ability to resist removal once exposed to the erosive agents, but this stability is considerably influenced by soil management and the level of certain soil constituents.

The two main factors of soil fertility that exert the greatest influence on the above are, firstly, the soil nitrogen levels and, secondly, the closely inter-related organic matter levels.

Nitrogen is often the limiting factor to maximum plant growth, where rainfall is adequate. Its replacement by fertilisers is costly. Phosphorus is the other widely deficient major nutrient and superphosphate answers this problem effectively at present.

The organic matter exerts its main effects on the stability or cohesion of the soil. Besides affecting the removal of the soil by a given force of an erosive agent, it has the added effect of modifying the ease with which rain water may enter the soil. A soil in good structure absorbs much more water, so decreasing the quantity that will be available to act as an erosive force, i.e., run-off is decreased.

The only way in which the element nitrogen can be replaced in the soil effectively on a large scale is by the utilisation of the bacteria that live in the small nodules on the roots of leguminous plants. This group includes the clovers, medics, lucerne, peas, beans, etc. The bacteria have the ability to take the nitrogen of the air and supply it to these plants while they are growing. On rotting of the plant the nitrogen remains in the soil in such a state that other plants can utilise it.

In many areas it is still difficult to select suitable plants, carrying these bacteria, that do an efficient job of raising the fertility level. However, over much of the more favoured areas of southern Australia subterranean clover (*Trifolium subterraneum*) grows prolifically; whilst not an ideal plant, having some disadvantages, it does do a very good job in building soil fertility rapidly. Perhaps its greatest disadvantage, particularly from the point of view of soil conservation, is its tendency to leave the soil rather unprotected during the summer

Fig. 1.—Old cultivation land on the Wagga Research Station in 1945 — useless for cereal cultivation and providing very poor grazing.

months if not handled with extreme care. As the expectancy of summer rain decreases, so, therefore, does this objection.

One method of utilising subterranean clover in wheat farming is the system known as clover-leyland. One form of this has been practised on the Wagga Soil Conservation Research Station since the recommencement of farming there in 1946. It has also been included in the Run-off and Soil Loss Experiment, where it is compared with the unfortunately still widely used wheat-fallow rotation.

THE CLOVER-LEYLAND-WHEAT ROTATION.

The system, as practised at present on Wagga Station, is essentially a fertility building rotation, involving the following general programme.

1. The arable land is divided into three paddocks, one of which is cropped to wheat each year, i.e., individual paddocks are cropped every third year. At present the wheat is sown on a summer fallow, ploughing being carried out during the late spring (October-November) and the wheat sown the following autumn.

2. Two pounds of subterranean clover and one pound of wimmera rye are sown with the wheat from a grass seed attachment to the combine. It should not be necessary to continue this practice indefinitely, for as the soil population of clover seed builds up there will be sufficient hard seed left to carry over the fallow-crop period and thus obviate the need for further sowing of pasture seed.

3. An annual application of 90 lbs. of super per acre is applied every year, whether

Fig. 2.—Another area on the Station stabilised temporarily by mechanical measures, now being returned to full production under the clover-leyland-wheat rotation.

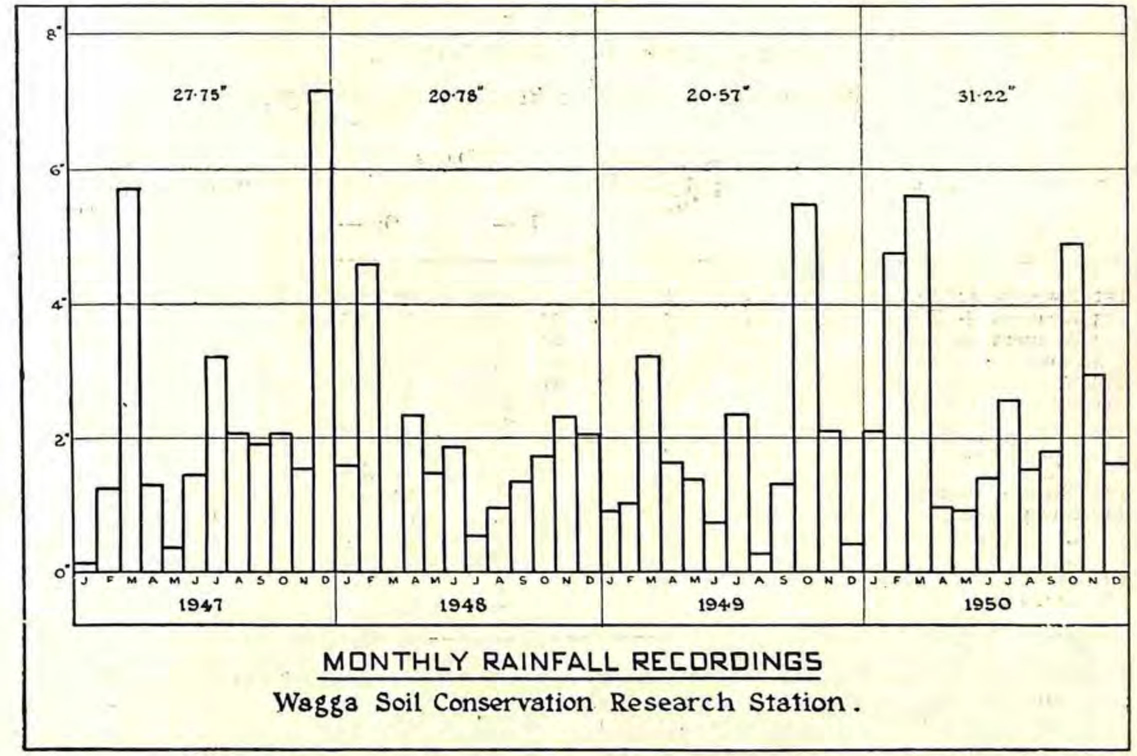

Fig.

under crop or leyland. It may again be possible, after a few years, to reduce the level of topdressing owing to residual effect.

Particular emphasis is placed on subterranean clover as a plant with considerable soil improving potential, and every effort is made to ensure maximum growth and effect of this plant every season. At Wagga we have a wheat crop, one full year ley and a second year ley, fallowed in October, then wheat again the following autumn.

Earlier it was stated that the only other major nutrient widely limiting maximum plant growth was phosphate, and to ensure complete success of the ley system it is necessary to remove this possibility by the liberal use of superphosphate, particularly during the introductory cycles. The results after a period of years of maintaining the present topdressing programme will be worthy of close study. Recent investigations by C.S.I.R.O. have tended to indicate that continued heavy applications, particularly to permanent pastures, results in far less subterranean clover dominance in later years, giving a more balanced type of pasture and better residual cover.

Other possible refinements to the present programme will be discussed later, these including such things as the elimination of the fallow period, etc.

THE ROLE OF STOCK IN A LEYLAND SYSTEM.

As will be seen by reference to Table 1, the leys have a very high carrying capacity over the winter-spring months. This table is a reproduction of the grazing records of Paddock Arable C at Wagga Station for the last seven months of 1950. Between the 20th August and the 22nd December, the stock depastured on this 39-acre paddock were at the rate of almost five dry sheep per acre (actually, 4.97).

TABLE I.

Grazing Records—Paddock Arable C.

Wagga Soil Conservation Research Station—1950.

Stock.	Dry Sheep Equivalent Rate.	Dates. In—	Dates. Out—	Days.	Grazing in Dry Sheep Days.
151 Ewes (about to lamb)	1⅓	8 June	10 July	33	6,237
23 Weaners + Bull	7	20 Aug.	21 Aug.	1	168
23 Weaners + Bull	7	22 ,,	31 ,,	9	1,502
2 Cows + 1 Calf	8	28 ,,	31 ,,	3	48
148 Ewes + Lambs	1¼	31 ,,	10 Oct.	40	7,400
41 Cows + Calves	8	23 Oct.	31 ,,	8	2,624
88 Cows + Calves	9	3 Nov.	5 Nov.		1,584
,, ,, ...	9	8 ,,	15 ,,	7	5,544
,, ,, ...	9	30 ,,	1 Dec.	1	792
175 Ewes + Lambs	1½	1 Dec.	13 Dec.	13	3,406
127 Sheep	1	13 ,,	22 ,,	9	1,143
,, ...	1	13 ,,	22 ,,	9	1,143
,, ...	1	5 Jan.	8 Jan.	3	381
200 Sheep	1	12 ,,	15 ,,	3	600
79 Sheep	1	19 ,,	23 ,,	4	316

Reference to Fig. 3 will show the monthly rainfalls for the period. It is also well to remember that but a few years previously this was unproductive, barren, eroding country. To-day, after five years of conservation management it is able to carry such stock numbers under conservative stocking rates.

Table II shows the stocking rates for the three arable paddocks and several comparison paddocks for the three years 1948-1950. These rates were obtained by conservative stocking. All stock have been converted to Dry Sheep Equivalents, using standard procedure.

TABLE II.

Stocking Rates (Dry Sheep/Acre) for Leylands, and comparable Paddocks.

Wagga Soil Conservation Research Station—1948–49–50.

Paddock.	Area. (Acres).	1948. State.	1948. Rate.	1949. State.	1949. Rate.	1950. State.	1950. Rate.
Arable A ...	31	L–F	0·76	F–W	0·36	1–L	2·5
Arable B ...	58	1–L	0·82	L–F	0·84	F–W	0·1
Arable C ...	39	F–W	0·16	1–L	0·61	2–L	2·4
School ...	50	I–P	0·78	I–P	1·02	I–P	2·0
Bangalore ...	24	S–I–P	0·17	S–I–P	0·94	S–I–P	1·8
Military ...	106	S–I–P	0·57	S–I–P	0·83	S–I–P	1·08

State Abrev.—L–F = Ley-Fallow. 1–L = 1st Year Ley. F–W = Fallow-Wheat. 2–L = 2nd Year Ley. I–P = Improved Pasture. S–I–P = Semi Improved Pasture.

Note.—Normally, fallowing of the second year leys is carried out in October. The second year ley in 1950 was not so treated, and remained leyland till the close of the year.

It is noticeable that in both 1948 and 1950 the first year leys have a higher carrying capacity than the permanent improved pastures in School Paddock, a state that certainly would not be achieved from a stubble paddock of an exploitive rotation. Although no authentic figures are available, it is suggested that maximum carrying rates (under conservative management) for such stubbles would be in the order of 0.4-0.5 sheep/acre over the annual period.

The centre of Fig. 4 shows a portion of paddock Arable A, from which it was omitted to sow the subterranean clover with the wheat in 1949. On either side can be seen the vigorous clover. Fig. 5 shows a close-up of the ley, representative of either side of the unsown strip, in September, 1950. Note the feed and soil protection available at this stage, and compare with Fig. 6, taken on the same day, of the unsown strip in the centre of Fig. 4. There is little feed available here and a considerably different run-off and soil loss potential between the two areas. This, and the difference in skeleton weed growth, are discussed later.

It might be apt at this point to sound a word of warning regarding the use of stock on leys. At all times conservative stocking rates should be observed, the grazing of the leys being regarded as secondary to their soil building and protecting properties. If they are to have maximum effect along these lines, they must be allowed to develop fully, without becoming over rank, at all times maintaining complete ground cover. It is particularly important that they be allowed to seed down annually and the ley paddocks should enter the summer carrying a good

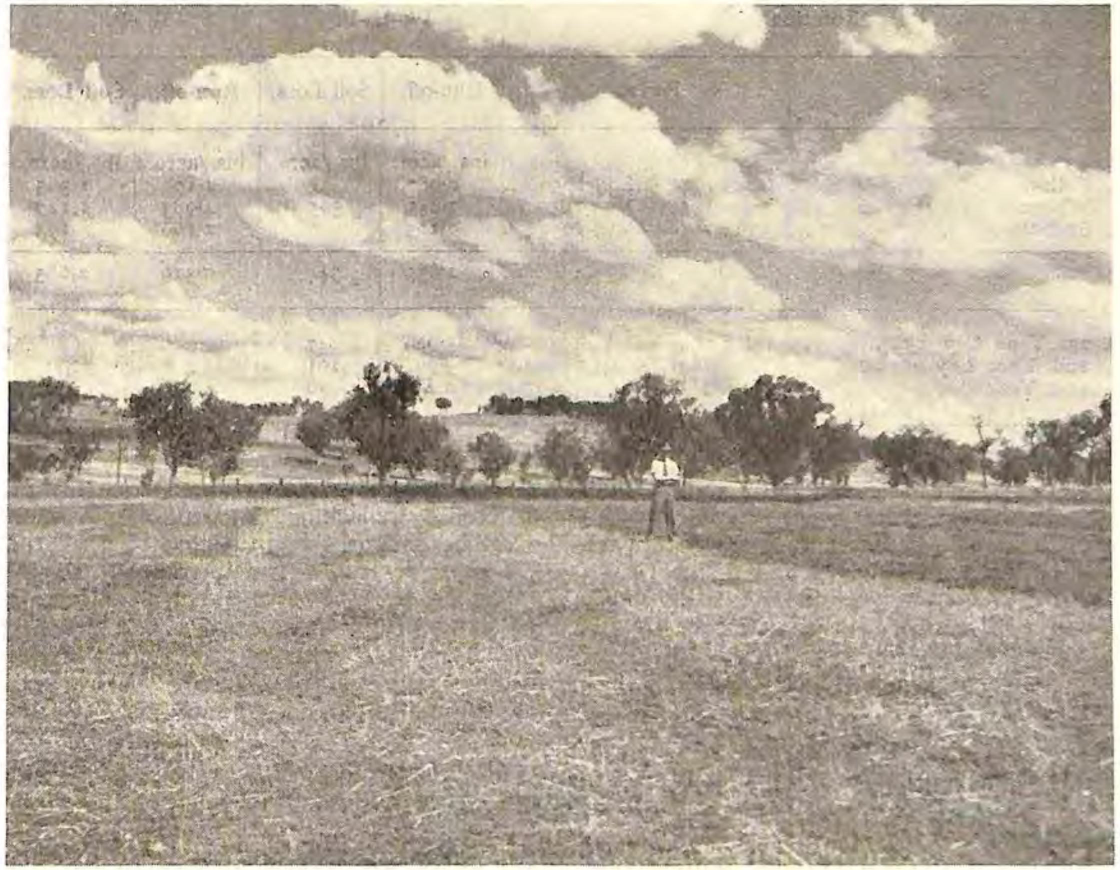

Fig. 4.—Portion of Paddock Arable A. showing a strip not sown to subterranean clover with the wheat the previous year. Compare with sown portions on either side of this strip.

cover of vegetative material. The reason for this latter point will be seen in the following section.

EFFECT ON RUN-OFF AND SOIL LOSS.

The year 1950 was an ideal one for the development of the clover on ley lands and allows a good comparison to be made of the soil protecting properties of this system.

Table III shows the results of various stages of the two rotations, wheat-leyland-fallow and wheat-fallow, in the Run-off and Soil Loss Experiment at Wagga. The installation of this experiment was completed during 1947, at the beginning of which year the various treatments were initiated. As a result, sufficient time has elapsed for the trends of results to begin to show, but it will be many years before the true relationships on the long-term basis become apparent. For this reason only the 1950 results are presented here, showing the relationships after four years' divergent treatment.

TABLE III.

Run-off and Soil Loss Results.

Wagga Soil Conservation Research Station—1949–50 *Season.*

Rotation.		W.-L.-F.		W.-F.	
Stage.	Period.	Run-off.	Soil Loss.	Run-off.	Soil Loss.
		ins./acre.	lbs./acre.	ins./acre.	lbs./acre.
1. Fallow	Oct., 1949—May, 1950 ...	0·087	31	2·170	1,365
2. Wheat	May, 1950—Dec., 1950 ...	1·641	305	4·983	1,127
3. Stubble	Jan., 1950—Oct., 1950 ...	0·105	8	2·166	193
	Totals	1·833	344	9·319	2,685
4. 1st Year Ley	Oct., 1949—Dec., 1949 ...	3·006	447	...	...
5. 2nd Year Ley	Jan., 1950—May, 1950 ...	3·902	191	...	...
6. 2nd Year Ley	May, 1950—Oct., 1950 ...	0·484	28	...	...

Considering, first, stages 1, 2 and 3, it will be seen that in every case there is considerable difference between the two treatments. In the cases of stages 2 and 3, the reason for this difference could be attributed to the protective effect of the sub-clover growth. During stage 2, there was vigorous sub-clover undergrowth beneath the wheat, besides added protection from the more vigorous wheat crop, while in the case of stage 3, the stubble initially had the clover trash from the previous year underneath and is latterly carrying a vigorous leyland growth as compared with the by now relatively bare wheat-fallow stubble.

In the case of stage 1, this source of difference is lacking, and another reason must be sought. It is suggested that the vigorous leyland growth turned in at fallowing is responsible either by affecting soil structure, giving improved stability, or the straight-out effect of the organic matter itself giving the soil a greater capacity to absorb water quickly, so diminishing run-off.

If the first possibility is the case the soil is better able to retain its cohesion under the depreciating effects of cultivation and grazing whilst the clods are less liable to slake down and cause a crust on the surface when exposed to the beating action of rain.

One particularly important point brought out by a study of Table III is the reaction of the leyland plots over the summer of 1949-50. When stages 4, 5 and 6 are considered (the period was split this way to enable comparison with stages 1 and 3, and 4 and 5 should be added to compare with 1, and 5 and 6 to compare with 3), it will be seen that the leys lost considerably more water than either fallow, but less soil than the 2-term fallow, and more water than the stubbles, but only slightly more soil than the 2-term stubble.

Reference to Fig. 2 will show that this was a rather wet summer, three months between October and May with recordings approaching or exceeding 5 in.; in other words it was an exceedingly unfavourable summer for the leylands, their most vulnerable period.

Another important factor here is the grazing of this experiment. All plots are bulk grazed, only cropped plots ever being fenced off. As a result the leys are considerably overgrazed during the summer months, and by the commencement of growth of the sub-clover in 1950, the second year ley plots were almost completely bare, a condition that can, and should, be avoided under actual field conditions.

This need for care in the handling of the leys has already been mentioned, but would appear to warrant repeating.

SUB-CLOVER AND WEED CONTROL.

As already stated, from the conservationist point of view, one of the greatest disadvantages of sub-clover is its tendency to dominate the sward, eliminating other less palatable species, with the result that, when the dry paddocks are stocked, the cover present can easily be completely removed. However, from the agronomic side

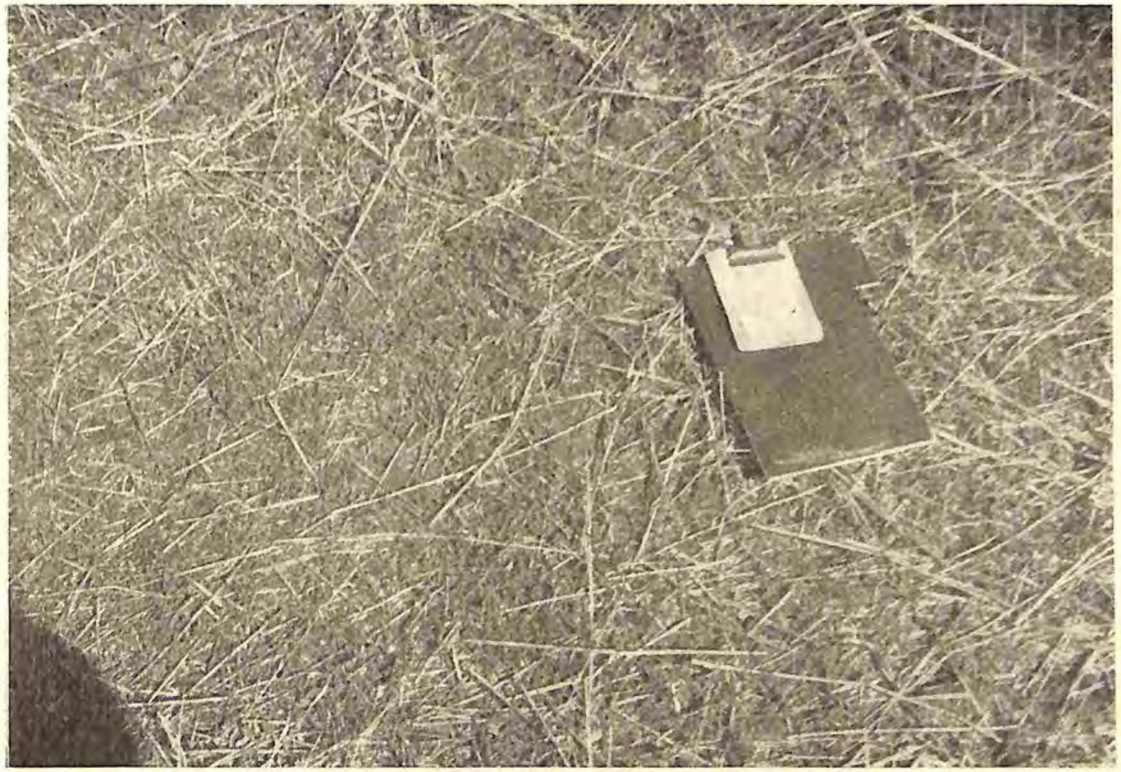

Fig. 5.—A closer view of the poor vegetative cover on the strip in *Fig.* 4 unsown to subterranean clover the previous year.

this dominancy has considerable value. Moore and Cashmore[2] found it to be exceptionally valuable in the control of St. John's Wort, whilst Morrow *et al.*[3] remarked upon the absence of Cape Weed from leys in later years as compared with the adjoining volunteer natural pasture otherwise similarly treated.

In 1949, subterranean clover was accidentally omitted from portion of Arable A Wagga Station. (See Figs. 4, 5 and 6.) It was quite noticeable that there was a considerable difference in the growth of skeleton weed on this area as compared with the rest of the paddock. In order to test for the significance of this difference, two observers each threw a 4 x 1 link quadrat randomly 25 times over:—

1. The unsown strip.
2. The remainder of the particular bay.
3. The remainder of the paddock.

For each throw the following observations were made:—

(a) Number of skeleton weed plants were counted.

(b) An estimate of percentage ground cover from all vegetative material.

(c) An estimate of percentage ground cover from skeleton weed.

(d) Notes on the development of skeleton weed plants.

(e) All skeleton weed plant encountered within each quadrat were clipped and bulked into separate samples for each observer for each area.

These bulk samples were allowed to air dry and were weighed. (Fig. 7 shows these clipped samples.)

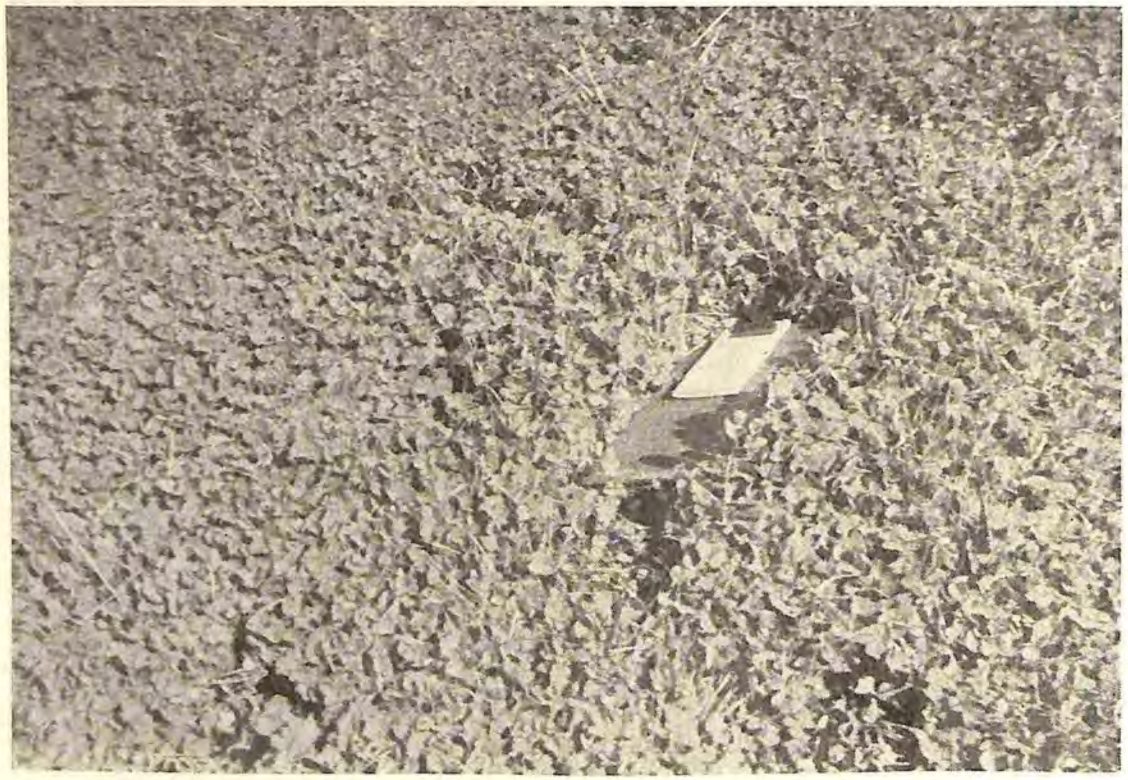

Fig. 6.—A good stand of clover during the ley period of the rotation.

TABLE IV.

Effects of Vigorous Sub Clover Growth on Skeleton Weed.

Results of Observations—Wagga Soil Conservation Research Station.

Paddock Arable A—5th February, 1951.

	Unsown Strip.			Bay Remainder.			Paddock Remainder.			Significance.
	Observers. 1	Observers. 2	Aver.	Observers. 1	Observers. 2	Aver.	Observers. 1	Observers. 2	Aver.	
Number Skeleton Weed Plants (per quadrat)	20	31	26	16	19	18	16	17	16	P < ·20
Percentage Ground Cover (Total)	72	66	69	91	96	93	87	91	89	P < ·05
Percentage Ground Cover (Skeleton Weed)	8·6	7·4	8·0	1·8	1·6	1·7	2·1	2·6	2·4	P < ·05
Total Weight of Skeleton Weed Plants (oz.)	6·9	7·1	7·0	2·4	1·7	2·0	2·4	2·2	2·3	P < ·01

In no case was the difference between observers significant at P = ·20

Whilst the above results showed no significant difference between numbers of skeleton weed plants per unit area, it does show difference in the development of these plants as shown by ground cover and weight of vegetative (skeleton weed) material.

It would appear that there is a slight difference in plant numbers, but 25 quadrat throws were insufficient to show up this difference at a significant level. The most striking difference was in the development of the plants present. On the unsown strip the plants were nearly all mature, well developed plants, flowering, or past flowering, plus numerous dead or almost dead, slightly developed plants. Over the rest of the paddock, and the bay, the plants were mainly young and weakly developed, many were still in the rosette stage, with others just running up to head. There were not the dead plants present here, except on occasions where odd patches of more mature plants were struck, probably areas where ley development had been weak.

It is suggested that the vigorous winter ley caused the death of the majority of the skeleton weed plants and with the wet early summer a considerable germination of fresh seedlings took place. On the unsown strip these seedlings have failed to establish, being killed off by the already well established plants during the dry later summer. Over the remainder of the paddock and bay these seedlings have not had the same competition and have managed to survive thus far.

Summarising, in this instance the vigorous winter clover growth has not effectively reduced the skeleton weed population, but it has considerably affected the development of the plants and possibly, had conditions been less favourable to skeleton weed in the early summer, a considerable reduction in plant numbers would have been recorded.

POSSIBLE VARIATIONS OF THE WHEAT-LEYLAND-FALLOW ROTATION.

(a) Proportion of Leyland to Crop Years.

As stated earlier, the wheat-leyland rotation at present practised on Wagga Station is essentially a fertility building system being used in conjunction with the various mechanical controls to restore to full production an area that had previously passed into complete unproductivity.

It may be that the wheat-leyland-fallow line eventually will reach a stage past which no further increase in fertility results with passing time; at this stage the level of soil fertility has reached the optimum for the wheat crop and there would be no further uplifting effect on yield. It now becomes possible to adjust, within a safe margin, the outgo of soil nutrients and damage to physical structure caused by cropping and stocking, to the soil improving value of the leyland periods.

This may be done by altering the rotation from fallow-wheat-leyland (one wheat crop in three years) to a rotation with a slightly higher frequency of cropping, e.g., two crops in five years, as in the rotation wheat, wheat, leyland, leyland, fallow, or wheat, wheat, three years leyland.

In other words, it is possible to pass from the fertility building to the fertility maintaining stage, which is the ideal system of land utilisation, i.e., maximum production under a permanent system of agriculture. If this can be done, a further increase in profit is obtained and maintained. If it be found the fertility line starts to fall again, it means the extra step taken has been too great and an exploitive system re-entered.

As yet there is little to suggest just how and when this happy medium can be struck. Factors likely to affect the time when the conversion can be effected, and the ratio of crop to leyland years increased, include:

1. The original state of degeneration of the land. However, it would seem that there is very little land long under cultivation in southern N.S.W. where soil structure and fertility have not been seriously depleted.

2. The reliability of effective subterranean clover growth in the district. The more frequently clover grows well, so the shorter the proportion of leyland to crop needed to

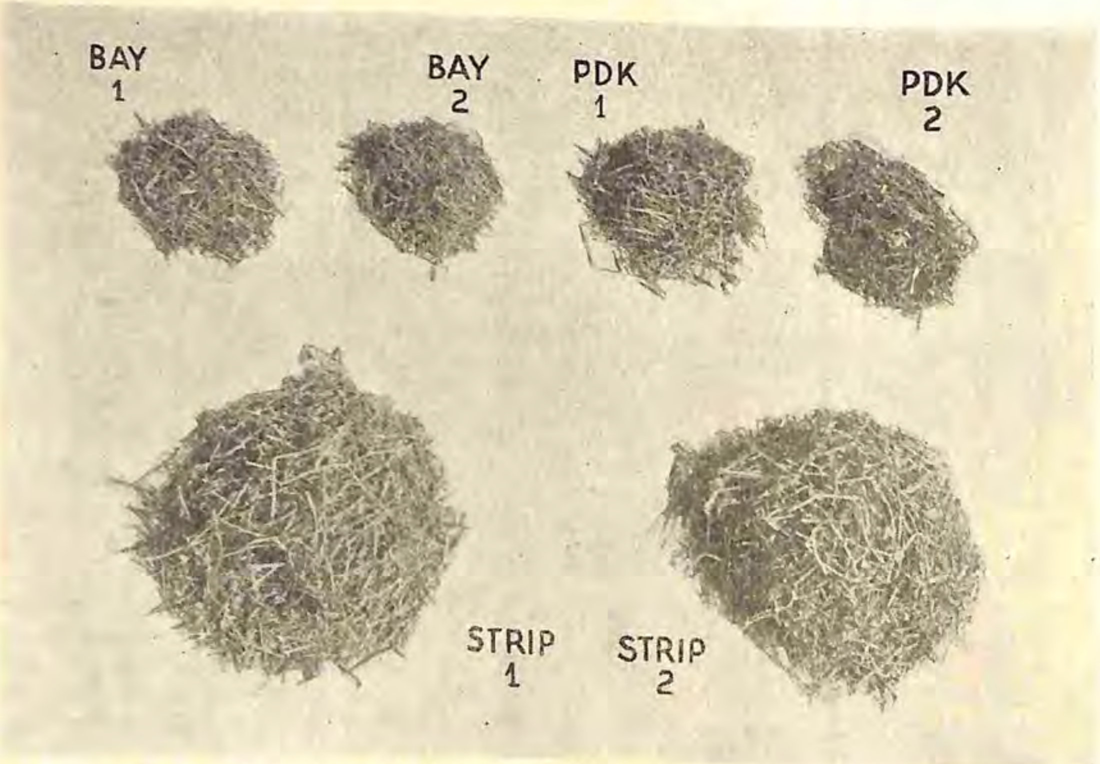

Fig. 7.—The bulked clippings of Skeleton Weed from various portions of Paddock Arable A. February, 1951

maintain the soil at its maximum productivity and stability. The less reliable and poorer the sub-clover growth, the longer the period of leyland required.

(b) Cultivation After a Ley Period.

It will be seen that if maximum value of the clover leyland system is to be obtained, advantage should be taken, if possible, of the opportunity presented to dispense with the period of fallowing, when a loose unprotected soil is fully exposed to the erosive forces of nature.

In the past, two main reasons have been advanced in favour of fallowing: (i) weed control, (ii) conservation of moisture, the second being more or less dependent on the first, there being little difference in the moisture lost from cultivated and uncultivated areas providing neither is carrying excessive weed growth.

Since, as pointed out earlier, subterranean clover's dominance of the sward tends to leave the land relatively free from active vegetative growth over the normal fallow period, the above reasons for fallowing are at least partially removed.

The ideal seedbed preparation from the point of view of soil conservation would appear to be a short autumn preparation. Morrow *et al.* found that wheat yields after fallowing and non-fallowing (autumn preparation) were not significantly different for the first crop after a leyland period at Rutherglen. They decided, considering all factors, that it was more profitable to grow wheat without a fallow after leyland periods in that district. There is less expense of seedbed preparation whilst added grazing is obtained, and a very important point, the sub-clover is allowed to seed down, making a reseeding with the crop unecessary.

Factors likely to affect the success of such a practice include:—

1. Time available between the opening rains and sowing time; ploughing would probably need to be carried out some time early in March, certainly before the beginning of April.

2. The power and machinery available. It may not be possible to handle large areas by this method and some fallowing may have to be done the previous spring to allow the required area to be handled by the plant available, but a minimum area should be so treated.

CONCLUSIONS.

This discussion has been confined to the clover leyland system, and as such has application in the more favoured climatic areas of the southern and central wheat belt of the State. Much that has been said, especially with regard to soil fertility and soil conservation, is applicable to the whole wheat belt and can be taken as points for consideration in the case of other fertility building legumes.

In short, any plant that will raise the level of soil nitrogen and organic matter has a distinct potential for the reduction of soil erosion. Just how great this potential is will depend on the growth habit of the plant and the efficiency with which it fixes nitrogen and makes vegetative growth, together with the efficiency with which the farmer handles it under his particular conditions.

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CONTROL OF EROSION ON DAIRYING LANDS.

BY

C. G. McMahon, H.D.A., Soil Conservationist.

In the Goulburn sub-district of the Metropolitan Soil Conservation District, dairy farming is of considerable importance, especially in such districts as Mittagong, Moss Vale and Robertson. Although not so spectacular as in some areas of the State less favoured climatically, nevertheless erosion is widespread and has seriously depleted fertility and production on many farms in these areas.

Experience has shown that sound erosion control technique is not so much dependent upon mechanical measures, but rather the introduction of wise land use and management, particularly in relation to pastures.

This factor is of importance when applied to dairying lands from which the supplies of milk and milk products are seriously falling short of present-day demands.

THE ECONOMIC FACTOR.

The present-day trend indicates a gradual drift away from dairying into other industries, showing comparatively higher return for correspondingly less effort. Moreover, the farmer is aware, from his experience of high labour costs, that it is costly to produce roughages; consequently, it would appear logical that the practice of feeding and grazing stock on improved pasture land should receive high priority, as labour costs in this regard are relatively low.

Increasing production, therefore, by methods of soil and moisture conservation and improved land usage is of considerable importance to the farmer and the State.

The following are instances relating to pasture management and control of erosion on dairying lands, with reference to work

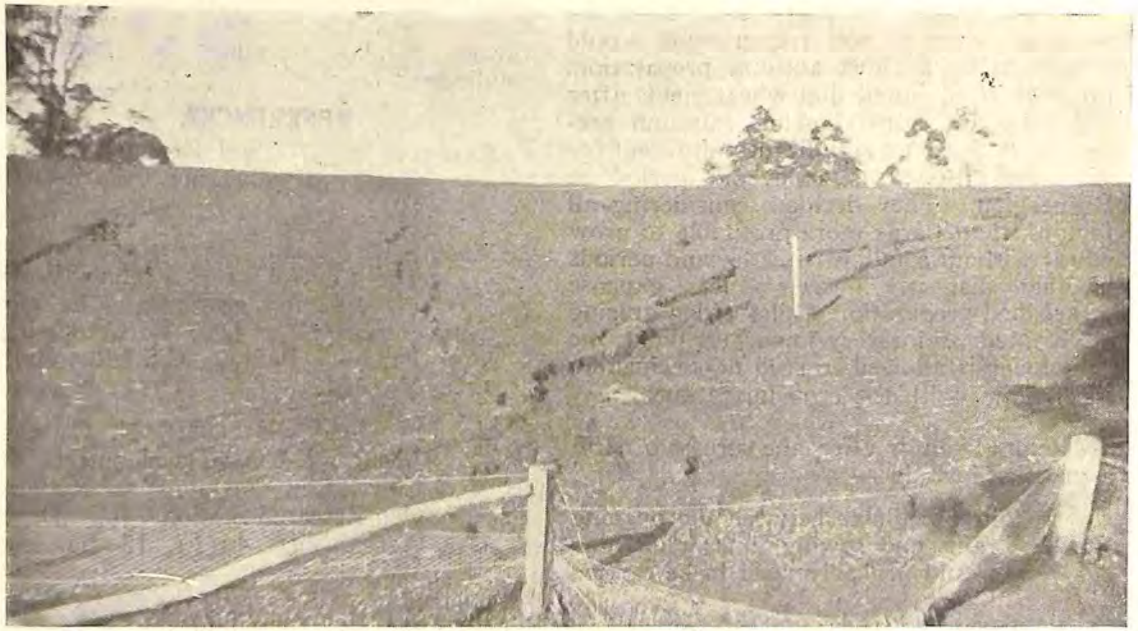

Fig. 1.—Cultivated land subject to serious erosion in the Robertson district.

carried out by individual farmers who co-operated with the Soil Conservation Service on an extension or demonstrational basis.

The combined value of pasture improvement and soil and moisture retention has been demonstrated in the Bega Valley on undulating granite country by means of:—

(a) Contour furrowing;

(b) Sowing, manuring and topdressing of improved pastures on the strip-farming method;

(c) Sowing of sub-clover and applying fertiliser on areas not at present convenient to cultivate.

Almost a third of one farm, comprising 360 acres, has been sown on the strip-farming method, whilst the remainder is being contour-furrowed, topdressed and sown in the usual way.

Levels for the furrows were surveyed on a 3 ft. vertical interval, making the furrows approximately half a chain apart.

During the first year, the first, fourth, seventh and tenth strips between the furrows (from top of slope) have been ploughed, worked down and sown. In the second year, the second, fifth, eighth and eleventh strips are to be ploughed and sown. In the third year, the third, sixth, ninth and twelfth strips are to be treated likewise.

In addition to controlling the erosion, the furrows are designed to ensure almost complete absorption of surface run-off and conserving it for the benefit of the pasture.

Checks, constructed of earth at half-chain intervals along the furrows, will localise the water, and prevent over-topping at low spots, e.g., natural depressions or old gully fills.

During subsequent cultivation the efficiency of the furrow to absorb water and control erosion depends on maintenance, and this can be attended to after the strips have been sown and sufficient seed of the mixture retained to sow along the furrows themselves.

PLOUGHING AND SOWING CONTOUR STRIPS.

A light mouldboard was used to invert the furrow slice to a depth of three inches; subsequent working was with a disc harrow,

Fig. 2.—Cultivating and planting row crops up and down the slope increases run-off and accentuates erosion.

followed by a spiked harrowing to produce a light mulch, the object being to preserve the furrow slices intact as far as possible and so encourage the re-establishment of the better types of native perennial grasses.

This helps to secure a close sward of grass cover to resist erosive agents and maintain organic matter in the soil; it also facilitates penetration of moisture and reduces run-off.

Preservation of the native grass cover is important as it is desirable that a well-balanced pasture mixture contain both annual and perennial species, and the most important soil binding plants in any mixture are the clovers.

By the aid of an electric fence, rotational grazing has been introduced and the entire area strip grazed under a system of controlled stocking.

Suitable pastures comprised autumn-sown introduced species such as lucerne and phalaris; superphosphate was used at the rate of 2 cwt. per acre at sowing and regular topdressing of 2 cwt. per acre each year.

Fig. 3.—These gullies which formed in arable land are now stabilised by a change in land utilisation involving protective pasture cover.

On the less fertile areas a temporary pasture, consisting of 4 lbs. of subterranean clover, was sown in the autumn, followed by pasture harrowing, and 2 cwt. of superphosphate broadcast each year, the object being to sufficiently raise the soil fertility level when the area will be re-sown to permanent pasture.

CHANGES IN LAND USE TO CONTROL EROSION.

On the red loams of basalt origin in the Robertson district, where the rainfall average is particularly high (60 inches per annum), extensive row-crop agriculture on hilly arable land has increased the degree of erosion hazard, and farmers are realising the fallacy of up and down slope crop culture and its resultant increase in run-off and loss of fertile top soil following heavy rain.

Evidence of diminishing fertility is indicated by increasing soil demand for more liberal fertiliser applications on those areas where constant cropping has been practised over the years.

The introduction of a new farming technique is now in progress, and with it the value of pasture management is being realised, including the adoption of such methods as the sowing of introduced grasses and clovers for soil renovation and fertility-building purposes; this is being followed by sub-division, rotational grazing, judicious stocking and spelling of the land.

Such methods involve changes in general farm planning with re-orientation of land use and these are being included in a demonstration now in progress on hilly cultivation land.

The main objects of the demonstration are:—

(a) To conserve soil and moisture by contour furrowing the entire area.

(b) In conjunction with the above, topdressing, liming and sowing of introduced grasses and clovers to build up the fertility and humus content of the soil.

Fig. 4.—Contour furrows reduce run-off and erosion at Wyldes Meadow.

(c) Sub-division, with rotational grazing and other measures considered necessary to improve the carrying capacity and increase production.

SOWN PASTURES.

Preparatory work for sown pastures included eradication of rabbits, and liming at the rate of 1½ tons per acre.

The corrugated or culti-packer-roller was used prior to sowing, the mechanical action of this machine consolidating the light textured, loose, red volcanic soil.

Autumn sown pasture mixtures were used, and on establishment the contour furrows were constructed, these being hand-sown with seed on completion.

Subsequent management will include rotational grazing and control of stock to ensure a satisfactory seeding during the first and second years. It is most desirable that the pasture be allowed to seed in the early stages of growth, and therefore a low rate of stocking with frequent spelling will be enforced, unless abnormal growth occurs, depending on the seasonal conditions prevailing.

An annual topdressing of superphosphate and pasture renovation will be carried out, using pasture harrows or a rigid type implement such as an empty rigid-tyne seed drill.

Suitable pasture mixtures for the reclamation of wornout lands in this district have been used. For temporary pastures Italian rye and subterranean clover are used with a seeding rate of 8 lbs. per acre. Annual top-dressings of superphosphate per acre will be carried out.

When the soil has reached a reasonable standard of fertility the area will be re-sown with a permanent pasture mixture, e.g., perennial rye, Akaroa cocksfoot, red, white and subterranean clovers; with the soil improvement brought about by the previous pasture, conditions should be most favourable for its establishment.

Fig. 5.—Erosion reduced and production increased by contour furrows and sown pastures in the Robertson district.

Subterranean clover has proved to be most economical for raising the fertility levels of soils to the stage where the better types of introduced grasses will flourish, and also provide a protective cover to safeguard loose cultivated soils from the eroding action of heavy rains.

CONTROL ON STEEP DAIRYING LANDS.

Effective control of run-off and erosion on steep dairying lands and the gradual building up of impoverished soil has been achieved by the application of sound principles of pasture management and soil conservation adopted by Mr. Cox, of "Melross," Kangaroo Valley.

Results are reflected in the raising of the soil fertility level, which has become seriously depleted due to continual intense cropping and stocking on steep slopes, and steadily increasing production.

This gradual building-up process and progressive results obtained therefrom are reflected in increased carrying capacity with improved pasture now forming the basis of feeding for production; the pastures provide the principal drought fodder reserve also by conservation of surplus in good seasons.

Temporary pastures, consisting of 2 lbs. of subterranean clover and 1 cwt. super. per acre sown in the autumn showed results in the initial stages. Further areas were treated in this way and 3 lbs. of subterranean clover and 1 bushel of perennial rye per acre was sown after ploughing and liming at the rate of 1½ tons per acre. Regular harrowing and topdressing with 2 cwt. super. per annum was carried out.

Sub-division of the farm into 43 paddocks took place, rotational grazing was introduced and stock grazed to distribute farm-yard manure evenly; the resultant increase in organic matter and building up of humus content stimulated the pastures which formed a dense cover and considerably reduced run-off.

Contour furrowing the area has resulted in the retention of run-off, with increased absorption, giving rise to a more prolific

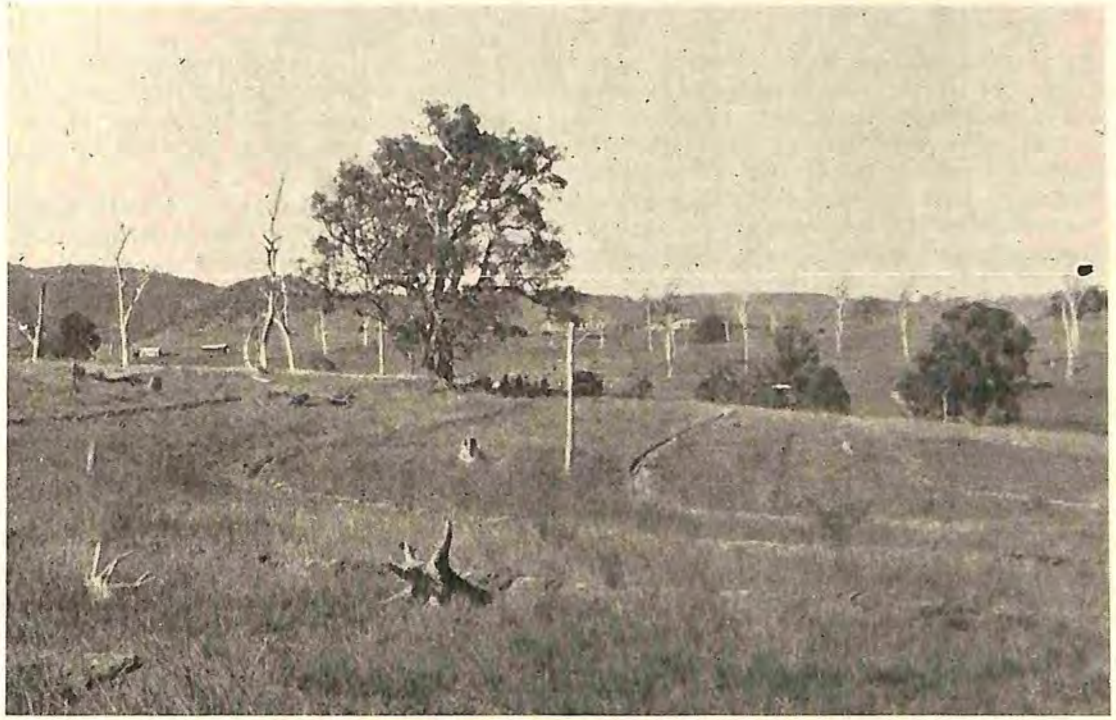

Fig. 6.—Pasture furrows being installed prior to strip sowing of improved pasture in the Bega district.

Fig. 7.—A dense sward of perennial rye grass and subterranean clover prevents erosion in the Bowral district.

growth of feed. Increased growth of vegetation, both in and surrounding the furrows has further reduced run-off and prevented erosion. The fact that after four years the contour furrows require re-opening clearly indicates that erosion, although greatly reduced, is still taking place; without contour furrowing and improved grassland management this class of country loses surface soil at an alarming rate.

It is the owner's proven experience that contour furrowing is essential on our sloping coastal country if run-off and erosion is to be controlled. Money expended and labour and time involved has paid handsome dividends, providing a sound investment and also a basis for sound farming practice and wise land use.

CONCLUSION.

Cropping of land continuously and stocking it indiscriminately results in the loss of large quantities of plant food and humus from the soil by erosion; this leads gradually to soil deterioration and diminishing productivity. It is, therefore, essential that this humus supply be replenished, and this can only be brought about by careful fertility building and soil conserving farming practices.

As part of a wise land use and erosion control programme for hilly dairying lands, essential practices are as follows:—

(a) Conserving soil and moisture by the use of minor mechanical control measures, e.g., contour furrowing.

(b) Establishing introduced grasses and clovers to restore depleted soil fertility.

(c) Sub-division of area and rotational grazing combined with the use of pasture renovators to ensure the proper distribution of animal manure and so build up the humus content.

(d) Annual topdressing and the cutting and harvesting of surplus pasture to improve the sward and build up the carrying capacity.

FOREWORD

BY

E. S. Clayton, H.D.A., Commissioner.

WITH the increasing activity of the Soil Conservation Service of New South Wales and expanding farmer co-operation, the erosion position is steadily improving, and given a continuation and expansion of these, the outlook is distinctly promising. The enthusiasm to work with the Soil Conservation Service shown by the farmers of this State is very gratifying. It is a most hopeful sign that farms will be conserved: that the productivity of the lands in general will be maintained; that a stable and permanent agriculture will be achieved in N.S.W.; and that we will be able to feed our present population on present standards. However, we have to take care of a considerable population increase in the immediate future. In the light of this the results, though encouraging, leave no room for complacency. On the contrary, the indications call for redoubled efforts, both collectively and individually, now that we have seen what can and what should be done to conserve our lands for food production.

We have to review our own food position in the light of a world with overstrained land resources, where population is annually increasing at a staggering rate, while the world's area of land capable of producing food, is yearly decreasing. There is no room in this situation for Australian complacency considering our crop production in relation to our now rapidly increasing population. We may in a few years be short of some of the foods which are now produced in sufficient quantities for export.

The Soil Conservation Service is now well established and is carrying on its service to the lands and the farming community in most of the critical areas in this State. The pattern of activities and the objectives are taking definite shape. We aim, with the co-operation of the landusers, to correct the damage, past and present, and to prevent the continuation of accelerated erosion. Our objectives include the protection and stabilisation of the Catchment Areas which feed the streams, the preservation of the farming and grazing lands so that their productivity can be retained, the stabilisation of production from the soil on the highest level compatible with land use stability, and the universal adoption of conservation farming in the interests of a permanent agriculture. We have now no great untapped resources of good land. Our future rests upon the lands we already have and which we are now cultivating or grazing. Some of our agriculture has been exploitary; some of our lands have been destroyed by the unwise uses to which they have been put. We have learned that there is no permanent security in destructive use of land.

The Soil Conservation Service, working with many hundreds of farmers in N.S.W., has shown that erosion can be prevented without great expense, farming can be stabilised on a permanent basis, the land improved in its productivity and yields can be maintained, and in some cases even improved by conservation farming. Here is the answer to the depressing problem which confronted us a few short years ago. We are through the most gruelling early period. We know the general lines along which to proceed and it is now a matter of applying conservation methods to all the lands requiring attention in the shortest possible time.

You may say "why the need for hurry now?" Knowing how to stop erosion will not of itself stop it. Obviously the work has to be done. That takes time in such a big State as this, and all the while good lands which need protection are going. The longer they are left before treatment the more soil will have been lost; the deeper will be the gullies, the more work will be required and the greater will be the cost. Also remedial work, while it can save what soil still remains, cannot put back that which has gone down the streams.

Unless soil conservation work can be effectively applied, particularly to all the lands requiring it in the fertile mixed farming districts on the Western Slopes, within the next twenty years we may never attain satisfactory stability. The position may, of course, be stabilised in later years, but it will be on a lower level of productivity and the cost will be greater.

If it could be made stable within the next few years, this country would be better off and the stabilised production would be on the highest level still possible. That is why there is need for haste.

THE IMPORTANCE OF WISE LAND USAGE

BY

J. M. LOGAN, H.D.A., Soil Conservationist.

RESEARCH work is an essential part of any large scale soil conservation programme; without it the person engaged in the control of erosion in the field is without a thorough knowledge of the erosion process and the causal agencies and is consequently placed under a severe handicap. In order to obtain the necessary information, Soil Conservation Research Stations were established in key positions in the State and experimental work commenced at an early date after the formation of the Soil Conservation Service.

On each Station specially designed experiments were installed so that precise measurements could be made of the run-off and soil loss from different land treatments. A description of the collection equipment used has already been published in this Journal, and the results of measurements following specific rains on Wagga and Wellington Research Stations have also received some mention. Recordings from such experiments can only be reliably interpreted after the experiment has been conducted for some years, but following the very wet years recently experienced it is now possible to ascertain certain trends. Ultimately much of our information will be placed on a quantitative basis and important factors will receive fresh emphasis. In this article a review will be made of the results of experiments carried out at Wellington over the past three years, and their significance discussed.

EFFECT OF LAND USE ON RUN-OFF AND SOIL LOSS.

Experimental plots were primarily designed to measure the effects of land use on both run-off and soil loss. At Wellington there are four basic treatments in seven plots, viz., wheat-grazing oats-fallow rotation; wheat-fallow rotation; permanent pasture; and land retired from cultivation. These plots are arranged in three blocks with the treatments randomised so that statistical analysis can be carried out. (Plots are on a gravelly clay loam with a slope of 4% and are 182 feet in length).

Details of the land treatments are mentioned here as it has been found that these have an important bearing on the erosion problem. Fallowing for the growing of wheat is carried out in late September or early October, and the fallow kept fairly cloddy until near sowing time, when it is worked down to a fine seed bed. After harvesting the stubble on the wheat-fallow rotation plots is retained until the next fallowing (a period of roughly ten months), grazing being carried out whenever feed is available in the stubble. On the other hand, the stubble of the wheat-oat-fallow rotation is cultivated without burning as soon after an initial grazing as weather conditions will permit. This fallow is very open at first and is worked down and sown to oats in the autumn. The oats are used for grazing in the late winter and early spring and these plots are then left as leyland until they are fallowed in the following spring. The permanent pasture consists mainly of lucerne and Wimmera rye grass, whilst the retired plots are land that has been retired from cultivation and now carries a volunteer pasture of barley grass, burr medic and wire weed. Both permanent pasture and retired treatment receive periodic grazing.

Results of this experiment are shown by histograms (Fig. 1) which illustrate the run-off and soil losses from each treatment for the years 1948-49, 1949-50 and 1950-51. In each case the year has been commenced at the beginning of the crop period, the time when fallowing, the major land condition change, takes place. Treatments bracketed together in the diagram represent the various phases of the one rotation.

These figures show the importance of the land use factor in relation to both soil and water loss. Except for 1950-51 when circumstances were exceptional, the fallow-wheat portion of both rotations shows a

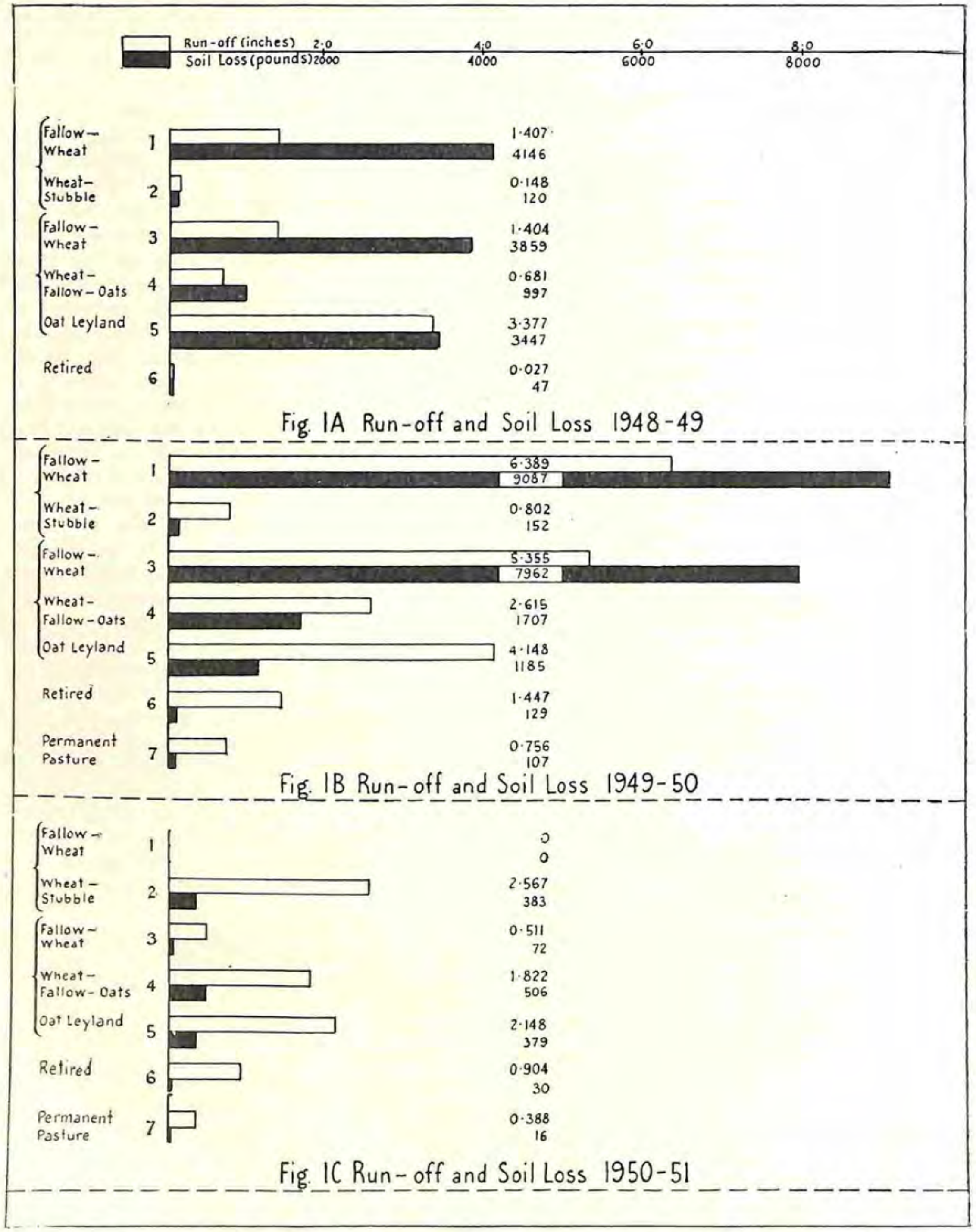

Fig. 1.—Annual run-off and soil losses from different land treatments in inches of water and pounds of soil per acre.

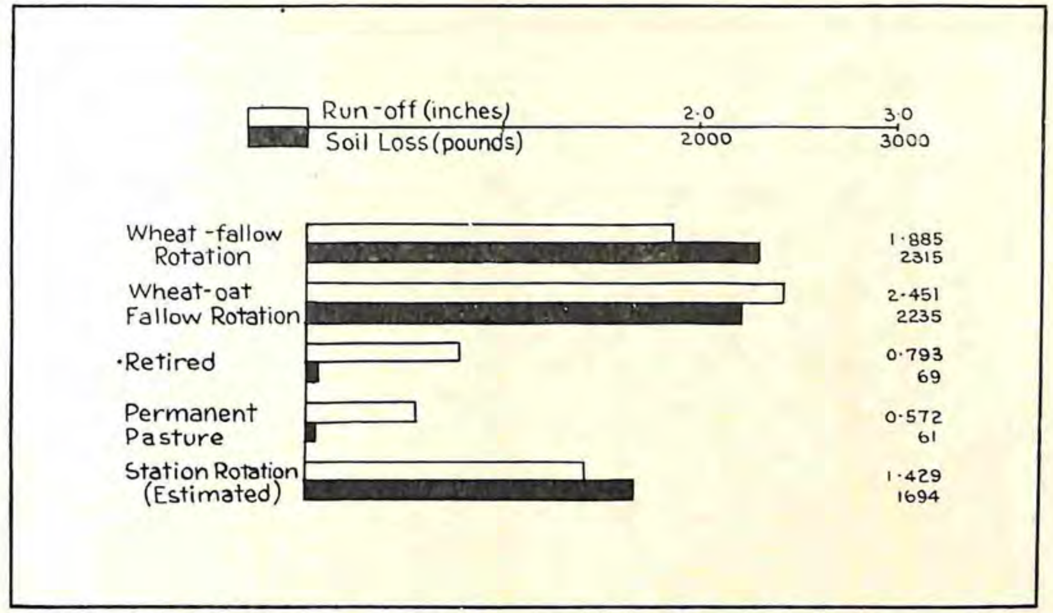

Fig. 2.—Average annual run-off and soil loss from different land treatments.

high run-off and the highest soil loss of any treatment. When compared with the wheat-stubble, land retired from cultivation and permanent pasture treatments, these results plainly demonstrate the effectiveness of a good cover in preventing soil loss. (Soil losses from the fallow-wheat plots were up to 80 times the loss from the permanent pastures and 60 times that from the wheat-stubble and retired plots.)

As far as water loss is concerned, the oat leyland treatment has resulted in quite high losses, thereby demonstrating the adverse effects of stock grazing the whole of an annual crop under conditions where new growth will not be available to provide cover.

With regard to the 1950-51 figures, the apparent anomalies are explained by the rainfall and cropping details. Rainfall intensities were comparatively low during this period and the open cloddy fallows were able to absorb most of the rainfall. On the other hand, soil compaction and some minor rilling had already taken place in the cropped plots and this influence carried over from the previous year brought about the high run-off figures. The run-off and soil loss recordings within each rotation have been totalled and the average annual losses determined in order that the effects of land use over a period of years can be seen. These results are shown in Fig. 2 together with an estimate of the results of the rotation at present being followed in the Station paddocks; this rotation includes four years lucerne and six years of wheat-fallow rotation. This estimate is based on the results of the various treatments included in the experimental plots, and because it does not take into consideration the effects of contour cultivation and the soil building of the rotation, is higher than actually occurs in the field. An examination of these results clearly reveals that land use plays a major role in determining the amount of run-off and soil loss that takes place.

EFFECT OF RAINFALL ON RUN-OFF AND SOIL LOSS

As run-off commences when the rate of precipitation exceeds the rate of infiltration into the soil, the intensity of the rainfall is of great importance in relation to soil and water loss. In addition, high intensity rain has a greater shattering effect on soil aggregates and brings more soil into suspension to be carried away, thereby further increasing the soil loss. Table 1 gives an analysis of the intensities of some of the erosion causing rains, together with the resultant

*3409—3

TABLE I.—Influence of Rainfall on Run-off and Soil Loss.

Date.	Rainfall Details in Points.								Run-off and Soil Loss Details.					
	Duration (min.)				Total.	Intensity Group.			Fallow-Wheat.		Retired.		Oat Leyland.	
	10	20	30	60		Under 2 in./hr.	1 in. to 2 in./hr.	Over 2 in./hr.	Run-off %.	Soil loss/in. rain.	Run-off %.	Soil loss/in. rain.	Run-off %.	Soil loss/in. rain.
1949.														
9th Feb. ...	29	34	36	36	88	60	...	28	...	...	...	...	7.6	72
11th Feb. ...	66	127	133	135	135	8	...	127	33.0	1,472	0.8	26.0	73.8	1,179
21st Feb. ...	34	50	57	66	100	19	61	20	50.3	667	0.5	4.0	69.4	451
20th April ...	6	8	10	18	178	178	...	...	...	...	...	...	10.8	14
3rd May ...	16	18	18	18	55	28	27	...	...	...	...	...	3.1	19
21st May ...	40	52	53	81	214	112	47	55	21.3	629	0.5	9.0	48.3	560
1950.														
18th Jan. ...	48	49	49	70	377	299	8	74	9.3	46	...	...	9.0	8
4th–7th Feb.	29	34	48	56	392	341	12	39	1.1	10	0.4	0.3	7.1	6
30th March	19	24	32	58	226	204	22	...	9.8	177	...	...	6.5	5
	20	23	36	41										
1–5th April	30	31	40	50	395	277	118	...	43.5	957	9.7	9.4	21.3	138
	22	24	30	38										
7th April ...	38	44	55	63	74	18	16	38	53.1	1,678	4.1	3.7	31.7	116

(It is interesting to note that the "C" values usually used in the calculation of discharges correspond fairly well with the figures recorded here.)

run-off (as a percentage of the rainfall) and soil losses (in pounds of soil loss per inch of rain).

The highest run-off percentage (73.8%) was recorded from the oat leyland treatment as a result of the high intensity rain of 11th February, 1949, when the intensity reached four inches per hour. This rain also caused considerable soil compaction which played a large part in causing a 50% water loss from a lower intensity rain ten days later. High run-off percentages were also recorded in April, 1950, when, although intensities were not so high, almost continuous rain for a period of ten days so saturated the soil that infiltration was very low with regard to the latter part of the rainfall.

High rates of soil loss also resulted from these rains, the highest being on the 7th April, 1950, when some high intensity rain concluded the long period of wet weather. This figure was almost equalled on the 11th February, 1949, when loss from a fallow as a result of a heavy rain was 1,472 pounds per acre per inch of rain. Included in Table 2 are the effects of the erosion causing rains on the oat leyland and the retired treatments as this further illustrates the effect of rainfall on soil and water losses.

EFFECT OF SLOPE LENGTH ON RUN-OFF AND EROSION.

Length of slope is an important factor in relation to run-off and soil loss. Experiments in the U.S.A. would indicate that run-off from the longer slopes is slightly less than that from the shorter slopes. Also, for low intensity rains, soil losses are less on the longer slopes, but for high intensities are much greater. The length of slope experiments at Wellington show a similar trend but all differences are very small. In the soil loss figures there is little difference between the long and short plots, but there are large differences between the two agricultural treatments on each slope length. These results, however, are only derived from short lengths of slope, the longest being only 182 feet, whereas lengths of over ten times this figure are frequently found in the field. It is on these long slopes that concentration of the run-off often results in serious rill and gully erosion with very high soil losses.

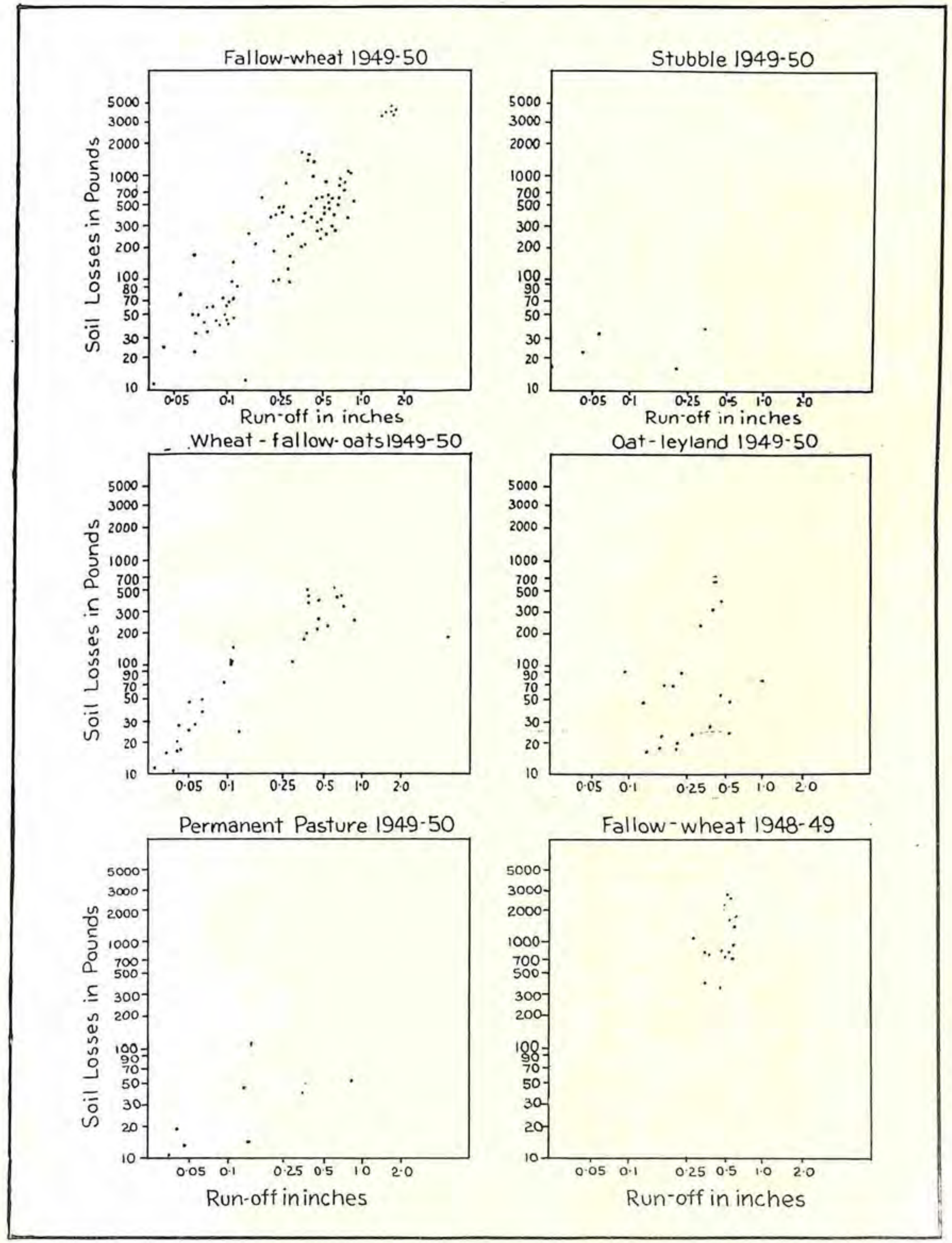

Fig. 3.—The relationship between run-off and soil loss per acre plotted on logarithmic scales.

RUN-OFF AND EROSION.

Run-off and soil loss, although they are different processes, have some distinct relationships which enable them to be considered together. Thus, under conditions where high water loss takes place, high soil losses can be expected, although land use can and does play an important modifying part. Fig. 3 shows the correlation between run-off and soil loss for the various land treatments during 1949-50 when extremes of rainfall intensity were not experienced and when soil moisture contents were consistently high. In these diagrams each dot represents one recording of run-off and soil loss. The increase of soil loss as the run-off increases is illustrated; particularly is this apparent in the fallow treatment.

The importance of the land use factor in relation to erosion and erosion control is also illustrated by these diagrams which show the rapid increase of soil loss as run-off increases on the fallows, as contrasted with the small increase on the pasture plots.

The last diagram of this figure shows these relationships for the fallow plots for the year 1948-49. Comparison with the diagram for 1949-50 shows the effect of high rainfall intensity; the rapid increase of soil loss shown here being a result of the high intensity rain of 11th February, 1949.

SEASONAL NATURE OF RUN-OFF AND EROSION.

As land treatment and rainfall have a definite seasonal aspect in this and many districts, it is only reasonable to expect that the run-off and soil loss which these factors largely influence, would also show a seasonal trend. Fig. 4, which is based on the mean water and soil loss for each treatment for the various portions of the year, shows that this is so at Wellington. It has already been shown that the fallow-wheat period is the one during which the greatest losses take place, and a subdivision of the year points to the second period (harvesting to sowing) as the one in which the greatest part of these losses occur. This is to be expected as it is in this period that the fallow is worked down to a fine tilth in preparation for sowing, and also that this is the time of the year when rainfall hazard is greatest. Table 2, which is based on information taken from the Report of the Stormwater Standards Committee, presents the rainfall intensities which can be expected in this district. Comparison with Table 1 reveals that, with one exception, it could be expected that the intensities recorded over the past few years would be equalled and probably exceeded quite frequently. This table, however, does not show the time of the year in which these heavy rains are to be expected, but an indication can be obtained from the Station pluviograph records. In Table 3 the monthly rainfalls are divided into three intensity groups, viz., less than 1 inch per hour, 1-2 inches per hour; and over 2 inches per hour. As these records only cover a seven year period, the number of days in each month recording

TABLE 2.—Rainfall Intensities which may be expected at Wellington.

Frequency.	Rainfall in Points. Durations in Minutes.				
	10	20	30	60	1,440 (24 hr.)
1 in 5 years ...	50	67	80	100	278
1 in 10 years...	55	77	90	110	314
1 in 20 years...	63	87	105	130	360
1 in 100 years	78	110	130	160	450

TABLE 3.—The seasonal Nature of Rainfall at Wellington.

This table shows the mean number of points at the various intensity rates that have been recorded at this Station over the past seven years.

Month.	Points of Rain at Specified Rates. Less than 100 per hour.	Between 100 and 200 per hour.	Over 200 per hour.	No. of days recording more than 2 inches.
January ...	188	15	20	8
February ...	209	36	42	5
March ...	127	14	8	5
April ...	144	29	5	2
May ...	162	11	8	2
June ...	241	1	...	2
July ...	177	5	...	2
August ...	157	6	2	...
September ...	169	6	2	1
October ...	205	21	61	4
November ...	163	23	27	7
December ...	96	33	14	7

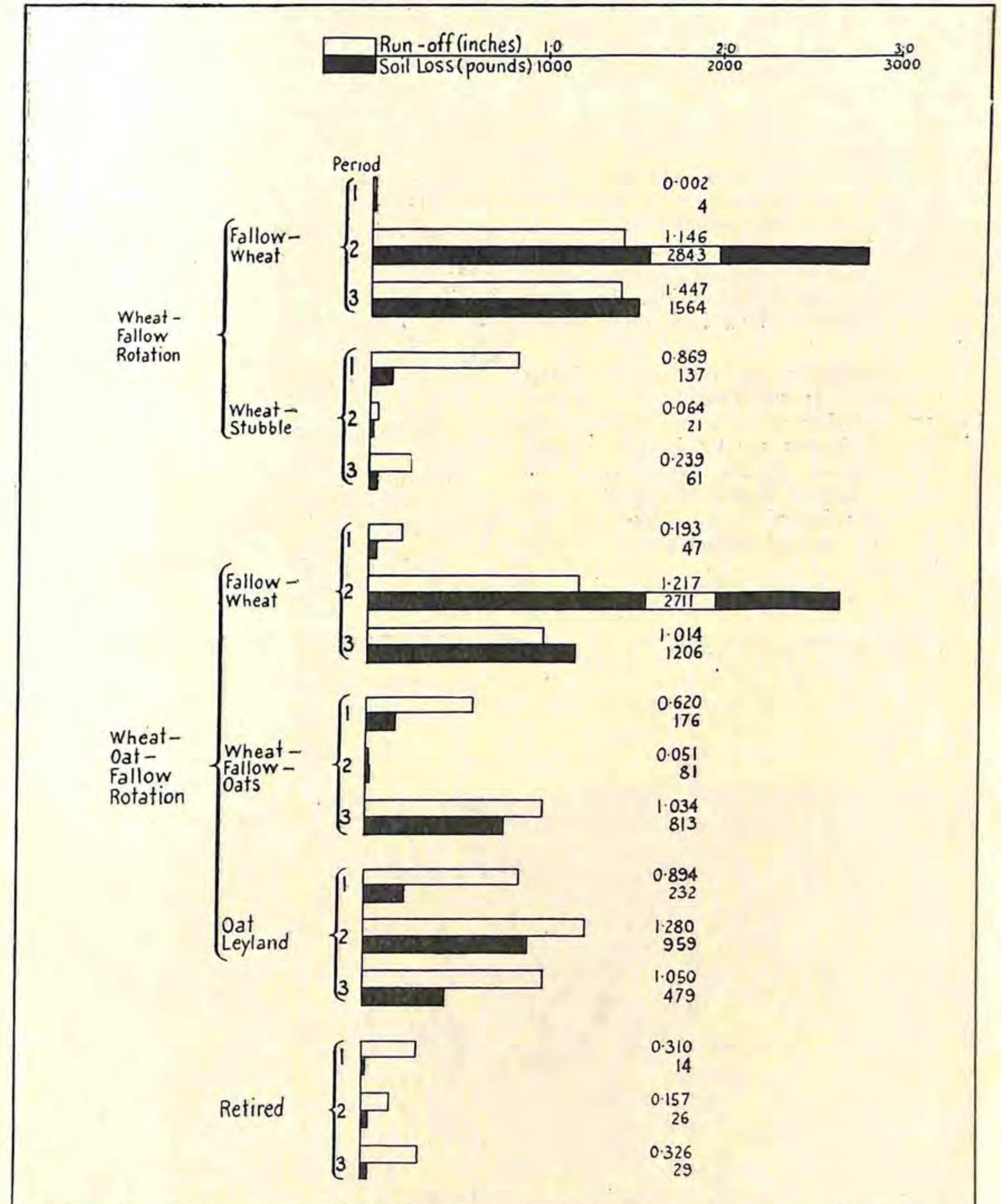

Fig. 4.—The seasonal nature of run-off and soil loss:—
Period 1 = Fallowing to harvesting.
Period 2 = Harvesting to sowing.
Period 3 = Sowing to fallowing.

over 2 inches have been determined from the past sixty years' records, so that the figures for the shorter period may be verified. It will be seen from this table that the summer months experience the high intensity rainfall.

The effectiveness of newly fallowed land in absorbing the rainfall and preventing run-off is shown by the very low figures recorded for the first period in both rotations and also in the second period of the wheat-oat-fallow treatment. On the other hand, the extreme hazard of the longer, more finely worked fallow that has been partially compacted by rain is quite apparent.

An examination of results of similar experiments (unpublished) at Cowra Research Station give further confirmation of the Wellington results in this regard. In fact, because of the longer period of record, the effect of the abnormal winter and spring rains of 1950 is less, and the losses of the second period are even more outstanding.

APPLICATION.

Increased knowledge of the erosion process materially assists in the formulation of practical control measures. The information gained at Wellington is of value because it draws our attention to a number of vital points that may otherwise be overlooked. Factors influencing run-off and erosion may be grouped in quite a number of ways, each of which may have some advantages, but the following is suggested because it has application when control is to be considered.

Group A. Factors Over Which No Control Can Be Exercised.

1. Rainfall.
2. Degree of slope. (Bench terraces do influence this factor, but they are not used in this area.)
3. Inherent soil characteristics.

Fig. 5.—The wise use of crop residues and herbage assists in the prevention of erosion on fallowed land.

Fig. 6.—An arable paddock on Wellington Research Station carrying a soil building pasture of lucerne and Wimmera rye grass.

Group B. Factors Which Can Be Controlled or Modified.

1. Land use.
2. Length of Slope.
3. Some soil characteristics, e.g., structure, porosity, which can be altered favourably or unfavourably by land usage.

Control of erosion in any region resolves itself then into the adapting of the land use and length of slope to suit the existing rainfall, degree of slope and soil type of the locality. Thus under specific conditions of rainfall, slope and soil, certain land use principles must be adhered to and lengths of slope allowed if soil stability is to be maintained. The work with which we are most familiar is that dealing with length of slope, graded banks, pasture furrows and similar works as means of decreasing the length of slope. There is, however, a very real danger that we may become over enthusiastic concerning this factor and neglect to consider land use and soil characteristics.

The figures given in this article emphasise the importance of land use and show that wise land utilisation should be given a place of prominence in any erosion control programme. Thus on the wheatlands of the Wellington district the reduction of the time under fallowing to the minimum consistent with satisfactory preparation of the land for cropping will reduce the period of hazard. In the same way the use of crop rotations which reduce the frequency of fallowing will be beneficial. The arable paddock shown in Fig. 5. although protected by graded banks is under a period of permanent pasture which greatly reduces the liability to erosion and at the same time builds up the soil fertility and structure.

In order to grow many crops it is essential that the land be cultivated for some period and thereby be susceptible to erosion. However, the use of soil improving rotations and practices, and the avoidance of those operations that have a harmful effect on the soil, will enable the soil structure to be maintained in a state that will allow rapid infiltration and thus increase resistance to erosion. Thus soil building rotations which include a period under grass and legumes have an important role in the prevention of soil erosion. Fig. 6 illustrates how stubble and clover can be utilised to prevent erosion on the fallow. Some has been ploughed under to build up soil structure and fertility and some has been retained on the surface as a protective mulch.

Although this research work has only been in progress for a short period, most valuable information is coming to hand. Whilst undue emphasis cannot be placed on the quantitative aspects of such short duration experimental work, it is felt that these results at this stage do place the various contributing factors to the problem in perspective and so provide a satisfactory basis for the planning of erosion controls.

VEGETATION SURVEY OF THE MARINE SAND DRIFTS OF NEW SOUTH WALES

Some Remarks On Useful Stabilising Species

BY

G. W. Mort, H.D.A., District Soil Conservationist.

AND

B. R. Hewitt, B.Sc., Soil Conservationist.

PART II (*Continued*).

In Volume 5, No. 2, of this Journal, a detailed survey was made of the plant species occurring on the littoral sand drifts of New South Wales.

In Volume 6, No. 2, two of the most important primary stabilising species, Marram (*Ammophila arenaria*), and Sand Spinifex (*Spinifex hirsutus*) were described in detail.

In this and later articles it is intended to describe in detail several secondary species being tested at the four coastal sand drift control centres conducted by the Soil Conservation Service, together with observations made during the last four years on the habit of growth and culture of each. In the first instance, some of the more important mat-forming plants will be described, and in later articles the shrub and tree species will be dealt with.

Many of these species are indigenous to New South Wales and material can be obtained locally for their propagation, but several have been introduced from other States and from overseas and to date only limited quantities of seed or vegetative material are available for sand stabilisation projects. With the further development of the sand drift nursery areas conducted by the Soil Conservation Service seed supplies should be more plentiful and within a few years there should be sufficient seed available for other public and private bodies to undertake small projects of their own.

CREEPING GROUNDSEL.—*Senecio crassiflorus D.C.*

(Latin Senex. an old man, alluding to the white down.)

Distribution.

It is not known accurately when this species was introduced into New South Wales, but due to the fact that it appears to be localised in the Newcastle district it is thought that it may have been brought in with ballast from South America in the sailing days. This plant is now naturalised in Australia and has spread fairly extensively from Belmont to Stockton, where it was recorded as early as 1910, but until recent years was not known in other coastal districts of New South Wales.

Since the initiation of sand drift control experiments by the Soil Conservation Service in 1946 this species has been given several trials at selected localities along the coast and to date excellent results have been achieved from all plantings. Fig. 1 illustrates a dense sward of creeping groundsel about two years after planting on a bare windswept dune at The Entrance North, Tuggerah Lakes. It would appear from tests carried out that this plant will prove invaluable for vital exposed areas, particularly in close proximity to the beach, where

Fig. 1.—Dense sward of creeping groundsel (*Senecio crassiflorus*) which has covered the sand, preventing sand drift at The Entrance North.

a small quantity of sand is collected from time to time. This has the effect of a light topdressing; however, with six inches accretion of sand or more the plant is often completely inundated and destroyed.

Botanical Description.

Perennial, softly white—tomentose all over, stems prostrate or slightly ascending, leaves alternate, leuceotate; inflorescence large, mostly solitary, terminal; sometimes other inflorescences arise from axils of leaves, immediately below the first terminal inflorescence; one outer row of involucral bracts; ray flowers yellow, in 2-3 rows, female; ligulate style, branches truncate; pappus of white capillary hairs, disc flowers yellow, tubular and bisexual. Fruit, a seed-like achene, enclosed in the calyx tube.

Habit of Growth.

The stems, which are prostrate or slightly ascending, form a dense mat sometimes covering great distances in one season. The plant spreads rapidly and forms adventitious roots readily at the nodes; however, growth is usually slow during the summer and autumn, and more vigorous as the spring approaches and flowering commences. Fig. 2 illustrates how the trailing stems of creeping groundsel quickly stabilise the surface of the sand. It would appear from observations that a considerable amount of viable seed is produced annually about November, but to date only a few seedlings have been seen and no trials have been made to determine the germination of such seed.

As this plant has been known in the Newcastle district for about forty years and has not spread from the littoral areas where it was first recorded, except on to the other beach areas, it can be safely assumed that it would never become a serious weed. In view of this, its encouragement on areas of coastal sand drift in this State is strongly recommended, particularly in situations of extreme exposure and in close proximity to the beach.

Propagation.

Time of Planting.

To date propagation has been attempted only by vegetative means and, provided there is moisture in the sand, this can be carried out almost at any period of the year; however, best results have been achieved by planting out cuttings at or about flowering time.

Preparation of Cuttings.

Cuttings about twelve inches long are taken from the parent plant, including, if possible, the terminal shoot. These should be kept moist until commencement of planting operations, and under such conditions will keep fresh for several days.

Planting.

Cool showery weather is the most suitable for planting, but some good strikes have been achieved even in hot weather, provided the plants are buried deeply in moist sand which has been firmly pressed around the cuttings. It is preferable to leave only about two inches of the plant above the surface as this ensures retention of moisture in the plant during the early establishment period.

The espacement of plants depends largely on the purpose for which they are being used, but where other protection is not available, in the form of brush or marram grass, spacing should be kept to a minimum, say two feet for quick establishment and satisfactory coverage. However, where other temporary protection is provided, 3-4 feet espacement would be adequate. Under normal conditions and with periodical light applications of sulphate of ammonia, this should ensure a complete cover within 2-3 years.

SAND DANDELION.—*Arctotis stoechadifolia Berg.*

(Greek arktos, a bear; ous otos, ear: alluding to the shaggy winged achene).

This plant has five well marked varieties and this particular variety is probably *var. decumbens.*

Distribution.

This is a native of South Africa and apparently all the localities given for it are in the Cape Region. The genus is limited to South Africa with the exception of one species which extends to Abyssinia; many species are of value as garden plants, including the species dealt with.

Fig. 2.—Creeping groundsel (*Senecio crassiflorus*) protects sand from erosion.

Fig. 3.—Good growth of Sand Dandelion (*Arctotis stoechadifolia*) on pure sand.

It was introduced into Australia some years ago, probably as a garden plant and has been tried on the sand drift areas of Western and South Australia, as well as this State, with excellent results. Already it is considered to be amongst the best sand binders in Western Australia; although not fully investigated under our conditions it is proving a very promising species.

Botanical Description.

Perennial, softly white—tomentose all over; stems prostrate or ascending; leaves obovate-cuneate to lanceolate, the lower one lyrate, the upper ones sessile and toothed; heads large, showy, solitary, terminal; involucral bracts in several rows, the outer ones with long linear points, the inner ones broad and scarious; ray-flowers female and fertile; ligules white with yellow base; disc flowers dark, tubular, bisexual; achene silky 5-ribbed, 2 lateral ribs winged and incurved towards the middle one, giving the appearance of a 3-celled fruit; pappus of 7-8 pink oblong scales.

Climatic Requirements.

This plant is essentially a summer growing variety and appears to favour a temperate to warm moist climate; however, it has been used to advantage in some very dry areas in South Africa and should prove useful under similar conditions here. In this State it is growing in several very exposed situations and is maintaining an effective cover throughout the year. For this reason it could probably be planted with success all along our coast.

Habit of Growth.

The habit of the plant is such that it forms a compact mass of vegetation over the areas it occupies, as indicated in Fig. 3. The blowing of sand onto it should be beneficial in that it would further consolidate the sand. This plant is, however, somewhat susceptible to salt spray and should be excluded from the most exposed situations close to the beach, where creeping groundsel has proved most suitable.

Most sand binders in warm countries suffer from exposure of their stems to the sun, or the burning effect of the hot sand. This, however, makes most of its growth during the summer and the rooting stems are well protected by the cover of leaves and the deposit of humus.

In Western Australia it has been found that the individual plants are not long lived and will die back from the base upwards. There is every reason to believe that this occurs during winter, when the movement of drift is greatest. Repopulation of these areas by means of seed takes place and cover is once more restored.

In New South Wales, however, the setting of viable seed is rare, but as it does not appear to suffer to the same extent from die-back in this State, the stands of this species have not shown, to date, any marked degree of deterioration, and with light applications of sulphate of ammonia, annually, a vigorous dense sward of leaves and stems is maintained.

The possibilities of this species as a sand-binder are impressive for the following reasons:—

(1) It is apparently a psammophyte (sand-loving plant) suited to poor, deep, free sands.

(2) It is extremely hardy and will withstand dry conditions.

(3) Its vigorous rooting and stoloniferous habit renders it admirable for holding loose sand in position, and by this means it is capable of extensive vegetative growth.

(4) Its dense growth of leaves affords its rooting system adequate protection from the sun, and is of material value in preventing wind erosion.

(5) It provides a large amount of humus which should aid further growth on deep sands. These dead leaves also assist, together with the dead stems, in building up a firm surface to the sand.

Economic Importance.

This is essentially a psammophyte (sand-loving plant), and appears to be one worthy of encouragement in littoral areas. It is not likely to prove a weed, but at the same time experiments are being conducted under quarantine conditions to ensure that it does not spread to arable soils. The plant is not known as a weed in its native country, South Africa.

Propagation.

Time of Planting.

To date propagation by cuttings has been somewhat disappointing in trials carried out in this State, and although some measure of success has been achieved by planting at all periods of the year most satisfactory results have been obtained following autumn plantings, particularly when carried out in showery weather.

Usually establishment is not rapid, growth being very slow for the first six to twelve months, but on the development of two or three stolons, the plants become more robust and will cover extensive areas in one year.

Preparation of Cuttings.

Due to the excellent development of adventitious roots along the young shoots, the best planting material is obtained from the stolons produced around the outer margins of the parent plant. Cuttings about twelve inches long are selected from these stolons, preferably during cool, moist weather and kept moist until planting operations are commenced.

Planting.

Planting is carried out in a similar manner to that described for creeping groundsel, burying the cuttings about 9 inches and leaving 3 inches above the surface.

Due to the slow establishment in the early stages, some form of protection, either by planting marram grass or laying ti-tree brush barriers is recommended in vital areas, but in some less exposed areas good results can be obtained by planting this species as closely as two feet.

PIG FACE.—*Carpobrotus aequilaterus N.E. Br., Syn. Mesembryanthemum aequilaterale. Haw.*

Distribution.

A native of Australia, pigface is widespread throughout the country, but usually found on loamy or calcareous soils near the coast, or on saline soils inland. It is particularly common along the beaches of the North Coast of New South Wales.

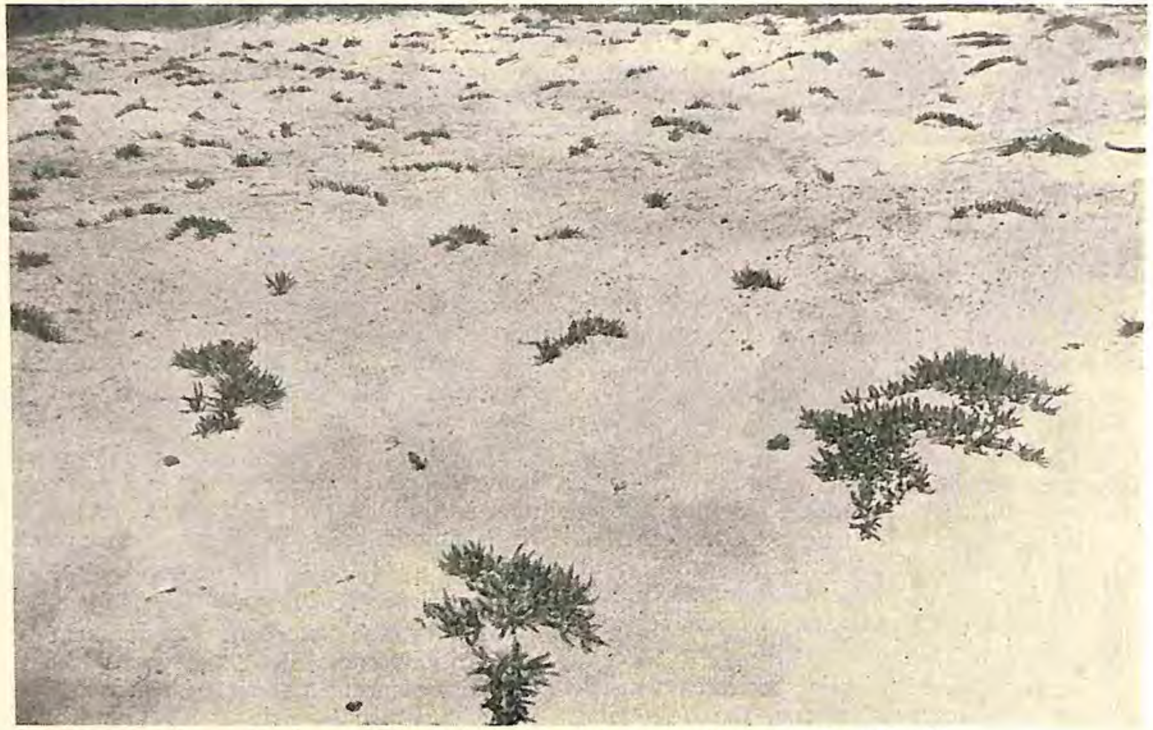

Fig. 4.—Newly established Pigface (*Carpobrotus aequilaterus* at Port Kembla.

Botanical Description.

A prostrate, succulent, perennial herb about 6 in. to 1 foot high, with opposite triangular smooth leaves $1\frac{1}{2}$ to 3 inches long, fused and stem-clasping at the base. Flowers usually solitary, terminal or in the upper axils large and purplish-red. Petals spreading to about $1\frac{1}{2}$ inches diameter, numerous and linear. Stamens numerous. Styles 8-10. Perianth tube obconical nearly 2 cms. long, 2 keeled. Fruit a succulent capsule over 1 inch long, usually red, edible, which opens in slits at the depressed summit. Seeds smooth, reddish-brown.

Climatic Requirements.

This plant seems to survive under most climatic conditions in Australia but favours a temperate to warm climate with fair rainfall. It is chiefly a spring and summer growing plant flowering from October to January.

Habit of Growth.

The stout prostrate stems of pigface run over the surface of the sand and root at the nodes. New runners are formed at these nodes, which in turn send out more growth until finally a dense mat of succulent leaves prevents any further sand drift. If covered with a small quantity of sand the plant will survive and grow through it to form a new mat over the previous one; however, deep inundation for an extended period is injurious and may result in complete destruction. Figs. 4 and 5 illustrate the amount of cover achieved in 10 months with pigface at Port Kembla. It is essentially a stabilising plant for dune slopes in the lee from onshore winds, but many successful attempts have been made to use it on the windward slopes almost to high tide level and in some areas it has proved satisfactory. It has been particularly useful on steep slopes such as road cuttings in stabilised sand dune areas. Wire netting may be required to prevent "slips" until the plants are firmly established.

Economic Importance.

Pigface is undoubtedly amongst our best sand and soil binders in this State and has in the past been used on many small reclamation jobs, but the cost of planting is a big

Fig. 5.—The same area as shown in Fig. 4 ten months later.

factor, when considering major stabilisation projects.

The fruits of the plant are edible and the juice of the leaves is said to check dysentry.

Propagation.

Time of Planting.

Following recent investigations at Port Kembla and Tuggerah Lakes Entrance, it appears that, with some protection, it can be planted at any time of the year with reasonable chances of success, but being a summer grower best results are obtained from spring planting, in order that it will be firmly established before the following winter.

At Port Kembla pigface was planted in October and November, 1946, and, although the sand was dry and windswept, the cuttings rooted well and continued growing without any apparent setback. There was evidence of early growth after the November rains, and although the sand was not held entirely much of the surface had been covered by the prostrate stems before the end of March, 1947.

Preparation of Cuttings.

Rooted cuttings about 6-12 inches in length should be selected from any vigorous patch of pigface and kept moist and in a cool place pending setting out. If stacked together for long periods heating will take place, thus reducing the vigour of the resultant plant.

Planting.

This is best carried out by two men in such the same way as with marram grass, that is, one man opens a slit in the sand (preferably when damp) with a spade, the other man carries the cuttings, placing one in each hole, each plant being pressed firmly into the sand with the foot. About 2-3 inches of the plant should be left above the surface.

Further tests are being carried out to determine the best spacing for varying conditions, but on present indications, 2 ft. x 2 ft. spacing is preferable for rapid coverage, while 3-4 ft. spacing is sufficient for any area where speedy stabilisation is not essential. If planted farther apart scouring may

Fig. 6.—A stand of Pigface at The Entrance North, Tuggerah Lakes, planted between light brush barriers for protection during establishment.

take place between the plants thus forming hummocks, a condition always detrimental to any stabilisation programme. Fig. 6 shows a stand of pigface at The Entrance North, Tuggerah Lakes, planted between light brush barriers for protection during establishment.

COASTAL OR TWINING GUINEA FLOWER. —*Hibbertia volubilis Andra.*

(Named by Andrews in 1800 after George Hibbert, a London merchant.)

Distribution.

Hibbertia is an almost entirely Australian genus of small, erect or scrambling shrubs which are common in the coastal region, particularly in the eastern States. This species seems to be confined to the sand dunes of New South Wales and Queensland coasts and is widespread in this State between Kiama and the Queensland border, where many dense stands occur.

Botanical Description.

This is a perennial, woody trailer; leaves stem-clasping, entire, 2-3 inches long, obovate to lanceolate silky-hairy underneath. Flowers very large and nearly sessile; petals yellow usually obovate-cuneate, notched and slightly undulate on the upper margin; stamens numerous, anthers oblong opening in 2 parallel slits; fruit opening along the inner suture, seeds ovoid or subglobular, usually reddish-brown, shining more or less enclosed in the aril which is often jagged or fringed.

Climatic Requirements.

Being a native of N.S.W. and Queensland, this plant seems to favour a temperate to sub-tropical climate with a rainfall of more than 20 inches. The climatic limits of growth have not yet been determined, however, and further investigations will be carried out to ascertain the limits of satisfactory propagation.

Habit of Growth.

Coastal guinea flower is a spring and summer growing perennial, prostrate and mat-forming in nature. The long runners extend for long distances over the sand, later spreading by means of adventitious roots, sometimes rather sparse, to form a dense mat of leaves and stems, thus prohibiting any further migration of the sand surface.

It is often found in the hind-dune thickets as a sub-dominant species, but usually the denser stands occur on the top of the fore-dunes extending on occasions to the high tide limit. Several places are known where this species alone has stabilised the windward face of the dunes and is maintaining its hold in spite of severe gales.

It appears to flower spasmodically throughout the year and ripe seed can be collected at almost any period, but spring and summer are the most favourable flowering seasons, the best seed being available from February to April.

Economic Importance.

As a primary stabiliser of drift sand it has many features, but it is more frequently used as a secondary sand binder after the initial sand movement has been checked. It is one of the important plants for this purpose in this State, but propagation methods will have to be improved before any large scale planting can be attempted.

Propagation.

Some success has been achieved by sowing seed of this species in the autumn, but due to the very slow growth in the early establishment period this is not recommended where a quick cover is required.

Several attempts have been made to obtain suitable cuttings for propagation purposes, but owing to the sparseness of adventitious roots planting by this method often results in almost complete failure.

In view of the availability of more suitable plants for primary stabilisation and the difficulty of establishing the species either by seed or root cuttings large scale planting is not advisable. However, following the stabilisation of the sand surface, the inclusion of this plant in any control plan, together with other secondary species will ensure a good permanent cover.

Having now dealt with the major herbs of a low, trailing nature, which are being utilised in the experimental stabilisation programme conducted by the Soil Conservation Service, it is the intention in the next article to discuss the more important shrub and tree species which have shown promise in trials to date. Many other species have been undergoing trials, several of which are proving invaluable for the fixation of our coastal sands; these will be mentioned in later articles.

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