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THE JOURNAL OF THE SOIL CONSERVATION SERVICE OF NEW SOUTH WALES

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FOREWORD

BY

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

THE climate, soils, type of cropping and farming methods vary greatly in New South Wales. The climate alone varies from a Mediterranean type of rainfall in the Southern and Riverina districts to almost the opposite in the Northern, North-western and North Coastal districts, from moist and humid on the coast to cold and wet on the tablelands, intermediate on the Western Slopes and hot and dry further inland. Yet patterns of soil conservation have had to be worked out by the Soil Conservation Service to overcome the problems of erosion associated with these different conditions.

It is becoming evident that these problems are being overcome. The methods which are achieving this are also giving benefits in the way of increased productivity as well as stabilising the land. This is evidenced in the widespread adoption of the methods by farmers. Landowners in practically every major part of the State are readily adopting the methods we have developed and are expending their money on the application of these methods to their farms. They would not do this if the methods were not sound and they could not afford to do it if the methods did not fully justify the expenditure.

Now as to the methods themselves. They were not accidental. They had to be soundly based on a knowledge of the agricultural potentialities of the district, the climate and the soils. Methods then had to be conceived to fit the needs of each area. They had to be tried experimentally and then further tested and modified, where necessary, to suit each major variant of soil and climate. This involved constant research work and testing in the field. The average observer sees only the finished application to some individual farm and does not see the constant research work that is going on and which forms the foundation for the field work on farmers' properties.

Though there are, perhaps, some notable achievements to the credit of the Soil Conservation Service the fact is that far too little research and investigation has been carried out to date in this important sphere. What has been done has been achieved under great difficulties and in the face of serious shortages of staff and facilities.

One of our greatest needs is more useful information about soils, not just the classification of them but how they behave under various treatments and why, what are their needs and what are the effects of different types of tillage. What amounts to an agricultural revolution is going on at present. Agricultural methods, particularly tillage practices, are changing very rapidly and the improvements and developments in agricultural machinery continually open up new possibilities and call for improvement in agricultural techniques.

There are many methods and machines for soil conservation work the same as there are for cultivation and sowing and though all have their specialised use no one machine or method is universally applicable throughout the State for efficient soil conservation.

We have closely correlated our research work with the application in the field of the methods devised. This is one of the reasons for the ready adoption of our methods by farmers.

Throughout the world it too often happens in research work that a series of inadequate and unrelated snippets of a complex major problem are worked out and the farmer is then expected to assimilate indigestible morsels of information and apply them to his farming operations. In my experience this is unreasonable and unrealistic. It leaves the farmer with a more difficult task than the research worker.

The Soil Conservation Service of New South Wales has endeavoured to overcome this universal weakness. It does not hand the farmer a piece of information and leave it to him to fit it in to his farming practices as best he can. The Service plans with him and works with him in the field to fit the knowledge into his system, in many cases the actual earth work is done under our plant hire scheme.

Undoubtedly there is need for more useful research work but there is equally great need in Australia, as elsewhere, to bridge the gap between the research and its application to the farm and the latter requires a different type of skill and a wider knowledge. Actually it is as difficult to effectively integrate new practices into a balanced farming system as it is to unearth the new practice.

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REGENERATION OF MARGINAL LANDS IN THE NEW SOUTH WALES WHEAT BELT.

BY

L. G. Kaleski, B.Sc.Agr., Chief Soil Conservationist.

In considering regeneration of marginal lands it is necessary to have in mind what we mean by the term "marginal". For the purposes of this paper, I have in mind those lands upon which a farmer, exercising plenty of hard work and having an adequate amount of rural knowledge, skill and financial resources, would not earn a good living.

LOCATION.

In New South Wales the term "South-West Marginal Wheat Area" was officially used in the nineteen-thirties in connection with the rehabilitation of a large number of landholders who had been settled on light soils of a sandy nature, including mallee soils. These lands were situated in Western Riverina, between the Murrumbidgee and Lachlan Rivers, between the 13-inch and 15-inch isohyets, and were settled on a basis of the farmer making a living primarily on a wheat-fallow rotation.

Because of low rainfall and wind erosion, average wheat yields during the nineteen-twenties were very low. When wheat prices fell in 1930, this method of land usage became uneconomic; later, farming areas were substantially aggregated to allow grazing to become the major land usage. To-day there is very little wheat grown in this area.

In the eastern areas of New South Wales, Davies has referred to many millions of acres of marginal land which may be made highly productive under intensive grassland improvement practice. These lands are mainly in the podsol belt, between the 25-inch and 50-inch isohyets. The improvement is envisaged by the use of fertilizers, trace elements, lime, legumes, rhizobium and high quality grasses.

A third group of lands, much of which is or was marginal on the abovementioned standard, is now described, namely the gully-eroded lands within the western slopes of New South Wales, mainly red-brown earths between the 16-inch and 25-inch isohyets.

EROSION SURVEY.

The Erosion Survey of New South Wales, carried out by the Soil Conservation Service during 1941-43, indicates the following position:—

Area of land within western slopes of New South Wales, 52,000,000 acres.

Area of land affected by gully erosion, 16,000,000 acres.

ACQUISITION OF SOIL CONSERVATION RESEARCH STATIONS.

In order to study and devise measures to remedy this position, the Soil Conservation Service acquired five Research Stations within the wheat belt during 1940/1946, at Wagga, Cowra, Wellington, Gunnedah and Inverell. Some of the activities on these are now used to illustrate methods of reclamation of marginal lands within the New South Wales wheat belt.

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In each case the lands rise from gently sloping, formerly arable lands to steep slopes up to 30 per cent. and to cliffs in the case of Gunnedah.

The steep upper lands had in each case been cleared of timber; pastures on these and the intermediate slopes had been eaten bare by long continued overstocking and the depredations of rabbits. Excessive run-off from these higher lands flowed across the lower arable lands, gouging out deep and frequent gullies down every flow line. Because of the removal of huge amounts of topsoil and the physical obstruction of the gullies, the lands had been abandoned for cultivation prior to 1945, and had reverted to sparse weedy pasture.

RESEARCH STATION WORKS.

Land Use Planning.

The method of classification and land use planning, as developed in the United States a few years previously, was modified and used in classifying these lands and planning the future soil conservation works.

The classification used was as follows:—

A. *Land Suitable for Cultivation.*

1. No special soil conservation practices necessary.
2. Simple soil conservation practices, e.g., contour cultivation, adequate rotations, etc.
3. Intensive soil conservation practices, e.g., in addition to (2) above the installation of diversion banks, graded banks, grassed waterways, etc.

B. *Land Suitable for Grazing.*

4. Land suitable for sown pasture, too steep for regular arable production, but from which an occasional crop can be taken under protective mechanical measures.
5. Permanent sown pasture on steep slopes permanently protected by absorption or diversion banks and pasture furrows.
6. Very steep, sometimes rocky areas, which can be improved only by broadcasting seed and fertiliser, and on which very limited stocking should be practised.

C. *Lands Unsuitable for Cultivation or Grazing.*

7. Lands which should be retained under forest or planted to forest, and from which stock should be excluded.
8. Cliffs, lakes, swamps and similar unusable and untreatable land.

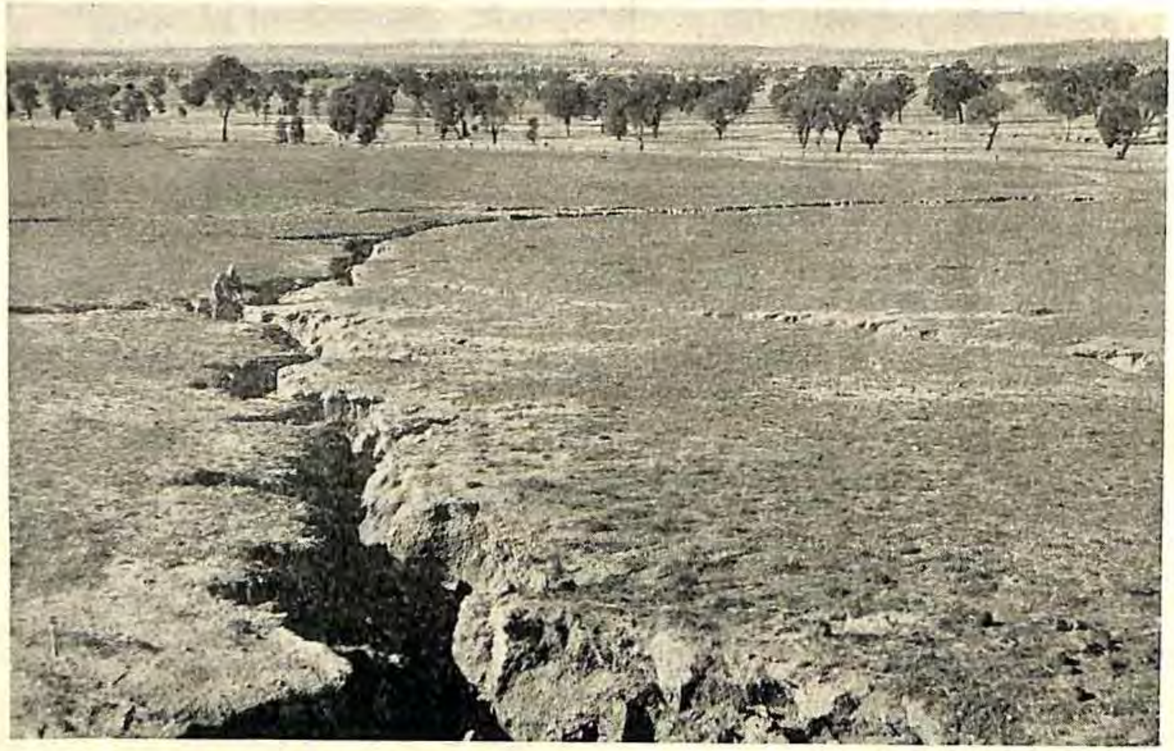

Fig. 1.—Badly eroded formerly arable land on Wagga Soil Conservation Research Station in 1945.

Soil Conservation Land Usage.

Having classified the lands the next thing to do was to implement the classification.

It was apparent that practically the whole of the internal fencing on all Stations was unsuitably located. The first soil conservation measure, therefore, was to pull out practically the whole of the internal fencing and re-fence on the contour on a land-use plan basis. Most of the original fencing had already fallen down or was in an otherwise ineffective state, compatible with the severely depreciated state of these lands.

There was no land in Class I, i.e., land requiring no soil conservation measures, on any of the Stations. There were very limited areas in Class II and the main consideration in respect of the arable lands was the Class III Group, i.e., the lands requiring intensive mechanical soil conservation measures.

On all Stations this involved, firstly, massive diversion banks on low grade (0.25 per cent. to 0.4 per cent) at about the 8 to 10 per cent. slope to intercept any uncontrolled run-off from the higher lands and take it round the slope to dams and/or waterways and lead it to safe disposal areas.

Below these absorption or diversion banks, the gullied Class III arable lands were then treated mechanically by gully-filling, graded banking, grassed waterway construction and contour working and sown to the "wheat-subterranean clover ley-fallow" rotation in the south and the "five-year stubble mulch wheat-five year lucerne ley" rotation in the north.

The Class IV lands above these received somewhat similar mechanical treatment, but permanent pastures of lucerne, Phalaris and subterranean clover in the south and lucerne and Rhodes grass in the north were sown. These lands range to about 15 per cent. slopes.

Class V lands, i.e., steep natural pastures, were not ploughed, but intensively contour-furrowed on 1 to 3 feet vertical intervals and Wimmera ryegrass and subterranean clover and superphosphate scarified in the south and Rhodes grass and liverseed grass (*Urochloa panicoides*) in the north. These lands range up to 30 per cent. slope. On the northern Stations massive level absorption banks were used instead of pasture furrows, because of the high intensity of summer storms.

Class VI lands represent the steepest grazing lands on which hand broadcasting of fertiliser and perhaps seed is of value on small areas, and aerial topdressing on larger areas. On the Research Stations Class VI lands were limited in extent.

The Class VII lands, i.e., land at present under forest or which should be planted to forest for soil conservation purposes, with stock excluded, were well represented.

The Service is raising 75,000 trees per year in its Station nurseries. In earlier years these trees were mostly used on the Stations and other Crown lands. Existing timber stands, particularly on ridges, were thickened and extended, corners of paddocks formerly severely eroded were planted, shade and shelter belts were established on all boundaries and Station roads and the farm forest was accorded its own particular place of importance in land classification and the implementation of plans for wise land usage on these Research Stations.

Class VIII lands, the cliffs, swamps, etc., were very limited in area.

RESULTS ACHIEVED.

Results have been measured in three ways: firstly, by measurement of the changes in the vegetation and decrease in the run-off and soil loss from the areas concerned; secondly, by the production of crops and stock during the decade this work has progressed; and, thirdly, by the impact of this phase of soil conservation work on the rural community as indicated by the extent to which they have undertaken similar work on their own holdings at their own expense.

Vegetation on Hill Lands.

At Wagga Station slopes of the hill lands are about 20 per cent., with 30 per cent. maxima.

The marginal state of these lands prior to soil conservation development is illustrated by records of permanent quadrats located at random in 1947 throughout the hill lands. Typical quadrant counts are:—

Year.	1948.	1950.	1953.
Military Paddock. Quadrat 4W.			
Bare ground	90%	55%	0%
Stipa-Aristida spp.	Sub-dominant	Dominant	Absent
Subterranean clover	Occasional	Present	Dominant
Cow Paddock. Quadrat 4.			
Bare ground	62%	0%	0%
Skeleton weed	25%	Present	Absent
Subterranean clover	2%	Dominant	Dominant
Wimmera ryegrass	4%	Present	Sub-dominant

In Military Paddock the sheet-eroded stony ridge was, in 1948, devoid of any vegetation over 90 per cent. of its surface area and the sparse vegetation consisted of *Stipa* and *Aristida* spp., which are of low forage value. By 1953 this paddock had been reclaimed to the state of complete ground cover by subterranean clover and the low value species had been crowded out.

In Cow Paddock, once cultivated, but abandoned to thin weedy pasture prior to 1945, bare ground was reduced from 62 per cent. in 1948 to zero in 1953 and skeleton weed crowded out by a dense pasturage of Wimmera ryegrass and subterranean clover.

Over 100 acres of the steep hills of the Research Station, marginal to a state of having been almost completely unproductive because of erosion, have been similarly transformed from practically bare stony ground to highly productive pastures at present carrying two sheep per acre, and with considerable further improvement now possible by the introduction of *Phalaris tuberosa* at this stage.

Run-off and Soil Loss from Conserved and Unconserved Catchments.

At the southern end of Wagga Soil Conservation Research Station are two small catchment areas, side by side, each of 25 acres and of similar 15 to 20 per cent. slopes. One catchment area has been soil-conserved by the installation of level pasture furrows at 2 feet vertical intervals, sown with Wimmera ryegrass and subterranean clover and topdressed with superphosphate each year since 1950. The other catchment area remains untreated. At the outlet of each a measuring weir and water stage recorder have been installed.

The soil-conserved catchment area is grazed at the rate of 2 sheep per acre as against 1 sheep per acre on the untreated; in 1952 the amount of run-off from the soil-conserved catchment was one-fifteenth that of the untreated catchment, the maximum rate of run-off was one-seventeenth, and the amount of soil lost was a trace as against 10.3 tons from the untreated area. Nineteen fifty-two was the wettest year (26.2 inches) since the installation of the measuring weirs and recorders.

It would be better to retain all or most of our rainfall on the farms by reclaiming marginal lands by soil conservation farming and grazing land usages; thus the problems of roadside erosion, siltation and flooding could be mitigated at the source of the trouble instead of at the end point.

At *Gunnedah* in 1946 the mechanical soil conservation works had just been completed on approximately 300 acres of very seriously eroded lands up to 30 per cent. slopes. Run-off from these lands previously concentrated at one point in the north-eastern corner of the Station, passed through a railway culvert, across the main north-western highway and spread across the Mooki river flats.

In January, 1947, a storm of 595 points in 90 minutes was recorded. Just prior to acquisition of the Station, previous storms of much less volume and intensity had twice resulted in run-off which destroyed about 10 chains of railway embankment, road and adjacent lower boundary fence, the run-off being estimated to reach the rate of 500 cusecs, or nearly 2 cusecs per acre.

The installation of the mechanical soil conservation measures so reduced the amount and the rate of run-off, that in this record storm, even though every furrow, bank and waterway flowed to capacity, there

Fig. 2.—An area of subterranean clover-wimmera ryegrass ley in 1953 in the same paddock as in Fig. 1, eight years after installation of mechanical soil conservation measures and the adoption of wise land usage.

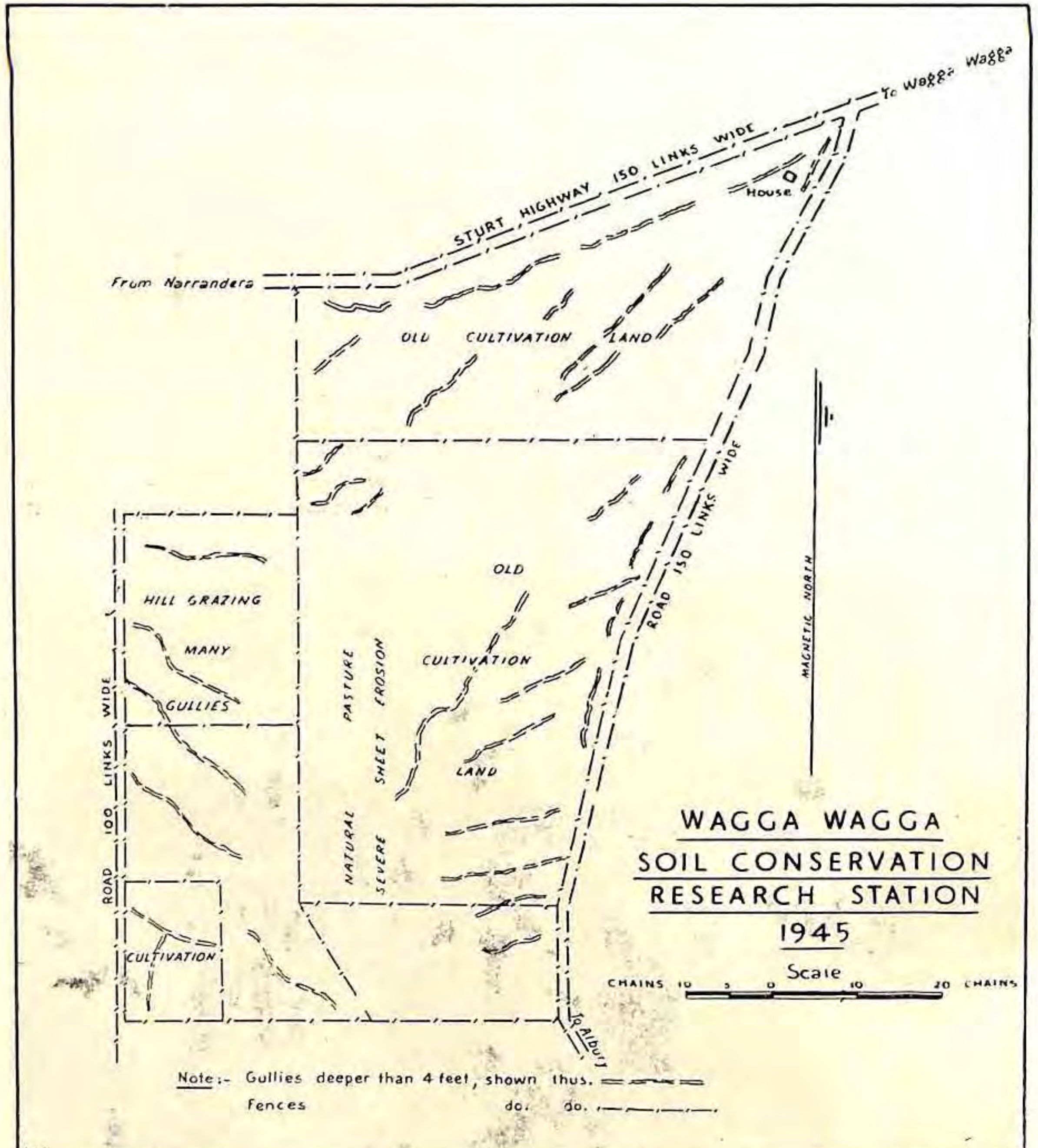

Fig. 3.—Land-use, internal fencing and erosion on Wagga Research Station at the time of acquisition in 1945.

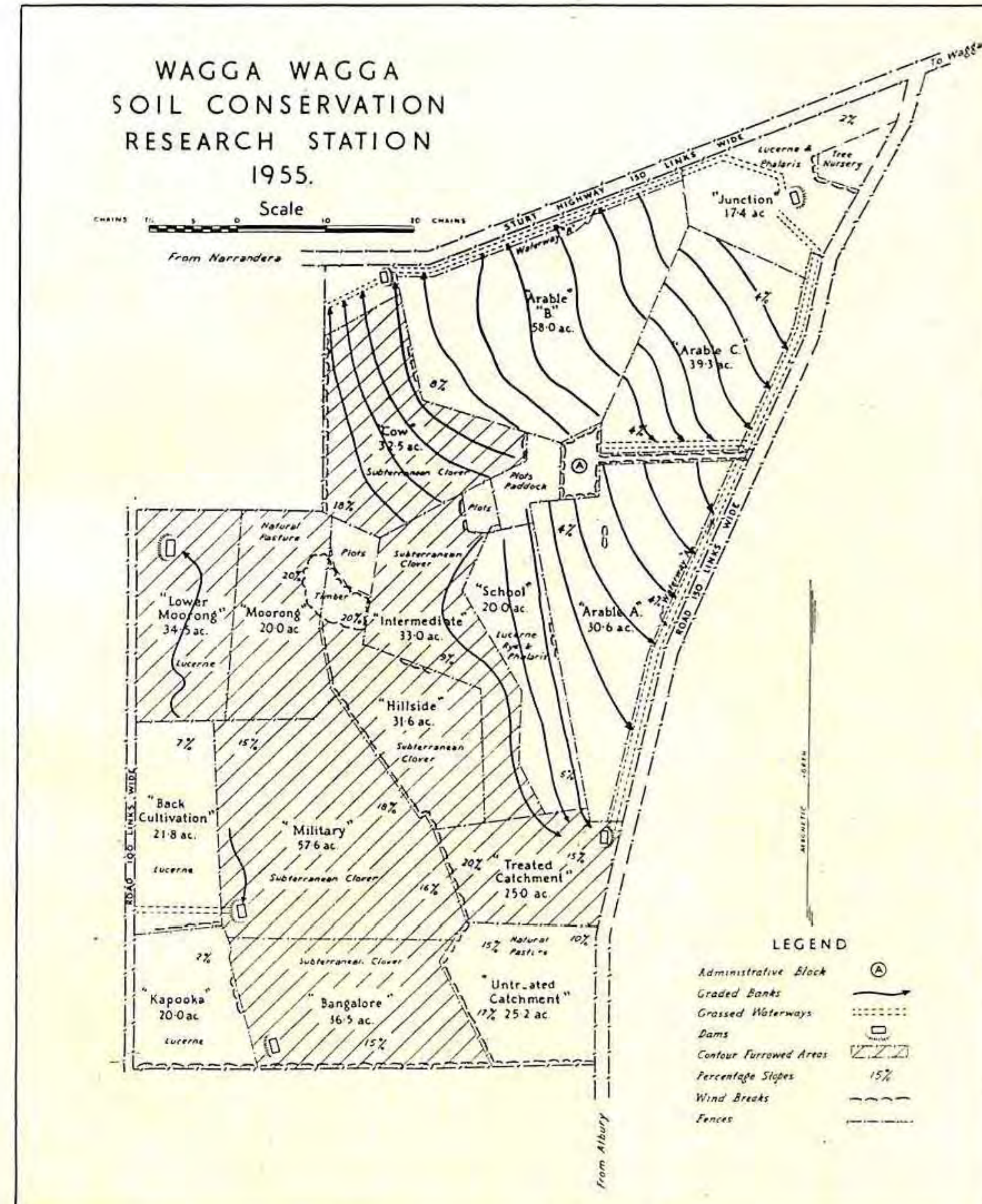

Fig. 4.—Present land-use, soil conservation measures and subdivision of Wagga Research Station following classification of the land according to capability.

was no damage either to Station lands or to railway embankment, road or adjacent lower lands.

Since 1947, the vegetative, as well as the mechanical soil conservation measures, have been installed and there is now seldom any run-off at all.

The water is now practically all absorbed and used in situ for the production of crops and pastures, resulting in high yields on lands which prior to 1946 were saw-toothed with gullies and out of arable production.

Run-off and Soil Loss Under Different Land Usages.

On the steepest section of the arable lands on the Wagga Station (9 per cent. slopes) an experiment was laid out in 1948 in plot form to ascertain run-off and soil loss under various forms of land use. Each plot is 132 feet in length, i.e., the normal distance between graded banks on slopes of this nature.

Results from 1948 to June, 1955, are as follows:—

Treatment.	Run-off Inches.	Soil Loss Tons per acre.
Wheat-fallow (6 plots)	10·93	9·14
Wheat-ley-fallow (9 plots)	7·37	5·45
Upland lucerne (3 plots)	4·38	0·48
Improved pasture (3 plots)	3·27	0·25

Nearly 50 per cent. more water and 70 per cent. more soil is lost by farming under the wheat-fallow system than the wheat-ley-fallow. During these seven years also about three times as much water and thirty times as much soil has been lost from land under wheat-fallow than from adjoining land under lucerne or improved pasture.

Pasture Production.

The next method of ascertaining the value of land classification and soil conservation farming is to measure stock carried and yields of crops.

On the whole Wagga Soil Conservation Research Station the 550 acres were in such an eroded infertile state that less than half a sheep per acre was carried prior to acquisition and development of the Station in 1945-46. Since 1947 the previous stock-carrying capacity of the whole Station has been increased from 0.5 to 2 sheep per acre as follows:—

	Sheep per acre.
1948	0.68
1949	0.91
1950	1.60
1951	1.90
1952	2.01
1953	2.10
1954	1.70

The slight regression in 1954 was associated with an unusual climatic year.

Annual pasture production on Wagga Station has been at least trebled in quantity and quality in seven years.

At *Wellington* the story is similar. Most of this 500 acres is arable, but, instead of a three-year rotation of wheat—subterranean clover ley-fallow at this Station, the land usage includes a rotation of six years' wheat-fallow followed by a five-year lucerne ley.

Prior to 1948 the grazing figures were in the vicinity of 0.5 sheep per acre over the whole Station area. Following development in 1946 and 1947 the average grazing rate over the whole Station during the period 1948-54 has been 1.4 sheep per acre and on the lucerne leys, comprising more than a quarter of the Station lands at any one time, the average grazing rate has been 2.58 sheep per acre during 1948-54.

At Wellington, as in the case of Wagga, it is clear that pasture production has been trebled in seven years on lands which were out of cereal production and marginal for stock because of erosion.

In respect of quality of the pasturage fat stock from both Wagga and Wellington, fed on pasture only, have been regular prize winners at local Agricultural Shows in recent years.

Fig. 5.—The front paddock at Wellington Soil Conservation Research Station in 1945 abandoned for cultivation.

Wheat Yields.

At *Wagga* undulating arable lands were out of production because of sheet and gully erosion. No wheat had been grown for many years. The first crop grown by the Service in 1946, after gully filling and construction of graded banks, waterways and contour cultivation, produced 1.5 bushels per acre. By 1954, in paddock Arable C, yields were available of three crops grown during a period of nine years on three wheat-subterranean clover ley-fallow rotations. The yields were:—1948, 12 bushels; 1951, 18 bushels; 1954, 30 bushels. (1954 crop yield is an equivalent, based on a 38 cwt. per acre cut of hay.)

There is at present at Wagga Station a very interesting sight. Some graded banks built of topsoil in 1946 have recently been levelled and the bank lines incorporated in the arable area. The wheat along these old lines is yellow and stunted. On either side the soil which has had the benefit of the protection of the banks and of three subterranean clover ley rotations for nine years is producing a dense vividly green crop, which promises a very high yield for 1955. The yellow spindly crop lines are truly representative of the 1946 marginal condition of the land and will yield practically nothing.

At *Wellington* the results have been similar. The "Front" Paddock of 70 acres, following regular wheat growing without rotation for about 40 years had, by 1945, degenerated into a deeply gullied and sheet-eroded scalded area, abandoned for cultivation and so lacking in structure and fertility that even the black oats in 1946 were sparse, spindly and yellow. Mechanical soil conservation measures were installed and the paddock sown to its lucerne ley and heavily fertilised, grazed and renovated for five years. In 1952 the cereal phase of this rotation was commenced in this paddock and wheat was sown. The yield was 42 bushels per acre. There is a similar story on the remainder of the Wellington Research Station lands.

Thus at Wagga and Wellington lands which were marginal, i.e. capable of producing only very low yields of cereal crops in their existing state, because of erosion, have been raised to the highest yielding lands in their respective districts, with yields at least double the New South Wales average.

Adoption of Soil Conservation Land Usage by Farmers

The third method adopted for measuring the value of the land classification, mechanical soil conservation measures and wise land usage adopted on the Soil Conservation Research Stations, is to examine the number of farmers who have followed the lead given and the extent of their work.

In New South Wales as a whole there are 73,000 rural landholders of whom about 35,000 have an erosion problem of some sort. The properties of 13,000 of these landholders have, on request, been inspected at least once by officers of the Soil Conservation Service.

During the last five years more than 4,500 landholders, the total area of whose farms exceeds 6,000,000 acres, have carried out mechanical soil conservation works to the Service's design and 2,500 farmers have hired the Service's plant to do so at cost to them of £500,000. Most of this work is being carried out in the wheat belt within the 16,000,000 acres affected by deep and frequent gullies. Possibly more important than the amount of work that has been completed is the fact that after five years' assessment of the value of this work, at a time when wheat prices are falling heavily, the demand by farmers is still rising sharply. In one only of the Service's twelve Soil Conservation Districts, Riverina, there are at present date 240 outstanding plant hire applications of value exceeding £100,000.

Fig. 6.—The soil conserved land at Wellington Station producing high yielding crops in 1953.

CONCLUSION

In conclusion I would say it is quite feasible to double the output from crops and stock and farm timber at low capital cost, from all the eroding arable farms in the western slopes of New South Wales by land-use, planning and soil conservation farming.

We know this can be done because it *has been* done on so many representative farms from the Victorian to the Queensland border.

And finally, farmers throughout these areas are rapidly becoming aware that in 1955 it is more economical to increase their output 100 per cent. by spending £3 or £4 on each existing acre than to buy new land at £30 or £40 per acre to achieve the same result.

ACKNOWLEDGMENT

The work of many officers of the Soil Conservation Service stationed on these Research Stations is fully acknowledged.

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SOIL CONSERVATION ON THE NORTH COAST

By

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

In 1951 the North Coast Soil Conservation District was established with headquarters at Kempsey in order to meet the needs of the farmers in that region with erosion problems. This district embraces the area from the Queensland border in the north to Stroud in the south, and west to a line roughly along the eastern escarpment of the Great Dividing Range. It was subsequently divided into three sub-districts with technical officers located at Casino, Kempsey and Taree.

GENERAL TOPOGRAPHY AND LAND USE.

The region comprising the North Coast District incorporates eight major river systems and numerous minor creek and river valleys, which originate on the eastern fall of the Dividing Range. Generally speaking, the headwaters of these rivers are located in steep, rugged forest lands, but eventually meander through the coastal plain, where, in the majority of cases, rich alluvial flats have been formed. These are the areas upon which the North Coast has built its reputation as one of the leading dairying districts of Australia.

In addition, during the last fifty years or so, dairying has been extended to some of the less favourable undulating and ridge country between the river valleys. With the extension of pasture improvement methods and the opening up of various areas of soils of volcanic origin, such as the Big Scrub country near Lismore, Dorrigo and Comboyne, this region has become even more widely known for its dairy production. However, although dairying and timber getting are the principal industries, there are numerous others from which the farming community derives a living. Beef cattle are prominent in the lower rainfall regions of the mid and upper river areas where the rough conditions are seldom suited to dairying, and these are often brought to the coast for fattening prior to marketing. Furthermore, due to the somewhat sub-tropical conditions experienced, bananas are a major industry in various selected localities, and truck crop farming, particularly peas, beans and tomatoes for the city market, is becoming more important each year. Other tropical fruits, citrus, pigs and poultry are also important subsidiary industries. Potatoes, which were formerly an important crop in such districts as Dorrigo, now appear to be giving way to dairying, but nevertheless are still prominent in some districts.

Between the more fertile valleys, the ridge country of poorer soil types has in most cases been left in its natural state under Eucalypt and scrub forests or managed as State Forests. The more open of these offer limited grazing possibilities for beef cattle.

SOILS.

A wide variety of soils exist within this District ranging from the deep, absorptive volcanic soils in the Big Scrub areas to shallow, light grey clay loams derived largely from shales. These latter soils are found chiefly on the ridge country between the river valleys. Also, light sandy soils are common in some districts, particularly the Upper Clarence River Valley. Tea-tree swamp and heath country derived chiefly from marine sand is a very common feature along the greater portion of the coastal hinterland. Although these soils comprise a large proportion of the North Coast, the alluvial flats on the major river and creek systems support most of the population.

CLIMATE.

A wide variety of climatic conditions are experienced throughout this district ranging from sub-tropical in the far north to cold tableland conditions on parts of the Dorrigo Plateau. Although temperatures are mild along the coastal fringe, frosts are more or less frequent during the winter months in areas more remote from the coast.

The area experiences considerable variations in seasonal rainfall from year to year, the wettest period being in February, March and April when cyclonic rains of high intensity often occur. From past records, however, although these months are almost invariably wet, the late winter and spring months are often deficient in rainfall. For this reason, despite the fact that at Dorrigo the average annual rainfall exceeds 70 inches and at several places in the far north it exceeds 60 inches, rainfall is a determining factor for plant growth due to its irregular nature. This is apparent in the fluctuating levels of production.

Furthermore, from the point of view of erosion damage, this variation is important, as high intensity rains often occur following long dry springs and hot summers, thus reaching the soil at a period of high erosion hazard.

EROSION

As a result of a survey carried out by officers of the Soil Conservation Service during the period 1940-45 on a County basis, the extent of erosion in the area embraced by the North Coast District was determined. This is summarised in the following table.

Moderate gully erosion, 81 sq. miles.

Sheet erosion, 5,478 sq. miles.

No appreciable erosion, 13,246 sq. miles.

Factors Causing Erosion

Injudicious Stocking.—In the lower rainfall areas of the region, particularly on the poorer types of soils, this cause has brought

Fig. 1.—Valuable topsoil has been lost from this bean-growing land in the Port Macquarie district as a result of conventional up-and-downhill cultivation.

about the partial destruction of the better natural perennial pasture species which have been replaced by annuals of doubtful value, resulting in a reduction of ground cover. On some of the lighter soils this has started sheet erosion, and, in certain districts, severe gullying of the natural depressions.

Soil Types.—Soils on the North Coast vary considerably in degree of erodibility; some of the lighter soils with friable subsoil being most susceptible particularly in natural gully lines.

Climate.—As mentioned earlier, the irregular nature of the rainfall in this region is often a determining factor in causing erosion. The high intensity rains, so often experienced during the late summer and early autumn, occur at a time when ground cover is sparse and when land is being prepared for autumn sowing of crops and pastures. In recent years, this factor alone has caused a considerable amount of erosion on such areas.

Land Use.—In view of the favourable climatic conditions for the winter production of vegetables, particularly on the hillsides around Tweed Heads, Coffs Harbour, Macksville and Port Macquarie, large areas in these districts are devoted to such crops. As a general rule, these areas are prepared for sowing during the autumn months and frequently suffer severe damage either in the preparation period or shortly after sowing. This condition is often accentuated by the common practice of up-and-downhill cultivation, illustrated in Fig. 1, which is considered by most farmers to be the only method of cultivation possible on these steep slopes.

Furthermore, the growing of potatoes in friable soils, such as are found in the Dorrigo district, has not only led to the loss of valuable topsoil, but has also depleted the fertility of these soils. Even after the crop has been harvested, regeneration of these areas with the natural grasses and clovers

Fig. 2.—Graded banks, grassed waterway and rotational cropping have protected this land at Port Macquarie from erosion.

is particularly slow, leaving the soil exposed to the elements for a considerable period unless sown to pasture immediately.

Another crop which causes a considerable amount of sheet erosion is bananas, which, in its early establishment period, leaves the greater part of the ground surface exposed to the weather. As it is most important to reduce competition from weed growth, clean cultivation is usually practised, rendering the soil highly susceptible to erosion. This erosion hazard is usually reduced following the development of an overhead canopy of leaves and the laying of trash on the surface.

Hillside lands devoted to dairying, particularly when sown to corn and other fodder crops, are not considered to be so highly vulnerable as the areas referred to above. This is due to a number of factors: firstly, the areas sown to fodder crops is not extensive and often consist of small paddocks reasonably well protected by grazing areas on either side; secondly, during recent years there has been a gradual, but marked changeover, from fodder crops to pastures; and thirdly, much of the fodder cropping undertaken is initiated during the spring and early summer months when the danger of erosion is not so great.

Method of Cultivation.—As mentioned earlier, the usual method of cultivation for sloping country on the coast is up and down hill, as most farmers contend this is the simplest way. This theory has no doubt been fostered by reason of the fact that few ploughs are in existence which can effectively throw the furrow slice uphill when working on the contour, thus resulting in the soil being continually thrown downhill, particularly when worked with a hillside plough. This difficulty has now been largely overcome with the advent of the chisel plough, which is capable of working the soil to a depth sufficient for almost any crop without turning it over. This has been

Fig. 3.—Level pasture furrows in the Bellingen district reduce run-off and help to promote pasture growth.

borne out on several contoured areas where conventional ploughs have been entirely dispensed with, to the decided benefit of the landholders concerned.

Another problem encountered in one area is a soil that clogs conventional ploughs, and it is considered by the landholders concerned that the rotary hoe is the only implement capable of tilling the soil satisfactorily for their crops. This has resulted in the development of a harpan and the surface is left in such a pulverised condition that serious erosion is inevitable. During periods of prolonged rainfall, the loose top soil becomes saturated and is often swept off the hill to the hardpan with devastating effect, as shown in Fig. 1.

Burning Off. Although very little concrete evidence is available which would indicate any extensive damage from this cause on the North Coast, it has been clearly illustrated on numerous occasions that burning off on steep hillsides has increased the run-off from such areas and resulted in sheet erosion of varying degrees. It has been stated on numerous occasions that burning produces a beneficial effect by reason of the fresh growth of grass which usually follows. However, at the time of the year when this is usually carried out, namely, the early spring months, rainfall is usually deficient and the damage is often caused before a satisfactory grass sward can be obtained.

CONTROL MEASURES.

Due to the steepness of hillsides which are being utilised for cultivation, the general principles of conservation works as adopted in other areas of the State cannot always be applied in this district.

Graded Banks. Owing to high land values in some of the more favoured truck crop areas the construction of graded banks is not favoured by landholders by reason of

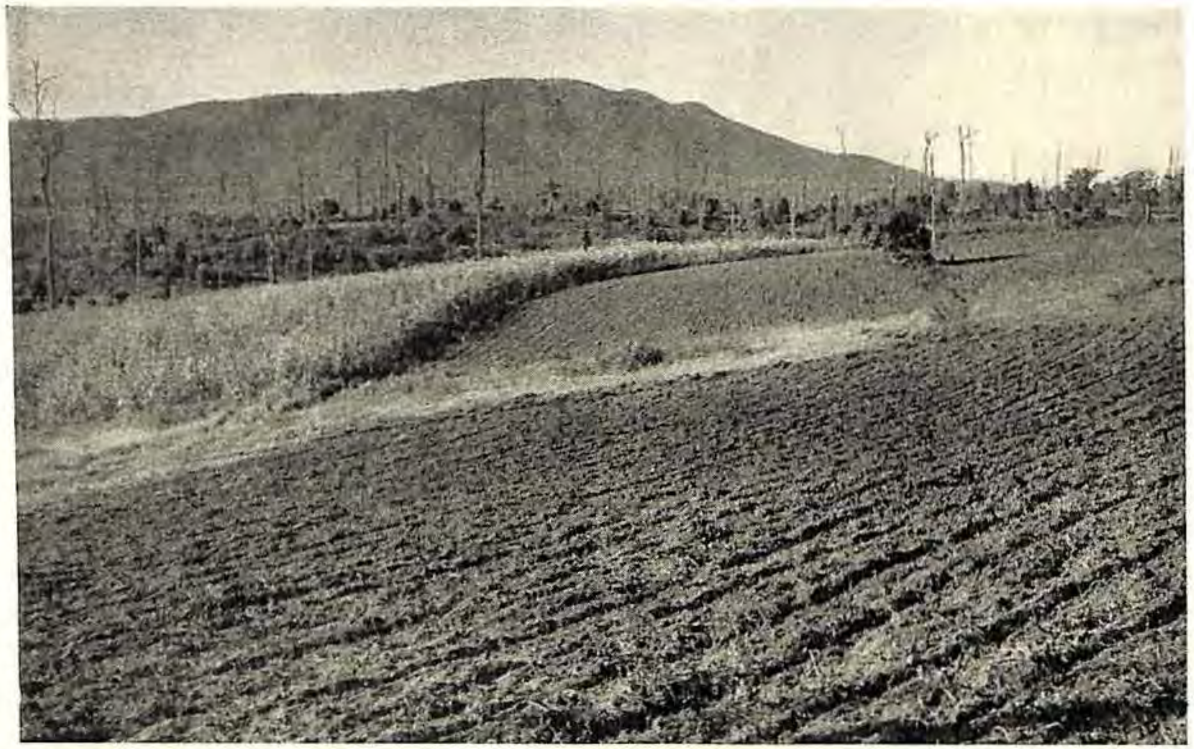

Fig. 4.—Contour strip cropping, small graded banks and a well-grassed natural depression control excess run-off from hill country in the Eungai district.

the area of ground either laid idle in the banks, or which is difficult to work. Furthermore, continual working on the contour between banks on such land tends to move the soil downhill, with the result that subsoil is exposed on the uphill side and on the lower side accumulation of topsoil either tends to form a bench terrace, or in some cases fills the channel of the bank. This necessitates frequent maintenance of the banks which, in most cases, involves the hire of suitable plant to undertake the job.

This position has been overcome to some degree on isolated properties where conventional ploughing has been discontinued, the landholder in question switching over to the chisel plough, or some other tyned implement, for all land preparation for crops. In most cases, this practice has brought about a better absorption of rainfall and an improvement in soil structure generally. The greatest benefit from this general trend in cultivation practice has been observed on properties where higher powered tractors are in use. This is considered due to the greater depth of penetration possible under such conditions. Fig. 2 illustrates an area where rotational cropping is practised between graded banks.

Deep Ripping. Another measure adopted in this district, for the prevention of erosion on cultivation paddocks and for the better utilisation of rainfall in both cultivation and pasture areas, is deep ripping, with either a heavy road ripper or various other types of subsoilers. This has been particularly beneficial on old cultivation areas which have developed a hardpan through years of ploughing to the same depth, but marked increases in growth have also been observed in pasture areas on some of the shallower hillside soils in the Kempsey and Macksville districts. It is still too early to say for what period this benefit will continue.

Contour Furrows.—These have been constructed under a wide variety of conditions in numerous places, with varying degrees

Fig. 5.—Contour strip cropping has effectively controlled run-off from this property at *Comboyne.*

of success. They have been constructed with a number of different implements, such as single and double-furrow ploughs of various types, and in some cases small graded ditcher blades. Success with these works has been largely dependent on the size and spacing of furrows. However, the greatest benefit has been observed on areas where inter-furrow renovation of pastures has also been practised.

In certain cases requests have been received to design the furrows with spacings wide enough to allow these renovation implements and manure spreaders to move between the furrows unhindered. On some of the steeper hillsides this often necessitates the construction of furrows with a greater capacity in order to accommodate the heavy rains experienced in this region from time to time. Needless to say, there are periods of high intensity storms and cyclonic rains, when even these furrows are incapable of handling the excess run-off, particularly on heavy soils where absorption is poor. Fig. 3 illustrates the use of pasture furrows on a dairy property in the Bellingen District.

Other Methods. In addition to the above measures which have been confined largely to dairying properties and truck crop areas, other soil conserving activities have included the contour planting of orchards and banana plantations and the adoption of a system of strip cropping where conditions were suitable and suitable plant was not available for the construction of graded banks. See Figs. 4 and 5. Also several areas have been provided with contour guide lines where landholders were desirous of adopting a system of contour renovation of pastures or contour planting of crops. Fig. 6 illustrates an area of potatoes planted on the contour at Comboyne.

Fig. 6.—Erosion has been checked by planting these potatoes on the contour Comboyne district.

CONCLUSION.

Although soil erosion is not as spectacular on the North Coast as it is in many of the inland districts, nevertheless it places an important restriction on the future utilisation and development of farming lands in the undulating to hilly areas. The fact that eroded areas are frequently revegetated rapidly as a result of the high rainfall has apparently been responsible for apathy on the part of many landholders. However, there is a gradual awakening to the fact that fertility of these soils is declining and low fertility grasses, such as carpet grass, are rapidly spreading and smothering pastures which previously consisted of more valuable species. Furthermore, declining yields from row crop areas are creating an awareness of the loss of fertility and top soil from such areas. This has brought about a steadily increasing application of conservation methods in these districts.

SURVEY OF LOWER NAMOI DISTRICT

BY

J. M. McGrath, H.D.A., District Soil Conservationist.

LOWER Namoi District, with Headquarters at Gunnedah, is one of the two recently formed Districts of the Soil Conservation Service of New South Wales. Its boundary embraces an area of approximately 9,000 square miles.

The District comprises the whole of Liverpool Plains Shire and Coonabarabran Shire with Namoi Shire and part Tamarang Shire.

Officers are located at Gunnedah Research Station, Narrabri Sub-district Office and Coonabarabran Sub-district Office, in addition to the District Office and extension activities within Liverpool Plains Shire located at Gunnedah.

TOPOGRAPHY.

The District is influenced by three major ranges which in turn shape the catchment of three major streams.

The ranges of prominence which affect the pastoral and agricultural pursuits of the District are the Nandewar, Liverpool and Warrumbungle. Mount Kaputar, the highest peak of the Nandewar Range, rises to 4,500 feet above sea level and is periodically snow-capped.

Rivers of importance are the Namoi, Mooki and Castlereagh: tributaries that feed the Namoi have a marked bearing on the various communities situated on the lower reaches of the Namoi. These tributaries, the Manilla, Macdonald, Mooki, Cockburn and Peel rivers merge as one at Gunnedah and form the Namoi River, and become part and parcel of the great river systems which finally flow into the Great Australian Bight in South Australia.

The Castlereagh River which has its origin at the foot of the Warrumbungle Range near Coonabarabran finally flows into the Barwon River below Walgett.

The rivers and ranges which are within or bound the District largely dictate the activities of landholders in their pastoral or agricultural pursuits. They are also responsible for widespread devastation during abnormal floods. Topographically the District is divided into steep mountainous to hilly areas, lands sloping away from the hills and suitable for both grazing and agricultural pursuits and the plains which offer a great potential as farming and grazing areas.

A large tract of land known as the Pilliga State Forest occupies approximately 623,161 acres and is sparsely inhabitated. This Pilliga Scrub Area represents the bulk of the poorer soils of the North West and is set aside as a State Forest Reserve.

The topography of the District and principal communications are shown in Fig. 1.

CLIMATE

Lower Namoi District is subjected to extremes of heat and cold, ranging from about 18 degrees F. to 115 degrees F. Spring and autumn are very short in duration, winter is usually of about four months duration with summer extending over approximately six months.

Average yearly rainfall varies from 18 inches to 27 inches. Areas in close proximity to the Nandewar and Warrumbungle Ranges enjoy a milder climate with a 27-inch rainfall. The western edge of the Pilliga Scrub is limited to approximately 18 inches of rain annually.

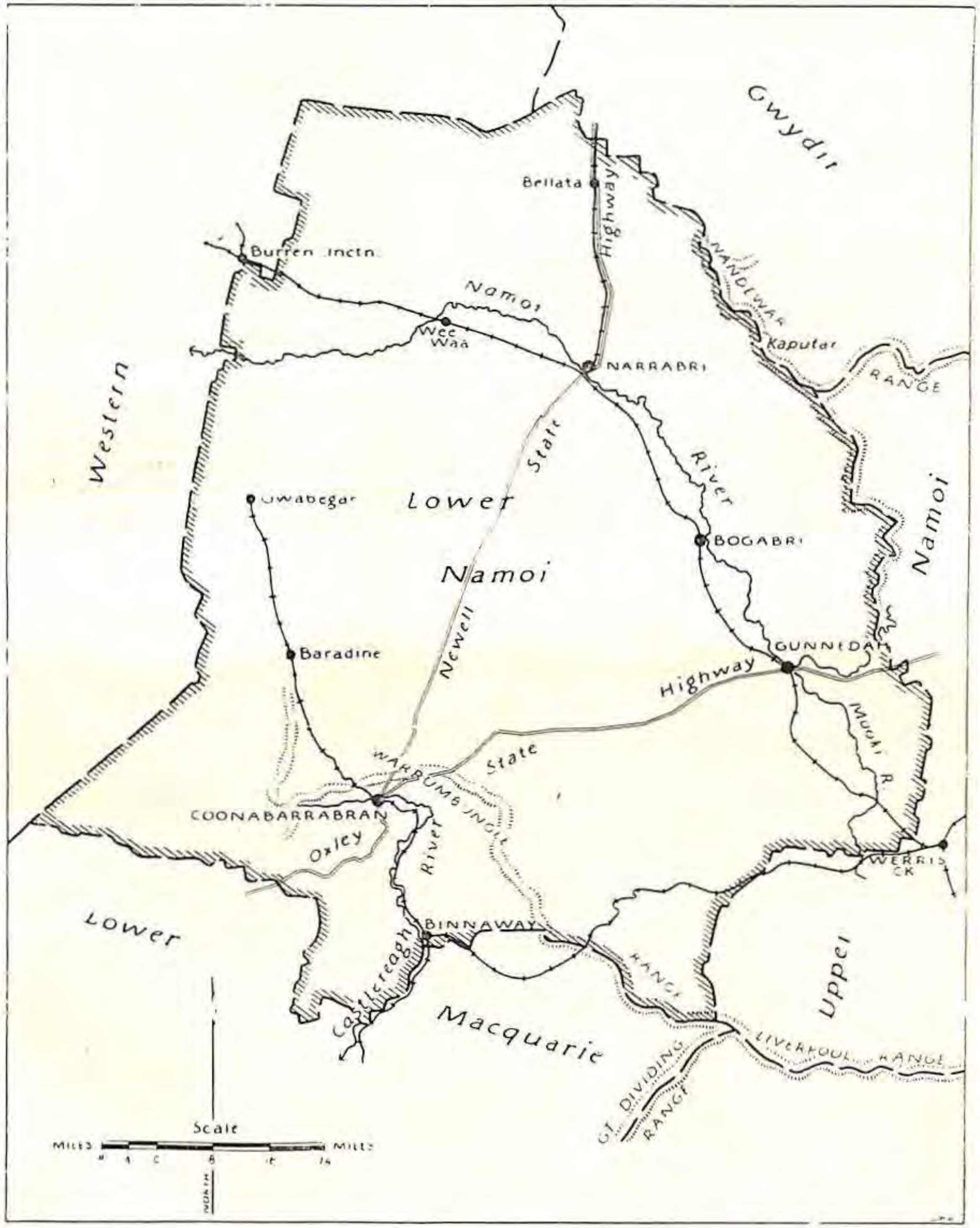

Fig. 1.—Topography, principal towns and communications in the Lower Namoi Soil Conservation District.

Summer rainfall predominates throughout the district with high intensity storms frequently occurring.

SOILS

As is to be expected a wide variety of soils occur within the district and for general classification can be divided into four groups:—

(*a*) The North Western Slopes which lead away from the Nandewar Range, comprise soils characterized by red-brown earths, chocolate basaltic and brown wavy gilgai soils, together with a grey brown soil of an acid nature.

(*b*) The North Western Plains comprises vast expanses of brown, grey to black soils of the plains. These heavy self-mulching soils of the artesian basin have been formed by depositions of the tributaries of the Darling River.

(*c*) The Pilliga Scrub area consists of a variety of red soils associated with alluvial sandplains, commonly known as sandstones. These soils have been leached over a long period and have lost a lot of their fertility.

(*d*) The area influenced by the Warrumbungle Range, being the South Western portion of the District within Coonabarabran Shire, comprises a wide variety of soils. They comprise sandstones, red brown soils and grey and brown soils, associated with the Slopes.

A dominant feature of North Western Soils is their great depth. Usually the soils of the North contain sufficient phosphates which are available for plant growth to eliminate the necessity to use superphosphate fertilizer in the production of cereal crops.

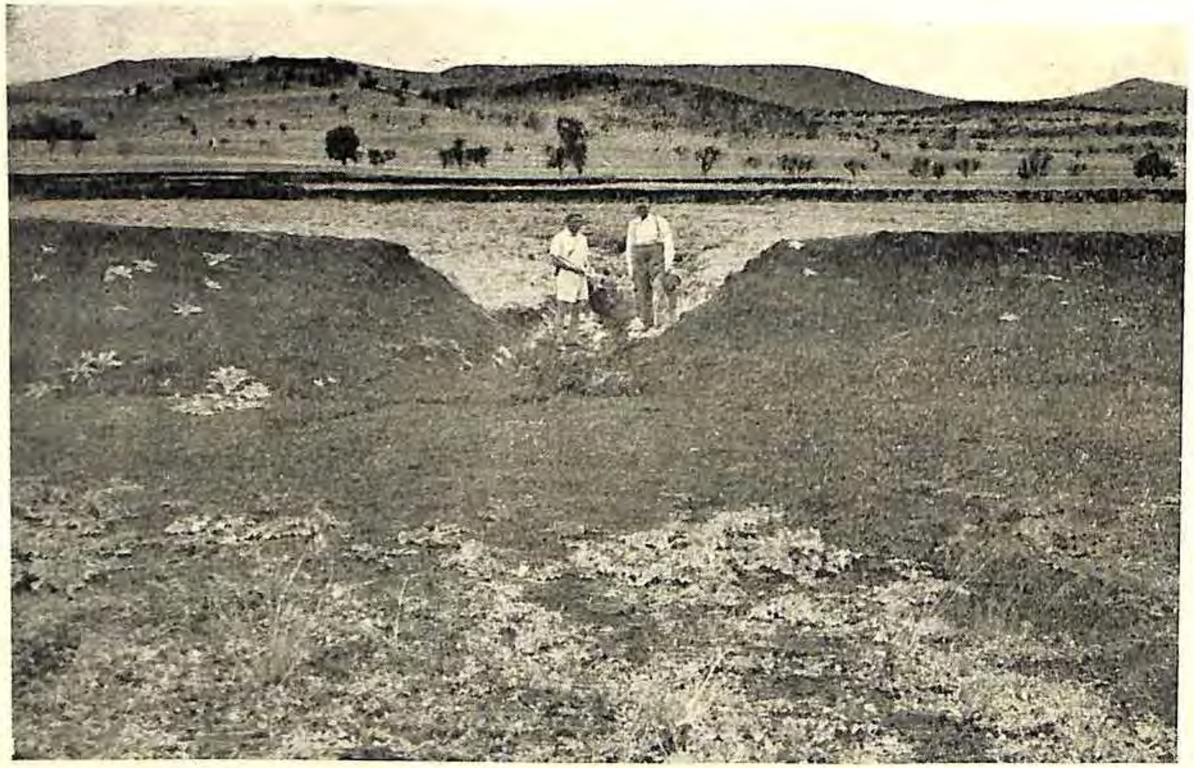

Fig. 2.—Self-mulching soil is difficult to consolidate and newly constructed earthworks across gullies are liable to occasional failure.

LAND USE

Agriculturally the North West Slopes and Plains and Central Western Division offer a vast potential of production and rural wealth.

There are still vast acreages undeveloped mainly because of the large holdings still in existence.

Wheat, wool, beef and mutton form the basis of rural production. An increase in establishing improved pastures could greatly increase the production and quality of both sheep and cattle.

The adoption of suitable crop rotations does not receive the attention it deserves. Too often the growing of wheat is the prime outlook of the man on the land to the exclusion of a wise land use policy with deleterious results to the soil. A suitable and beneficial alternative to several successive cereal crops from one paddock is the sowing of lucerne and a clover or medic with the last wheat crop. Using a lighter sowing of seed wheat the crop is stripped for grain leaving the stubble as a protective cover for the leguminous crop.

Fig. 3 shows typical wheat land on the slopes controlled by banks.

Much of the sheet and gully erosion prevalent throughout the arable lands of the district is a direct result of overcropping.

The trend of to-day is towards increased acreages of fodder crops such as lucerne, millets, sorghums, oats and sudan grass. These crops are utilised as green fodder crops for grazing and are either stripped of grain or cut and baled or stacked.

Dairying, pig and poultry raising are very minor in their role towards mixed agricultural production in the District.

Landholders have not yet arrived at the stage where they can truly say they are engaged in mixed farming in place of wheat culture.

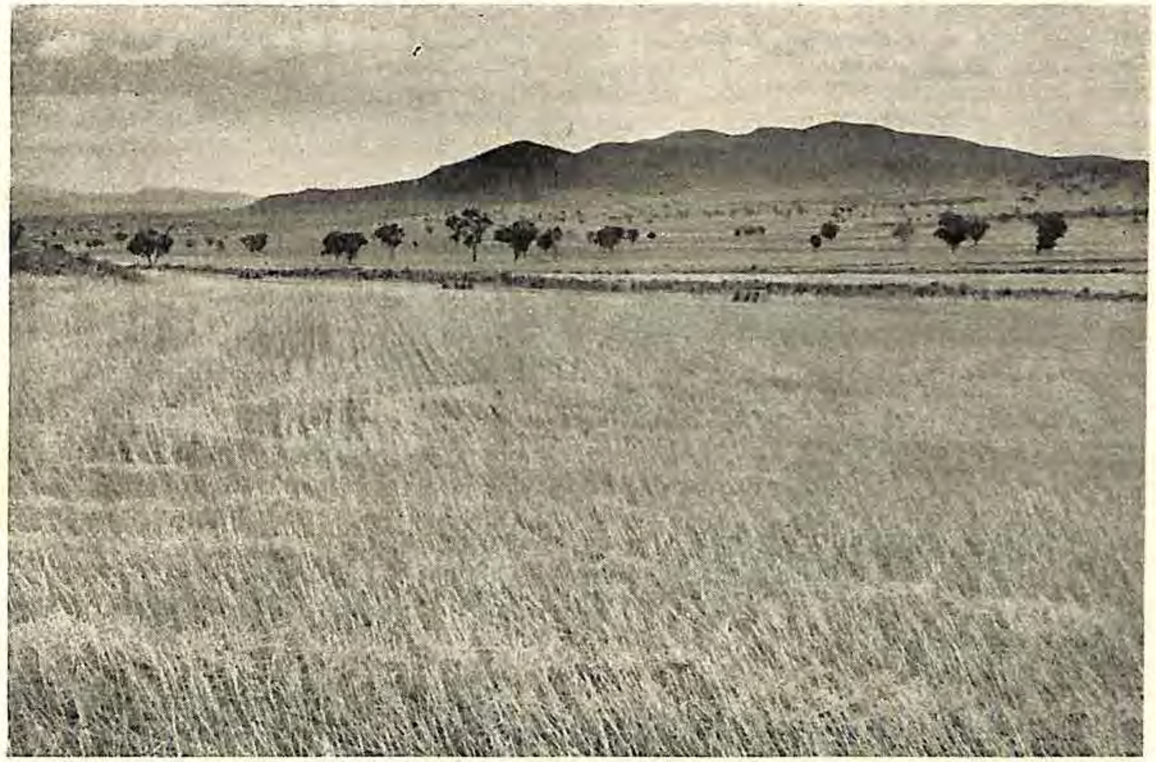

Fig. 3.—Typical sloping wheatland protected from erosion by graded banks.

SOIL EROSION.

Right throughout the slopes leading from the hills and ranges the erosion position is serious.

Of recent years, particularly since the boom days of 1950, landholders are gradually getting their agricultural machinery further up the slopes in search of new and rich lands for crops.

Severe sheet erosion occurs during practically every storm experienced in the District on arable land under fallow or crop. This is very noticeable on land that has been farmed for some years. Virgin country possibly survives two or three years before accelerated sheet erosion occurs.

The inevitable gully erosion manifests itself in the wake of sheet erosion. The fallacy of reploughing or scarifying after a severe storm, which caused sheet erosion, is evidenced by the gullies that form if no palliative or remedial measures are adopted to counteract the uncontrolled flow of run-off.

This potential hazard must be overcome by checking with banks or a change in land use. Whichever method is adopted, it is quite certain that the land-use programme must be one suitable to the topographical and soil conditions prevailing. The remedial measure of bank construction does not solve the landholder's problem.

No effort is being made in this article to classify the district into types and severity of erosion. The district comprises, in the main, very rich soils and most of the erosion problems have a solution that can be implemented.

In approaching the desired control and eventual arresting of erosion, two dominant factors exist in this district in control by the construction of a system of banking.

The first principle involved is the correct soil classification and the second one the correct type of bank most suitable to the soil type.

The red-brown earths are suitable for level or graded banks. The grey and black soils or the brown wavy gilgai soils, all of which are readily self-mulching and develop cracks during dry weather, are most advantageously protected by graded banks with wider bases than those constructed to control erosion on a red-brown earth type of soil.

The apparent weakness of the self-mulching type of soil to consolidate makes it liable to intermittent cracking in dry periods with consequent tunnelling and aggravated gullying.

The most difficult problems are associated with roads and travelling stock reserves. These confined spaces do not offer much in ultimate safe water disposal. The only solution lies in the control of lands, falling towards or adjoining roads, with every remedial measure utilized in soil conservation and the checking of road drainage channels with suitable structures and the preservation of abundant grass cover. Lack of understanding between landholders and road authorities is one of the major causes of roadside erosion. There is insufficient cohesion between the parties concerned, the problem is not an individual one but requires the co-operation and patience of all concerned.

CONCLUSION.

Soil erosion within Lower Namoi District can be gradually eliminated if the problem is vigorously attacked by all concerned. The landholders, the Pastures Protection Boards, the Shire Councils and Department of Main Roads must unite to preserve our agricultural wealth.

The purchase of suitable machinery for erosion control work by landholders should be encouraged on large areas or mixed farming areas susceptible to erosion. Earthmoving equipment, however small, is a necessity and part of the standard farm equipment. Earthmoving contractors operating at reasonable rates are most desirable.

The Soil Conservation Service of N.S.W. will assist any landholder to effect the necessary design and layout of mechanical control measures and enable a contractor to proceed along the correct lines.

The ultimate control of erosion in Lower Namoi District is in the hands of the man on the land. The immediate solution is his recognition of a national tragedy occurring at his front door.

CONTOUR STRIP CROPPING ON WHEATLANDS AT WELLINGTON

BY

J. J. Huston, H.D.A., Officer-in-Charge.

In this article it is proposed to examine the suitability of strip cropping as a means of erosion prevention on wheatlands and other features of a contour strip cropping programme which was carried out over a period of six years at Wellington Research Station.

Strip Cropping and the possibilities of adopting this method of soil conservation to various types of conditions in N.S.W., was discussed by Kaleski in two articles published in 1946.(1) Now it is proposed to give details of an actual test of contour strip cropping in association with wheat growing at Wellington. Figure 1 shows a general view of strip cropping at Wellington Research Station. In this case the uncropped strips have been mown in an effort to control weed growth.

In the United States of America, where 2,000,000 acres were being used for strip cropping by 1938, and in many other countries, this practice has found wide favour as means of erosion control and as a means of obtaining greater infiltration of rainfall into the soil.

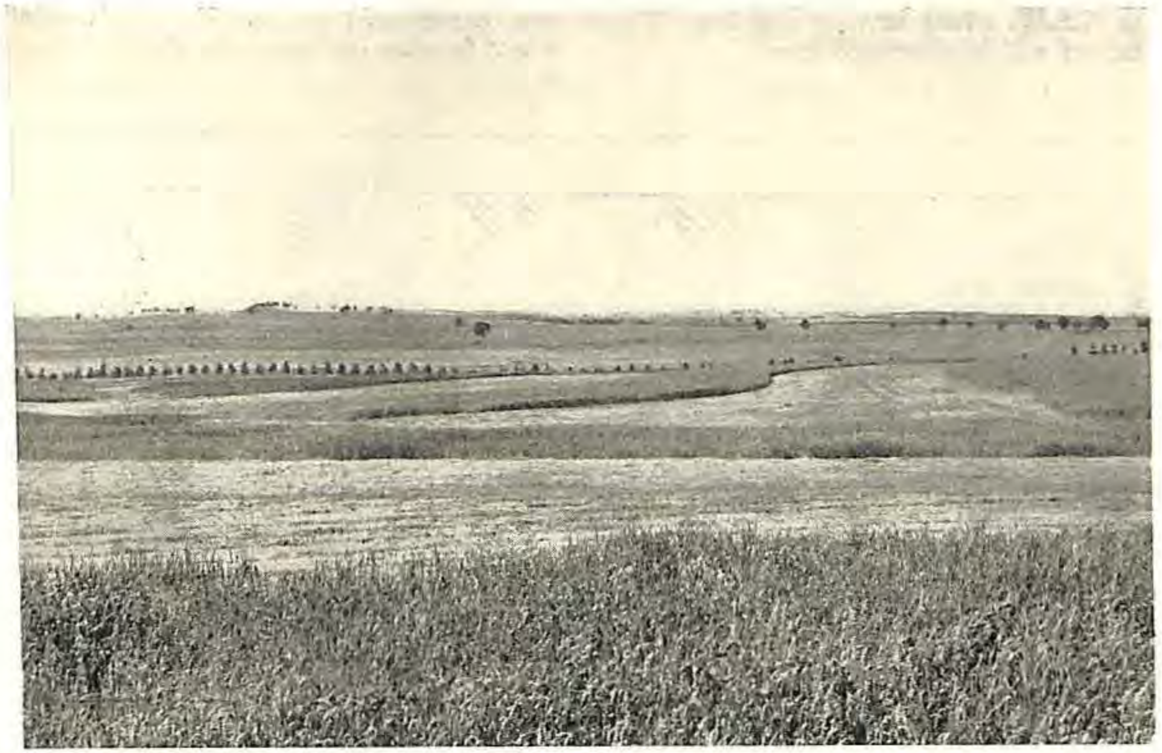

Fig. 1.—A general view of strip cropping at Wellington Research Station.

Contour strip cropping is an ideal practice to associate with a proper system of crop rotations. The use of alternate areas for cropping on a particular slope fits in very satisfactorily with crop rotation programmes. The proper rotation of crops leads to the maintenance or the improvement of fertility in the soil and therefore results in more effective growth of plants on the surface of the land. Effective vegetal cover is Nature's own buffer against erosion.

The value of graded or absorption banks as a means of erosion control is enhanced by the use of strip cropping between the banks. Less free water flows on the surface and greater infiltration takes place—thus providing an additional safeguard against damage on overtopping when phenomenal rains occur.

In effect, strip cropping, used in areas of suitable rainfall, soils and climate, combines satisfactorily with most of the desirable cropping and conservation practices. However it has certain disadvantages when used in N.S.W. wheat farming districts. These factors will be discussed later.

METHOD OF LAYOUT

An area of 58 acres with heavy red loam soils, containing some stone and gravel was selected for the investigation. The slopes varied between 5 per cent. and 8 per cent. and erosion was noticeable—particularly on the lower parts of the area.

A gully 1 ft. to 2 ft. deep in the main drainage line of the paddock was filled before designing the strips.

Contour lines were surveyed to provide strips varying between 66 ft. and 100 ft. wide. The strips were narrower and more frequent on the steeper portions of the paddock where greater control of run-off was necessary but the width of each strip was increased as the grade decreased and the need for control lessened.

A point to be considered in designing any conservation system is convenience in farming or working the land as is required for the particular type of crop or crops. For this reason the boundaries of individual strips were varied slightly from the contour to obtain strips of even width. No difficulty was experienced in carrying out normal wheat farming operations on these areas.

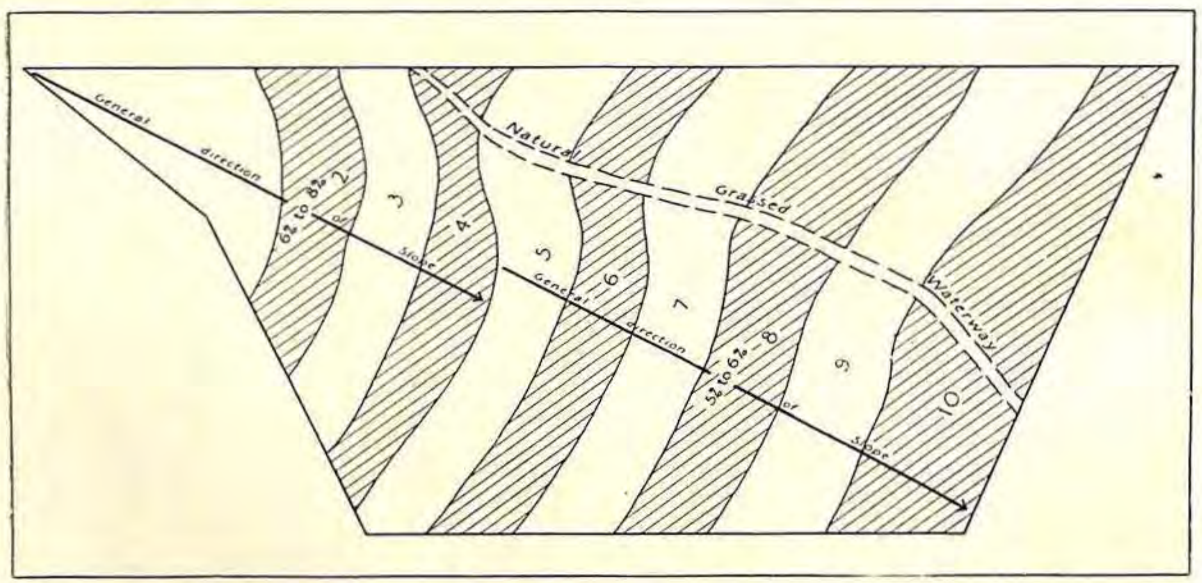

Fig. 2.—Plan showing layout of strip cropping. Note the comparatively even width of each strip.

Complete details of the actual layout are shown in figure 2. On this plan the shaded strips, marked 1, 3, 5, 7, 9, and 11 were cropped during the first year and the plain strips, marked 2, 4, 6, 8, 10 and 12 were cropped in the second year. This practice was continued throughout the period of the investigation—each strip being cropped to wheat every second year.

The uncropped strips were allowed to carry volunteer pastures with the stubble. These pastures consisted mainly of woolly burr medic (*Medicago minima*), black oats and various other weeds.

FARMING METHODS AND MANAGEMENT.

In late October or early November each year the stubble strips were ploughed to a depth of 3 inches or 4 inches, using a mouldboard plough. If the growing season was late and the burr medic had not seeded the mouldboards were removed from the plough to obtain a working at the same depth without turning the sod. This practice allowed some of the medic plants to remain on the surface and mature seed.

After a few years a large build-up of medic seed occurred in the soil and the percentage of medic plants in the pasture increased accordingly. Recent investigations in New South Wales and Victoria have shown that high quality wheat is grown on soils that support vigorous legume growth during the ley period.

Stubble was ploughed in or left on the surface and this provided further means of keeping the soil open for the absorption of rainfall. No doubt some of the stored soil nitrogen was used in the process of rotting the straw but the incorporation of the stubble in the soil was part of a scheme which led to the vigorous and very useful growth of the medics, which in turn were responsible for building up considerably the supply of available nitrogen.

Fig. 3.—The condition of a fallow after ploughing without turning the sod.

After the initial ploughing the land was cultivated as required to conserve moisture, kill weeds and to prepare a seed bed for the wheat crop which was sown in May each year. The implement used was a rigid tyne cultivator or "duckfoot".

Fig. 3 shows the surface condition after the land has been ploughed—some of the stubble has been mixed with the soil, while the remainder is left on the surface.

EROSION CONTROLLED.

The design and associated farming practices ensured complete absorption of rainfall except in the year 1950 when the record rainfall of 5,049 points was more than double the annual average for the district. During that year a stream of clear water flowed continuously for several weeks down the main drainage line of the paddock. Minor erosion occurred on the fallowed strips but only where cultivated land was in contact with the flowing stream. The soil which was washed from the fallow was intercepted by the grass cover and deposited on the unworked strips. For this reason very little soil was removed from the paddock by erosion.

As a result of this experience in 1950 the main drainage line was allowed to revert to grass and within two years it became a stable natural waterway. Fig. 4 shows the vigorous growth of this waterway.

Stable natural depressions such as the one shown here are ideal for disposing of surplus run-off from graded banks. Their use for this purpose eliminates the need for artificial waterways which are expensive to construct.

Fig. 4.—Vigorous growth on a natural grassed waterway.

PRODUCTION.

Yields of Wheat and Carrying Capacity.

The average yield of wheat was 21 bushels per acre. As the land was in poor condition at the outset through erosion and the build-up of fertility was only gradual, this yield is considered to be satisfactory.

A feature worthy of emphasis was the high quality of the wheat grown on these strips. Samples were tested each year at a local flour mill and the gluten content varied between 12 per cent. and 16 per cent. The wheat was eagerly sought by a local miller for blending with lower quality wheats.

The actual yields of wheat grown under the strip cropping system compared favourably with yields obtained in an adjoining paddock which was farmed on a wheat-fallow-wheat basis. However, the stock carrying capacity of the same adjoining paddock was double that of the strip crop area which only carried the equivalent of one dry sheep to two acres throughout the period of the investigation.

Figure 5 shows a strip of ripe wheat. The yield per acre in this case was 21 bushels.

ADVANTAGES AND DISADVANTAGES.

In earlier sections of this article the various advantages of strip cropping as practiced at Wellington Research Station have been explained and emphasized.

The main advantages are:—

1. *Control of Erosion.*
2. *Almost complete absorption of rainfall.*
3. *A build-up of general fertility and nitrogen content in the soil.*

However strip cropping is not without rather serious limitations when used in conjunction with wheat growing in districts such as Wellington.

Fig. 5.—A strip of wheat ready for harvesting.

The main disadvantages are:—

1. *Weeds.*

Because the stubble strips were not stocked for approximately seven months of the year, black oats and many other weeds grew practically unchecked. Consequently large reserves of weed seed were built up in the soil. The presence of weeds—particularly black oats—is certain to cause reduced yields in wheat crops.

2. *Reduced stocking rates.*

As the strip-cropping area was not available for grazing for more than half of the period stocking rates were reduced accordingly. During the period of the investigation the area carried only one sheep to two acres whilst an adjoining paddock, used on a wheat-fallow-wheat basis carried one sheep per acre or double the amount.

3. *Strip Cropping and Rotational Grazing.*

Rotational grazing, that is the alternate usage and resting of areas, is beneficial to both stock and pastures. For this system to operate satisfactorily a large number of paddocks is required so that the pastures can be rested for a reasonable period after stocking and thus have time to reach full production before being stocked again.

In this case strip cropping prevented one of twelve paddocks on the farm from being used for grazing during half of the period. Moreover the paddock was unavailable for grazing during the spring when the highest production can be expected from natural pastures.

Suitability of Strip Cropping for use at Wellington.

It is considered that all of the advantages gained by strip cropping could also be gained when wise farming methods are used with other systems of cereal growing. Wise farming methods would include: incorporation of stubble in the soil, contour cultivation with graded or absorption banks where necessary, and fallowing after the natural medic seed has matured.

A lucerne-wheat rotation is being used on most of the arable land at Wellington Research Station. Consistently higher wheat yields, comparable wheat quality, and much more grazing have been obtained than from strip cropping.

Overall results from strip cropping have been unsatisfactory mainly because no suitable crop or crops are available to grow in conjunction with wheat or oats. In districts of New South Wales where there is adequate rainfall to grow row crops such as corn, soy beans and potatoes in conjunction with the closer growing, erosion resisting cereal crops, strip cropping must have great potential value as a conservation farming practice. If a payable crop could be found to combine satisfactorily with wheat growing in the drier farming areas then the future of strip cropping could be assured under those conditions as well as in the higher rainfall areas.

Reference (1) Kaleski, L. G. 1946. *Journal of Soil Conservation Service of N.S.W.* Vol. 2, Nos. 1 and 3.

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SNOW LEASE MANAGEMENT

BY

A. C. TAYLOR, B.Sc.Agr., Soil Conservationist.

INTRODUCTION

THE Snow Lease belt of New South Wales is all contained within the area dedicated in 1944, as the Kosciusko State Park. This State Park extends from the Victorian border in the south to near Brindabella in the north, a distance of some 100 miles, and from the Murray River in the west to Youk Gap in the east. At its greatest width, the Park is approximately thirty miles wide.

The area of the Kosciusko State Park is approximately 2,130 square miles. The elevation ranges from 7,328 feet at Mount Kosciusko to 1,100 feet along the Murray Valley.

The value of the pastures, which are predominantly snow grass (*Poa caespitosa*), within the Snowy Mountains areas was recognised shortly after their discovery by Currie and Evans in 1829 ([1] and [2]) and for more than 100 years, grazing rights to the more attractive country have been keenly sought by members of the grazing community.

Before the Kosciusko State Park Trust was set up in 1944([8]), the snow leases were grazed more or less indiscriminately, and were definitely exploited in the process. Thousands of sheep travelled hundreds of miles from the western parts of New South Wales, as well as from localities adjacent to the Snowy Mountains, to the snow grass pastures in summer. Unfortunately, little thought was given to the future welfare of the area. In many instances, pastures were grazed far beyond their capacity and fire was frequently used in an attempt to extend the areas suitable for grazing.

In 1944, this pattern of management was radically changed. With the setting up of the Kosciusko State Park Trust, the Summit area—an area of severe erosion hazard, principally above 6,000 feet—was withdrawn from lease; the size of the individual leases was reduced; the number and type of stock permitted in each block was fixed, a definite grazing season was decided upon and the use of fire as an agent of management was restricted.

In the country of lower elevation—say below 5,000 feet—these amendments have considerably lessened the erosion hazard. Under the present policy, grazing can be carried on safely below this elevation, except on critical situations, such as bogs, steep slopes and areas seriously damaged by erosive processes prior to 1944.

The harsh climate above 5,000 feet necessitates the adoption of more stringent views on land-use and management. Severe frosts, heavy rainstorms, high winds and a very limited growing season combine to give an environment which will not now permit of extensive grazing. Had the present restrictions on snow leases been in force from the time of discovery of the area, it is not improbable that even now limited grazing could be carried on safely in much of the higher country. However, the serious depletion of soil cover and the deterioration in the water-holding capacity of boggy areas, both brought about principally by indiscriminate grazing and burning in years gone by, will not now permit safe grazing on all the high country. The damage caused prior to 1944 is such that, in most instances, only complete withdrawal of all stock and complete abandonment of all other vegetation-destroying practices will prevent further deterioration and perhaps permit some degree of recovery.

The value of the snow leases to the grazing industry generally, and to the small landholder in particular, is undeniable.

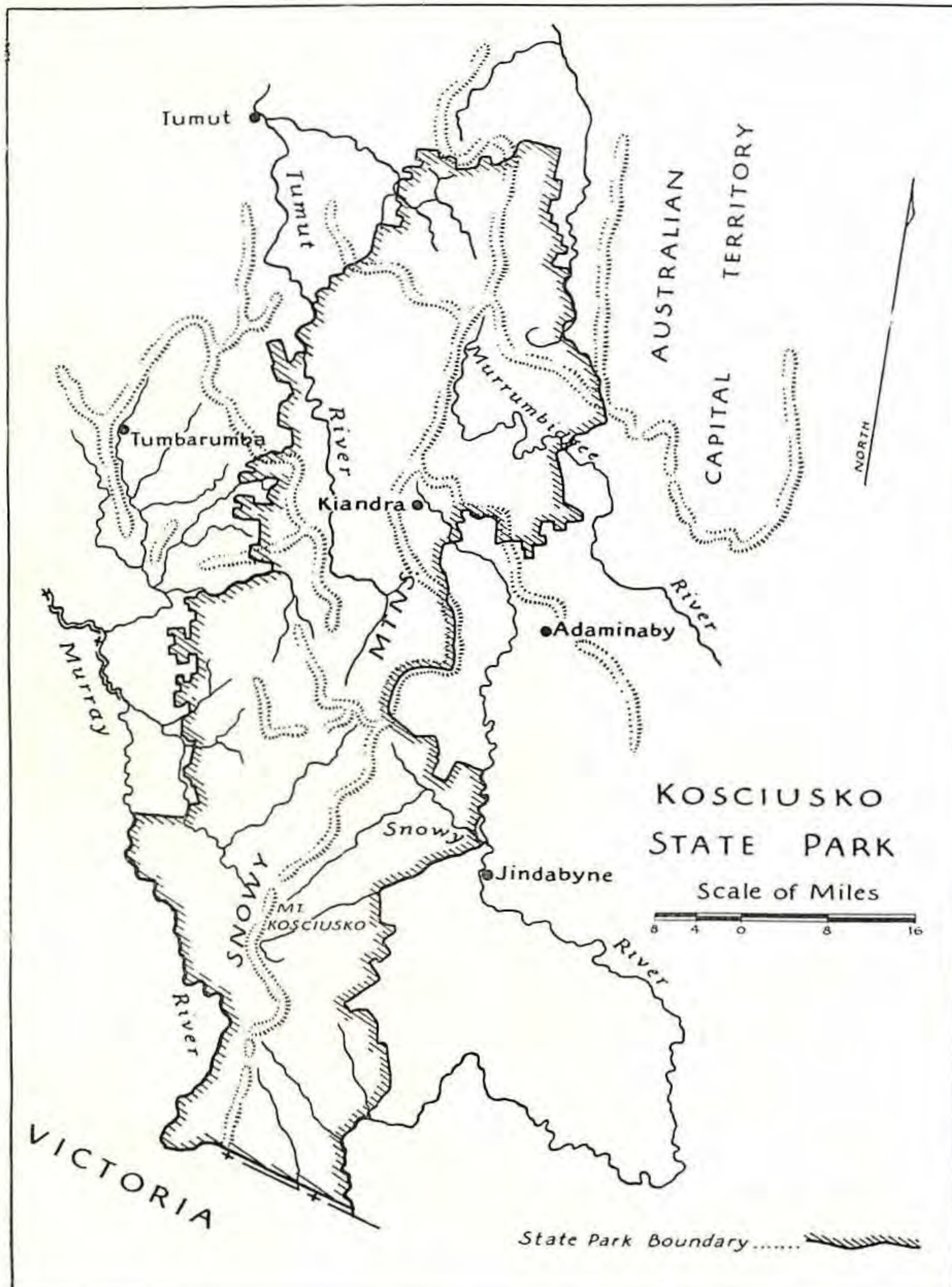

Fig. 1.—Map of Kosciusko State Park.

Under the present administrative policy, the 223 Snow Leases and ninety-six Permissive Occupancies available for occupation within the Kosciusko State Park, representing in all an area of some 923,000 acres, have a permissible carrying capacity of 283,600 sheep and 27,500 cattle. The annual rental accruing from all Snow Leases and Permissive Occupancies, if every available block was taken up, would be £10,900. Consequently, the grazing industry is able to depasture all stock in the State Park at the rate of 5.8 pence per sheep equivalent* for a period not in excess of six months each year. Admittedly, other expenses are involved in Snow Lease management, e.g., Shire Rates, droving, mustering, drenching and general supervision, but even so, it is suggested that the annual rental is most generously low.

* One head of large stock is taken as equivalent to six sheep. This figure is suggested in the Special Conditions applicable to Snow Leases and Permissive Occupancies (5).

Despite the acknowledged value of the Snowy Mountains as a grazing reserve, the role of the area as a source of water for many of our major streams is of greater importance. One of the special conditions pertaining to Snow Leases and Permissive Occupancies states that "the primary function of the land under lease or occupancy is to provide and maintain a constant water supply by the protection of its water-gathering and water-holding capabilities" (5). That grazing and grazing influences are, in some cases, detrimental to these capabilities has been strongly debated in many quarters.

Many of the claims made in relation to Snow Lease welfare by men of considerable experience in the mountains have a factual basis, but others have no reasonable justification. It is intended to discuss the more significant of all these claims, so as to present the more critical problems of grazing management.

Fig. 2.—Part of Happy Jack's Plain which is typical of areas used for summer grazing. (SMHEA Photo.)

FOOD PRODUCTION.

It is claimed by many graziers, particularly those with Snow Leases, and also by people not directly concerned with the grazing industry, that Australia's need for an increased food production justifies grazing in all parts of the Snowy Mountains. The author emphatically agrees that food production must be boosted, but not at all costs. Who of us would advocate the raising of vegetable crops on our sporting arenas? A basic maxim of land-use is that the pressure on all lands must be governed by the capabilities of those lands, rather than by sectional interests. This statement is undoubtedly applicable to the Snow Lease belt.

There are millions of acres of freehold country in the Southern Tablelands Area capable of carrying increased stock numbers through pasture improvement—without any danger of erosion. This land should be used to increase our primary production before we advocate extensive use of areas valuable for reasons other than those concerned directly with primary production. The more erosion-hazardous country within the Kosciusko State Park should not be sacrificed to carry sheep and cattle which should never, in consequence of the great advances made in the sphere of pasture improvement, need leave the lowlands.

Undoubtedly, the day will come when pressure on our tableland country will reach such a pass that utilisation of our alpine and sub-alpine pastures may become necessary. Scientific and technical men are not unmindful of this (even now preliminary studies pertaining to more intensive land-use are being undertaken) but they do feel that the lower country, with relatively simple management problems, should be utilised to the full before intensive grazing in the high country is considered.

The fact that many graziers, with not unduly large properties, are able to manage without recourse to Snow Lease grazing indicates that lease areas are not essential to the survival of these graziers, as such. Some

Fig. 3.—Large areas of snow gum woodland killed by bushfires in the Snowy River Valley. (SMHEA Photo.)

graziers, with average-sized freehold areas improved to a high degree, would not consider Snow Lease grazing in their overall management programme. Others, now undertaking extensive pasture improvement at lower elevations, look upon Snow Leases as but temporary relief for their lower country. They appreciate the fact that once their own country has been fully improved, they will be able to feed adequately sufficient stock to provide a more than comfortable income. Such attitudes are in the Nation's best interest, as they contribute to sound grazing practice (involving leguminous pastures), without permanently encroaching upon areas best reserved for catchment purposes.

GRAZING OR WATER YIELD.

When the value of the Snowy Mountains catchments, as sources of water, is extolled, some people express doubt as to which is the greater—the return from grazing or the potential return from the Snowy Mountains Scheme. This doubt has no grounding in fact.

Within the Murrumbidgee Irrigation Areas, agricultural, horticultural and animal production was valued at £8,280,266 for the year 1953-54 (3). This figure represents a return of £28 per acre foot of water distributed. If the estimated supply of irrigation water from the Snowy Mountains Scheme—970,000 acre feet (11) is achieved, the potential increase in rural production, on comparable figures, could be valued at £27,160,000 per annum.

Furthermore, the tremendous hydro-electric capacity of the Scheme—in the vicinity of 3,000,000 kilowatts (11)—will yield power to a value exceeding that of the water supplied for irrigation.

Away from the financial aspects, consideration should be given to the diversification of farming which is possible with irrigation. Such farming is of great importance to Australia, both socially and economically, and should be encouraged wherever possible.

The grazing industry would have to supply, from the Kosciusko State Park, wool and meat to the value of more than £29 4s. 0d. per acre, for it to compete with the value of water yielded from the mountains. Even the most staunch supporter of Snow Lease grazing will admit that this figure is not being approached in the mountains, as yet, nor is it likely to be approached, even with intensive pasture development.

Because of the importance of the above figures and of the enormous capital being invested by the Nation in the Snowy Mountains Area, any steps which move towards protection of the Kosciusko State Park for water supply purposes must be supported. At the slightest signs of erosion, siltation or increasing flood peaks, reasons must be sought and the findings of qualified scientists and technicians accepted, regardless of private considerations.

Grazing practices and water yield cannot be considered as separate entities. Discussion of the latter necessitates consideration of the former, as removal of vegetation, whether by grazing, regular burning of bush-fires, affects the relationships between soil and water. Damage caused by rain-drop splash, run-off and frost action increases with decreasing soil protection and this is just as true of the snow lease belt as any other land.

Not only has grazing reduced soil stability by depleting vegetative cover, but it has also modified the part played by bog and swamp communities in maintaining catchment area efficiency. These moist areas are capable of holding large quantities of water—as much as six times the actual weight of soil material involved (11)—and releasing it slowly to the streams. In numerous situations, this capacity has been greatly reduced by burning and the trampling of stock, with the result that the flow of some streams has become discontinuous and irregular. The small storages involved in the Snowy Mountains Scheme could be seriously affected by this change in the pattern of stream flow. In the interests of water yield, maximum vegetative cover should be preserved wherever possible and further damage to bog areas should be prevented.

BUSHFIRES v. REGULAR BURNING.

Arising from the fact that, when grazing influences are withdrawn from snow grass country, there is an accumulation of dead grass on the soil surface, it is often claimed that heavy grazing and/or regular burning-off is necessary to prevent bush fires. In some quarters, it is claimed that dead and inflammable snow grass presents a fire hazard which, unless removed, will result in damage to vegetation and soil more severe and extensive than that caused by regular burning, in the event of an uncontrolled bushfire.

Such reasoning implies two doubtful assumptions—firstly, that regular burning as now undertaken on many Snow Leases, does less harm over a long period than a occasional bushfire every fifteen or twenty years, and secondly, that bushfires are unavoidable.

Discussing the first of these assumptions, there is no conclusive proof available, as yet, to indicate which type of fire damage is the more serious. Both types of fires have similar effects—killing and maiming of vegetation, encouraging overdense regeneration of trees and shrubs, exposure of soil to erosive influences, destruction of bog areas, modification of soil structure and fertility and alteration of catchment hydrology—but after a severe bushfire, the evidence of damage is much greater and more obvious than after small-scale burning undertaken at regular intervals.

Nevertheless, it is not inconceivable that the soil loss incurred and the hydrologic modification caused by regular small fires over twenty years or more should be as great as that brought about by one bushfire during the same period. When attention is drawn to the extensive tracts of snow gum killed by the 1939 bushfires, it must be remembered that probably the majority of the trees would have recovered, but for the removal of regrowth by browsing sheep. Here, it is evident that the question of fire damage is inseparably bound up with land-use factors—burning without grazing would prove to be less serious than when the two influences are combined.

The second suggestion, that bushfires are unavoidable, is to a large extent a negative attitude towards fires. Undoubtedly some fires are not man-made, and as such present a difficult problem of control. However, so far as the Snowy Mountains are concerned, the most serious fires have started outside the State Park and adjoining forests, and it would seem that the worst threat comes not from the fuel supply within the area, but from inadequate precautions along the western and south-western borders.

It is the author's opinion, an opinion supported by most scientific bodies interested in the Kosciusko State Park, that burning of all kinds is fundamentally wrong and not in the best interests of the mountains generally. If this fact can be accepted by parties which advocate regular controlled burning as a fire precautionary measure, it must direct their fire prevention efforts towards complete eradication of all bushfires, by abolition of all burning, by preparedness, education and other positive steps.

WITHDRAWN AREAS ERODING.

The statement is frequently made that areas now withheld from grazing are eroding more quickly than when stocking was permitted. This statement refers in particular to the Summit Reserve and to the country at the head of the Valentine and Rocky Plains Rivers. These areas have been officially free from grazing since 1944 and 1950 respectively but considerable illegal grazing has taken place since those times.

Many competent judges agree that erosion is accelerating within particular sections of the worst eroded areas, even since the withdrawal of stock. Severe erosion damage between Curruthers Peak and Mt. Twynam, and in the vicinity of Cup and Saucer Hill, is extending, much of it at an alarming rate, but such deterioration can hardly be attributed to the absence of stock.

In actual fact, the damage caused in these areas prior to the removal of stock and the abolition of burning, was so great that the mere absence of these grazing influences is not sufficient to permit rapid recovery. The severe climate mentioned earlier imposes such a strain on Nature's recuperative powers that only slowly, if at all, will the scars now in evidence be healed. Indeed, many people think that positive erosion control measures will have to be employed if already extensive damage is to be restricted.

It is not agreed that erosion damage is on the increase in those areas not so severely eroded and now relieved of grazing. It may be true that the proportion of dead grass contained in the snow grass tussocks is on the increase, but the actual amount of healthy, vigorous grass within these same tussocks is also increasing. Eventually, a stage will be reached where the amount of dead grass becomes constant, with a steady return of organic matter to the soil and a regular production of new, green grass. Then, the perfect balance probably existing before the advent of sheep, cattle and burning will have been reattained. The mere fact that country free from stock is losing its bright green colour should not be taken as an indication of deterioration and increasing erosion.

Along with the claim under discussion, it is often maintained that snow grass tussocks thatch down and shed vast amounts of water which would otherwise soak into the soil. Although this phenomenon has not actually been observed, it is quite within the bounds of possibility. Such shedding of water should not cause undue concern, as the same action probably took place before the coming of man into the area. While there is such an excellent cover of grass on the alpine soils—there is apparently sufficient water entering the soil to give outstanding growth—there is little danger of erosion, except along gully lines, stock pads and bridle tracks, and little possibility of silt-laden water reaching the streams.

Fig 4.—Terracetting caused by burning and overgrazing near Smiggins Holes.

ERODED TRACKS RE-VEGETATING.

The suggestion that old tracks, formerly used to a great extent, and areas once stripped of their protecting vegetation are now everywhere re-vegetating satisfactorily, is not accurate. In some instances, tracks on gentle and sheltered slopes, have grassed over to a great extent, but in far more localities series of parallel tracks have eroded down to bedrock. Within the Summit Reserve and in various other situations, tracks are still eroding, despite the reduced usage over the past eleven years.

Along some of the stock routes within the State Park, the degree of erosion is most severe. Large quantities of soil have been removed, after trampling has killed the overlying vegetation, and rocks and boulders now make progress difficult. Such damage is obvious along the route from the Summit Road to Dead Horse Gap, along the route from Nimmo to Kidman's Hut and in numerous other localities. Here, it is evident that once a track is discarded because of erosion damage, stabilisation does not necessarily follow.

CASE-MOTH DAMAGE.

In many instances, small areas damaged by "case-moth" infestation during the last decade have recovered satisfactorily and are now quite well grassed. Some graziers attribute this recovery to their efforts at killing the case-moth by burning the dead snow grass. Other people point to the recovery of these areas under grazing as evidence that stock are not responsible for erosion damage in the Snowy Mountains.

The areas of "case-moth" damage which have recovered most satisfactorily are in the Summit-Smiggins Holes area. Despite the fact many of the areas killed by the moth have been subject to grazing since the damage occurred, the extent of this grazing has not been generally heavy, and it is considered that stocking during the time of recovery would not have had much effect on the ultimate recovery. A number of damaged areas have been observed regularly since 1950, and although some grazing of the young snow grass tussocks has taken place, the grazing pressure has not been high.

Unfortunately, the same cannot be said of the "case-moth" areas at the head of the Valentine and Rocky Plains Rivers. Here, despite the fact that the leases were withdrawn in 1950, the grazing pressure on damaged areas has been considerable—many sheep straying on to the withdrawn blocks from adjoining leases. Since 1952, when these areas were first inspected by the author, small tussocks of snow grass have been observed on the soil surface, uprooted by grazing animals, while many of the shrubs reported by Morland ([1]) in 1951 have been browsed over by straying stock. This interference with natural regeneration of damaged areas has resulted in severe erosion with soil lost, in some instances, to a depth of two feet.

Although there has been no extensive damage by "case-moth" or similar insects in recent years, it is essential that Snow Lessees should be aware of the damage caused by burning of the dead grass patches in an attempt to wipe out the pest. Firstly, the insects are usually not present when the dead grass is burnt, though there may be some concentration of the larvae around the fringes of the damaged areas; these larvae are able to burrow deep into the base of the tussock where they frequently avoid damage by fire. Secondly, the removal of the dead snow grass mat by burning damages young plants developing on the area, as well as exposing the soil to erosive forces. Qualified entomologists ([2]) feel that recovery of areas damaged by the "case-moth" has taken place in spite of, and not because of, burning the dead grass, and their opinions should be respected.

MUDDY MOUNTAINS STREAMS.

Some people who contribute to discussion on the erosion problem of the Kosciusko State Park state that muddy streams were not seen in the mountains prior to the advent of the Snowy Mountains Hydro-electric Authority. This may be generally true, as the major streams of the area are renowned for their clarity and the amount of suspended sediment carried down these watercourses is probably less than in other parts of New South Wales. However, Carruthers Creek, the southern-most tributary of Blue Lake Creek, has been observed by the author to carry a large quantity of suspendable material after heavy storms, e.g., on 3rd May, 1955. This stream rises in one of the most spectacularly eroded areas of the State Park, completely outside the bounds of Snowy Mountain Authority engineering undertakings, and it is reasonable to assume that other streams in the vicinity would carry similar quantities of soil in suspension.

The fact that muddy streams are not observed more frequently away from areas in which the Snowy Mountains Authority is working can be attributed to one principal reason. This is that the dense mat of vegetation, especially adjacent to the watercourses, acts as a natural sieve and withholds much of the potential silt load from the streams. Whether this phenomenon is to the advantage of catchment areas generally is debatable, as appreciable areas of vegetation have been killed by the silt which they have trapped.

It is not unlikely that more soil material is transported by mountain streams as bed load, (i.e., swept along the stream bed by the force of water) than is carried in suspension. Large deposits of coarse sand and gravel, too heavy to be carried in suspension, are frequently observed along most of the mountain streams.

Therefore, the clearness of mountain streams should not give rise to complacency regarding the stage of erosion and catchment deterioration reached in the State Park. Much serious damage can be caused by unwise land-use practices, before stream pollution becomes evident.

INCREASED STOCKING RATE.

Some Snow Lessees feel that, if burning was prohibited in the Snowy Mountains, it would be necessary, in the interests of bushfire prevention, to increase stocking rates, so as to remove surplus growth normally destroyed by regular burning. Conservationists oppose this suggestion as such a policy would lead to excessive grazing of

Fig. 5.—An eroded slope on Snowy Plain. All grass has been destroyed by overgrazing.

the more attractive areas and eventually to severe erosion. At the same time, in those areas not favoured by stock there would be the same accumulation of dead and unpalatable grass, so that the aim of fire-hazard removal would be defeated.

Moreover, Newman([9]) has claimed that an increased carrying capacity would be contrary to the interests of the grazing industry, as beyond a certain stocking rate sheep condition falls off despite the apparently plentiful supply of fodder. Such stock behaviour has not been noted by the author, but it would be borne out by the haphazard grazing pattern which sheep have been observed to follow—heavily grazing some areas and completely neglecting others.

LONGER TENURE.

A number of prominent Snow Lessees have been known to express the opinion that Snow Leases should have a longer tenure that the present seven years, so as to enable lessees to carry out pasture improvement programmes from which full economic benefit could be obtained during the period of lease.

Such an opinion implies that pasture improvement can be satisfactorily undertaken in the mountain areas. Apart from the technical difficulties—selection of species, transport of seeds, fertilisers and machinery, seedbed preparation and subdivision—involved in such an improvement programme, there are a number of other possible objections. Costin([4]) has shown that the trace element status of the Alpine Humus Soils is probably approaching critical levels for stock health. The chemical fertility of these soils is closely associated with the organic matter content of the surface horizons and as the humus content of the top-soil has been depleted over the years by grazing and burning, it is understandable that some fertility problems should arise.

Fig. 6.—Severely eroded area near Cup and Saucer Hill. The snowgrass was killed by "case-moth" larvae, and erosion was accelerated by burning and grazing.

If pasture improvement is undertaken on a large scale, the more vigorous pasture species, supporting considerably more stock, would make heavier demands on the soil's chemical fertility. Whether the soil would be able to meet this demand permanently, without the use of uneconomical quantities of fertiliser, is not yet known.

Native White Clover (*Trifolium repens L.*) has been growing in the Snowy Mountains for many years, without the use of artificial fertilisers but frequently with heavy dressings of animal manure. Nevertheless, it has not been producing the bulk of green material of which it is capable when adequate phosphate fertilisers are supplied. Consequently, no observations on its avidity and soil depleting powers have been possible. However, the possibility of fertility complications arising under pasture improvement and more extensive grazing should not be overlooked.

It is noteworthy that once clover is introduced into an area of snow grass pasture, this area is preferentially grazed by stock, until ultimately the snow grass is replaced by more grazing-tolerant species. This could indicate that with pasture improvement snow grass will be largely lost from the pasture and replaced by species of different growth habits. Whether this replacement could affect the water yield of particular catchments is another question as yet unanswered.

The extension of the lease period to enable pasture improvement would introduce another difficulty. Bodies interested in the catchment value of the mountains would naturally have to ensure the success of such programmes, by thorough investigations before hand and then by the setting down of minimum requirements. Special conditions would have to be drawn into lease agreements, whereby Snow Lessees would be obliged to carry out so much improvement each year, and such conditions would not be popular with graziers who do not favour pasture improvement on their own freehold country.

CONCLUSION.

The foregoing discussion has been intended, firstly, to show why grazing interests in the Snow Lease belt of New South Wales must always be subordinated to the preservation of the area for catchment purposes and, secondly, to indicate the ways in which present Snow Lease management is interfering with this preservation. The nature of the Snowy Mountains area is such that no positive progress will be achieved with its overall conservation, until all interested parties, whether their interests be in grazing, water yield, forest production or recreation, have a clear understanding of the reasons why certain measures are advocated and certain practices discouraged by those who have the ultimate welfare of the mountains at heart.

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SCALD RECLAMATION EXPERIMENTS IN THE BOURKE DISTRICT

BY

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SOIL EROSION has caused widespread loss of land in the more arid portions of New South Wales and it is the purpose of this article to outline the causes of erosion, and in particular, of wind erosion, and the difficulties attendant to the reclamation of wind eroded lands. The experimental methods used in the Bourke district, and the general results from this work also are briefly outlined.

The Bourke sub-district extends from Nyngan in the south to the Queensland border, from a line drawn approximately north-south through Brewarrina in the east, to the Paroo River on the west. The area comprises some of the more arid portions of the Western Division, the average annual rainfall varying from 10½ inches at Wanaaring to 15 inches at Brewarrina. High summer temperatures, when most of the rain falls, further decreases the effectiveness of such rains.

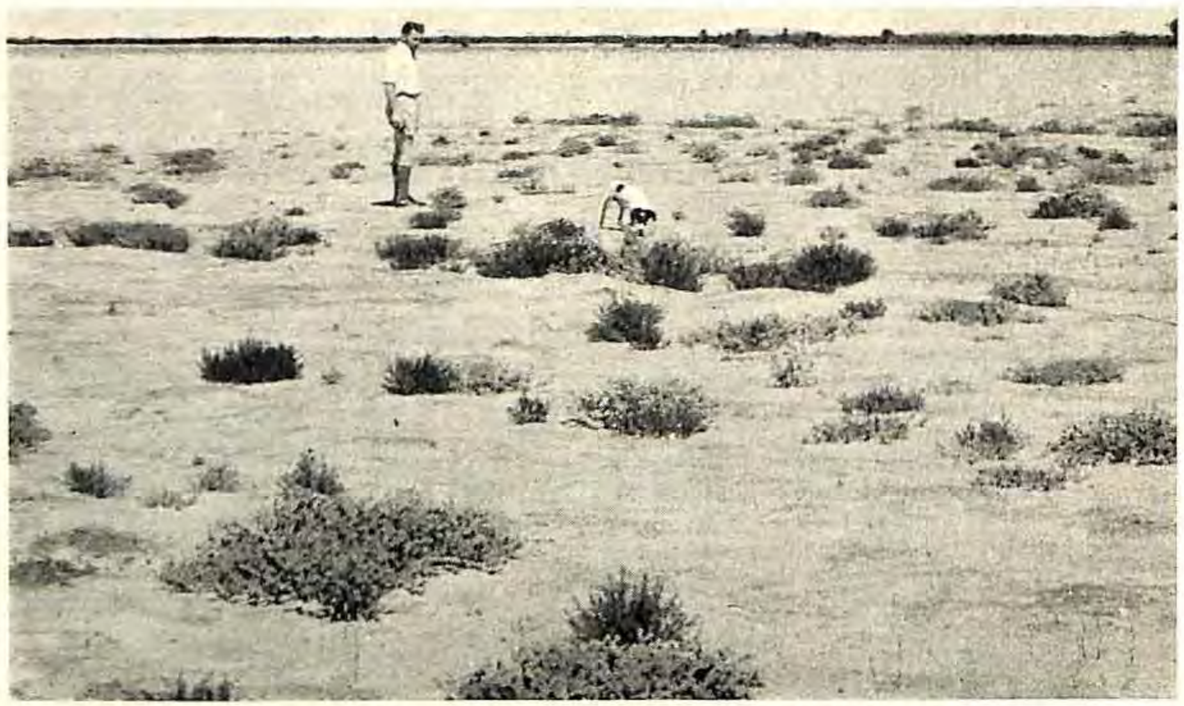

Fig. 1.—Annual and perennial saltbushes sown on ploughed scald October, 1952, photographed October, 1954. Note scattered copperburr and untreated scald in background and smooth slaked condition of ploughed ground.—D. H. Congleton, "Iddavale", Collerina.

The topography over the majority of the area is flat to very slightly undulating, this area lying under the 500 feet contour, with a few isolated hills and ranges widely scattered throughout. In the south and south-east of the district the country becomes undulating and lies between the 500-1,000 feet contour.

Due to the general low relief over the majority of the district and lack of rainfall, wind is the main cause of soil erosion. This does not ignore the fact that water erosion is a very serious cause of loss of productivity, particularly on the more undulating portions of south-east corner of the district. Water erosion, particularly the sheet erosion that is so prevalent in the Cobar and Byrock areas, can be treated by the methods developed for the prevention of water erosion on pasture lands of the higher rainfall zones.

WIND EROSION.

Wind erosion varies both in amount and type. The amount of erosion is determined, primarily, by the degree of protection of the soil by vegetation, and also by the soil type. Wind erosion will not occur on any soil type while there is adequate protection by grass, herbage, or tree cover. The characteristics of the soil determines the forms which erosion will take. Scald formation and wind sheeting are the two main forms of wind erosion, both being associated with varying amounts of sand drift.

Scalding is the process involved in the formation of "a bare area produced by the removal of the surface soil by wind, with the consequent exposure of the subsoil which is, or becomes, relatively impermeable to water". (Beadle,[1].) The subsoil generally consists of a medium to heavy clay. These

Fig. 2.—Old Man Saltbush sown on scald ploughed in June, 1952, photographed October, 1954.—J. F. Crawford, "Ramsay Park", via Coolabah.

areas are known popularly as claypans over most of this district, but this term is best applied to dry lake beds and overflow channels such as the Cuttaburra and Kulkyne Creeks.

Three conditions must be fulfilled before scalds are initiated:

(a) the soil must be unprotected by vegetation;

(b) the surface soil must be susceptible to drift. Scalding occurs in grey soils where the surface soil is lighter in texture than the subsoil, or where there is drift of sand from nearby lighter textured soils.

(c) The subsoil must contain sufficient clay to be able to cement the sand together and so form a layer of earth which is resistant to wind action and which is relatively impermeable to water.

Wind sheeting occurs when the first two conditions are fulfilled but the characteristics of the soil profile are such that there is insufficient clay to cement the sand grains together. This form is very common on the lighter textured red soils of the Bourke district, on which soils the susceptible sand fraction is continually being removed to give a compacted wind-swept surface, but without the exposure of a clayey subsoil.

In the area described in the introduction, covering many soil and vegetation types, both of which often occur as complexes, there are four main types of wind erosion classes. Because of the size of the area and the complexity of both soil and vegetation these are, of necessity, of a very general nature and in any particular area many variations in these classes may be found.

These classes, and the nature of the soil and associated vegetation are:—

(1) *Areas not susceptible to wind erosion.* These areas comprise the firm or crabholey grey or black soil plains supporting mitchell grass (*Astrebla Lappacea*) and neverfail (*Eragrostis setifolia*), and/or bladder saltbush (*Atriplex vesicaria*). These species may occur with or without a tree cover; tree cover where it does occur being composed mainly of black box (*Eucalyptus bicolor*) and coolabah (*E. coolabah*) along the rivers and overflows and/or gidgee (*Acacia Cambagei*) and brigalow (*Acacia harpophylla*). These soils, by virtue of both their physical and chemical characteristics, are resistant to wind action even when denuded of vegetation.

(2) *Areas susceptible to wind erosion with the formation of scalds with varying amounts of sand drift.* There are many variations in the soil and vegetation of this wind erosion class, but the main soil characteristic is a light textured surface soil, usually a brown or red-brown loamy sand, sandy loam or loam, overlying a brown or red-brown clay. These soils may support either a dense gidgee or brigalow scrub of which the pastures are characteristically poor, mainly herbaceous with copperburrs (*Bassia* sp.) and saltbushes (*Atriplex* sp.) predominating with a small percentage of annual grasses such as button grass (*Dactyloctenium radulans*), burr grass (*Tragus australianus*) and katoora (*Sporobolus actinocladus*).

Along the Culgoa and Warrego rivers and their adjacent overflows, scalding occurs where the drift from the adjacent light-textured country contaminates the surrounding heavy soil channels, these being treeless or having a tree cover of black box, gidgee or brigalow. A further class of country susceptible to scalding occurs in the south-east portion of the district, adjacent to the Bogan River. In this area red to red-brown sandy loams overlie light brown to brown clays and support an open to heavy scrub cover of leopardwood (*Flindersia maculosa*), wilga (*Geijera parviflora*), bimble box (*Eucalyptus populifolia*), and white pine (*Callitris glauca*). In the north-west quarter of the district several complexes of soil and vegetation are found, the basis of which is the recurrence of small flood channels and overflows. Between the channels are lighter textured rises covered with white pine, mulga (*Acacia aneura*), bimble box, ironwood (*Acacia excelsa*) and other scrub species. These slight rises form scalds following the removal of the timber and depletion of the ground cover (usually consisting of wire grass (*Aristida arenaria*) and niggerheads (*Enneapogon* sp.) with severe scalds forming along the edges of the grey soil channels.

(3) *Areas susceptible to wind sheeting.* Wind sheeting is the characteristic form of wind erosion on the class of land known locally as the "soft red country", and also of the more level areas of the "hard red country". The soils of both these areas are undifferentiated red to red-brown sandy loams or loams, the texture of which increases with depth to a loamy clay or light clay. The texture of the soils of the "hard red country" is heavier than that of the "soft red country" leading to a higher degree of compaction following wind sheeting. Heavy stone and gravel throughout the profile is characteristic of the former class, being only light or completely lacking in the latter. Because of the gently undulating topography and the stone and gravel cover, the "hard red country" is more resistant to wind sheeting, although less so to water sheeting, than the "soft red" areas. The stony soils of the former class support mulga, and bimble box predominantly, with varying amounts of wilga, beefwood (*Grevillea striata*), kangaroo bushes (*Cassia* sp.) and quinine bush (*Alstonia constricta*), with a ground cover of wire grasses (*Aristida* spp., predominantly *A. jerichoensis* with occasional *A. arenaria*).

In most areas the tree and scrub cover is dense enough to prevent wind erosion even in the absence of a grass or herbaceous layer, but depletion of this lower layer renders this soil very susceptible to sheet erosion by water. On the other hand, the "soft red country" supports open to dense stands of mixed scrub, the type depending on variations in the soil. Generally speaking, the characteristic species in the tree and scrub layer are wilga, leopardwood, beefwood, gidgee, mulga and ironwood, with bimble box mostly confined to the heavier textured flats on which water usually lies following rain. The ground cover varies from dense, woollybutt (*Eragrostis eriopoda*) pastures on the more sandy portions to a poor, open herbaceous pasture of copperburrs, annual saltbush and annual grasses where the soil is slightly heavier and the scrub more dense. Wind sheeting has occurred on this class of country where ringbarking and clearing, followed by depletion of the ground layer, has taken place.

(4) *Areas susceptible to severe sand drift and dune activation.* Areas of which this form of wind erosion is characteristic lie mainly to the west of the Darling and Culgoa Rivers. The soils are deep sands generally arranged in ridges or dunes, these often being separated by overflow channels. The sand ridges are timbered variously with mulga, belah (*Casuarina cristata*), rosewood (*Heterodendron oleifolium*), wilga, white pine, brigalow, silver leafed ironbark (*Eucalyptus melanophloia*), or combinations of these species, usually with a dense pasture of woollybutt or spinifex (*Triodia Mitchelli*). The tree and scrub cover on the interdune area depends on the nature of the soil, whether a heavy grey soil channel or a sandy loamy corridor. In the former case the channels support either black box or Yapunyah (*Eucalyptus ochrophloia*) with brigalow and gidgee in some areas, while in the latter the white pine is usually less dense and the other scrub species more dense, than on the ridges. Where these sand dunes lie contiguous to grey heavy soils severe scalding occurs around their periphery due to the drift contaminating the clays, but on the actual dunes severe sand drift is experienced only following the depletion, or complete removal of the timber and grass cover.

FACTORS INHIBITING SCALD REGENERATION.

Factors inhibiting, or preventing, the natural regeneration of scalded and wind-sheeted areas owe their origin to the nature of the eroded surface, namely, the bareness of the surface, the readily available supply of movable sand grains, and, in the case of scalding, impermeability to water.

The bare, unprotected surface permits unrestricted wind flow over the eroded surface and in consequence any seed which may lodge on the area is quickly removed. Further, in conjunction with the readily available supply of movable sand grains, it permits the bombarding of the young seedlings with sand grains moving at high velocities. The action of wind has been more fully discussed in an earlier issue of this Journal (Darley[2]). This environment is made even more inhospitable to plant growth by the high temperatures recorded on such a bare surface as compared to the surface with a cover of vegetation. Numerous observations made at various times of the year indicate that scald surface temperatures exceed shade air temperatures by amounts varying up to 20° F. in the winter and 45° F. in summer. The absolute maximum recorded is 160° F., the shade temperature at the same time being 112° F. (Beadle[1]).

The difference between wind sheeting and scalding with respect to factors inhibiting regeneration and reclamation, is in the penetration of water into the eroded surface. On a wind sheeted surface, moisture penetration is limited because of rapid run-off, hence this form of wind erosion is analogous to sheet erosion by water. If the wind-sheeted surface was perfectly flat, which, of course, it rarely is, penetration of water into the soil would be comparatively rapid, although slower than the non-eroded soil, due to some degree of compaction. On the other hand on a scalded surface, swelling of the clay in the surface few inches serves to form a seal following wetting so that the soil becomes

Fig. 3.—Checkerboard furrows ploughed and sown to annual saltbushes May, 1954, photographed October, 1954. Note water held in bays and furrows. These bays will be further divided in subsequent years, to assist spread of saltbushes.—J. F. Crawford, "Ramsay Park," Coolabah.

impermeable to moisture. The impermeability of the eroded surface leads to excessive water loss, firstly, by excessive run-off where any slopes exist, and secondly, by the high rate of evaporation brought about by high wind velocities and high surface temperatures. This high rate of evaporation is significant with regard to small showers of rain, which, although sufficient to benefit plants growing in non-eroded soil, are rapidly evaporated from the scald and so do no more than to reduce the surface soil temperatures for a short period (Beadle[1]).

Thus the factors inhibiting, or preventing, regeneration on a scalded surface are:—

(a) high surface temperatures during the summer months;

(b) high rate of evaporation and water run-off;

(c) high wind velocities and rapid movement of sand grains over the scald surface;

(d) the slow rate of infiltration of water;

(e) the low concentration of seed on, and within, the soil.

SCALD RECLAMATION.

In order to bring about reclamation of wind eroded country it is necessary to overcome some, if not all, of the factors retarding regeneration that are listed in the preceding section. The principal factors are high wind velocities, lack of moisture, and absence, or very low concentration of, seed of colonising species. The most effective means of overcoming these factors by mechanical methods is by ploughing (which encourages penetration of water and prevents rapid run-off, and at the same time lowers wind velocities and surface temperatures). Seed of plants species suitable for colonisation is then introduced onto the ploughed surface.

The scalded surface may be ploughed in different ways, the most common methods being:

(1) Complete ploughing.

(2) Ploughing strips at various distances apart.

(3) Ploughing single furrows haphazardly across the surface.

Fig. 4.—Good stand of annual saltbushes established on ploughed scald following good initial rain.—J. F. Crawford, "Ramsay Park," Coolabah.

(4) Ploughing single furrows on the contour.

(5) Ploughing single furrows in a checkerboard pattern, that is, two sets of parallel furrows at right-angles to each other, the parallel furrows being 10-12 yards apart, thus dividing the scald into squares.

In the Hay and Bourke districts experimental programmes have included all of the above methods except the third. Where seed has not been sown, irrespective of the method of ploughing, the treatments have been partial or complete failures owing to the slaking down, or silting up, of the ploughed or furrowed area before perennial plant species become established. Also, seed blowing in from surrounding non-eroded areas does not penetrate into the treated scald farther than the three or four chains from the edges due to the retarding effect of the outside furrows on the surface wind velocity. It is a necessity for the successful reclamation of scalded land that seed of perennial, as well as annual, plants be introduced onto the area so that colonisation over the whole of the area can commence following the first good fall of rain.

The other basic treatments may be considered, neither of which prevents water flow or lowers wind velocities across the whole of the erodible surface. The first of these is to sow seed on the bare scald without disturbing the soil surface. It has been suggested that this method may be effective for special cases, for example over small areas, subject to frequent flooding, but even in this case the high cost of collecting seed, and the danger of all of the seed being removed by strong winds or floated off by water, would eliminate this method as a practicable control measure. The second method is to place obstructions on the scald to trap wind-blown sand grains, thereby producing water-absorbent islands of soil which serve as nuclei for the spread of vegetation. For this method to be effective it is necessary that the obstructions should be numerous and at right-angles to the wind flow, and secondly, that a supply of wind-blown sand should be available. If the latter condition is fulfilled it follows that the surrounding country providing the sand is itself being eroded and will consequently become scalded if the condition continues to exist. It is better to preserve non-eroded soil than to remove existing timber cover, particularly if the timber is green, in an attempt to reclaim nearby scald, perhaps ineffectively. From observation made within the Bourke district it is considered that this method would rarely, if ever, be completely effective, and bears no comparison to the results obtained from progressive checkerboarding and sowing seed along the furrows.

PROGRAMME AND LOCATION OF EXPERIMENTAL AREAS

Four experimental areas are located throughout the Bourke district to give a wide coverage of erosion on various classes of country. Investigations on these areas were made possible only by the fullest co-operation of the landholders who also supplied the tractor, plough and fuel, for carrying out the experiments. It is planned to set up other areas to include classes of country not covered by the existing areas. The experimental areas are located on the following properties:

(1) "Moonagee", owned by Mr. G. Killen, situated on the eastern bank of the Bogan River, about 16 miles north of Nyngan in the 15½ inch rainfall zone.

(2) "Ramsay Park," owned by Mr. J. F. Crawford, lying 22 miles north-east of Coolabah, about 3 miles from the Bogan River with an annual average rainfall of 14½ inches.

These two properties are representative of land subject to minor severe scalding along the Bogan River and its channels. Two main vegetation associations occur throughout this area, the Black Box Association which is confined to the Bogan and its cowals and channels and the Wilga-Leopardwood Association occurring on soils which are light red-brown and light brown sandy loams overlying medium clays. Scalding is rife on this latter soil type, the lighter-textured surface soil being removed by wind action, mostly with the formation of soft scalds, although some areas of hard scald have been observed.

(3) "Iddavale", owned by Mr. D. H. Congleton, located on the east side of the Culgoa River, approximately 17 miles upstream from Collerina, average annual rainfall being approximately 14 inches. Two main classes of country occur on this holding, firstly a heavy grey clay-supporting coolabah (*Eucalyptus Coolabah*) and gidgee, and secondly, a brownish fine sandy loam surface soil overlying a red-brown clay subsoil supporting gidgee. Erosion is confined to this latter soil type and in many areas of open gidgee the loose surface soil has been completely stripped off to expose the clay subsoil. This form of erosion is characteristic of much of the area to the north and north-east of Bourke.

(4) "Toorale", owned by the Berawinnia Pastoral Company, Manager, Mr. B. Stalley, is located approximately 30 miles south-west of Bourke on the Louth Road and with an average annual rainfall of 11½ inches. The scalded area consists of a fairly broad open zone of red-brown clay from which the surface soil has been removed by wind. Originally this soil type supported bladder saltbush with open gidgee around its edges where heavy grey soils supporting mitchell grass forms the major soil type.

Briefly, investigations on scald reclamation on these properties are divided into:

(1) Species trials, in which different plant species are tried out as to their suitability for reclamation work, that is, their ability as initial colonisers.

(2) Methods of establishing these species. This entails mechanical methods of breaking the scald surface with agricultural implements.

These two lines of investigations are carried out in conjunction with one another.

To the present time, species trials have shown that the most suitable plants for the initial colonisation of scalded surfaces, under the methods of establishment investigated, are members of the saltbush (*Atriplex* sp.) group. In particular, most success has been obtained by using the following species as a mixture, the seed being broadcast over the area, or along the furrows, without any further covering.

Flat-topped saltbush (*Atriplex inflata*).

Annual saltbush (*A. pseudocampanulatum*).

Pop saltbush (*A. spongiosum*).

Bladder saltbush (*A. vesicarium*).

The first three of these species are quick-growing annuals which give a good cover and seed heavily in the first year. Even under very adverse seasonal conditions these three species manage to make some growth and set seed. Bladder saltbush, on the other hand, grows more slowly, but, as it survives for about eight years, once it is established, seasonal conditions are not so important for its survival. These plants have been discussed in more detail in an earlier issue of this journal by Condon and Knowles([2]), ([4]). There is no commercial source or mechanical method for collecting these seeds which are harvested by hand.

Mechanical treatments of the scald surface were as outlined in the preceding section. Ploughing roughens the soil surface permitting the entry of seed and increases the infiltration of water. Beadle([1]), states that the density of the plant community which develops on a freshly ploughed scald is governed by a number of factors:

(1) The time of year at which the ploughing is done (winter ploughing being more satisfactory than summer).

(2) The amount of seed in the soil immediately before wetting, hence the advantage of broadcasting seed of colonising species onto the treated area.

(3) The amount of rain in the first fall, as infiltration is greatly decreased after the first fall due to the slaking down of the clods formed by ploughing. In most cases the rough newly-ploughed surface has slaked down to a more or less smooth surface by the end of the second year.

Compared to other treatments complete ploughing has given very disappointing results in the Bourke district. This has been due to the winter rains being insufficient to germinate the seed of the colonising species, serving only to slake the ploughed ground so that heavy rain in the spring and summer are ineffective. On both Ramsay Park and Iddavale trial plots that were completely ploughed by ripping to a depth of 12-18 inches have, in one year, reverted to an almost scald-like surface. On "Ramsay Park'" a small area which was ripped by Mr. Crawford during October, 1954, reverted to a similar condition six months later. Plants that do manage to establish are incapable of replacing themselves, the smooth surface not being favourable for the retention of seed or for further penetration of water. The results of complete ploughing are not in keeping with the cost of treatment or results of other less expensive methods. Similar poor results have been obtained with other treatments involving ploughing, for example, strip ploughing, either haphazardly or on a checkerboard pattern.

Furrowing serves three purposes, firstly it disturbs the surface of the soil permitting the rapid entry of water, secondly it reduces the wind velocity over the soil surface and serves as a trap for wind-blown sand and seed, and finally, it provides check banks which serve to retain the water in the furrows and on the bays between the furrows, for a relatively long period. Beadle[1] states that as far as water retention is concerned, the checkerboard system is the most efficient but not necessarily the most desirable system, since high water levels commonly occur when the soil in the furrow has been compacted after the first rain. Under these conditions drowning of established seedlings is a common occurrence.

Fig. 5.—These furrows once carried good saltbush and copperburr but area returned to scald conditions because of lack of follow up treatment.—Hungerford district.

In the Bourke district checkerboard furrowing, about 10-12 yards between the initial furrows, has been found to be much more effective than contour furrows. Silting and sanding up of the contour furrows also aids in their rapid breakdown, checkerboard furrows not being affected to such a large degree. A further advantage of checkerboard furrows is that water is held on the untreated scald surface due to the slight embankment around the squares. However, irrespective of the method used, numerous observations both in this and other districts, have shown the futility of attempting any mechanical method of treating the scald surface without following this treatment up with the broadcasting of colonising species.

Once the colonising species have become established along the furrows of the checkerboard and have commenced to seed the checkerboard is subdivided, again in a checkerboard pattern, by furrows up the middle of the existing bays. These furrows are also sown to colonising species but with a higher proportion of the perennial saltbush, the total seeding rate being lighter than the initial sowing as there will be some migration of seed from the established furrows. This, and further subdivision, usually three or four times, is necessary to provide further suitable conditions for seed germination. Experiments in the Bourke district show that this method is the most suitable, as well as the most economical, method of reclaiming scald to give a complete cover. Checkerboarding without sowing of colonising species and without any further treatment is practically useless, but when progressive checkerboard furrowing with broadcasting of suitable species along the furrows is carried out there is every element of success for the reclamation of scalded land. Figure 7 illustrates the method employed in progressive checkerboarding whereby the initial bays are further subdivided twice or preferably three times.

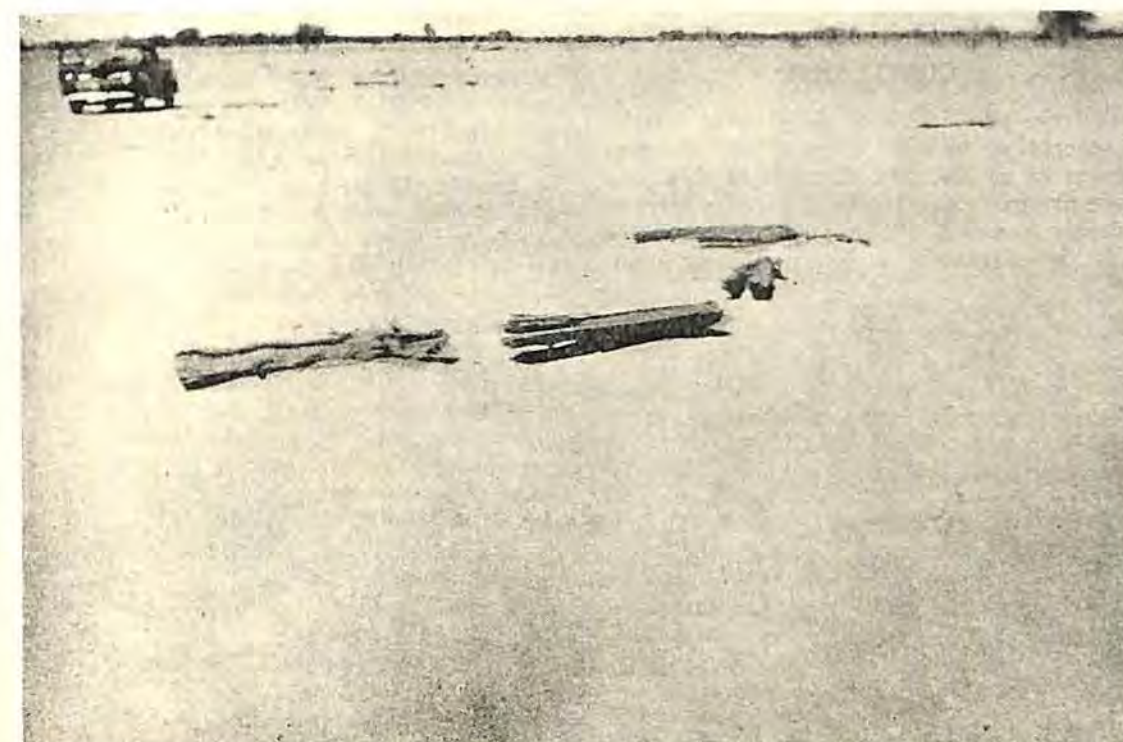

Fig. 6.—These old posts were strewn over a scald with the view to assisting reclamation. They have been there for several years without result.—Euston District.

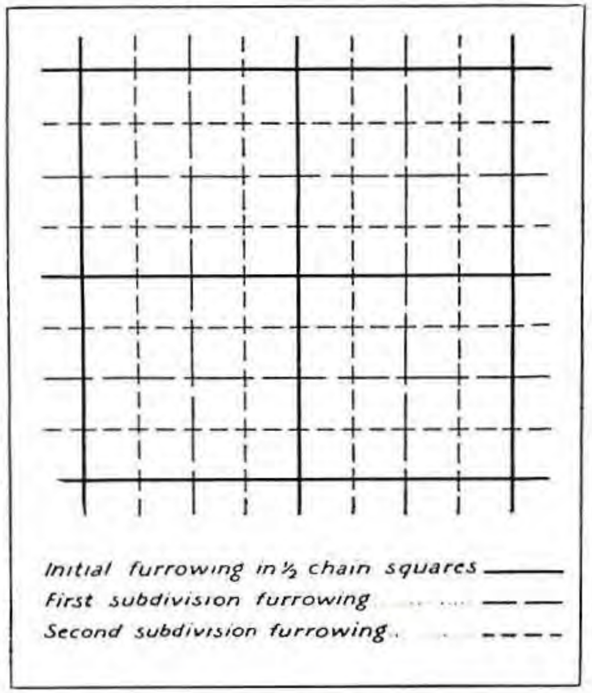

Fig. 7.—Checkerboard furrowing subdivided by intermediate furrows in successive years.

CONCLUSION.

A large proportion of the Bourke district is susceptible to wind erosion with the formation of scalds, and throughout this area there are extensive tracts of country already severely scalded. The environment on a scald is extremely unfavourable for plant growth, regeneration only taking place, if at all, during very good seasons. Methods of reclaiming scalded land aim at improving the immediate environment by lowering surface wind velocity, increasing the infiltration of water and preventing water run-off. This is attained by checkerboard furrowing and the broadcasting of colonising species, annual species to give a quick cover, perennial species to give a stable pasture.

Checkerboard furrowing without the introduction of such plant species is useless as furrows revert to scald within a few years, therefore broadcasting of seed is essential. Further, checkerboarding without further subdivision is practically useless as the spread of colonising species onto the inter-furrow areas is very slow, conditions there being unfavourable for the germination of such species. There is every necessary element for the successful reclamation of scalded land in progressive checkerboarding and broadcasting of colonising plant species such as flat-topped saltbush, pop saltbush, annual saltbush and perennial saltbush.

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FOREWORD

BY

E. S. Clayton, H.D.A. (Commissioner), Soil Conservation Service of N.S.W.

In Australia until recent years the conservation of water resources meant, in the minds of the many, only one thing: the building of storage dams and reservoirs to hold water. The importance of soil conservation on the watersheds was not appreciated. That outlook is being gradually changed in this country and water engineers, land surveyors, land users and the general public are gradually becoming better informed on the great improvements in catchment efficiency which soil conservation activities can achieve. The necessity for such practices is also being recognised as, without them, catchment areas deteriorate and their water production capacity is injured.

The way in which water is released from a catchment area has an important effect on the flow of the stream. When it is released as surface run-off it comes off quickly in irregular volumes, flooding streams during storms and leaving them almost dry between rains. Erosion and siltation are inevitable under these conditions. But when conditions are such that water penetrates into the soil and is later released downwards through the soil, the action is much slower. Water must then pass through the labryinthine passageways in the soil, subsoil, gravel and rocks of the high country. This takes time. The water is thus released steadily over a much longer period and feeds into the streams long after rains have ceased. This continuity of flow is most desirable—in fact it is essential. The water so produced is clear and free of erosional debris. In this process the soil does not release all the water to the stream. Some is retained in the soil itself and some moves slowly down slope within the soil-covering or downward into the underlying porous rock materials. This constitutes the ground water that feeds the springs and maintains some stream-flow during dry periods. This ground water, together with the seepage from the surface water areas, raises the water-table in the valley lands and feeds inclined porous layers that supply artesian basins. It is a very valuable form of water yield and its usefulness should never overlooked in a dry country like Australia. Unless catchments are in a condition to allow water into the soil in these intake areas, how can ground water be replenished?

Man has greatly interfered with the water-yielding lands by settlement and other activities on the watersheds. The general effect of settlement in high catchments has been to reduce the amount and efficiency of the vegetative cover, in fact in some cases to entirely remove it. Roads with their impervious surfaces have greatly increased run-off and diverted and concentrated the water. Innumerable flats and valley basins have been gullied and so drained of their stored water.

All these activities on watershed lands are detrimental to good water production. The main effects are that less water soaks into the soil, the run-off is greatly increased, soil erosion is accelerated, flood peaks as well as total volume of run-off is vastly increased, so also is siltation of stream beds and reservoirs and the run-off is not good, clear, usable water.

Few realise how varying is our stream flow due to this lack of natural catchment storage capacity (i.e. glaciers, snow, high swamps, etc.) on the catchments. Lacking these water regulating conditions the rain runs off the catchment too rapidly; consequently the extremes between high and low stream flow are much too great. A few instances are given below to illustrate this point.

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The following recorded flows, in acre-feet, of some of our most important rivers serve to illustrate how lacking in continuity is the flow :—

Murray :	*At Albury.*
Average annual flow ..	3,705,403
Maximum monthly flow ..	1,301,580
Minimum monthly flow ..	8,910
Lachlan :	*At Reids Flat.*
Average annual flow ..	232,432
Maximum monthly flow ..	329,940
Minimum monthly flow ..	0
Hunter :	*At Singleton.*
Average annual flow ..	650,326
Maximum monthly flow ..	1,328,606
Minimum monthly flow ..	0

The same fluctuations of flow obtain in most of the rivers throughout the Continent.

These figures reveal how essential it is that we prevent any further deterioration of the high catchment areas, otherwise very early in our national history we will be virtually without reliable water.

It should be clear that soil erosion must be prevented in the vital catchment areas. To achieve this, of course, soil conservation measures must be employed.

Already there has been a great deal of destruction of river banks and valuable alluvial lands have been lost along some of the rivers, particularly on the coast. On the Macleay, for example, many acres of some of the richest land in the State have been lost by river bank erosion. The primary cause has been accelerated run-off from the catchment area.

With many high catchment areas unwisely used, when the flood rains occur, they bring down, not the rich fine-grained material from a vegetated catchment area to build up the river flats, but the coarse erosional debris scoured out of ever-deepening and widening gullies. Now, sand, gravel and large stones are carried down the torrent and deposited on the river flats. The use of these marginal lands of poor quality has resulted in the scouring away of many valuable pockets of alluvial flats downstream. These useful creek flats would have been quite safe had the steep country on their watersheds not been settled.

This deterioration of the catchment has in turn sent the debris down the river and the damage this has caused to the riverbanks over the whole length of the river is becoming an increasing cause of deterioration of the river itself. Irregular river-flow and peak floods are constantly with us.

PLANNING SOIL CONSERVATION IN THE UPPER NAMOI DISTRICT

BY

T. F. MAU, H.D.A., District Soil Conservationist.

NO person could claim to be a competent agriculturalist or pastoralist unless he loves and understands the soil and knows how to keep it stable and how to maintain it at a high level of fertility.

Soil erosion and declining soil fertility have been so widespread and so much on the increase that we must realise that our basic methods have been wrong. (See illustrations 1 and 2.) We must get right back to fundamentals and build a better foundation for our agriculture and animal husbandry. There is no point in having the most modern superstructure built on poor foundations when better foundations are available. Similarly, it is not logical to practice the most modern and up-to-date methods of crop raising and stock raising unless the soils which support and nourish the crops, and, through these crops the domestic animals, are in their best possible condition.

Fig. 1—Land damaged by the adoption of wrong methods—Manilla District.

Fig. 2.—The same land as in Fig. 1 photographed from the same spot three years after completion of control work—the right methods bring their reward.

These foundations cannot be restored overnight. The achievement of a permanent, sound agriculture calls for a long-term plan, firstly, to stabilise the soils, secondly to improve their fertility and, thirdly, to maintain them at the highest level of fertility which can be attained.

The first step in this direction is the preparation of a farm plan showing such features as fence lines, drainage lines, watering points, approximate direction of slopes, access lines, areas of paddocks and the present land-use. The purpose of this plan is to present an over-all picture of the present condition of the property. A more complete picture is shown if contour lines are set out on the plan but these are not essential.

The next step is to classify the areas into such classes as those suitable for grain production, areas suitable for annual fodder crops, areas suitable for pasture improvement, areas suitable only for natural pasture, areas for restricted grazing and areas not suitable for further development.

We are now in a position to consider the first stage of our conservation programme—that of soil stabilisation. This step calls for experience in determining the lands which require mechanical protection and those which can be kept in stable condition by good land-use only.

Two of the main concepts by which this classification is made are:—

1. If land can be kept permanently covered by vegetation, either alive as growing crops and pastures or dead, as crop residues and stubbles, little erosion damage would occur. But we know that few lands fall in that category under our conditions.

Fig. 3.—Land which was too badly gullied for successful cultivation—banked and worked on the contour to stabilise the soil and retain moisture—Manilla district.

Cultivation land is laid bare in the preparation of seed beds, prolonged droughts prevent crop development to provide adequate stubble cover and pasture lands, even when well managed, may be laid bare by prolonged drought, grasshopper plagues or accidental fire.

2. The development of land for agriculture or stock raising can change the run-off co-efficient or, in other words, the proportion of rainfall which runs off the land. This change in the run-off coefficient may, for instance, be the result of clearing woodlands and then establishing pasture,—a procedure which may result in greater run-off,—or it may be the result of the changes in soil structure and composition, resulting from prolonged cultivation and grazing, even if carried out in accordance with the best recognised practices. As the organic content of the soil is reduced and the micro-organisms in the soil are interfered with, the soils can be altered in their capacity to absorb rainfall.

If such changes result in greater run-off, the natural waterways become over-loaded and commence to scour. This causes a drop in the base level of the natural drainage system and even if the adjacent lands are well covered with vegetation they can be damaged by overfall erosion. Any decline of water intake by the soil or drop in fertility affects the quantity and quality of the protective vegetative cover and sets the soil on a continuous and accelerating down grade. It is only a matter of time before such country becomes subject to severe damage by soil erosion.

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Loss of protective cover and increasing run-off must be met by a system of mechanical earthworks to restore, to a large extent, the balance previously existing.

The use of pasture furrows, absorption banks, graded banks, diversion banks, waterways and silt traps can, with well-considered use of the land, hold up water more effectively than on the same country in its virgin condition.

We can now revert to our farm plan and mark on it the earthworks required. This calls for careful planning to find the best location for the disposal and use of run-off, the best location of water supplies, farm roads, fencing and shade or shelter belts. Officers of the Soil Conservation Service are available to advise and assist in this detailed planning.

The landholder now considers how much of this work he can undertake during the next twelve months, and where these initial works would give the greatest benefit. Having a plan which sets out his over-all requirements he can also decide whether he will hire plant, procure his own or use a combination of both, whereby the larger earthworks are done by the hire of large equipment and the smaller works done by the adaptation of his farming plant.

The design and location of works will be done free of charge by the Soil Conservation Service if the landholder requires this assistance.

The second stage of building soil fertility can proceed concurrently with the programme of soil stabilisation but it must be realised that the benefits of a fertility-building programme are lost if soil erosion and excessive run-off are not first arrested.

To build soil fertility, we can add artificial fertilisers or we can grow pastures and allow the grazing stock to add fertilising materials to the soil, or we can grow legumes which supply nitrogen from the air to the soil in a form available to other plants, or we can plough in green manure crops. The rate of improvement is, up to a point, proportional to available moisture.

Fig. 4.—The same land as in Fig. 3 photographed from the s me spot seven years later. This land is now in the final year of the pasture phase of the rotation. (Note growth of tree lots in the background).

Whatever method or combination of methods is used they can be of little avail if run-off from storms sweep away the stock manures and other fertilising ingredients with the surface soil, ingredients which have been put there at so much effort and expense.

It must also be remembered that these earthworks are not solely for the purpose of preventing the down-hill movement of soil. They play a major role in the conservation of water. By reducing run-off to a minimum they raise the effective rainfall and this is very important in a dry country such as ours.

From unprotected lands that have been damaged by erosion, surface run-off can account for as much as eight inches of our annual precipitation in a typical year. By adoption of soil conservation practices this can be reduced to two inches or less. On many treated areas there has been no surface run-off for years. A saving of two or three inches of the annual rainfall can mean the difference between success or failure of some crops and pastures. Therefore, the importance of this aspect in soil conservation can be realised.

In general, the main factors limiting crop and pasture production in these districts surrounding the towns of Quirindi, Tamworth, Manilla and Barraba, are :—

1. Inadequate soil moisture.
2. The low level of soil humus.
3. The need for additional sulphur and nitrogen in the soils.

Therefore, to meet these deficiencies the basis of a conservation plan for sloping

Fig. 5.—Land in the initial stage of stabilisation. This photograph shows how the run-off water is guided to storage dams to provide water supply for subdivision of the paddocks and suppleme tary irrigation.—Tamworth District.

wheatlands of the Upper Namoi District, would be:—

1. Provision of a well-designed system of protective banks with safe outlets.
2. Contour cultivation between banks. (See illustration 3).
3. Elimination of stubble burning as a regular practice.
4. A broad crop rotation to include a long period under pasture containing legumes and suitably fertilised. (See illustration 4).
5. Sound cultivation and grazing practices.

Where such plans are operating the results to date are most convincing and contrast vividly with the condition of country before treatment. (See illustrations 1 and 2).

On grazing land the first necessity is to control rabbits. Soil cannot be conserved where rabbits are not effectively controlled. The next step is to hold water and organic matter on the soil by the use of absorption banks and pasture furrows. Under our conditions the absorption bank is most valuable on lands which are not to be used for growing grain crops. The value of absorption banks will be dealt with in a following article. Pasture furrows can be effectively used between absorption banks.

The next consideration is a plan of subdivision to enable stock to be adequately controlled. Quick grazing of small paddocks has many obvious advantages over the grazing of larger paddocks for long periods. It should be realised, however, that the condition of the pasture determines when an area should be spelled, not, as is often the case, the condition of the stock.

Fig. 6.—A tree lot of River Red Gums and Yello. Box eight years after planting in the drought year of 1946. These trees were never artificially watered in the field — not even when planting—Tamworth district.

Subdivision of paddocks is often dependent upon water supply but a well-considered conservation plan can often result in the water being guided and stored where it is most wanted. (Illustration 5). Even though all these storages may not be permanent, the provision of many watering points allows more even grazing and reduces the danger of denuding pasture around the few isolated watering places, as these often become the focal points for severe soil erosion. Stock also benefit when they have shorter distances to travel to water.

The smaller paddocks enable greater variety of pastures to be used and facilitate the closing of pasture areas during lush seasons for the purpose of making pasture into ensilage or pasture hay. It is essential to increase fodder reserves when the stock carrying capacity of a property is increased.

Rotation of grazing is important in the control of such stock diseases as intestinal worms. Any measures which increase production per acre will reduce the necessity to over-use land and, as such, are very important conservation measures.

Another important consideration of grazing land is to separate, as far as practicable, land with different potentials or characteristics. For instance, soft or highly fertile country should be separated from hard or poor country as a measure to prevent stock from grazing the good country heavily and neglecting the harder, poorer country. Steeper country with a high erosion potential should be separated from the safer country so that it may be given preferential treatment. In this connection, the conservation programme should be planned to build up the production of land less liable to soil erosion so that the land liable to erosion need not be over-used.

Land along the main watercourses should be kept well grassed as a measure to prevent over-fall erosion of the valuable adjacent country which may later lend itself to the requirements of supplementary irrigation. It is often worthwhile, therefore, to fence vulnerable sections of such watercourses into long narrow paddocks to facilitate grazing control.

Well placed shade and shelter belts are important in inducing stock to spread and graze more evenly. Protection from extreme heat and extreme cold mean a great deal in successful stock raising. Stock will tend to concentrate on pasture land adjacent to isolated shade and shelter trees. In this regard the conservation plan should provide for well placed shade and shelter belts. Often these trees can also serve to provide a reserve of fodder and play their part in providing cover for useful insectivorous birds. They also serve to break the force of prevailing winds which can be detrimental to soils, plant growth and stock.

Trees can be established without watering if the right species and methods are used. (See illustration 6). The most important factors are a well prepared fallow to store soil moisture, deep planting in contour furrows and the selection of species suited to the particular environment. Inter-row cultivation for the first two seasons will induce rapid growth. Young tree plantings must be protected from rabbits, hares and stock. The necessity for protection and early cultivation provide a reason for recommending that the trees be planted in "blocks".

I have outlined the main factors considered in preparing a conservation programme. This has, of necessity, been sketchy as generalisations are difficult to make and often dangerous. Each property presents its own particular problems and, therefore, the detailed planning must be prepared on the spot to meet the specific requirements of the holding.

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STUBBLE MULCH MACHINERY TRIALS

BY

K. P. BRIDGE, H.D.A., Officer in Charge.

RESULTS of a Runoff and Soil Loss Experiment carried out at the Research Station, where plots of 1/40 acre are on a 5 per cent. slope under various agricultural rotations, show the necessity for stubble mulching on sloping country used for wheat growing. During the years 1950-1954, five times the amount of soil was lost under a Wheat-Stubble burnt rotation than under the Wheat-Stubble mulched rotation. Twice the amount of soil was lost under a Wheat-Fallow rotation as against the Wheat-Stubble mulch rotation.

At the request of the Standing Committee on Soil Conservation, the Department of Commerce and Agriculture imported to Australia stubble mulch machinery in use in the United States of America. The machinery trials carried out at Gunnedah Soil Conservation Research Station in 1953 and 1954 proved useful to test the imported implements against machines in general use in Australia.

EXPERIMENT AND RESULTS.

The paddocks in use during the trials had four years continuous wheat growing prior to the 1953 sowing. The 1952 crop yielded nine bags per acre and the amount of straw at the initial cultivation stage was heavy and erect.

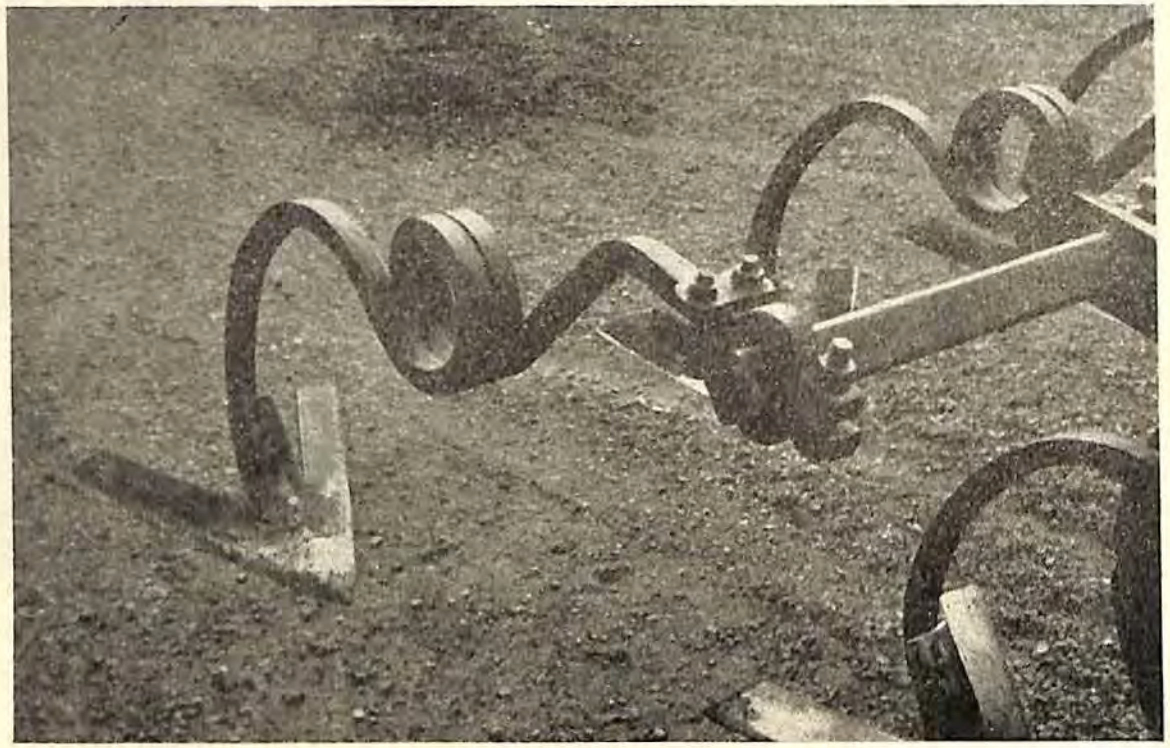

Fig. 1.—Portion of Dempster carrier fitted with spring tynes and 16 inch sweeps for seed-bed preparation.

The two paddocks were each divided into 72 plots, one plot for each of the factorial combinations of initial cultivation, seed bed preparation, sowing and landpacking. The initial cultivation implements were: 1, Disc Harrows; 2, Scarifier and 3, Dempster Carrier with 30 inch sweeps. The implements for seed bed preparation were: 1, Disc Harrows; 2, Scarifier and 3, Dempster Carrier with 16 inch sweeps. (Fig. 1). The sowing was carried out with: 1, Combine and 2, Disc Seeder (Fig. 2). The 30 inch sweeps used for initial cultivation and 16 inch sweep for seed bed preparation are shown in Figure 3.

The treatments for packing soil after sowing were: 1, Land Packer (Fig. 4); 2, Rotary Treader (Fig. 5); 3, Rotary Treader reversed and 4, Nil.

The soil in both paddocks grades from a brown clay loam at the top of the paddocks down to a black self-mulching clay at the bottom of the paddocks. All plots in both paddocks were laid out on the contour due to the slope of the land and graded banks in the paddocks. Therefore any possible effect from the differing soils down the slope had not been eliminated.

INITIAL CULTIVATION.

Although the two paddocks were grazed with sheep from the previous harvest (December) to the initial cultivation (February) the stubble in the paddocks was still bulky and erect at the time of cultivation.

1. Disc Harrows were weighted to get penetration and also to break up the straw. They worked the ground well, maintained even penetration, good weed control and left the stubble on the surface of the soil. Where moist areas were met there was no build up of soil on the discs and the soil was turned evenly.

2. The scarifier choked up and would not handle the straw. Disc Harrows unweighted with very little set on the discs were run over the area to overcome these difficulties. A fair amount of straw was broken and

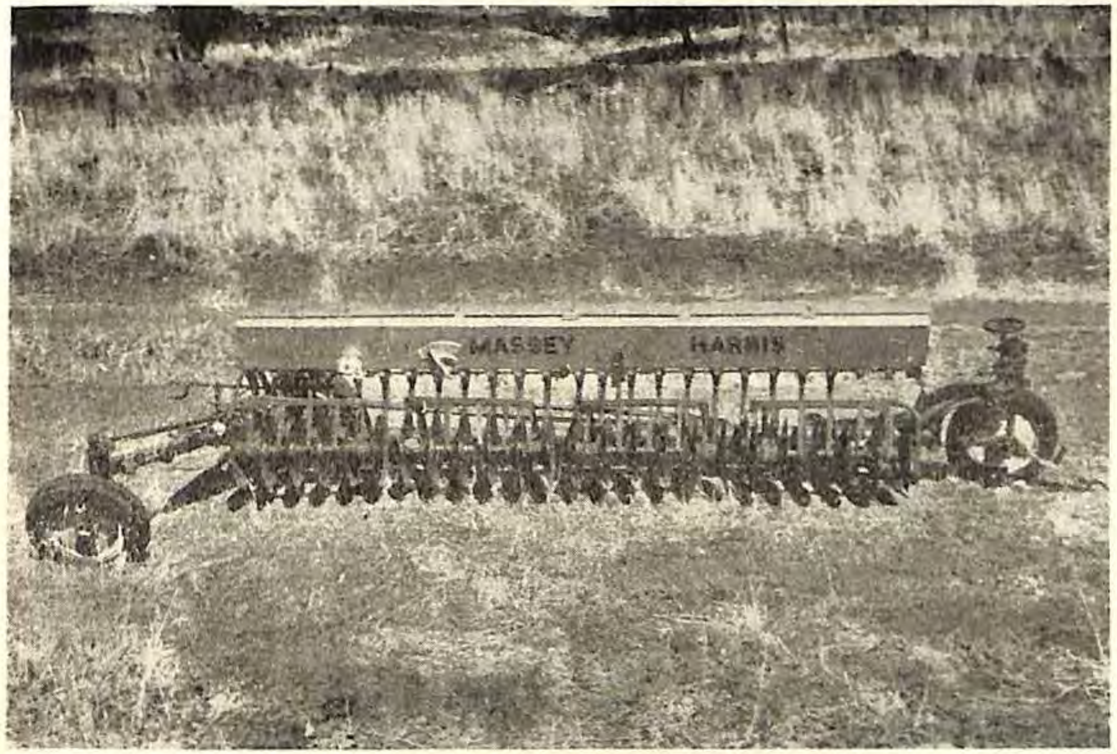

Fig. 2.—The disc seeder used in stubble mulch trials.

Fig. 3.—Rigid tyne of Dempster carrier fitted with 30 inch sweep with 16 inch sweep on the ground for comparison.

stubble was knocked down in the direction of travel. The scarifier then handled the straw with only minor blockages leaving the surface cloddy with the straw on top. Weed control was good and an even cultivation carried out.

3. Dempster Carrier with 30 inch sweeps. Three 30 inch sweeps were attached to the Dempster Carrier for the initial cultivation. More sweeps could have been attached to the carrier but three was considered a maximum load for the W6 tractor used. The ground was broken up well and a good initial cultivation carried out. Surface cover was left intact and weed control was good. Did not leave large clods on the surface under ideal conditions but where ground had dried out large clods were prevalent. Depth of cultivation with this implement varied considerably. (Fig. 6). In this class of soil depth of initial cultivation is not considered so important but on lighter soils this uneven initial cultivation may be detrimental.

SEED-BED PREPARATION.

Two seed-bed preparations were carried out during the period March to June following good falls of rain; 493 points in the first instance and 175 points prior to the final cultivation. Some weed growth had taken place prior to the first seed-bed preparation and there was a considerable amount of straw remaining on the surface.

1. *Disc Harrows.*—This machine did a particularly good job of cultivation on land worked initially with the Dempster Carrier and 30-inch sweeps and Scarifier but covered the mulch where initial cultivation was with the Disc Harrows. Weed control on all treatments was good. Depth of penetration was even and maintained.

On the second seed-bed preparation there was a tendency for this machine to bury the straw especially after treatments with Disc Harrows or Scarifier and Disc Harrows.

Fig. 4.—The land packer used in these trials.

2. *Scarifier.*—This machine worked effectively but had a tendency to choke up following initial cultivation with the Dempster Carrier and 30-inch sweeps. The surface was slightly ridged, moderate clods and left straw on top of the ground. Weed control was good, depth of penetration even and maintained.

On the second seed-bed preparation just prior to sowing the Scarifier gave a very good seed bed, firm even bottom at the required depth and cultivation was free of weeds. Straw was evenly distributed over the surface of the ground.

3. *Dempster Carrier with 16-inch Sweeps.*—Stubble was handled well and the ground worked effectively. Despite attention to the depth control adjustment, the bottom of the seed bed was uneven due to moist areas through the cultivation. Fairly severe ridging of the surface occurred with the majority of the stubble on the surface. This ridging occurring in the first seed bed preparation made it difficult with the second seed bed preparation for it was impossible to obtain an even penetration. Any obstruction caused by stubble or wet earth packing on the sweeps accentuated the ridging and made wide furrows. Figure 7 shows typical ridging on the right and the furrow on the left was caused by moist earth packing on the left hand sweep. Weed control was good. Due to the ridging that occurred it was found that more soil moisture was lost by evaporation than the amount lost from Scarifier and Disc Harrow treatments. The Dempster Carrier has an overall width of 12 feet 6 inches and eleven spring tynes fitted with 16-inch sweeps were evenly spaced on the two tool bars (Figure 1).

SOWING.

Soil conditions in early June were good for sowing. Sowing was carried out with the Combine and Disc Seeder.

1. *Combine.*—This machine worked well but minor chokes occurred on treatments Dempster Carrier with 30-inch sweeps for initial cultivation, scarifier and Dempster Carrier with 16-inch sweeps for seed-bed

preparation. Also several chokes occurred on Scarifier for initial cultivation and Dempster Carrier with 16-inch sweeps for seed-bed preparation. The Combine sowed the seed evenly on the firm moist bottom of the seed-bed and no difficulty was experienced in maintaining the correct depth. This machine was the only one that would sow on graded banks and all banks were sown with the Combine. It was noticeable that, due to even sowing on treatments Dempster Carrier with 30-inch sweeps initial cultivation and in all seed-bed treatments involving the Dempster Carrier with 16-inch sweeps, there were a considerable number of places where seed was sown in loose soil above the firm bottom of the seed-bed. Although this had no adverse result with regards the germination in this case, it is thought that these observations would affect the germination where soil moisture was marginal for germination.

2. *Disc Seeder.*—This machine handled the stubble well and no choking occurred. Sowing was more uneven than with the Combine as the Disc Seeder has a cut of 13 feet 6 inches and where narrow undulations occurred the seed was placed near or on top of the ground. Seed was not always placed on the firm bottom of the seed-bed but was sometimes thrown in with the loose soil. It was not possible to sow graded banks with this machine. Conditions at the Research Station were more unfavourable for this machine than would be encountered in commercial wheat growing areas because of our small paddocks and experimental placing of graded banks. Where this machine was tested on land in the vicinity of the Station its performance was better than during the trials.

AFTER-SOWING TREATMENT.

1. *Land Packer* (*Fig.* 4).—This machine was used after sowing to consolidate the seed-bed. The machine was weighted and all observations showed it was effective in packing the soil, leaving it slightly ridged.

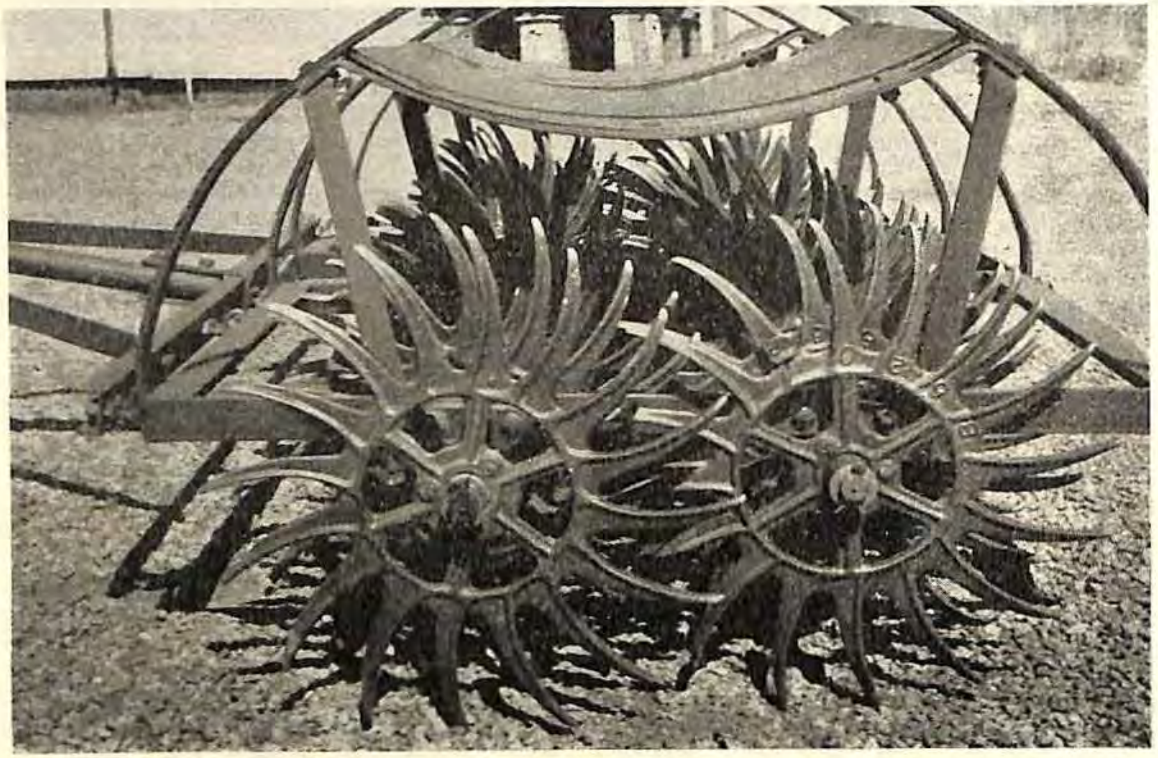

Fig. 5.—The rotary treader in reversed position.

2. *Rotary Treader.*—This machine was wieghted but although it packed the seed-bed it was not as efficient as the Land Packer for this operation.

3. *Rotary Treader Reversed* (*Fig.* 5).—One of the difficulties with stubble mulch farming is breaking down the stubble sufficiently and leaving the stubble on the surface so that it doesn't interfere with the secondary rooting system of the wheat plant. The carriage of the Rotary Treader was reversed and the machine was weighted. This machine did not have an effective packing action but did tease a fair amount of straw back to the surface from the seed-bed.

GERMINATION.

Good germination was obtained when the combination of Disc Harrows for initial cultivation, Scarifier and Disc Harrows for the seed-bed preparation and Combine for sowing was used. Where the Dempster Carrier and 16-inch sweeps were used for seed-bed preparation and the Disc Seeder for sowing the germination was inferior and uneven. The Land Packer was slightly superior to the other treatments when the combination of Disc Harrows initial cultivation, Disc Harrows seed-bed preparation and Disc Seeder for sowing operations was used. The Land Packer was evidently effective when used on a fine seed-bed.

Good germination was also obtained when the combinations Scarifier for initial cultivation, Scarifier and Disc Harrows for seed-bed preparation, Combine and Disc Seeder for sowing were used. Where the Dempster Carrier and 16-inch sweeps were used for the seed-bed preparation the germination was inferior. There appeared to be no difference between the after-sowing treatments.

When the Dempster Carrier and 30-inch sweeps were used for initial cultivation the only plots showing good germination were the combinations Dempster Carrier for initial cultivation, Disc Harrows for seed-bed preparation and the Combine for sowing. All

Fig. 6.—Initial cultivation with 30 inch sweeps leaves the surface rough and most of the straw standing.

Fig. 7.—Following initial cultivation with the scarifier, the preparation of a seed-bed with 16 inch sweeps leaves a rough surface and uneven bed.

other combinations were inferior and the combination Dempster Carrier and 30-inch sweeps initial cultivation, Dempster Carrier and 16-inch sweeps seed-bed preparation and Disc Seeder for sowing resulted in a very poor germination.

An assumed nitrogen deficiency was noticed in all germinating wheat seedlings 2 in. to 4 in. high seen as a yellow band just above ground level and one or two bands or blotches of yellow higher up.

GROWTH.

There was no evidence of a nitrogen deficiency in the plots at this later stage.

As in the germination observations the best plots were the Disc Harrows initial cultivation, Disc Harrows and Scarifier for seed bed preparation and Combine for sowing. (Fig. 8). The best plots were Disc Harrows for initial cultivation, Scarifier for seedbeed preparation and Combine for sowing. This combination gave an excellent germination and vigorous even growth. The plots on which the Dempster Carrier and 16 in. sweeps was used for the seedbed preparation were poor, leaving a lot of surface straw and uneven in growth.

Where the Scarifier was used for initial cultivation the resultant crop, although not as good as the best of the Disc Harrows initial cultivation plots, was quite good where the Disc Harrows or Scarifier were used for the seedbed preparation and the Combine used for sowing. Where the Dempster Carrier and 16 in. sweeps was used for the seedbed preparation and Disc Seeder for sowing, the crop was very uneven and a lot of straw still visible.

The crop was very uneven and patchy where the various combinations were used after initial cultivation with the Dempster Carrier and the 30 in. sweeps. The best plot in this combination was where the Disc Harrows were used for seedbed preparation and the Combine for sowing.

Fig. 8.—Good germination and even growth after cultivation and seed-bed preparation with disc harrows and sowing with combine.

Fig. 9.—Poor germination and uneven growth after cultivation and seed-bed preparation with sweeps and sowing with disc seeder.

Figure 9 shows very patchy germination and growth. Initial cultivation was Dempster Carrier and 30 in. sweeps, seedbed preparation Dempster Carrier and 16 in. sweeps and Disc Seeder for Sowing.

SUMMARY.

The most successful combination of machines during the trials was the Disc Harrows for initial cultivation, Scarifier for seedbed preparation and the Combine for sowing. The Disc Harrows were able to cut up the stubble, leave it on the surface, gave good weed control and an even penetration. The Scarifier also gave a very even penetration, level firm seedbed with the stubble on the surface. The Combine allowed the seed to be placed on the firm moist seedbed at a regular depth and did not turn any of the remaining straw into the topsoil to interfere with the secondary root system of the plants.

The same combination with the Disc Harrows replacing the Scarifier for seedbed preparation was quite good but there was a tendency on the second seedbed preparation to work the ground too fine and bury the straw.

The Scarifier was unsuitable for initial cultivation due to long straw remaining in the paddock but where the straw was broken to approximately 9 in. pieces a good initial cultivation was carried out.

It is necessary to carry out heavy grazing of the stubble with stock to knock the stubble down and break it up if it is to be handled efficiently with the Dempster Carrier with the 30 in. and 16 in. sweeps in the short time available between harvest and fallowing operations.

The Disc Seeder would prove very useful for sowing wheat or oats into stubble.

No definite results were obtained from soil packing treatments after sowing. These machines may prove useful on lighter soils.

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REGENERATION AREAS IN NEW SOUTH WALES

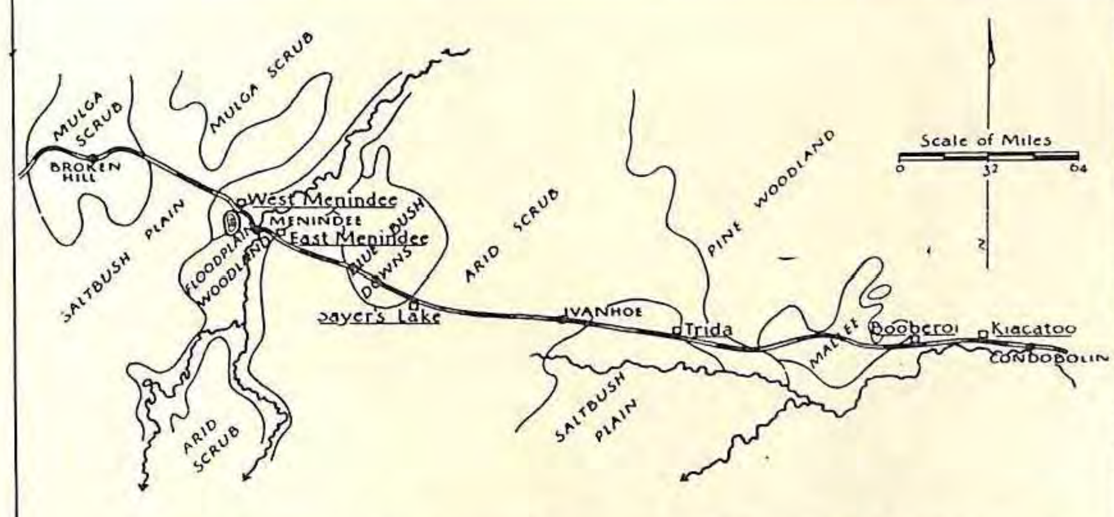
BY

M. E. Stannard, B.Sc.Agr., Soil Conservationist.

THE serious nature of erosion in western N.S.W. has long been appreciated, and soon after the inception of the Soil Conservation Service, a survey of vegetation and erosion of the whole of the west of the State was initiated by Beadle (1). This work was completed in 1946 and the vegetation of the whole of the region was classified into 22 associations, and the erosion and pastoral problems of each vegetation association was treated in detail.

In order to gain further understanding of the nature of erosion, and the pastoral problems associated with it, six areas were selected in different vegetation associations along the Condobolin-Broken Hill railway line. The size of these areas varies from 300 acres to 1,400 acres, and all include a range of soil and pasture types together with varying degrees of soil erosion. Fencing of three of these areas was completed in 1950 and a further two were completed in 1952. The fencing of the sixth area was completed in 1955.

The railway line from Condobolin to Broken Hill passes almost entirely through level to slightly undulating alluvial country, and on such country water erosion is of relatively minor importance. Wind erosion



LOCATION OF SOIL CONSERVATION SERVICE REGENERATION AREAS ALONG CONDOBOLIN - BROKEN HILL RAILWAY

Fig. 1.

of various forms is, however, widespread. Much of the country traversed by the line, such as the mallee scrub, suffers from little or no erosion. Other country, such as the arid scrub, suffers from widespread erosion of a minor nature and therefore does not constitute a serious problem. However, large tracts of relatively treeless or openly timbered country occur, and erosion on much of this country has been very serious in the past, resulting in large areas of scald or active sand ridges. It is on such country that the regeneration areas are situated.

A study of the soils and vegetation has been carried out on each area and the relationship between soils, vegetation and erosion has been elucidated. A study of the regeneration of eroded areas and the changes of the pastures has been continued since fencing, in order to determine the rate and mode of regeneration of the various forms of eroded surfaces and also the effect of climatic conditions on this regeneration and on the pastures of non-eroded soils.

A brief description of the areas and lines of investigation on each is given below. A more detailed report on each area will be given in subsequent issues of this Journal.

KIACATOO REGENERATION AREA.

This area, which totals about 460 acres is situated about 20 miles west of Condobolin near Kiacatoo siding and lies within the Lachlan river flood plain. Fencing was completed in 1950.

The area is generally lightly timbered but with some fairly dense clumps of myall (*Acacia pendula*), and occasional black box (*Eucalyptus bicolor*), and rosewood (*Heterodendron oleifolium*). The soils are generally fairly heavy in texture and vary from those possessing a shallow loamy surface overlying clay on the slightly elevated locations to heavy gilgai types in the lower situations.

Large areas of scald were present when fenced, and also large areas of uneroded soils, the former usually on the slightly

Fig. 2.—Kiacatoo Regeneration Area. Moderate scalding in the early stages of regeneration with roly poly (*Salsola kali*) and slender fruited saltbush (*Atriplex leptocarpum*).

elevated locations. A portion of the area has been subject to stocking for several years and much information has been obtained with regard to the effect of stock on pastures and scald regeneration. Many line transects and plots have been laid down and observations made at regular intervals so that any change in the pastures or the state of eroded soils has been followed throughout.

In addition to the study of the pastures by means of the transects and plots, special study of the more important pasture species has been carried out with a view to determining the persistence and longevity, reproductive capacity and reaction to grazing.

Various native pasture species from other parts of the State and also some introduced species have been sown on this area in order to determine their value in maintaining a stable pasture in this type of country.

With the information gained from these studies it should be possible to give advice as to management of pastures and the possibilities of reseeding, so that a more stable pasture can be maintained, thus reducing the risk of erosion under the varying climatic conditions experienced.

BOOBEROI REGENERATION AREA.

This area, of about 294 acres, is situated some 40 miles west of Condobolin near Booberoi Siding and the fencing was completed in 1950. It lies on the transition zone between the Bimble box-White pine Woodland (*Eucalyptus populifolia-Callitris glauca*), Association and the flood plain of the Lachlan river. The soils are generally light-textured in the surface with clay subsoils at relatively shallow depth, and there occurs only very occasional timber, such as white pine and bimble box. Severe and extensive scalding had occurred, but a good proportion of uneroded soils was included in the area.

Investigations have been undertaken along similar lines to those at Kiacatoo. Continued observations on line transects and plots have been carried out and also studies

Fig. 3.—Booberoi Regeneration Area. Typical severe scald with good regeneration taking place on minor scalding in the background.

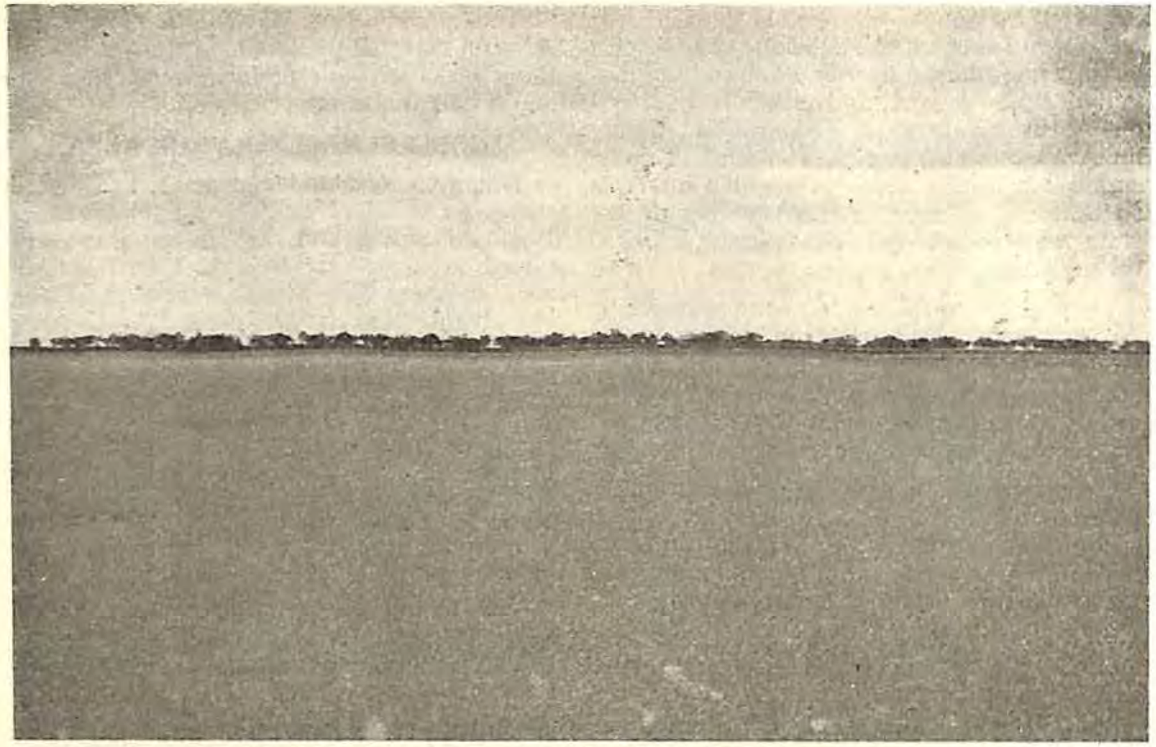


Fig. 4.—Extensive severe scald on Trida Regeneration Area.

on the individual pasture species. As stock have not been allowed on the area since fencing, clipping of the more important pasture species has been undertaken, in order to determine to some extent the effects of grazing on these species.

This area, together with the greater part of the bimble box-white pine country possesses a particular pasture problem in the widespread occurrences of the unpalatable and troublesome wire grass (*Aristida jerichoensis* var *subspinulifera*), and special attention is being given to this species and also to species of greater value which show possibilities of replacing the wire grass.

As with Kiacatoo, various native pasture species from other parts of the State, and also introduced species have been sown on this area.

TRIDA REGENERATION AREA.

This area, which is located about 130 miles west of Condobolin near Trida railway siding, and is of about 1,400 acres and fencing was completed in 1950. It is situated near the northern extremity of the great treeless plain of the south-west of the State, and is classified by Beadle as perennial saltbush (*Atriplex vesicaria*), association.

No timber occurs on the area, apart from black box in the depressed locations receiving local drainage. Soils vary from those possessing a light-textured surface with clay subsoil, to the heavier-textured gilgai soils. The former types, which occurred principally on the slightly elevated situations, were in general very severely eroded at the time of fencing.

It is considered that this area formerly supported a good stand of perennial saltbush but only occasional plants were present when fenced. Special attention is being given to this species and many trial sowings have been carried out to bring about its spread on both eroded and non-eroded soils.

Observations on transects and plots have been continued since fencing, and studies on the more important shrub and grass species have been undertaken. A reclamation trial

Fig. 5.—A transect for the study of George's bluebush (*Kochia Georgei*) on Sayer's Lake Regeneration Area.

involving various forms of mechanical treatment and the sowing of different species of saltbush, cereals and other species, was carried out in 1952, with very satisfactory results.

SAYER'S LAKE REGENERATION AREA.

This area which is situated about 55 miles west of Ivanhoe and near Manara siding includes some 1,040 acres and the fencing was completed in 1952. It falls on the edge of Beadle's bluebush (*Kochia pyramidata*), association and is of slightly undulating terrain with some slopes up to 2 per cent. The area contains some scattered clumps of timber, principally rosewood, belah (*Casuarina lepidophloia*), and nelia (*Acacia loderi*). The soils are for the most part sandy in the surface but possessing a clay subsoil at shallow depth, although some of the soils are highly calcareous and do not possess the clay subsoil.

Erosion was severe and widespread at the time of fencing, being generally in the form of mosaic of scalds and hummocks with some degree of sand drift. Water erosion in the form of small rills was present on the more sloping scalded areas.

Observations on transects and plots has been carried out at regular intervals since fencing and the effects of climatic conditions on the pastures and on eroded areas is being followed. Special attention is being given to the bluebushes and other shrubs, which not only provide good fodder but are also highly drought resistant and live for a long period, and therefore are very valuable in mitigating erosion.

EAST MENINDEE REGENERATION AREA.

This area, of about 700 acres is situated about seven miles east of Menindee and fencing was completed in 1952. It lies within the Darling river flood plain and supports scattered clumps of black box on the slightly raised sandy islands. The soils are mostly heavy-textured, grey and self-mulching, but the sandy islands and the adjacent areas together with other slightly raised patches possess a grey clay underlying the sandy surface. Some old consolidated sand dunes also occur in the area.

Erosion in the form of severe scalding was present on the borders of the box clumps on sandy islands and also on the small raised areas, whilst on the consolidated sand dunes, scalding occurred in association with some sand drift.

Observations on transects and plots laid down on both eroded and non-eroded soils have been carried out at regular intervals, and a special study is being made of some species, particularly Mitchell grass (*Astrebla lappacea*), and Queensland blue grass (*Dichantheum sericeum*), which occur on the heavier-textured soils.

This area is liable to flooding from the Darling river and this brings about great changes in the vegetation and the structure of the soils, although the flooding of scalded areas has little effect on regeneration.

WEST MENINDEE REGENERATION AREA.

The fencing of this area, which is located about nine miles west of Menindee, adjacent to the main Broken Hill-Menindee road, was not completed until 1955. It is of about 270 acres and is generally treeless apart from a few belah, and, although included in Beadle's bluebush association, the soils are much more sandy than those of the Sayer's Lake Area. On this area the soils include sand-ridge soils, truncated calcareous soils with plentiful sand hummocks and sandy clay flats.

Erosion in the form of scalding occurred at the toes of the sand ridges, and on the flats, whilst sand drift was common on the sand ridges and sand hummocks.

Observations have been initiated on transects and plots on the soils suffering from the various forms of erosion. A special study is being made on the bluebushes and

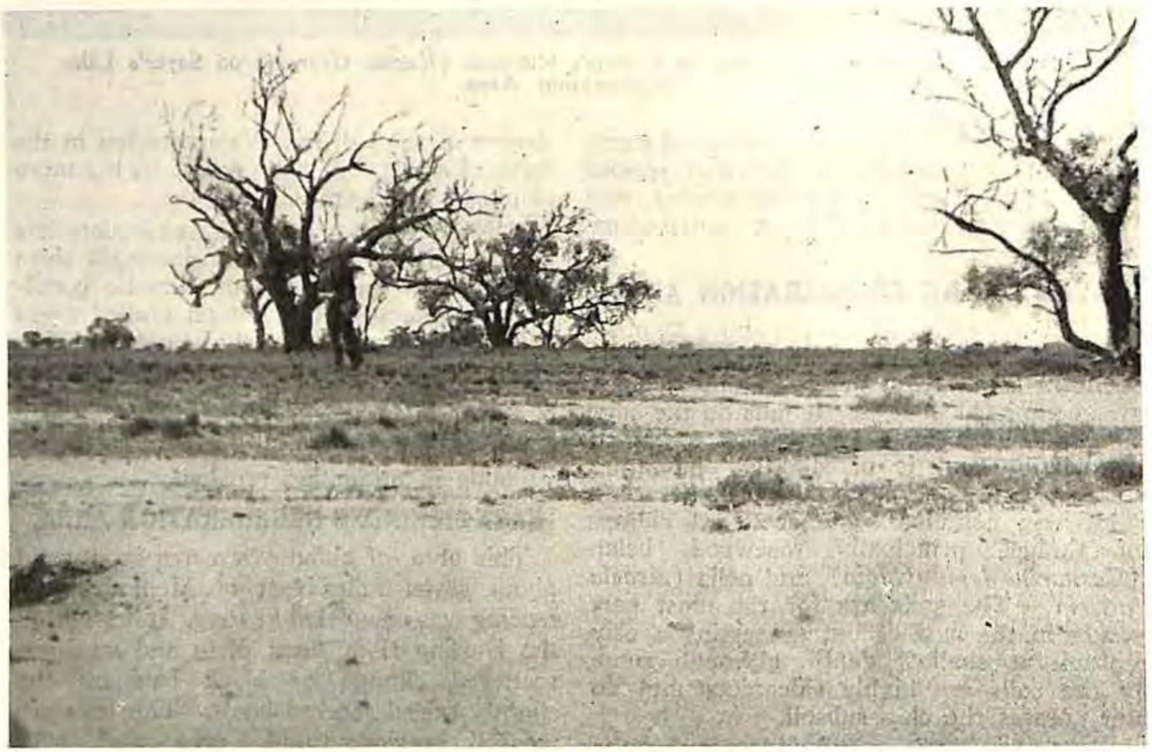


Fig. 6.—East Menindee Regeneration Area. Typical of scalding around the edges of sandy "islands" carrying black box (*E. bicolor*).

Fig. 7.—Clumps of sandhill canegrass or spinifex (*Zygochloa paradoxa*) with arabian grass (*Schismus barbatus*) stabilising loose sand on West Menindee Regeneration Area.

on the sandhill canegrass (*Zygochloa paradoxa*), which is very valuable in stabilizing drift sand.

CONCLUSION.

A good deal of very valuable information on the regeneration of eroded areas by natural or artificial means has been obtained from these areas, also considerable data on the native pasture species over a wide range of climatic conditions, and soil and vegetation types. Specific recommendations aimed at reducing the extent or risk of erosion and at the same time giving great improvement in the pastures can now be made for many districts, but such recommendations are more readily applicable in the better rainfall districts of the west.

A report on the results of investigations carried out to date will be given for each area in subsequent issues of this Journal. Such lines of investigation as already laid down may be modified or intensified as conditions warrant.

REFERENCES.

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CONSERVATION FLYING IN THE HUME CATCHMENT

By
T. J. Swadling, H.D.A., District Soil Conservationist.

The introduction of the aeroplane into the steeper pasture country of the Albury Soil Conservation Sub-district, east of the Hume Highway, has ushered in a new era of land use. The hard-to-get-at back paddocks are being topdressed from the air and, instead of being a neglected and doubtful asset, they are now taking their place as highly productive grazing lands.

The need for pasture improvement in these areas is as great as ever, even though the reduction in rabbit population brought about by myxomatosis has been a considerable help in improving the natural grass cover.

Much of this area is within the catchment of the Hume Reservoir and the need to reduce erosion and consequent siltation in the storage area cannot be too greatly stressed.

The whole area enjoys a good reliable rainfall of upwards of 27 inches per annum with much higher averages in the upper catchment and, once pastures are established, makes excellent grazing land. As the unimproved value of this country has been fairly low in the past and the potential carrying capacity when improved is so great, a considerable incentive exists for owners to carry out the necessary improvements, provided this can be done economically.

Fig. 1.—Typical country for aerial topdressing. **Note poor pasture cover and pasture** furrows in the foreground.

Fig. 2.—**Filling the loader from the bulk fertiliser supply.**

In many cases the cleared hills carry a quantity of subterranean clover which has been carried by stock from the improved and more accessible parts of the property and the only factor limiting growth of excellent pasture is a deficiency of phosphate in the soils.

Until some few years ago the Hume Catchment was relatively free from erosion but with subdivision of the larger properties and extensive clearing of the steeper country, signs of erosion have become increasingly evident. A series of excellent seasons over recent years have also served to mask the potential dangers and it was not until the extensive and disastrous bush fires of 1952 that landholders in the area began to take an active interest in erosion prevention.

Owing to the steep topography, areas where mechanical control measures may be used are very limited and it is necessary to attack the problem by other means.

For cleared areas subjected to grazing, no better protection has been found than a good cover of pasture. In these steep, relatively inaccessible areas the aeroplane offers a quick and economic way of applying both seed and superphosphate.

In New Zealand this method has found ready favour with the hill farmers and figures published recently show that over 200,000 tons of superphosphate were applied by air during 1954. This quantity of superphosphate was sufficient to topdress about 2,000,000 acres.

This programme in New Zealand was carried out throughout the year and was limited only by adverse flying conditions. Bulk handling of fertilisers and co-operative schemes between landholders also increased the operating efficiency.

Although aerial topdressing in New South Wales has not yet achieved the importance that it has in New Zealand, it is rapidly gaining favour and several commercial companies operate in the Albury area.

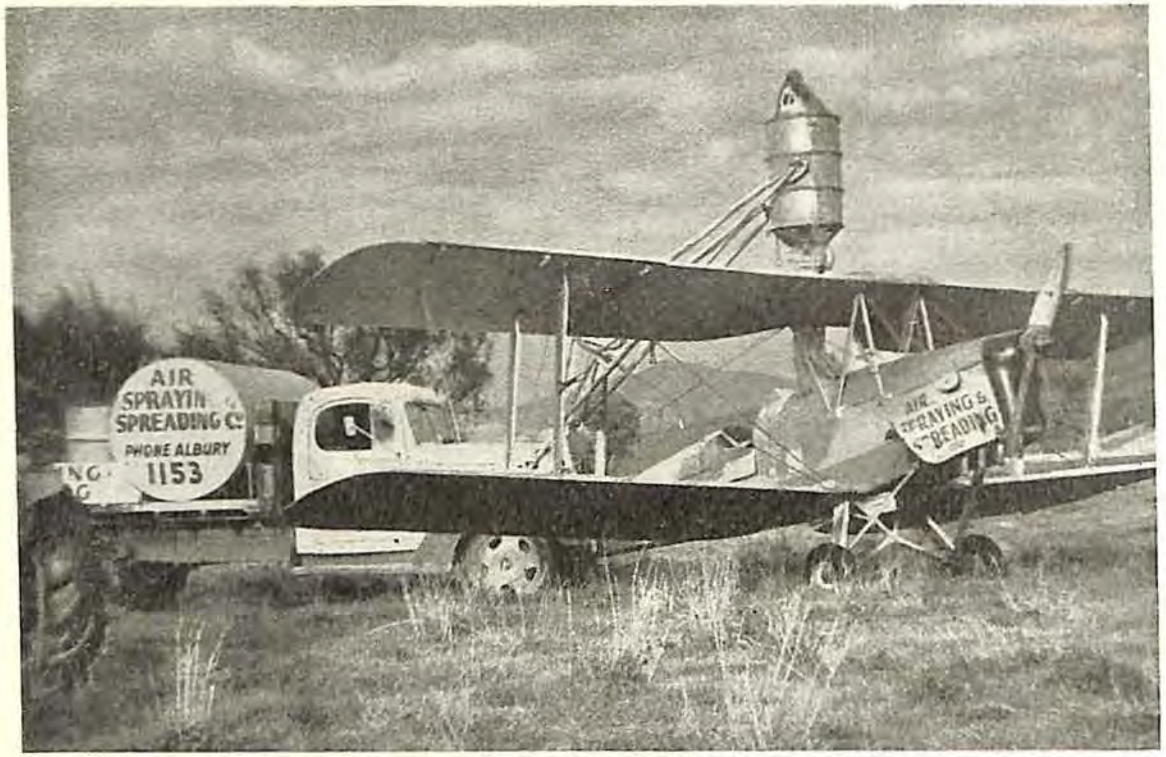

Fig. 3.—Superphosphate is transferred to aircraft by hydraulically operated loader.

LANDING STRIPS.

With the light planes generally used for this work, which are mostly Tiger Moths, a landing strip 500 yards in length with approaches free from tall trees and power or telephone lines are all that is necessary. An uphill or downhill aspect does not detract from serviceability although an absence of cross fall is desirable. The strip should, of course, be free of stumps, stones or large holes and generally any paddock that a car could be driven across at 30-40 m.p.h. is satisfactory.

For quick turn-round of aircraft it is desirable to have the strip located within a mile of the area to be treated. The quicker the turn round the lower the costs of the job.

Any flying time over 5 minutes per trip is considered uneconomic and with mechanical loaders the aircraft can be loaded on the ground in 30 to 60 seconds. A round trip of 5-7 minutes from take off to take off is considered by the pilots to be satisfactory.

HANDLING AND SPREADING.

All the companies operating in this area supply a mechanical loader and driver on each job in addition to the planes. The landholder is required to have on hand at the strip the necessary fertiliser and two or three men, depending on his own method of handling the bags or bulk supply.

In good flying conditions hard work is the order of the day and amazing quantities of superphosphate can be spread by two planes working on conjunction throughout the day.

The loader usually consists of a bin or container mounted on the front of a truck chassis and raised or lowered by hydraulic control. The bin is filled by hand from the platform of the truck or trailer used to transport the fertiliser to the strip. When the plane taxis up, the bin is raised and driven into position over the hopper of the aircraft. A canvas chute in the bottom of the loader bin is inserted into the aircraft hopper and the fertiliser transferred to the aircraft in a matter of seconds.

While the plane becomes airborne the loader bin is quickly refilled and ready for the returning second machine.

When spreading the super the plane is usually flown at about 100 feet altitude along the contour of the hills being top dressed. The fertiliser is discharged through a chute and is dispersed by the slipstream, landing in a swathe about 50-60 feet wide. Accurate dropping seems remarkably easy for the experienced pilots and an even spread without wastage is the result.

The aircraft hoppers are fitted with regulated chutes and any given quantity per acre can be applied. Granulated superphosphate does not appear to have a big advantage over ordinary superphosphate although less dust is apparent. In this country with large holdings the drift of this finer material seldom represents a complete loss since it falls on other parts of the property where its effects can only be beneficial.

FLYING CONDITIONS.

Ideal still air flying weather for top dressing is difficult to find and maintain. However, providing the wind is not too strong and is reasonably steady, top dressing may be carried out, although air currents over some valleys make the operation highly dangerous during certain times of the day. Normally, however, aerial top dressing can be carried out almost the year round in this region.

COSTS.

Various factors can obviously affect the cost of this work. However, the principal factors are the length of turn round for the aircraft from take off to take off and the quantity of fertiliser to be spread on a particular job.

Generally, however, the rates charged are in the vicinity of £6 to £7 per ton.

Fig. 4.—Soil Conservation from 100 feet up.

At first glance these rates may seem excessive. They do however represent only about 20 per cent. of the total cost of the superphosphate and landholders find that the cost of applying fertilisers by conventional methods are often very little less when labour, depreciation and wear and tear of machinery are all taken into consideration. The greatly increased carrying capacity more than covers the cost of topdressing.

Costs per acre may, however, be minimised by applying a heavy dressing of fertiliser initially, instead of lighter dressings over a number of years. Research shows that this results in a greater initial response from the pastures and this response is maintained for several years without the need for further applications. Where financial consideration permits, applications of 4-5 cwt. of superphosphate every 4-5 years are said to give excellent results.

CONCLUSION.

Aerial top dressing has proved in the Hume Catchment to be an economical and efficient method of improving country once thought impossible to treat. Pasture cover and stocking rates can be increased in this way rapidly and safely, while the improved pasture cover affords additional protection to these steep lands, reducing run-off and erosion to a marked degree.

The rapidity of this control by topdressing in the higher rainfall country is one of the more remarkable features of this work and good cover can often be achieved in the first season.

As the pastures develop and build up fertility in the soil the water-retaining capacity will increase. With efficient management and judicious stocking, particularly during the first few years, these treated lands should never pose a serious threat to the storage capacity of the Hume Weir.

Fig. 5.—Improved pastures on the Hume Reservoir foreshores respond to superphosphate.

Much planning and thought is necessary to ensure that the treated pastures can be utilised to their full capacity without detriment either to the pasture or to the stability of the soils. As the carrying capacity builds up, more subdivision of holdings, provision of stock water and management of stock with rotational grazing will be necessary. The greatly increased carrying capacity of the land will, however, more than compensate for this additional care.

As the aircraft operators improve their techniques and skill the tonnage dropped per day is being increased until today as much as 50 tons of fertiliser has been broadcast by two aircraft in a single operating day.

With further experience and the introduction of new equipment and techniques this rate will probably be improved upon still. The landholder should benefit from this increased efficiency by reduction in costs, until aerial spreading of fertilisers may become commonplace even on the more accessible parts of Australia.

Experience has already proved that aerial topdressing is a quick, efficient and cheap way of improving thousands of acres of poor quality pastures in the rough hills which comprise the greater part of the Hume Catchment. Only time alone can confirm the great part aircraft are destined to play in this important corner of our land in protecting the land from erosion and the reservoirs from siltation.

"GAMBARRA" DEMONSTRATION AREA

BY

J. H. Woolner, H.D.A., Soil Conservationist.

In the summer of 1946-47, the Soil Conservation Service commenced the task of reclaiming an area of arable land ravaged to a major degree by soil erosion. In this, the summer of 1955-56 is given a brief report on the results achieved in the past eight years by the combined efforts of the Soil Conservation Service and the landholders.

The work of this Service began with a contour survey, passed on to the technical planning of the extension services field staff and then the major plant of earth-moving equipment carried out the plan of control devised.

"Gambarra" Demonstration area included all of one farm holding and portions of two adjoining holdings. It is the complete catchment area of a minor valley and embraces an area of about 750 acres situated three miles north-west of Greenthorpe and between Grenfell and Cowra.

The whole area was arable land of slopes up to 8 per cent., all but a small part of which had been intensively cultivated on a

Fig. 1.—Useful pasture in an old gully, now protected from run-off. Note the perpendicular edges not grassed over.

wheat-fallow rotation for twenty-five years, until top-soil loss by run-off water, nitrogen deficiency and lack of humus had all contributed their share in reducing wheat crop yields on fallow land to a mere twelve bushels per acre in 1947 harvest.

Hand in hand with the gradually declining production came the development of "rilling", followed by gully erosion which reached major proportions by 1947.

The foregoing description could be the brief history of many thousands of acres of this district, which would rapidly deteriorate if returned to intensive wheat culture without the security measures of soil erosion control.

NINE YEARS LATER.

"Gambarra", in 1955-56, presents an example of complete erosion control. Production is equal to or better than its best as new land and is continuing to increase, with fertility rising by increasing degrees yearly, ample stock water supply of clear water and well nourished stock with light incidence of disease.

Waterways on this demonstration area were fenced on completion to permit of controlled grazing. More grazing has consistently been obtained from them than from the paddocks adjoining, while always keeping them protected by dense cover. On five occasions during the eight years it has been advisable to reduce the height of waterway cover by mowing and baling surplus high growth on some of them. In 1950 meadow hay to the amount of 500 bales was removed as surplus growth from waterways, and this year 300 bales have been harvested from three sections of waterway which were not grazed sufficiently frequently to maintain the essential short dense vegetative growth.

Water supply for stock and garden has always been in ample quantity since the conservation measures were installed. All

Fig. 2.—A first-class waterway carrying run-off from the south-western part of the demonstration into a dam.

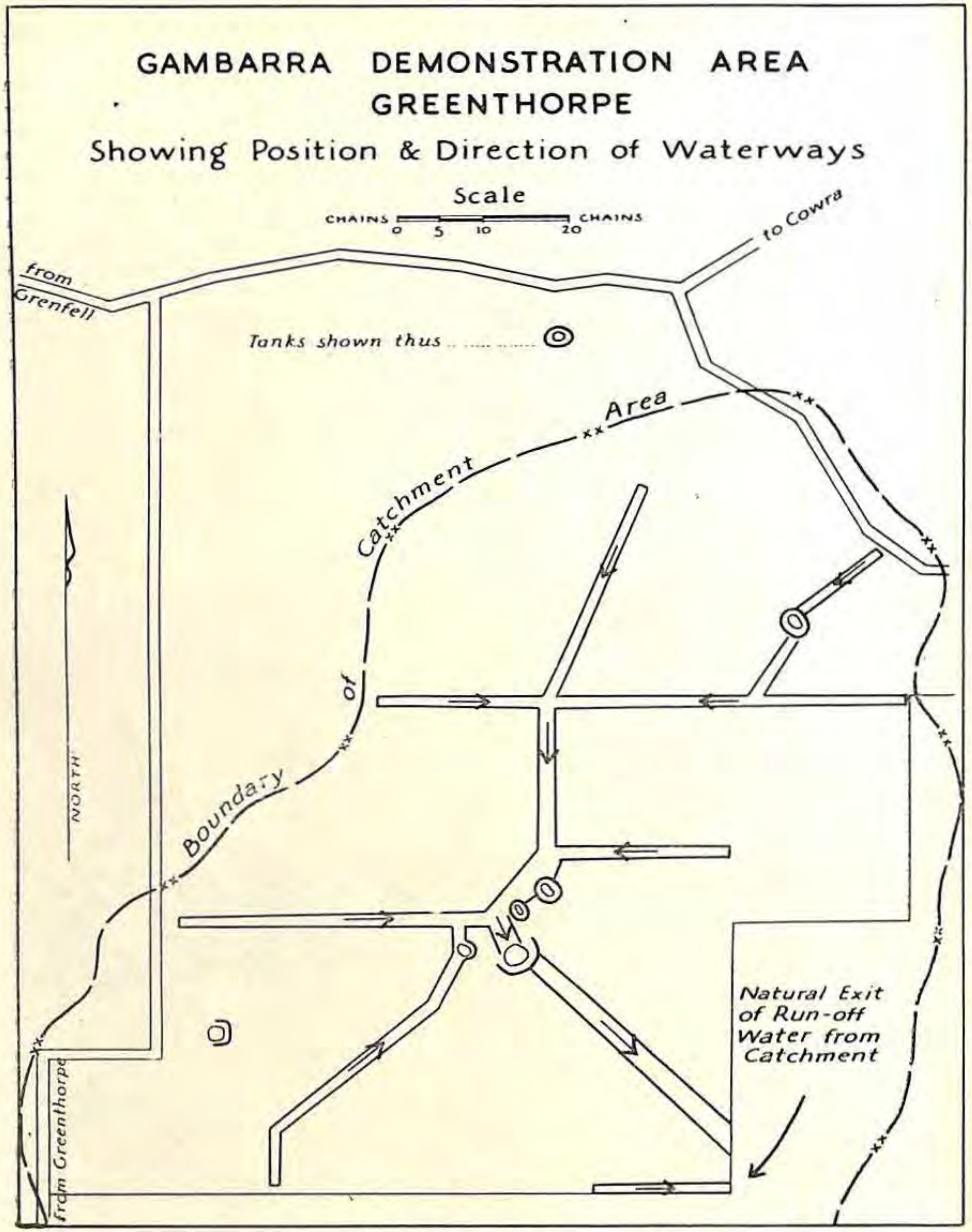

Fig. 3.—Plan of Gambarra Demonstration.

except one tank obtain their catchment from waterways alone and are holding clear, sweet supplies. In these later years the water run-off into tanks is quite small in size of flow but this small flow continues for many days after each fall of rain.

Since the mechanical part of soil erosion control work was completed in 1948, a suitable rotation of cereal crops and grazing has been adhered to with excellent results on the small complete farm area. The rotation adopted produces one third of the area under cereal crop each year. Two consecutive cereal crops, three years of subterranean clover-rye grass pasture and the major portion of a year as fallowed land, constitutes the six year programme for each of the three sections of this farm. In the spring of 1955, an area of about twenty-five acres has been utilized for meadow hay. It produced two tons per acre in this its first year as pasture after two consecutive wheat crops.

On this complete farm area of 385 acres, within the whole Demonstration area, Border Leicester cross ewes are run for fat lamb production. Four hundred ewes have been pastured continuously and the owner intends to increase this number now as it is evident over the last two years that a further 100 or 150 breeding ewes could be well fed without any possible risk of overstocking.

With spraying as a standard procedure for wheat crops, the problem of skeleton weed is no longer a menace to high yields. The winning wheat crop of this districts' competition, this year, has been grown on portion of the "Gambarra" demonstration area under contour farming practices, having the complete protection of graded banks. The competition judge estimated the yield of this crop to be 42 bushels per acre.

The landholders of this demonstration area have not cultivated the constructed graded banks as they are of the opinion that the small area of cropping land not sown is of little consequence on acreage yield and the maintenance of channel capacity is of greater importance. These permanent banks produce an abundance of pasture which is utilised to advantage in the grazing periods of the fields.

In several places throughout the area, eroded gullies were filled and returned to normal cultivation. These reclaimed pieces are no longer evident except after careful examination. A particularly large gullied watercourse in the central drainage line of the catchment was not filled in or treated in any way except to divert all run-off water from it to a constructed waterway. This gully was of dimensions uneconomical to fill. However, it has established the fact that the perpendicular edges will not readily revegetate, and the slumping of the vertical sides to a gentle slope proceeds at such a slow rate that a loss of useful area is sustained by neglecting to batter in the perpendicular edges of these protected gullies.

Also established is the fact that given their share of topdressing, with superphosphate, the old gully floors and sloping sides will quickly supply a really worthwhile amount of grazing for stock, which appear to favour the sheltered area. The prerequisite to this is that all run-off water be diverted and that only the rainfall actually falling in the gully itself be permitted in it.

WATERWAYS.

Treatment of waterways presents problems of farm management to maintain their utmost effectiveness. Upon them depends the safe disposal of run-off water resulting from high-intensity storms. A well-established lawn-like cover of vegetation is the desirable state of waterways. To have this at all times exercises the ingenuity of a farm manager.

Fencing of them to control grazing is an almost essential procedure. In lean years the available grazing from them will be greater than from the remainder of the field but must be discontinued while ample short, dense cover of herbage remains. In flush years, when the normal stocking rate is inadequate to cope with lush pastures in the fields, good practice would be to ensure sufficient stocking of waterways to maintain them at the desired short dense state. Allowing waterways to grow tall, bulky fodder, necessitating mowing, appears to reduce the density of the cover with consequent loss of effectiveness for a period. Grazing down moderately at more frequent intervals, in seasons of lush growth would appear to produce the desired results.

In conclusoin, there is no doubt in the minds of the owners of "Gambarra" Demonstration Area that this land, approaching ruin nine years ago, is now stable and high-producing and will remain as an example of results achieved from the co-operation of technical information, mechanical operation and good management.

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SOIL CONSERVATION ACTIVITIES AT SINGLETON

BY

W. Reynolds, D.D.A., Soil Conservationist.

THE Singleton Sub-district office was established in 1950 as one of seven sub-districts under the Hunter District of the Soil Conservation Service which has its headquarters at Scone. The area allotted to the Singleton Sub-district runs roughly from Jerry's Plains, through Broke, to Newcastle in an east-west direction, and is bounded in the north by the northern water-shed of the Williams River, thus including the greater part of the lands of the central and lower Hunter Valley.

TOPOGRAPHY.

This ranges from almost level along the river flats through undulating country which forms the bulk of the district to mountainous on the north and south boundaries. Average altitude is approximately 150 feet above sea level. Excluding the mountainous extremities, slopes up to 3 per cent. predominate with smaller areas up to 8 per cent. slope.

CLIMATE.

Climate is mild with an average summer temperature of 74 degrees, winter of 53 degrees. Rainfall fluctuates between 16 and 40 inches annually, but averages 28 inches per year, with spasmodic periods of semi-drought in the spring months. Proximity to mountains and unseasonal rainfall gives the Broke, Warkworth, Jerry's Plains belt a more severe climate. During the years strong

Fig. 1.—Severe sheet erosion near Jerry's Plains.

Fig. 2.—A gully more than ten feet deep near Mt. Thorley.

westerly winds, which are excessively dry, prevail for long periods in the spring and autumn, greatly retarding plant growth, particularly on the central Hunter area. These winds have not been so prevalent of late years.

SOILS.

Excluding the river flats the soils are generally poor in the southern and western portions of the district. These are of the Upper Marine Series consisting of shale formations, and conglomerates with some caps of Triassic Hawkesbury Sandstone. On the ridge on the western and northern sections the soils vary considerably in character from sandy, gravelly loam and alluvium, to heavy clay. Along the southern portions soils are generally alkaline of a sandy nature and low in fertility. The poorer soils and severe climatic conditions in the Pokolbin-Broke-Jerry's Plains area reflects strongly in the poor vegetative cover.

EROSION DAMAGE.

Other than stream bank erosion, which comes under the control of the Water Conservation and Irrigation Commission, flat lands adjoining the Hunter River show no appreciable erosion. Large areas to the west near Jerry's Plains show severe sheet and gully erosion, which is affecting production. Lesser but still serious degrees of erosion are to be seen in the south, north-west, north-eastern sections. Little erosion is evident in territory lying between Maitland, Cessnock and the sea. Around Eccleston, Dungog, and Seaham sheet erosion predominates, whilst in the Goorangoola, Mirannie, Camberwell and Broke belt, moderate gullying and serious sheet erosion are to be seen.

LAND USE AND VEGETATION.

West and north of Singleton the chief pursuits are the grazing of both sheep and cattle on large holdings remote from the river. East of Singleton one encounters

Fig. 3.—Revegetation of a hill that had been bare for thirty years at Mt. Thorley.

more cultivation and better soil types. Extensive grazing is carried out on the poorer soils which are heavily taxed by one or more of the following: Injudicious grazing, rabbits, drying winds and erratic rainfall, all of which are highly conducive to sheet and gully erosion.

The main natural grasses are corkscrew (*Stipa Sp.*), barley grass (*Hordeum sp.*) with areas of Queensland blue grass, couch grass (*Cynodon dactylon*) and white top (*Danthonia sp.*) the latter having been greatly thinned out by over-grazing, but with careful pasture management is making a slow comeback on some properties. Ball clover (*Trifolium glomeratum*), haresfoot clover (*Trifolium arvense*) and burr medic (*Medicago denticulata*) form the bulk of native legumes.

Of the natural timber, ironbark (*E. sideroxylon*), spotted gum (*E. maculata*) and black or river oak (*Casuarina leuhmanni*) predominate with an occasional white or yellow box. Much good milling hardwood timber is being cut in the mountainous Goorangoola-Mt. Carrow area.

Introduced grasses and legumes are Wimmera rye, Rhodes grass, *Phalaris tuberosa,* in conjunction with lucerne, Mt. Barker sub-clover, barrel and ball clover. Generous application of superphosphate is necessary to encourage growth of legumes.

SERVICE ACTIVITIES.

Since establishment of Singleton sub-district office of the Soil Conservation Service, plant has been operating mostly on the poorer, eroded areas to the south and west of Singleton, which have been grazed and farmed for more than a hundred years. Mechanical soil conservation measures are being implemented in an effort to assist in rapid pasture regeneration. These mechanical controls consist very largely of pasture furrows, which where necessary are used in conjunction with absorption and/or diversion banks, all forming part of a water absorbing system of land use which this district urgently requires. To demonstrate these techniques major demonstrations have been carried out by the Singleton plant at:—

Jerry's Plains: "Montrose" demonstration.

Mount Thorley: "Mount Thorley" demonstration.

Whittingham: "Castle Forbes" demonstration.

Near Oban Vale: "Green Hollow" demonstration.

The same plant has constructed nineteen minor demonstrations in the Vere, Mt. Thorley, Jerry's Plains, Ravensworth, Hebden and Singleton areas.

The Plant Hire Scheme is being favourably received in this district. Starting with hire of plant without operators, the stage has been reached where the whole Singleton plant, consisting of two bulldozers and ancillary equipment, has worked over thousands of acres in control of erosion. At the time of writing approximately 130 landholders within this sub-district have requested advice, inspection, or work on their properties, while hundreds of shelter trees have been supplied to people interested in building up farm shelter belts.

CONCLUSION.

The activities of the Soil Conservation Service in this, as in other areas, are being directed towards demonstrating the various techniques applied to soil conservation and at the same time encouraging the landholders to adopt whatever measures they can, within the limits of normal or modified farm machinery. The construction of banks and furrows is not the end of the programme —this must, to achieve maximum effect, be coupled with seeding, top-dressing, fencing (in some cases) and judicious grazing. After all, it is the development and maintenance of a good pasture sward that is the final goal. More detailed information regarding the results of mechanical works on the various soil types and pasture spp. in the various soil and climatic area of this sub-district will be given in a later article.

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HUNTER RIVER FLOOD RESTORATION

1. After the floods in February, 1955, Soil Conservation Service plant assisted in the rehabilitation of farms in the upper part of the Hunter Valley. Messrs. L. W. Smith and N. R. Nebauer of the Soil Conservation Service inspect a sanded area near Singleton. The pure sand deposited at this spot was blown about by the wind and at times made travel difficult on the Singleton-Putty road which is near the telegraph pole.

2. Rich cultivation lands were torn about by flood waters and here, on an area near Singleton, the flood scoured the soil away to plough bottom. About a chain further on, a heavy deposition of sand can be seen. This land previously carried a good stand of lucerne.

3. Sand, silt and debris was built up to the height of the fence. A bulldozer was used to move the silt and debris from one side of the fence to make it stockproof again. One problem continually facing landholders was "where can we put the sand?" Much work still remains to clean this fence of sand and debris on the other side and then remove grass and debris from between the wires and around the posts.

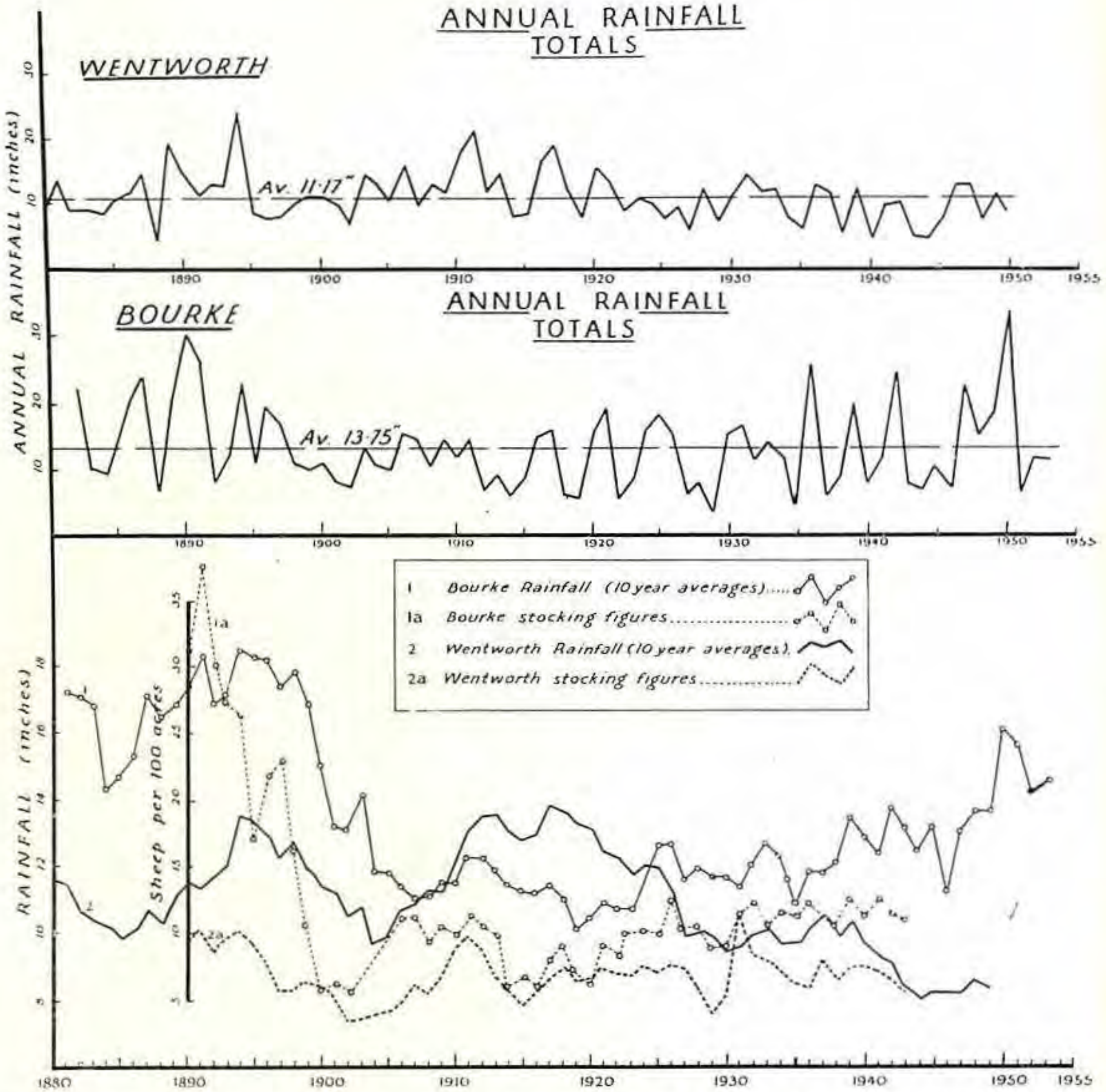

Fig. 2.—Relationship between stock numbers and rainfall regime in two districts, Bourke and Wentworth.

very rapidly to reach 15½ million in 1887, and was maintained near this figure for a period of ten years. From a figure of approximately 13½ million in 1897 there was a marked drop to 3½ million in 1902 following a series of drought years from 1898 to 1902, inclusive. By 1910 the figure had increased to 6½ million and stock population then became relatively stable, fluctuating between 5 and 7 millions to the present time.

The extremely heavy stocking which took place in the 1880's, allied with a rapid increase in the rabbit population over the same period, took heavy toll of the pasture and soils of the region. The deterioration of pastures and initiation of widespread erosion can be generally traced to this period, culminating in the great drought of 1902. Since that time there has undoubtedly been some improvement in the natural pastures but, where erosion was severe, little, if any, improvement has taken place and eroded areas have invariably increased with each drought.

Since 1902, the administration of lands within the region has been carried out by the Western Lands Commission operating under the Western Lands Act, under which all lands within the area are held under lease and alienation of land is not permitted.

With the exception of the mining city of Broken Hill, the area is sparsely populated and, apart from State highways and some main roads, road communications are poor. The larger towns of Broken Hill, Bourke and Cobar are connected to Sydney by rail. Mining has been an important industry in many places during the nineteenth century and has no doubt contributed largely to pastoral settlement. In recent years Broken Hill and Cobar have been active mining centres, while in the past such centres as Mt. Hope, Lightning Ridge, White Cliffs, Milparinka and many others were important.

CLIMATE.

The climate of this region is semi-arid to arid and, with the exception of a small area in the extreme north-east corner, the average annual rainfall is less than 15 inches, decreasing to about 5 inches in the extreme north-west. The occurrence of rainfall throughout the Western Division is highly irregular so that prolonged droughts are a common feature of the climate.

Yearly temperatures show a wide range and may vary from a maximum of 120°F. in summer to a minimum of 30°F. in winter. Mean monthly maximum temperatures for Tibooburra in the north-west corner varies from about 97°F. in January and February to about 64°F. in July. Temperatures tend to increase from south to north.

Relative humidities throughout the area are low, particularly in summer, during which the mean monthly humidity approximates 40 per cent., ranging up to 60 to 70 per cent. in winter. As a result of high temperatures and low humidities, evaporation throughout the Western Division is very high. Broken Hill in the Far West has a mean annual evaporation of 90 inches varying from 12 inches per month in the summer months to 3 inches per month during the winter months.

As in all agricultural or pastoral pursuits, the most important component of the climate is the rainfall. The main feature of the rainfall is, firstly, the low annual average over the greater part of the area and, secondly, the great variability in the amount of annual falls. There is a slight seasonal character in that the northern portion of the area receives a greater portion of its rainfall in the summer, while the southern portion receives a greater proportion in the winter months. This feature is shown diagrammatically in Fig. 1, where the monthly averages for Bourke, Coan Downs and Wentworth, located respectively in the northern, central and southern parts of the Western Division, are shown.

As stated previously, prolonged droughts are a common feature of the climate. Although the lack of rainfall is the prime cause of drought, other factors tend to accentuate the effects of low rainfall. High rabbit populations and infestation by grasshoppers take their toll on the pastures and help to initiate and accentuate soil erosion. Winds of high velocities, particularly in the summer months, rapidly desiccate the soil and vegetation, causing soil erosion and pasture destruction. Any dry period is rendered far more severe when strong winds are prevalent.

Some of the pasture species in the Western Division, particularly the saltbushes and bluebushes, can withstand long dry periods and will remain in relatively good health provided they are not subjected to excessive grazing. Many other pasture species are of good feed value, even when dried off, and such dry feed will be available until they disintegrate, which in some cases may be well over twelve months. One very dry year therefore will not necessarily cause a serious lack of feed, but when two or more successively dry years occur the dry pasture species will disintegrate and the bushes will die, particularly under grazing, causing widespread erosion and stock losses.

In order to reduce the severity of the longer dry period, the introduction or re-

Fig. 4.—Typical shrub woodland of bimble box (*Euc. populifolia*), white pine (*Callitris glauca*) and wilga (*Geijera parviflora*) on gently undulating country in the Mount Hope district.

establishment of the more persistent pasture species should be encouraged.

It is of particular interest to study the past climatic trend in this region, particularly from the point of view of its effect on early pastoral development and subsequent recession. In Fig. 2, the annual rainfall figures for two centres in the Western Division have been analysed to give the average annual rainfall for the ten years prior to each year, this analysis being presented as a graph. The ten-year period was chosen because it was considered that it would be long enough to dampen the effects of marked irregularities, but sufficiently short to show the short-term trends which have taken place during the eighty years for which recordings are available. Included on this graph are the stocking figures in the Pastures Protection districts surrounding the centres concerned. The total annual falls for each centre have also been graphed separately on Fig. 2.

Fig. 2 therefore shows many of the important features of the rainfall in the Western Division. The graphs depicting total annual rainfall for each centre serve to show the marked irregularity of annual falls from year to year. The percentage deviation from the mean at Wentworth is 26.9 per cent., while that at Bourke is 34.1 per cent. (Beadle (1)).

The graph of progressive ten-year averages is of particular interest in the case of Bourke and shows what happened in the early settlement of the Western Division. Up till 1898 the annual average rainfall for Bourke approximated 18 inches and during this time stock numbers in this district reached a peak of nearly 37 sheep per 100 acres, which is equivalent to approximately one sheep per 3 acres. It will be readily realised that this is more than a reasonable stocking rate for country receiving an 18-inch average rainfall. However, the succession of five dry years from 1898 to 1902, allied with a high stock population and a heavy infestation of rabbits, took a heavy toll of pastures and initiated widespread erosion.

Since that time Bourke rainfall has followed a fairly stable course, showing a tendency to increase over recent years. The graph of stock numbers follows fairly closely to that of the ten-year average rainfall.

The rainfall regime at the southern end of the Division is shown by the graph for Wentworth. The graph of annual totals shows much less variation throughout. Particularly important is that the years preceding 1900 are not greatly different from the average apart from a slight build-up due to high totals during the years 1881 to 1895. The drop into the trough in 1904 is much steadier than that at Bourke, and this same steadier drop is also repeated in stock numbers. Following the 1902 drought the rainfall trends at Wentworth show marked contrast to those at Bourke. From 1904 there has been a marked rise in the graph of ten-year averages to a peak in 1917 at which time the ten-year average almost reached 14 inches. After 1917 the graph shows a steady decline to a record low in 1944. Bourke, on the other hand, after reaching a record low in 1919, has shown a steady increase reaching a peak in 1950.

Stock numbers in the Wentworth district have remained fairly stable and have not followed the definite trends shown by rainfall.

These graphs show that there has been a considerable change in the rainfall regime over the northern part of the Division since 1900 and that this change was mainly responsible for the widespread depression which occurred in the Western Division at that time. In contrast, the southern portion of the Division was not subjected to the same marked change at the turn of the century, but rainfall trends have been more or less opposite to those of the northern portion.

LAND FORMS, SOILS AND VEGETATION.

The whole of the Division is included in that region of the State known as the Western Plains, but, although consisting of

Fig. 5.—Mulga (*Acacia aneura*) scrub on level sandy alluviums in the West Darling District.

Fig. 6.—Flood plain woodland of Swamp box (*Euc. bicolor*) with a tall growth of blue grass (*Dicantheum sericeum*) in foreground. (Photo. N. C. W. Beadle.)

more or less level country, there are large areas of undulating stony country with varying amounts of hills and ranges. The country in this region can be divided into three broad topographical units which are described below, along with the associated soils and vegetation. These topographical units, together with major vegetation formations, have been mapped on Fig. 3

Gently Undulating to Hilly, Stony and Gravelly Country.

This type of country occurs in two areas. Along the eastern border of the Division and lying between the Lachlan and Darling Rivers, there is an extensive area of gently undulating country, broken occasionally by steep hills and ranges, known as the Cobar peneplain. This country is derived from Silurian, Devonian and a small amount of Tertiary sedimentary rocks, mainly shales, quartzites and sandstones. Towards the south are limited outcrops of granite. The soils formed from the sedimentary rocks are generally shallow red-brown sandy loams and loams with varying amounts of gravel. The granite soils are deeper sandy loams and loams with no gravel. This country generally carries a good stand of timber, principally white pine (*Callitris glauca*), bimble box (*Eucalyptus populifolia*), Acacias and considerable variety of other scrub species. Such vegetation has been described as shrub woodland and grades into a scrub formation to the westward, with decreasing rainfall. Smaller areas of similar undulating country also occur on the north side of the Darling River.

The other main area of undulating country occurs on the west side of the Darling River, where the Barrier and Grey Ranges form a broad belt of undulating country running north from a point south of Broken Hill. Another extensive area occurs as a broad belt around White Cliffs, lying between the Barrier Range system and the Paroo River. This country in the West Darling region is composed principally of gently undulating

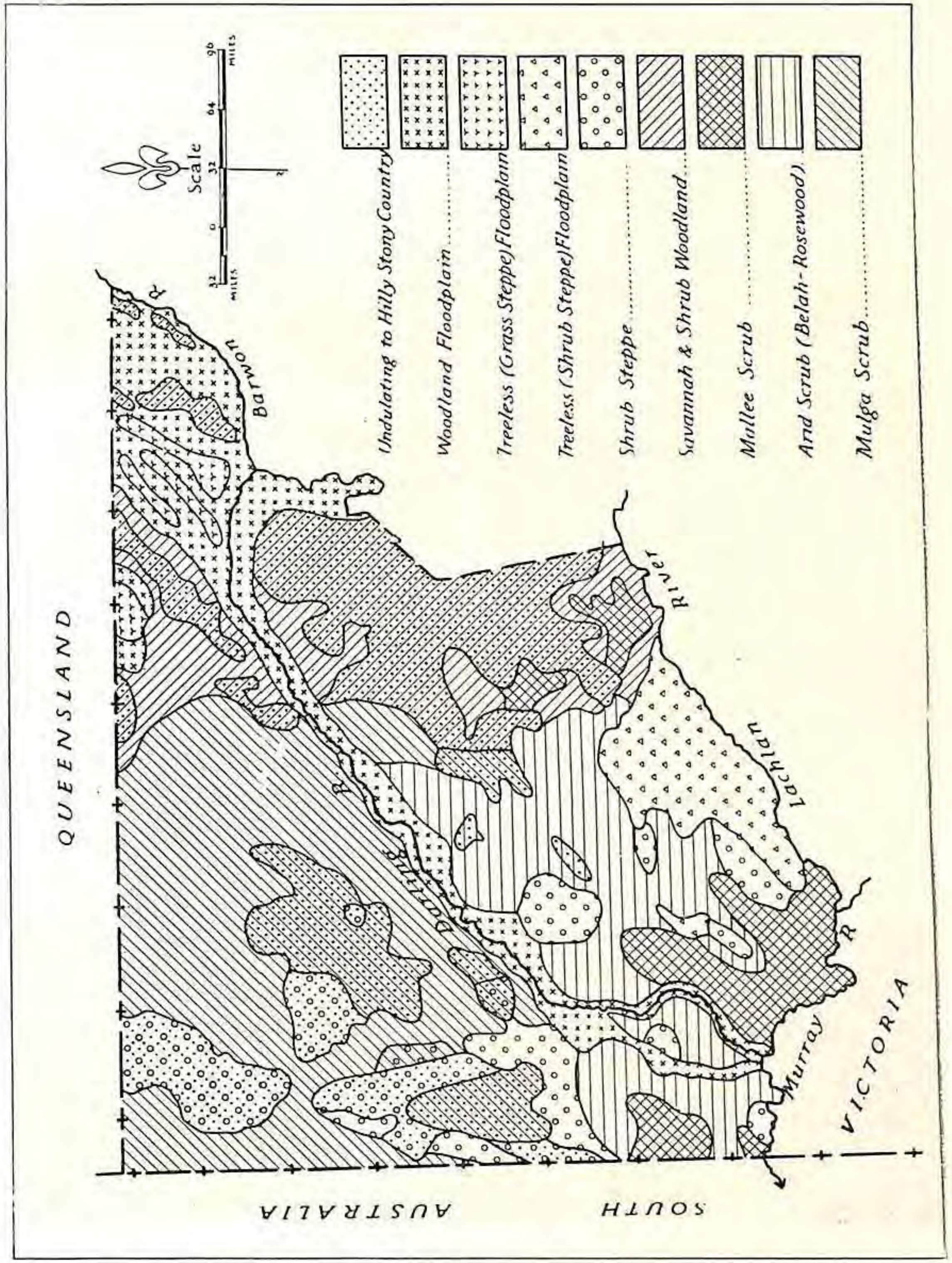

Fig. 3.—Land forms and Vegetation of the Western Division of New South Wales.

brown clay loam soils often with heavy gravel (gibbers), supporting a treeless shrub-steppe vegetation of saltbush (*Atriplex* spp.) and bluebush (*Kochia* spp.). Steep hills and ranges are scattered throughout and support a low scrub composed of mulga (*Acacia aneura*). A portion of this country is of gently undulating relief with light-textured soils, red sandy loams and loams, often gravelly or skeletal, and these soils also support mulga scrub.

Level to Slightly Undulating Alluvial Country not Associated with River Flood Plains.

Lying between and to the south of the two large belts of undulating country described above is an extensive plain dissected by the flood plain of the Darling River. This country is derived from Tertiary to Recent alluvium and is composed principally of sandy loam and loam soils with some areas of dune sands. Over the southern half these soils are light-brown calcareous sandy loams and loams and support an arid scrub principally of belah (*Casuarina cristata*) and rosewood (*Heterodendron oleifolium*), with an extensive belt of mallee scrub (*Eucalyptus* spp.), in the south.

In the northern section the soils are red-brown and red sandy loams and loams with limestone absent or at greater depths. These soils support an open scrub of mulga.

Throughout this plain are scattered areas of heavier-textured soils, clay loams and clays often with a sandy loamy surface, which support a treeless vegetation of saltbush and bluebush shrub-steppe or grassland. An extensive area of such country occurs in a broad belt around the undulating country of the Barrier Ranges.

Level Country of the River Flood Plains or Associated with it.

Running diagonally across the Division from the north-east corner to the south-west corner is the Darling River flood plain averaging about 10-15 miles wide over its middle reaches but narrowing to 3-5 miles in the lower reaches before joining the Murray River. The soils of the flood plain are mostly heavy grey clays, often self-mulching, with varying amount of lighter-textured soils on slightly elevated areas occurring as belts or islands within the flood plain. The heavy grey clays generally support a light to moderate timber cover of black box (*E. bicolor*), with coolabah (*E. coolabah*), in the more northern areas. This vegetation has been termed as flood plain woodland. Extensive treeless areas may also occur on these soils supporting a grassland of Mitchell grass in the north and shrub-steppe of saltbush in the south.

Fig. 7.—Treeless Flood plain (shrub-steppe) of bladder saltbush (*Atriplex vesicarium*) in the Booligal district.

In addition to the main flood plain of the Darling River, there are two other extensive areas of level country associated with river flood plain. Adjoining the Lachlan River in the south is an extensive area of heavy grey and brown clays supporting treeless shrub-steppe vegetation of saltbush. Another extensive area of such country occurs in the north-east corner of the Division where a number of smaller streams join the Darling River above Bourke. In this area heavy grey clay soils support a flood plain woodland of coolabah and black box or treeless grassland dominated by Mitchell grass (*Astrebla lappacea*).

EROSION.

In many parts of the Western Division, erosion presents a major problem because large areas of land have been made barren and unproductive. Under the arid conditions prevailing, regeneration of eroded areas is a very slow process. Some regeneration may take place in favourable seasons on favoured sites, but permanent regeneration is often hindered by recurrent droughts which may wipe out any progress made during favourable seasons. Natural regeneration is made difficult by the fact that eroded surfaces present a very unfavourable habitat for plant colonization and, consequently, mechanical measures are necessary to encourage regeneration. The nature of eroded surfaces and some experiments in reclamation methods have been described in earlier issues of this Journal (Beadle (1), Knowles (2) and James (2)).

The low rainfall may suggest that water erosion would not be a problem in this area. This is not the case, as storms of high intensity are relatively common and, where the soil is left bare and unprotected following drought, erosion damage can be severe on undulating country, resulting in severe sheet erosion allied with gullying of lower slopes and drainage lines. Much of the undulating country in western New South Wales is suffering from water erosion, the form of which depends on the nature of the soil and other related factors. Wind erosion may, and often does, occur on undulating country in conjunction with water erosion, but the eroded surface is similar to that resulting from sheet erosion by water alone and subsequent erosion and control is governed by slope characteristics, so that, for practical purposes, it may be considered as sheet erosion by water.

The principal areas affected by wind erosion occur on the level to slightly undulating country, there being a marked relationship between incidence of erosion and soil characteristics. Much of the Western Division is relatively free from serious erosion either by reason of soil characteristics which are relatively resistant to erosion, or due to the density of the timber and scrub cover. However, some types of soil are highly susceptible to erosion and, being naturally treeless or supporting a poor timber cover, are invariably severely eroded. Such areas are often associated with the heavy grey clays of the river flood plains.

Wind erosion may take several forms varying from the denudation of the soil surface with comparatively little associated drift, to a condition in which drift accumulation and dune activation is the predominant form. These several forms of wind erosion require different techniques for control and prevention. For this reason it has been found desirable to classify such erosion, firstly, on the basis of form of erosion and, secondly, on the degree of erosion.

In subsequent articles it is proposed to discuss the major factors affecting erosion and the various forms of erosion common to western New South Wales.

Acknowledgments.

Apart from the authors' own knowledge of this country, information contained in the above paper was also obtained from the following sources:—

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"ABINGTON" DEMONSTRATION IN THE COOLAH DISTRICT.

BY

E. T. Clark, H.D.A., Resident Soil Conservationist.

When asked why he had been one of the first to carry out soil conservation work in the district, Mr. J. Wansey, of "Abington", Coolah, stated that erosion was so serious that he had to carry out soil conservation work to the utmost or abandon the property.

Having this thought ever foremost, the owner set to work to control this problem to the best of his ability with farm machinery available on the property, consisting of a wheel tractor, plough and grader ditcher.

Over a period of ten years this work, after having been planned thoroughly, has gone on when time has been available from other farming work, each catchment being handled individually under guidance of the Soil Conservation Service.

When most of these catchments had been controlled, an area remained which was considered too badly eroded to be tackled successfully with farm machinery and this area was treated by the Soil Conservation Service under its demonstration programme.

This demonstration is located on the road connecting Gunnedah and Mudgee, and is approximately midway in the section between Tambar Springs and Coolah.

TOPOGRAPHY AND LAND USE.

The land consists mainly of undulating slopes of good rich soil which are suitable for wheatgrowing, with odd steeper slopes. The latter have mostly been cleared and used as grazing country for sheep and cattle, and it is from these slopes that there has been excessive run-off which had damaged the lower areas.

The "Abington" Demonstration is located on some of the minor slopes, where the slope ranges from 3-8 per cent., and which are used as agricultural farming land, being sown mainly to wheat. The soils are very friable and approach the self-mulching type of chocolate loam.

AREA BEFORE CONTROL.

Run-off from a partly cleared area of approximately 60 acres of grazing land discharged on to the demonstration area, causing large gullies to develop. Cultivation and cropping practices were carried out up and down the slopes in sections bounded by these gullies. This was increasing erosion and causing further gullying of the area, and as the owner did not wish to retire this particular piece of cultivation land to pasture, it was necessary to undertake control work.

Speaking of agricultural lands generally, it is often noticed that, although the land has not been overcropped excessively and rotational grazing or cropping may have been carried out over a period of years, crop yields are not what they should be.

When the area in question is examined it is mostly found that sheet erosion has been occurring for many years past and has been increasing without the landholder's knowledge. Because this is occurring, the yields per acre are diminishing

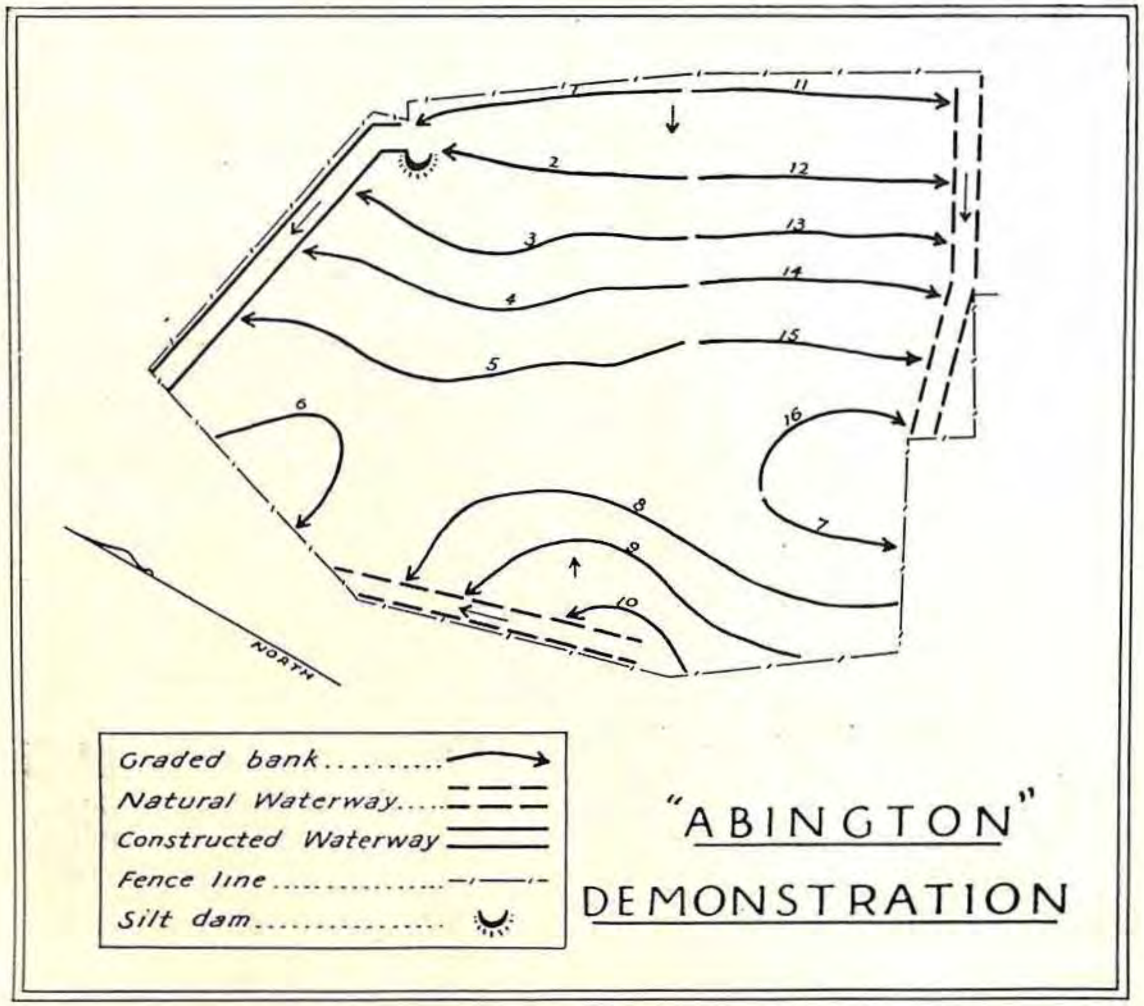

Fig. 1.—Plan of control works on "Abington" demonstration.

annually, the fertile top soil is being washed off and the crops are being sown in shallower soil each year.

WORKS UNDERTAKEN.

Control works carried out on this demonstration, assisted by sound agricultural practices, were designed to retain and stabilise the surface soil.

The demonstration area consisted of approximately 115 acres of cultivation land but did not include the whole paddock, as a further 50 acres of cultivation, with grazing land above on two of the slopes, had already been safely controlled by Mr. Wansey.

Waterways.

In the original plan of control developed by the owner in co-operation with the Soil Conservation Service, two grassed waterways were provided, both of which fitted in with this plan for the demonstration and formed safe disposal areas for banks number 8 to 16 in the diagram, Fig. 1. Having these available saved time as the banks could be connected to them immediately, the grass cover of couchgrass, the cross-section and disposal areas for surplus

water being all suitable. Previous planning such as this is a big advantage when carrying out soil conservation work, because establishment of a safe disposal area for surplus run-off is essential before other work can be done. This may cause delays while awaiting favourable conditions for satisfactory germination and growth to ensure that they can carry water safely.

One waterway 22 chains long and 55 ft. wide was constructed to form a safe disposal area for the overflow of banks Nos. 1 to 5 and the silt dam. This waterway was sown to Rhodes grass at approximately 6 lbs. per acre.

Graded Banks.

All banks in the demonstration area are of the graded type constructed on a grade of 0.3 per cent. which is a safe grade in this district.

Banks Nos. 6 to 10 are too large to cultivate and the land between them is worked on the contour. Banks Nos. 1 to 5 and 11 to 16 are smaller so that cropping of the banks and channels is practicable. Both types are suitable to cultivation land of moderate slope.

New methods of bank construction were developed on this demonstration. It has been observed that in the construction of soil conservation work in the past, very little emphasis has been paid to the location of the greatest depth of flow in the channel. In most cases this has not been detrimental, but in some cases, especially in graded banks, water flowing at unsafe velocity over a period of time tends to wear away a percentage of the constructed bank. Where the greatest depth of flow is close to the bank, the velocity of water is highest and may be sufficient to erode the bank along its length.

If the greatest depth is as far away from the bank as possible the damage is negligible. This still allows for the same size of channel and freeboard of bank, and the

Fig. 2.—Silt dam on the demonstration immediately after completion.

Fig. 3.—Graded banks showing desired location of greatest depth in channel.

Fig. 4. A park and channel constructed on this principle (see fig. 3.) after heavy rain—outlet in foreground.

Fig. 5.—Looking up constructed waterway towards silt dam.

construction time of such banks is not increased.

Banks and channels of this shape are constructed by increasing the depth of the ripping, in the uphill section of the channel area, after the first ripping has been dozed up to form a portion of the bank. The channel is cut in this deeper ripping and the batter of the bank extended further uphill than is normally the case.

This method of bank construction can be adapted to fit in with all types constructed and is equally as effective with the graded as with the absorption type of bank.

Silt Dam.

To act as a silt trap at the top of the constructed waterway, a dam of 900 cubic yards capaciy was excavated with dozer and ripper and will serve a good purpose at this location.

All work on this demonstration was carried out with a crawler tractor, ripper and dozer. A grader terracer was used to level the constructed waterway.

CONCLUSION.

Since completion of the earthworks this land has been cropped by contour working with satisfactory results. Grazing management is directed towards maintenance of good cover on the waterways and pasture land. The heavy rains of 1955 caused only minor soil movement in small depressions where old gullies had been filled, and in the waterways.

The property has changed hands since the work was commenced and the new owner, Mr. J. Donoghue, is very well satisfied with the control measures.

THE USE OF FERTILISERS CONTAINING SULPHUR IN SOIL CONSERVATION IN THE TAMWORTH DISTRICT.

BY

B. L. ROTHWELL, B.Sc. Agr., Soil Conservationist.

EVIDENCE has been accumulating for a number of years now that sulphur deficiencies exist in many New South Wales soils, especially in the north and north-west, and that responses to superphosphate have been due in many cases almost entirely to the sulphur content of the fertiliser. In one trial conducted by the C.S.I.R.O. at Armidale on a basalt soil, sub-clover did not respond to either phosphorus or nitrogen but the application of sulphates gave a 200 per cent. increase in yield six weeks later.

Trials on the wheatgrowing soils of the Tamworth District are showing that on extensive areas of these undulating red-brown earths and black self-mulching soils, sulphur is also the outstanding mineral deficiency. One particularly interesting trial conducted by a Tamworth farmer compared the effects of different levels of sulphur applied in different forms, as gypsum, super. and flowers of sulphur, on a two-year-old stand of lucerne, barrel medic and sub-clover growing on a podsolized red-brown earth. The rates of application were designed so that there was a gradation from approximately 6 lb. of sulphur per acre (½ cwt. super.) to approximately 25 lb. of sulphur per acre (1 cwt. gypsum) with a good range of rates in between. Several competent observers agreed that the response of the pasture in the different plots was in almost direct relation to the amount of sulphur per acre, no matter in what form it was applied. Quadrat clips confirmed their opinions and showed that the plots receiving 25 lb. sulphur per acre gave yields of the order of 3 tons of meadow hay per acre against less than half a ton on the untreated control.

Responses to sulphur have been obtained on a wide variety of other soils in the district ranging from shaley mountain soils to the alluvial flats of the Peel River. There are, of course, certain soils that have been found to give responses to phosphorus and nitrogen as well as sulphur—notably badly run-down wheat soils. Some have given a response to lime, but by and large, the most spectacular results have been from sulphur.

Although responses to sulphur have been noted on cereal crops as well as on legumes, that of the legumes is particularly significant from a soil conservation point of view, both because of their increased vegetative cover and because of their increased rate of nitrogen fixation and resultant stimulation of grass growth which improves soil structure, increases infiltration and reduces run-off.

In addition to this, it has been found by the C.S.I.R.O. that sub-clover needs more sulphur to maintain maximum protein content in the plant than it does for maximum growth. In other words, the quality of the feed might be seriously lowered by insufficient soil sulphur when to all outward appearances growth was normal.

Fertilisers supplying sulphur, therefore, assume a very great importance, not only in the fertility-building and wise land-use aspects of any soil conservation scheme, but also for increased stock returns and better stock health.

Fig. 1.—Poor native pastures immediately after banking.

COSTS OF VARIOUS FORMS OF SULPHUR.

Once it has been established that sulphur is the main mineral deficiency of a soil, it remains to decide the most economical and convenient method of remedying it. The most important fertilisers containing sulphur on the market are gypsum, superphosphate, sulphate of ammonia and flowers of sulphur, and before discussing their use in any detail, it is interesting to examine their cost in relation to their sulphur content. Prices quoted are in shed at Tamworth, December, 1955.

Although bulk gypsum is easily the cheapest way to buy sulphur, carriers are becoming rather reluctant to handle this commodity because it damages their tar-

Fertiliser.	Cost per cwt. *	Lb. S. per cwt.	Cost S. per lb. to nearest ½d.
	£ s. d.		s. d. s. d.
Gypsum—bulk	0 6 6	15 to 30†	0 5 to 0 2½
Gypsum—ground	0 12 0	15 to 30	0 9½ to 0 5
Flowers of Sulphur ...	4 0 0	105	0 9
Superphosphate	0 16 2	10 to 15†	1 7½ to 1 1
Sulphate of Ammonia...	2 10 8	31	1 8

* On rail at Tamworth. † Depending on purity of the sample.

paulins. Also, unless a front-end loader can be obtained there is a lot of manual work involved in shovelling it out of rail trucks and sieving or grinding it. For this reason ground gypsum in bags is becoming more popular and, as the demand rises, the firms supplying it are improving the quality of their product. It seems likely that before very long gypsum will be available with grain sizes suitable for application through the combine or for broadcasting.

Flowers of sulphur has the advantage that only a small volume is needed, thus reducing handling and transport costs, however, it has the disadvantage of being rather irritating to the mucous membranes, which limits its use from broadcasters.

The price of sulphate of ammonia restricts its use at present to high-value crops, but if the price should fall, it would be worth considering as it contains nitrogen as well and, if used judiciously, could be a great help in maintaining a good grass-clover balance in the early stages of grassland establishment when clover tends to dominate the sward.

METHODS OF APPLICATION.

For the present, gypsum and superphosphate seem the two most readily available and easiest fertilisers to use. It has been found in the Tamworth District that the most convenient ways to incorporate these fertilisers into the farm programme are:—

1. With lucerne under a cover crop of wheat.

2. With autumn renovation of old lucerne stands. Overseeding with barrel medic or sub-clover at this time is often an advantage as it increases ground cover and total production of herbage.

Fig. 2.—The same paddock three years later after sowing with lucerne and supering. Production increased by about 250 per cent. (compare fig. 1.)

Fig. 3.—Lucerne sown at (half-pound) per acre. In the strip on the left, fertilised with super, lucerne dominates. In the strip on the right, with none, black oats dominate the lucerne.

3. With sowings of pasture mixtures in the autumn.

4. By aerial topdressing or broadcasting on to hilly areas. In most cases some barrel medic or sub-clover seed is broadcast at the same time if they are not already present in the sward.

In all cases, if these fertilisers are used on banked country, their beneficial effect is supplemented by the extra moisture made available by the banks.

Figure 1, photographed in October, 1951, and Figure 2, photographed in November, 1954, show how poor upland grazing country has responded to contour banking and fertilising. After banking, the paddock was fallowed and sown down with lucerne under a cover crop of wheat fertilized with super at the rate of 1 cwt. per acre. By farming the country on the contour more water was held where it fell and lack of water is usually a big factor limiting plant growth in the Tamworth District; by topdressing with super the main mineral deficiency, sulphur, was remedied; by planting lucerne, a high-producing fertility-building plant was substituted for the thin weedy native pastures which did not give adequate protection to the soil, and the cash from the wheat cover crop paid for the seed and fertiliser. It is estimated that production from this paddock has been increased by about 250 per cent.

The general recommendation for this method of establishment is: ½ lb. to 1 lb. inoculated lucerne seed per acre, 30 lb. wheat per acre, 1 cwt. neutralised super. per acre on badly run-down land or 1 cwt. gypsum on most soils. One lb. barrel medic is often recommended as well, especially on the heavy self-mulching soils, and the mixture sown into well prepared fallow. The half-pound seeding of lucerne has been found to be quite sufficient provided that gypsum or neutralised super is used and the seed inoculated. Figure 3 shows a $\frac{1}{2}$ lb. seeding of lucerne. The strip on the left received 1 cwt. super per acre; the strip on the right none. The fertiliser stimulated the lucerne so that it dominated the black oats, while the growth on the untreated strip is mainly black oats. With these light seedings of lucerne, the saving in seed will usually pay for the super.

Renovation of established lucerne by cultivation is a regular practice on many farms, and if the lucerne is top-dressed as well as renovated, the resulting growth is liable to be spectacular. The lucerne itself responds most to spring renovation and fertilising, but if these are done in the autumn the associated clovers and grasses benefit more. From the points of view of winter feed, soil conservation and of overseeding improved clovers, autumn renovation is the better.

Generally speaking, there are very few paddocks sown to improved pasture mixtures in the Tamworth District. There is a number of reasons for this, but the main one is that lucerne is so easy to grow and so high-producing that no one has bothered much about other pasture species. Many attempts in the past to grow these grasses have not been very successful, Wimmera rye, for instance, tends to "run-out" after a couple of years and it is reputed to be too hot for phalaris.

However, lucerne, for all its virtues, has the bad fault of bloating stock from time to time, and does not give good soil protection. For these reasons, plus the fact that soil improvement goes on at a greater rate under a mixed legume-grass pasture than under a pure lucerne stand, it would be of great benefit if palatable grasses, such as Wimmera rye and phalaris could be grown successfully.

Fig. 4.—An improved pasture of phalaris, barrel medic, sub-clover and lucerne treated with superphosphate and growing on contour-banked country.

The indications are that once soil fertility has been lifted by the application of gypsum or super, by the growing of suitable legumes and by reducing water losses by contour banking, such grasses can be grown successfully. Figure 4 shows a mixed pasture of phalaris, barrel medic, lucerne, and sub-clover on a black self-mulching soil at Winton near Tamworth. The paddock had been banked and top-dressed with super.

Apart from the immediate benefits to any plan for conservation and soil improvement, incorporation of high-producing pastures in the rotation has other considerable benefits. A phalaris pasture for instance will give a body of feed when other perennials are at a low ebb. High yields of nutritious meadow hay can be cut from such a pasture, and phalaris seed is quite a profitable sideline.

Aerial top-dressing of pastures has not been carried out to any great extent in the Tamworth District, but those that have been top-dressed show remarkable improvement. One landholder broadcast gypsum over the banks and land beside a creek running through his property. It stimulated the clovers and crowfoot to such an extent that in the dry winter of 1954 there was always ample feed in this paddock. Many neighbours with similar country were hand-feeding.

CONCLUSION.

The use of fertilisers containing sulphur, especially in conjunction with contour banks, has great possibilities for increasing production in many areas similar to Tamworth where deficiencies of sulphur occur in the soil. The banks help alleviate the main factor limiting plant growth in these areas—lack of moisture—while the gypsum and super remedy two of the main mineral deficiencies directly, and the nitrogen deficiency indirectly, by promoting increased growth of legumes which fix free nitrogen from the air.

In the Tamworth District, a great deal of the stablisation achieved on erodible soils has been due to the increased growth of vegetation through the use of fertilisers in association with banks and contour farming.

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