EROSION CONTROL ON ORCHARD LANDS IN THE ORANGE DISTRICT

BY

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WITHIN the Orange Soil Conservation district we find a variety of soil conservation problems, including some local and very specialised aspects of soil conservation. They appear very important, and are indeed important for the agriculturist in that particular environment, as they are basic to the retention of his soil and the productivity of his land.

One of the most important of these problems is the serious erosion occurring on highly productive orchard lands. Fortunately methods have now been perfected by which this erosion may be completely eliminated.

SOD CULTURE.

Sod culture has been conducted by landholders in the Orange district for a number of years and has now reached a stage where the productivity of trees and good soil management practices have been correlated, so that landholders are now able to retain almost all the soil on their orchard blocks, and have not only maintained but improved the vigour of their trees, and at the same time considerably increased production.

Mr. W. B. Pascoe, Korre Lynne, Canobolas, Orange, one of the early fruit growers established in this district, planted his first orchard on the square-planting system but noticed that he lost a lot of soil due to cultivation. Mr. Pascoe then planted a second orchard, also square planted, but he took the added precaution of installing graded banks in this orchard during the early stages and then combining this banking with the establishment of a sod culture of subterranean clover.

A third orchard established recently by Mr. Pascoe has been planted on the contour, and it is the intention of the owner to establish a subterranean clover sod culture programme in this orchard as soon as the trees are well developed and tree root system established.

In Vol. 2, No. 4 of this Journal, the owner published a short article covering his experiences, which extend over a period of some thirty years, in soil loss and corrective measures for retaining soil on orchard properties in the Canobolas district. His experiences have proved of untold value to other orchardists in this area.

Inspection of all three orchards during October, 1951, revealed that in the first orchard planted some of the early banks, built by Mr. Pascoe with a horse and dray more than twenty years ago, had checked the rapid flow of water over the land and reduced soil loss while subterranean clover was being established. The orchard now supports an excellent ground cover of subterranean clover; the trees, although of very great age, show indications of excellent health and productivity.

The second orchard contains a very fine lot of trees, together with another excellent stand of subterranean clover. The banks were examined after a very heavy storm and the outlets showed only clear water running from the clover-pastured orchard area.

Mr. Pascoe stated that he would never return to the old methods of cultivation originally used in his first orchard, and that the quality of his fruit throughout has been highly satisfactory and his yields good. There is no doubt that the additional organic matter and nitrogen in the soil on this property, due to the continued growth of subterranean clover over a period of years, is reflected in the trees.

Fig, 1.—A graded bank in Mr. Pascoe's second orchard.

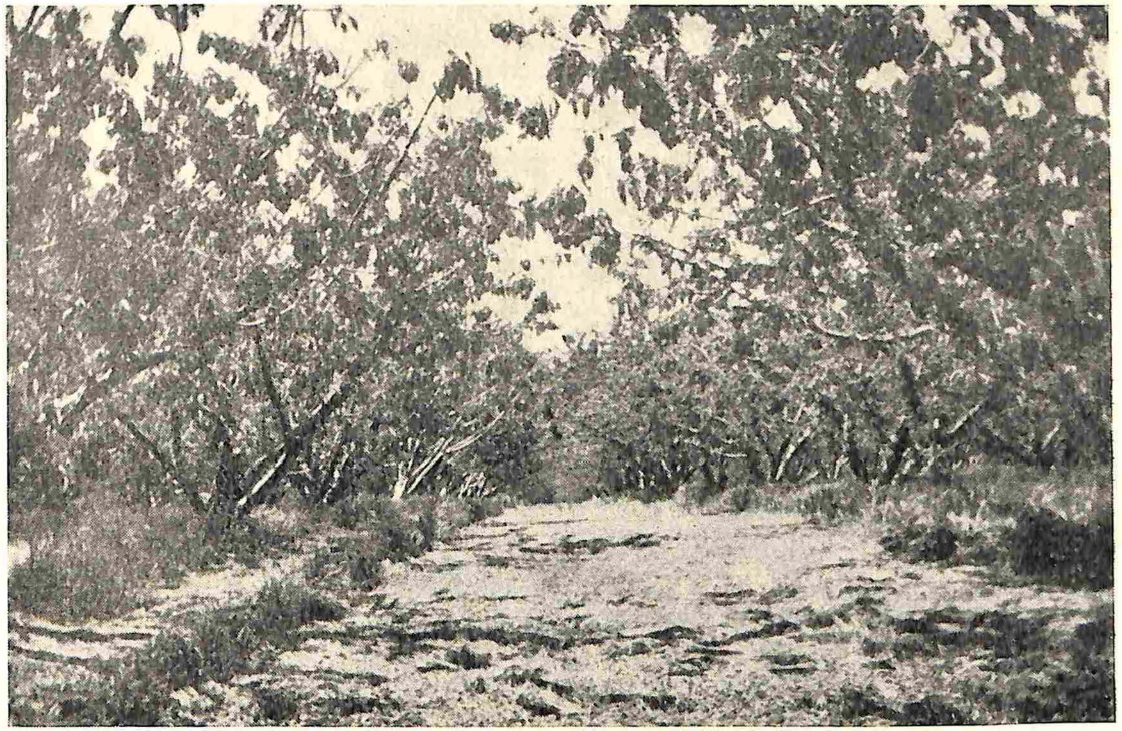

Fig. 2.—Mown subterranean clover between cherry trees on Mr. L. Cunick's property.

Fig. 3.—The effective use of *Phalaris tuberosa* in stabilising a formerly gullied waterway.

SOIL LOSS PREVENTED.

The second orchard is that of Mr. L. Cunick, who is located on the western side of Mount Canobolas. Mr. Cunick has a square-planted orchard, from which he found that he was begining to lose large quantities of soil. He was also faced with the problem of water from country above his cherry orchard coming through the orchard and aggravating his erosion problem. Some twelve years ago, after seeking advice from the Soil Conservation Service and personal inspection and advice from Mr. E. S. Clayton, he decided to establish subterranean clover in this cherry orchard and thereby correct and reduce the loss of soil resulting from clean cultivation practices.

After establishing this sod culture orchard he found that the vigour of his trees improved and to appreciate the present active vigour of these trees one has to inspect the area and view the orchard.

One of the outstanding features that was noticed during the course of inspections of this cherry orchard, as compared with other cherry orchards still subject to clean cultivation, was the remarkable absence of diseases.

Mr. Cunick states that he is now of the opinion that very little soil has been lost from the cherry orchard during recent years and that he is well satisfied with his yields.

Mr. Cunick recently planted another cherry orchard, but this time on the contour, which he proposes to plant down to subterranean clover for sod culture when the trees are well established.

YIELD AND QUALITY OF FRUIT.

The third orchard is that of Mr. E. J. Hoskins, who established sod culture in his orchard some eight years ago and the vigour of his trees has improved very much. The yields have improved and the soil loss has been eliminated.

Former plantings were on the square but more recently Mr. Hoskins has contour planted his orchards and established subterranean clover for sod-culture purposes.

Mr. Hoskins is of the opinion that the added nitrogen supplied by the establishment of subterranean clover has improved the vigour of his trees, increased the yield of his crops, and also stated that he thinks his fruit is keeping much better in cold storage, quoting as an instance that at the time of the interview (October, 1951) he was receiving 70s. per case for Granny Smith apples sold on the open market. The agent who sold the fruit stated that this was equal to the best fruit now coming to the Sydney market.

Clean cultivation has now been discontinued entirely on Mr. Hoskins' orchard and the old-scoured orchard is now laid down to subterranean clover which is well established.

In the early days Mr. Hoskins was forced to work his orchard only one way, across the slope, to reduce the soil loss while he was establishing clover in the orchard area. In the gully and rill lands he planted *Phalaris,* which has sealed this area permanently. This orchard is now entirely stable and there is no soil loss occurring on the property. The trees are in excellent condition and equal to any, while the crops have been very good and the quality of the fruit unsurpassed.

Mr. Hoskins gets over the fire risk in the orchard by regularly mowing the clover and allowing the residue to decay under the trees. He has thus built up a humus mat two to three inches thick over the whole area. Thus, all the rain that falls goes into the land, whereas under clean cultivation practices run-off amounted to a large percentage of the total rainfall.

Since the early establishment, mowing has been a regular feature of Mr. Hoskins' operations and has assisted in building up a mulch and destroying all types of weeds in the early period of establishment, when the subterranean clover was competing with all other types of vegetative growth.

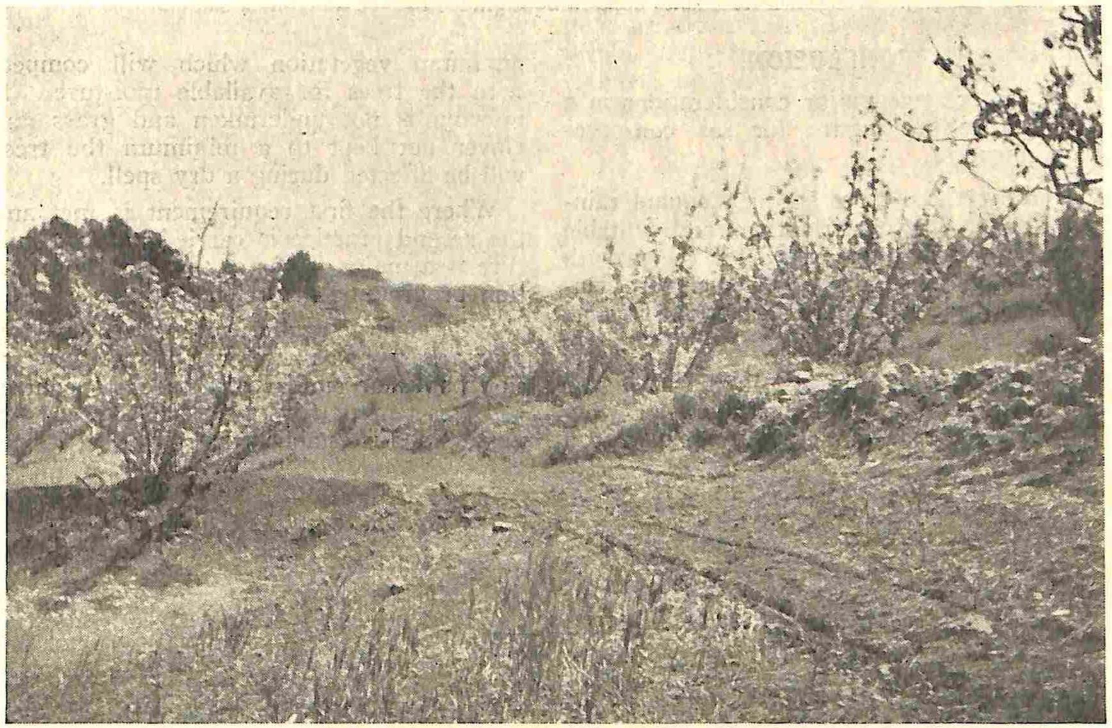

Fig. 4.—Graded banks built within an orchard as a preliminary measure to stabilising the area by sod culture.

Fig. 5.—Wellgrown trees in an orchard both graded banked and under sod culture.

CONCLUSION.

There are two major considerations in a sod-culture programme for soil conservation purposes.

Firstly, there must be an adequate rainfall, or means of irrigation, and suitable monthly temperature range for the growth of dense subterranean or other clover. Conditions in this regard are ideal in the Orange district.

Secondly, it is essential in the spring to mow continually the pasture growing between the trees and thereby reduce to a minimum vegetation which will compete with the trees for available moisture. If mowing is not undertaken and grass and clover not kept to a minimum the trees will be affected during a dry spell.

Where the first requirement is met and the second practice is carried out sod culture is a major factor in the soil conservation programme in orchard areas.

Where large gullies occur in existing orchards it is also necessary to install diversion banks or similar structures to control soil loss temporarily until such time as the pasture sod is established.

WATER DISPOSAL AND SPILLWAY PROVISION ON SCONE RESEARCH STATION

BY

A. R. Tewksbury, H.D.A., Officer-in-charge.

When establishment of Scone Soil Conservation Research Station commenced in November, 1948, a detailed survey was carried out to investigate the erosion problem and techniques of satisfactory means of control of serious erosion on this class of country which is typical of large areas of the Upper Hunter Valley.

It was found that vegetation was sparse on the steep country and lower slopes, due mainly to rabbit infestation and overstocking in the past. The main erosion problem, however, was one of major gullying.

Two main catchments of approximately 550 acres, comprising half the total Station area, were discharging their run-off at one point on to the Gundy road, which is the main access road to the Upper Hunter Valley.

In past years run-off from this catchment had caused very severe damage to fence lines, roads, table drains and also the valuable Segenhoe flats. The main flow after reaching the Gundy road found its way eventually down the centre of the farming lands, finally emptying into Page's River near Segenhoe House.

After flood rains a large portion of the lucerne and farming areas of this locality were flooded for short periods and received a large amount of erosional debris as well as waterlogging and damage to improvements. Large quantities of gravel and soil reached the river.

To combat this excessive run-off from the Research Station catchments, a control programme was instituted that would:—

(1) By the introduction of large absorption banks and dams, store and reduce the volume of run-off and prevent the water from both catchments reaching a common outlet simultaneously.

(2) Cut off the heads of all major gullies and so minimise flow and resultant erosion.

(3) Provide water for irrigation of gullies by siphon systems and assist their reclamation by the introduction of trees and the development of natural pasture regeneration.

(4) Decentralise watering points for stock so that there would be no concentration when watering, resulting in well worn cattle tracks and sheep pads up and down steep slopes.

With the introduction of these works a problem arose with regard to spillway provision and water disposal, as in nearly all cases of dam and bank construction the site of the works is controlled by these two factors.

The overall control programme is shown in Fig. 1 and it will be seen that the water disposal problem was relatively simple for Nos. 1, 2 and 3 banks and No. 3 dam, but some difficulty was experienced in finding and locating suitable spillway sites and disposal channels for Nos. 1, 4 and 5 dams.

These three dams were all sited on major gullies and the immediate topography prohibited surplus water being taken from the dams to remote areas. All overflow had to be led back to the gullies on which the dams were constructed. Spillway provision in all three cases was difficult and it was decided to rely wholly on kikuyu grass as a means of conducting the water safely to the respective disposal areas.

No. 1 DAM.

To provide a spillway for this dam of 2,500 cubic yards a bank $6\frac{1}{2}$ chains in length was carried off spill level and so located

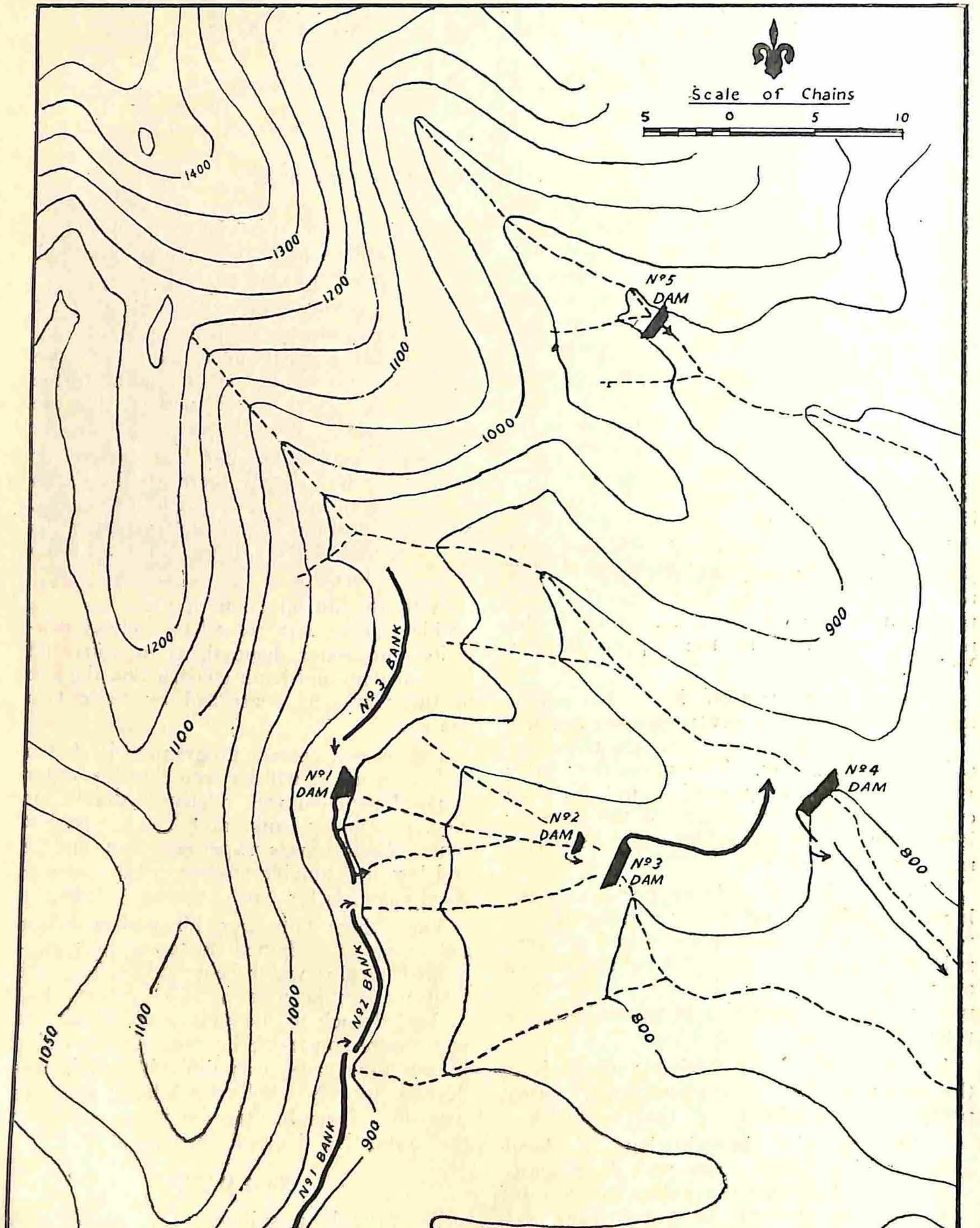

Fig. 1.—The mechanical erosion control works on portion of Scone Research Station covering a watershed of 550 acres.

to cut off three other active gullies. Near its southern extremity a notch weir type spillway was constructed so that it would dispose of its overflow into a stable rock bottomed gully and enter No. 3 dam approx. 300 yards away.

A notch 25 ft. wide was constructed in the finished bank and soil was dozed in below to form an apron or race leading to the gully bed chosen for the disposal area. This race was constructed 25 ft. wide to conform to the notch and when finished was on a 1 to 3 grade. The notch and race were completely sodded with kikuyu grass, top-dressed with soil, securely netted and pinned down.

The weir was designed to take 74 cusecs, based on a one in twenty year frequency. The maximum depth of flow at the notch was calculated at 0.9 ft., and 4 inches in the tail race when a maximum velocity of 8.5 ft./sec. was obtained. A freeboard of 2 ft. either side of the notch was allowed and considered safe. Since completion this weir has spilt frequently at a depth of three inches at the notch. No subsidence has occurred in the race and now that consolidation has taken place and the kikuyu sod has formed a very heavy mat it is considered the spillway will be effective. Cattle carried on the Station have continually grazed the kikuyu and this has tended to improve the cover, making the runners stronger and coarser and promoting a heavier binding effect underground rather than above.

No. 4 DAM.

A trapezoidal bank provides immediate spill for this dam of 3,000 cubic yards; the bank is heavily sodded to kikuyu. At the end of this short bank, 2.4 chains in length, the water is led away into a natural depression which ultimately empties into the gully on which the dam is constructed. This disposal point is stony and safe.

The overflow is kept away from the main gully by means of a low bank approximately 10 chains long. When this bank was under construction kikuyu runners were thrown in with the last dozer blade of soil and have since taken control of the whole bank.

Fig. 2.—No. 1 dam spillway showing notch outlet and heavy growth of kikuyu on race.

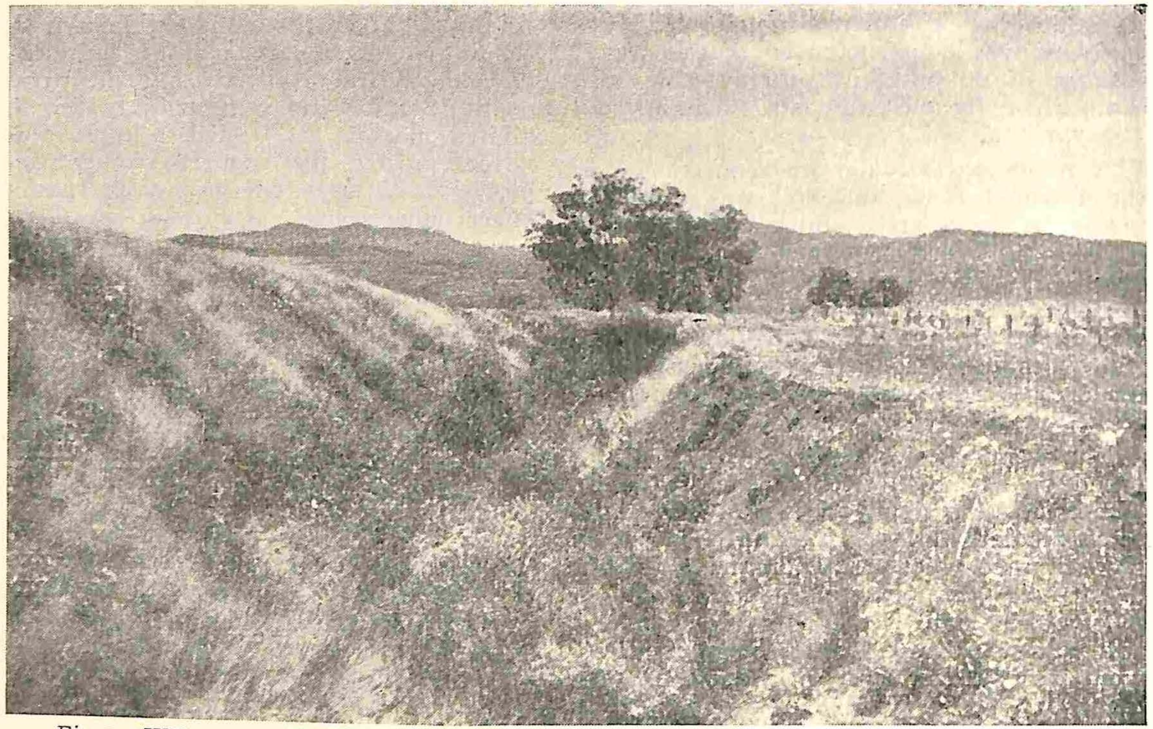

Fig. 3.—Willows and river oaks below No. 4 dam. These trees attained a maximum growth of 14 feet in two years under irrigation from stored water in the dam.

Where the disposal area showed bare spots, sods were introduced and it is estimated the kikuyu will soon cover the whole area.

Although this dam is essentially a soil conservation structure, it also provides stock water and supports per medium of a small irrigation system 22 willows, 21 river oaks, 25 silky oaks, 6 Tasmanian blue gums and a large clump of bamboos.

The willows and river oaks were planted in the main gully immediately the dam was completed and when the gully is considered too dry 300 ft. of 1½ hose is used to siphon water from the dam and it remains siphoning water onto all the trees for periods of up to three weeks. Willows and oaks have attained a height of 14 feet in two years below this dam, and the once active gully of 14 feet depth is now completely reclaimed. Water is emptied from the dam in controlled manner thus increasing its soil conservation value.

No. 5 DAM.

No. 5 dam is essentially a soil conservation dam, sited and built to buffer the initial run-off from 50 acres of very steep country in some instances attaining slopes of 70 per cent. The capacity is 2,500 cubic yards.

When seeking a spillway site for this dam it was found that the steep sides of the gully made it economically unsound to use the orthodox method of constructing a graded spillway to carry the overflow to a safe disposal site.

To construct such a bank would have necessitated an enormous cut in the spur on the southern side. It was felt this was not justified and an overshot spillway was decided upon. This was built on orthodox notch weir design and the downside batter of the dam was graded to 1 : 4. This formed the tail race for the overflow and particular attention was paid to consolidation while constructing it.

Care was taken to ensure that large stones and other hard materials were not included in order that when wetting occurred there would be no subsidence or slumping due to air spaces occurring when hard material broke down.

When the batter was completed a notch was cut in the centre of the wall 15 feet wide and 4 feet deep, allowing 2 feet for flow and 2 feet freeboard. It was calculated that the notch would discharge 144 cusecs. The maximum velocity this overflow would attain was computed at 11.5 feet per second.

The water discharging through the notch at a depth of 2 feet would lessen in depth to 0.75 feet on the tail race.

To prepare the spillway to take the discharge mentioned, the race was first carefully shaped to conform to the notch itself, 15 feet wide and side batters of 1 : 2 resulting in uniformity throughout. The whole spillway was then fully sodded with kikuyu, straw mulched, netted and pinned down.

The spillway was fenced off later to exclude stock until the kikuyu had fully established. The sod is now well established and should take the maximum flow designed for without damage.

CONCLUSION.

An endeavour has been made when constructing the spillways discussed here to use methods that are not economically too costly for the average landholder should be desire to make use of conservation works of this nature.

Notch weir and overshot spillway construction is quite common practice but generally in concrete, grouted stone or large stone secured by netting.

If sodded weir type spillways prove successful, the location of dam sites will be easier, as spillway provision ceases to be the governing factor in choosing the position of the dam wall. This applies more particularly, of course, to dams of the gully fill type.

In all soil conservation practice getting control of "top water" from steep country presents the most difficult technical problem. If this can be done high up the steep slopes, then the problem on the lower lands is greatly simplified and costs reduced accordingly. The land itself is also greatly benefited for grazing purposes.

On the Scone Station investigations on a field scale on this phase of the Upper Hunter problem indicate that successful results may be achieved.

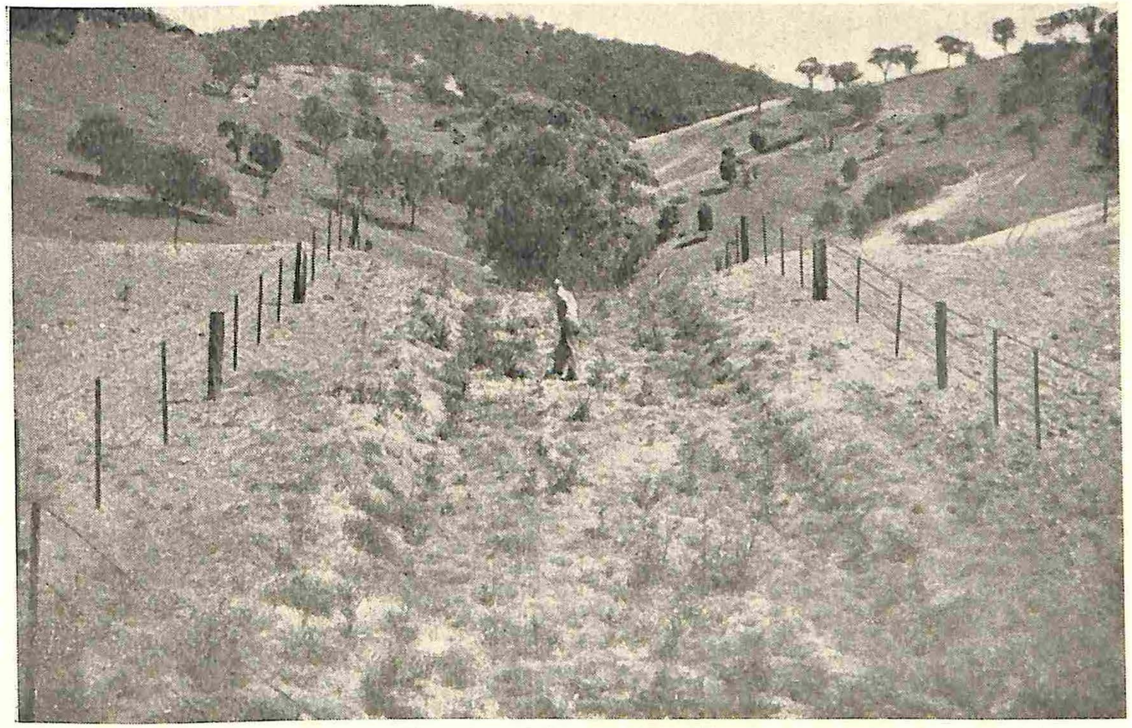

Fig. 4.—Overshot spillway on No. 5 dam, fully sodded to kikuyu, straw mulched and netted.

FURTHER DEVELOPMENT OF INVERELL SOIL CONSERVATION RESEARCH STATION

BY

J. S. Harris, H.D.A., Officer-in-charge.

In Vol. 3, No. 3, an outline of the establishment of Inverell Research Station was given by Stewart. It is now proposed to discuss further development since that date.

This Station was intentionally situated on some of the most eroded and exhausted land in the Inverell district with a view to providing a suitable area for experimentation into causes and remedies of erosion, and in addition for the purpose of demonstrating how effective conservation farming can actually be. The Station has now been fully developed, a comprehensive investigation programme initiated, and the Station is playing a valuable part in the general soil conservation programme throughout the Inverell district.

LAND USE.

Between 1946 and mid-1949 few stock were carried on the property in order to stimulate some vegetative cover on the formerly denuded and eroded lands. A very gratifying regeneration of pastures occurred. Valuable native grasses such as *Danthonia* spp. and Queensland blue grass (*Dicanthium sericeum*) reappeared and crowded out the heavy infestations of saffron thistle, Mexican poppy, Bathurst burr and other weeds which had gained a hold on the over-stocked and over-cropped land. In the latter part of 1949 it became necessary to stock fairly heavily to control the heavy stand of grass in the interests both of sound grazing management and in connection with completion of rabbit eradication.

Approximately 120 acres of a total area of 290 acres have been treated with graded banks and are used for rotational cultivation, the rest being topographically unsuitable for cultivation. Two machines of basin lister type have been used successfully to impound rainfall and prevent soil movement on inter-terrace spaces. They have proved most effective in the case of high intensity storms of comparatively short duration and it is felt that they can be used both in conjunction with graded banks and on untreated land.

Stubble from crops has been incorporated in the soil each season with beneficial results in soil tilth. As many as 1,250 sheep have been packed on to paddocks of up to 44 acres for short periods after harvest, eating out all weed growth and breaking up the stubble by trampling. The paddocks were then disc-cultivated and ploughed and no inconvenience was experienced in sowing the following crops. A crop rotation has been instituted covering a cycle of eight years with wheat, oats (principally for grazing), and lucerne as the main crops.

In 1949 an area of twenty-one acres was sown with pasture mixture as follows: White and subterranean clover and Wimmera rye, 2 lbs. each per acre and oats at the rate of 15 lbs. per acre. The purpose was mainly to revitalise the soil by growing a leguminous crop, with the oats as a quick-growing cereal for temporary cover. The paddock had been badly over-cropped with wheat and had originally been an orchard. Owing to wet weather conditions the oats could not be fed off without damage to the clover and so it was stripped. The paddock was then heavily stocked with sheep, from 56 to 176 in number, for several months with only short intervals between grazing. Despite this the clover thrived and seeded heavily, being suited by the wet season. Particularly good wheat crops should result from this introduction of legumes and incorporation of sheep manure, besides a decrease in erodibility of the soil arising from its increased fertility. These two

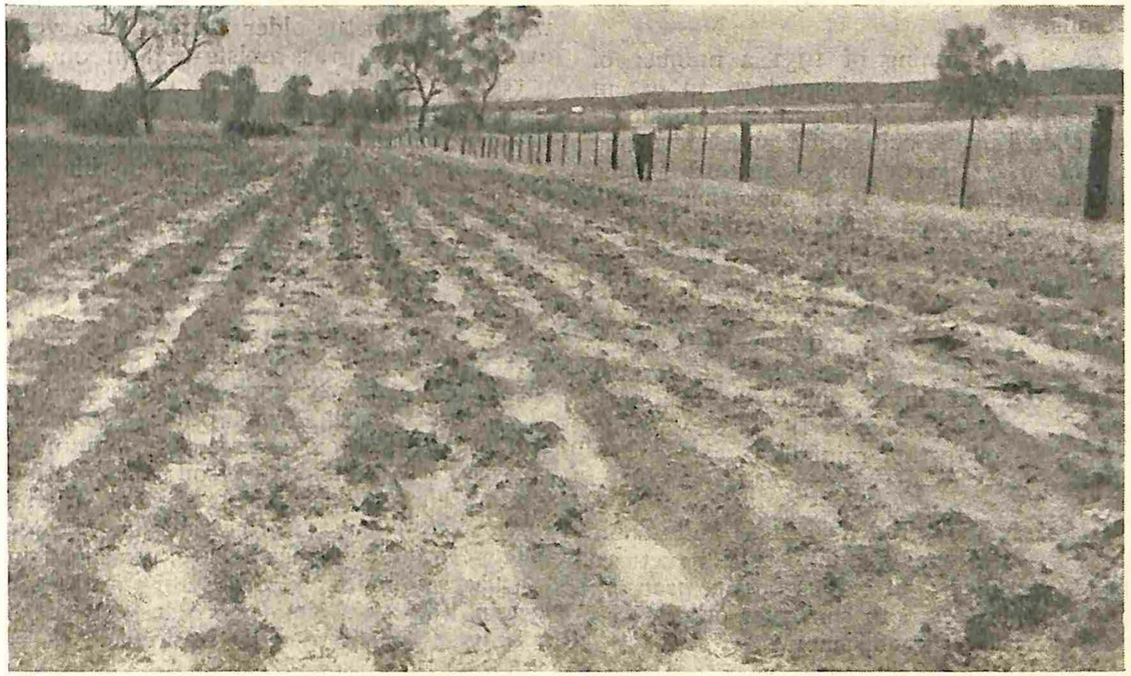

Fig. 1.—Arable land prior to sowing to maize after treatment with the Eddy basin lister.

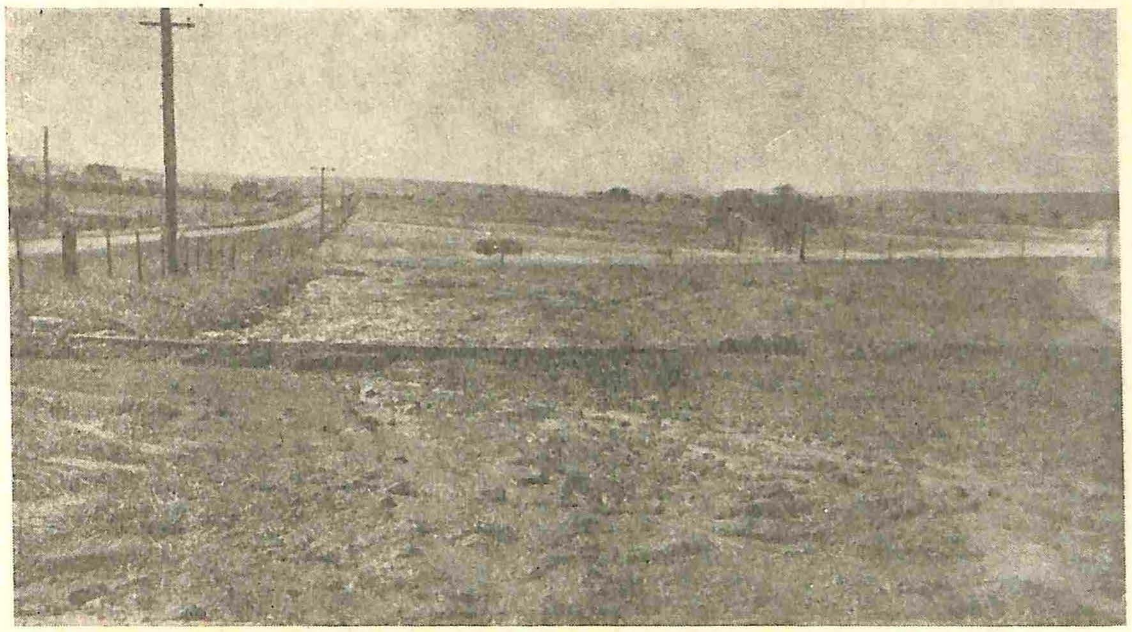

Fig. 2.—Soil movement on the Station in 1947 after 2 inches of rain, prior to soil conservation treatment.

clovers may not persist in this district, but are now being replaced by the naturalised trefoils.

At the beginning of 1951 a number of graded banks were enlarged to an extent where they could be cropped with no inconvenience during cultivation and harvesting operations. Earth movement had been investigated previously in these banks and it is now proposed to compare the observations with those obtained from the larger banks.

Two new dams have been excavated to control water and silt movement in gullies. The larger one has been used to supply water for gardening purposes and stock troughs thereby reducing the water level in readiness for further rainfall.

MECHANICAL WORKS.

Besides the graded banks and dams already mentioned a number of structures have been placed in gullies on the property and it is proposed to construct other types and observe their efficiency.

Another grassed waterway has been established to handle the overflow from a dam constructed across a watercourse. This has permitted the filling in of a gully which had been carrying the water. Kikuyu and paspalum have been established in the waterway. On the older waterways a very dense cover of grass exists and in one in particular *phalaris tuberosa,* paspalum and lucerne are competing, with *phalaris* gradually predominating. This grass appears to be very suitable for the purpose in this district. Rhodes grass (*Chloris gayana*) and liverseed grass (*Urochloa* sp.) have been sown on this Station, without success so far.

NURSERIES.

A grass trial nursery has been established containing many species of grasses and medics introduced from other countries, notably America and Africa, and a number appear to be suitable for soil conservation work. The most promising species will be further tested in sward trials at a later date. As difficulty has been experienced in the past in finding a satisfactory grass for use in waterways it is felt that this work may provide just what is required.

A tree seedling nursery is now producing a variety of species for distribution to landholders to be used for windbreaks and woodlots. Eucalypts have provided the bulk of

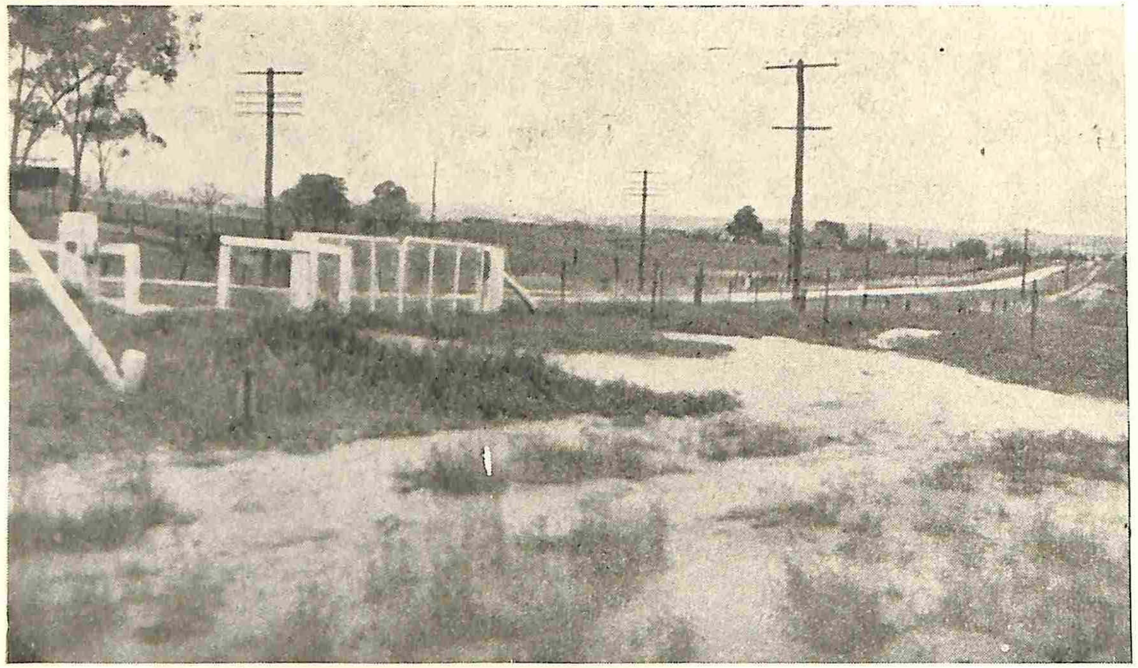

Fig. 3.—The main waterway, well established in 1950, carries a flow 9 inches deep in safety after heavy rains.

Fig. 4.—Dense growth of *Phalaris tuberosa* seals the main waterway.

Fig. 5.—Another section of waterway sealed with *Paspalum dilatatum.*

the output so far but other varieties are being introduced. Some tree planting has been carried out on the station but it is naturally well timbered and there is only limited scope for improvement in that direction.

MEASUREMENT OF RUN-OFF AND SOIL LOSS.

Run-off and soil loss experiments under different land usage on agricultural lands, different lengths of slope and under different conditions of grazing management on hilly grazing lands have been laid out and have supplied valuable data. Further investigations and experiments are being instituted. These, together with carefully compiled meterological records, are furnishing basic information for the efficient design of soil conservation works on landholders' properties throughout the district.

EDUCATIONAL PUBLICITY.

A number of screenings of Australian and American soil conservation films aroused great interest in this district and were attended by visitors from up to fifty miles away. The films were also shown at several schools and were followed by a visit of the pupils to the Research Station.

Soil Conservation Exhibits at Inverell and Glen Innes Shows have drawn attention to the extension and research activities of the Service, mainly by the display of photographs, distribution of pamphlets and an officer being present to discuss soil conservation matters with interested landholders of the district.

CONCLUSION.

The now fully developed Inverell Research Station plays an integral part in the long-term soil conservation programme for the Gwydir region. The Station serves as a demonstration for effective methods of wise land usage and mechanical soil conservation measures. Investigations have been instituted into the many phases of erosion and conservation of the basaltic soils of the region and valuable data, both short and long term, is being obtained.

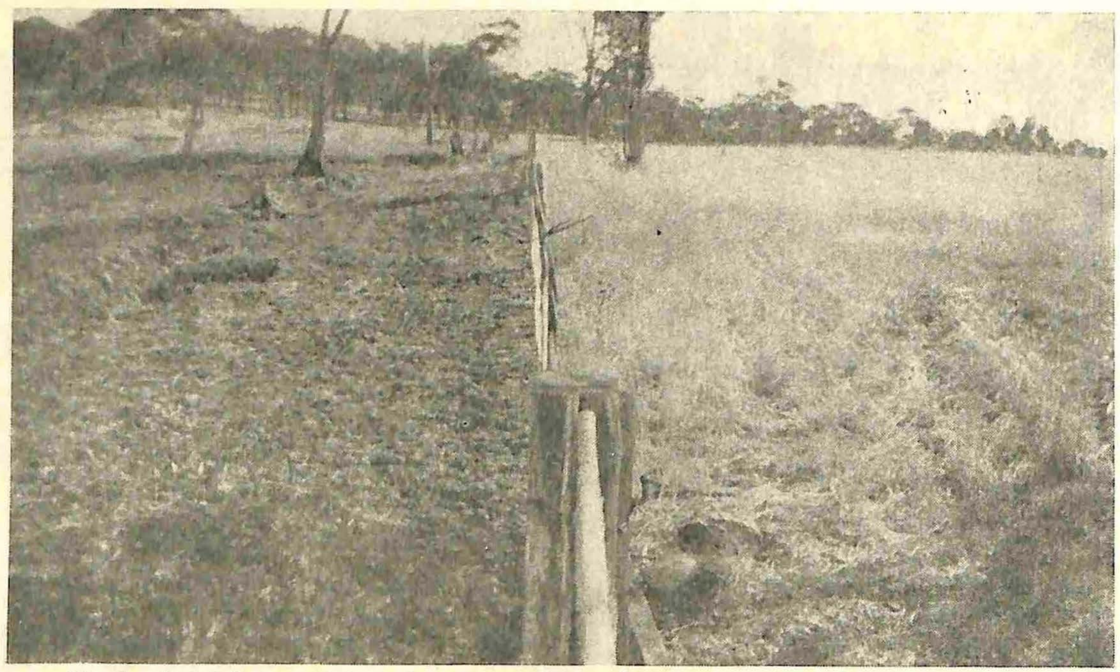

Fig. 6.—At left bare eroded stock route; at right well vegetated soil conserved lands on the Research Station.

SOIL CHARACTERISTICS AND SOIL CONSERVATION

BY

J. A. BEATTIE, B.Sc. Agr., Soil Conservationist.

THE farmer who wishes to achieve maximum efficiency in his operations realises that his technique is very largely the result of careful consideration of the properties of the soil he works. Similarly, close attention to soil characteristics is required in the practice of soil conservation.

AIMS OF SOIL CONSERVATION.

The immediate object of soil conservation is to reduce soil wastage. This can occur by transport and removal by concentrated water flow in gullies, by sheet removal in soil flow or as the result of a net downhill movement due to raindrop splash. The latter is unavoidable unless the soil is protected by vegetation while it is raining. Its rate is increased with higher intensity of rainfall and by decreased aggregation of soil particles. Soils with a high percentage of water-stable aggregates will resist the dispersive action of raindrops. The aim should therefore be maximum degree of plant cover and stable aggregation at all times to minimise such adverse effects.

Improvement in aggregation can be achieved by the inclusion of pasture or clover ley in rotations, by addition of lime or dolomite to base (mainly calcium) deficient soils, by methods directed towards building up soil organic matter content, for example, stubble mulching, and by cultivation as far as possible when the soil is at the optimum moisture content.

An indication of the fertility level in good agricultural soils in the textural range of loam to clay loam, as against sands and sandy loams, is again the percentage stable aggregation. Thus fertility raising rotations, which usually mean maximum plant cover over the year, achieve the triple result of increased marketable yield, higher fertility with better soil structure, and greater resistance to erosion.

In the prevention and elimination of gullies the first objective is the reduction of the amount and rate of surface run-off to a minimum. The rate is reduced by changing of the slope characteristics mechanically by contour cultivation, the use of implements which cause a ponding in the furrow, such as the basin lister, and by absorption and graded banks. This has the effect of holding the rainfall for a longer period during which infiltration can proceed.

CONTRIBUTING FACTORS TO RUN-OFF AND SOIL LOSS.

It should be remembered that concentrated water flow is only the immediate causative factor in the formation of gullies and the result of a number of previously fulfilled conditions. Bare fallowing during the period when intense rainfall may be expected, cultivation of too steep slopes, the removal of timber from steep slopes and hilltops, and cultivation to produce furrows running at any angle but at right angles to the direction of slope are examples of farming practices which should be reduced as far as possible. Added to these are unfavourable soil properties summed up in the inability of the soil to absorb rainfall at a sufficient rate, but any soil will erode into gullies if rainfall becomes concentrated in a line of flow downslope.

SOIL PROPERTIES IMPORTANT IN ABSORPTION.

The amount of water running off an area from any rainfall is reduced to a minimum where maximum retention on the surface and infiltration is aided by the presence of plant cover and by such practices as stubble mulching and inclusion of pasture in the rotation to increase the organic matter content of the soil, improve its structure, and in turn its permeability and absorptive capacity.

The permeability (rate of water transmission) of a particular soil profile (the succession of soil layers continuous down to the parent material from which the soil has developed) is limited to the permeability of the least permeable horizon (layer). Although the quantity of water which can be held in the topsoil is enormously increased by high organic matter status and good structure, there must be free drainage throughout the soil to allow water in excess of this quantity to percolate downwards, eventually reaching underground storage reservoirs or emerging in spring or stream flow. Otherwise it is obvious that it must run off the surface with the possibility of resultant erosion.

A problem arises in the determination of the amount of water in the soil immediately prior to rainfall. Attempts have been made to classify rainfall on the basis of the time interval between storms([1]). Recently a series of experiments has been reported with the object of determining the relation of antecedent soil moisture content to infiltration data for certain Riverina soils([2]). Finally it has been stated([1]) that the soil moisture content at the commencement of precipitation has a greater effect on infiltration rate for the first twenty minutes than any other factor. Continuous records of soil moistures would then appear to be of great practical value.

HARDPAN FORMATION MEANS REDUCED SOIL PERMEABILITY.

Probably one of the most important single factors under the control of the farmer in this regard is the development or prevention of the development of a ploughsole or hardpan, practically impervious to percolation of water. Particularly in heavy soils this effect results simply from ploughing at the same depth year after year. The remedy is obvious. In susceptible soils relief is obtained by ploughing at varying depths, and as a last resort, by ripping to break the hardpan. This could be done with a rigid tyne scarified fitted with narrow points. Needless to say, ploughing or cultivating at too high moisture content aggravates the trouble.

Fig. 1.—Black soils have an unstable crumb structure and are very liable to erosion under unsound land use practices.

Fig. 2.—A ripper can be used to break up impermeable soil and so improve water penetration.

USE OF ABSORPTION BANKS.

Where it is thought that absorption banks with closed ends, designed to hold depths of water up to a foot in the channel, allowing it to percolate downwards, should be installed in the solution of a soil erosion problem, consideration should be given to the need for well-drained soil in such cases. Vegetation will have a very hard time maintaining itself when water is held ponded for long periods after rainfall. This type of bank, and indeed any type, is then of greatest efficiency in soils through which water percolates readily, but in all cases should be provided with properly designed outlets for removal of water in excess of their capacity accumulated following successive high intensity rains.

In good agricultural soils, in contrast to soils of a sandy nature, well-drained soils mean soils of good structure. Often, soils of high fertility contain a high percentage of clay, for example, many soils of the northern wheatbelt, and are subject to loss of structure with decrease in their fertility level following exploitive farming. This loss of structure means decreased permeability due to puddling of the clay to fill the drainage pores. Thus more water runs off and an accelerated rate of erosion follows. Relatively fertile topsoil is removed, further reducing fertility. Once started a vicious circle continues, and to stop this, mechanical measures are necessary.

SPACING OF GRADED BANKS.

Spacing of graded banks, a very common means of mechanical erosion control, depends on the degree and length of slope on which erosion is to be controlled. Their exact spacing is at the point at which a length of slope remains above them such that if water is allowed to run down it, rilling is about to occur at its base. The presence of rilling between banks means that the spacing is too wide and that silt has been carried into the bank channels thus reducing their capacity and increasing the risk of overtopping. The position of this exact point of bank placement depends on the amount of run-off water and the ease with which the soil may be removed by waterflow. The amount of water running off depends on the balance between precipitation and infiltration and retention, the factors of which have been discussed in some measure above. A major consideration in the determination of initial bank spacing is therefore the infiltration capacity of the soil in question. It is possible that initial bank spacing and channel capacity could be defined more exactly for each soil type following such a study.

It will be noticed that the word "initial" has been used in the previous discussion. The amelioration of relevant soil and watershed properties following installation of a system of erosion control works is a problem for future attention but its effects operate in making the system "safer" so that it will withstand a greatly increased intensity of rainfall above that for which it was first designed. If these banks were then never asked to carry run-off water, they would still be of the greatest value as a guide to the contour cultivation of the area concerned.

THE ASSESSMENT OF RUN-OFF.

The generalised run-off equation is $Q = CIA$ [3], where Q is the critical rate of run-off in cubic feet per second, that is, the rate of run-off which can be just handled by the control system at a given point, C is the co-efficient of run-off, representing the ratio of the rate of run-off to the rate of rainfall and whose value is affected by the soil characteristics under discussion, I is the rainfall intensity in cubic feet per second per acre (approximately equal to the rate of rainfall in inches per hour) and A is the catchment area in acres. This equation gives a means of answering the problem of what capacity of bank channel should be provided for an area for which rainfall intensity records have been kept. The main difficulty in its exact evaluation lies in the determination of suitable values for C. Since C is dependent so largely on the soil factors affecting run-off, its exact measurement requires detailed investigation into the soil characteristics of each district.

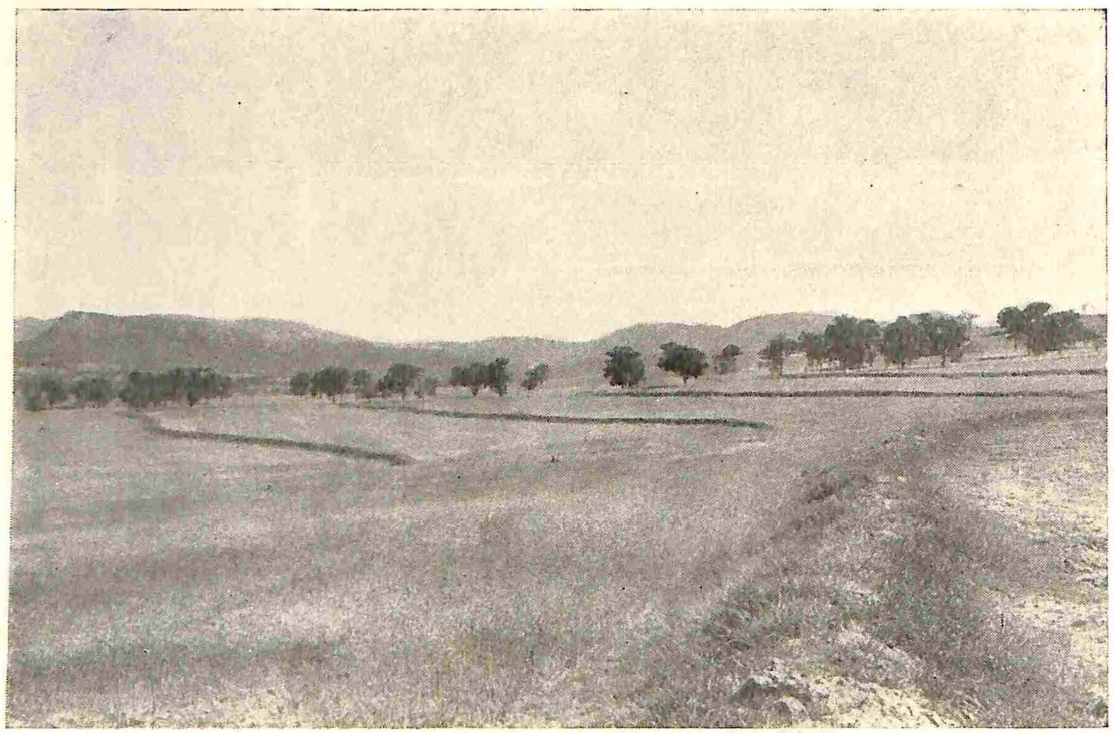

Fig. 3.—Soil structure, slope and climatic conditions are all factors affecting the correct spacing of graded banks.

C, for any soil type, may be considered in conjunction with a certain value of I, designated I_1, when the structural stability of a soil and its infiltration capacity may not withstand an intensity of rainfall above a certain critical value, at which breakdown into discrete erosive particles occurs and major soil loss commences. This is the point of interest especially to the Soil Conservationist, and appears to be especially applicable to erosion of the black basaltic soils of the Inverell District.

Ordinarily, control measures could not be designed of capacity to contain rainfall of intensity I_1 on the exposed soil because at this point such soil loss would occur that the bank channels would be filled and their purpose nullified. When soil breakdown occurs for values of I_1 close to the value for I for which it is considered economic and necessary to construct control works, for example, for a storm intensity of once in five or ten years expectancy, it is evident that improvement is needed in the stability of soil aggregation. To some extent a measure of this property is obtained in the determination of the degree to which soil structural aggregates resist breakdown when immersed in water and gently oscillated up and down. The application of this measure has yet to be fully developed.

CONCLUSION.

A necessarily incomplete account has been given of the application of certain soil characteristics (fertility, structure, stability of structural aggregates, infiltration capacity, mechanical composition) in relation to soil conservation. Their interdependence has been stressed and ameliorative measures noted where these can be effective in promoting greater resistance to, and recovery from, soil erosion.

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FOREWORD

BY

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

WHEN the Soil Conservation Service commenced its campaign against erosion it was realised that grass would have to play a major role. Soil that is deprived of the protection of surface vegetation is highly vulnerable to erosion and the best vegetational cover in most situations is grass. It was obvious that protection from erosion called for a more widespread and better utilisation of grass as cover for the land. There was need for a better understanding of its possibilities, more information regarding pasture management for particular purposes, and a general stimulation of interest in the use of grass.

Grass is actually our most important crop but it is not yet receiving the attention it deserves in this country. Insufficient research and developmental work have been carried out, and the knowledge in this country concerning grasses is altogether inadequate. Grass has been taken too much for granted, but the field of research is full of promise from the point of view of both economy of rural production and the control of erosion.

The Soil Conservation Service has used grass at every opportunity in its work, and already has had some gratifying successes and made some advances in the better utilisation of grasses. Virtually all grasses and legumes conserve the soil and improve its texture. They cover and protect it and are the most effective agents for reducing erosion on sloping land. They improve the fertility and the water absorbing and holding capacity. In this way they are useful not only while actually growing but also if they are turned under as green manure, left on the surface as a mulch or grazed by livestock and the residues turned under.

The need for grassland farming in a programme of erosion control becomes very apparent. It would have been most difficult to stabilise economically much of the country we have effectively treated without a full utilisation of grass. For many of the farms in the wheatbelt and the mixed farming areas there was no other way to plan a soil conserving and water controlling programme. Though introduced in our work for these purposes, the grasses under management quickly demonstrated their advantages in other important directions. The individual farmer was quick to recognise the economic possibilities of grassland farming and a wave of enthusiasm is commencing throughout New South Wales. In earlier years only those men in the subterranean clover and Wimmera rye grass districts in the southern parts of the State had developed pasture management. Farmers who had never before planted a grass or legume are now laying down appropriate areas of their farms to sod crops. This is being done not only on the properly planned grassed waterways which have become so widespread and so successful in soil conservation programmes in New South Wales but also in the farm rotations on the arable land.

Grassland farming means giving grasses, legumes and sod crops a more important place in the farming system. It means more and better feed for livestock by pasture improvement and management, more grasses and legumes in the crop rotations and better crops of hay and silage. It means more protective cover for the soil, grassed waterways, strip crops of grasses and legumes and the use of sod crops in other ways to help conserve soil and water. It results in better balanced and more profitable farming.

Our first need was for satisfactory grasses or legumes to meet the exacting requirements of grassed waterways. These are designed and constructed for the conveyance of large volumes of swiftly flowing water, and the grass, to be effective, must completely seal the soil and protect it from the erosive force of the water. Grasses for the stabilisation of gully bottoms were also needed. In the better rainfall portions of the southern parts of the State where subterranean clover and other useful plants can be easily established the problem was not so difficult. However, in the drier parts of the south and in the west and north-western parts of the State the problem was formidable. The grasses used in the south were quite unsuitable.

A great deal of work had to be done on the newly established Soil Conservation Stations to overcome the initial difficulty. Some grasses showed themselves to be outstandingly suitable to dry and difficult environments. Rhodes grass has been very successful in some difficult situations. It is also widely adaptable and is now extensively used in grassed waterways in the north-western and central western districts. It is also very successful in the Hunter valley, where it was hard to get a suitable grass for waterways and gully stabilisation. It has also proved most useful at Camden. Where rainfall is good or where overflows frequently occur, kikuyu has been a great help. It has safely carried remarkable volumes of water in such vital places as dam spillways, gully floors and overfalls. Also, assisted by the extra water it receives in such positions, it has been possible to extend the use of kikuyu for this purpose far out into dry inland country where it could not normally survive. The same applies to couch grass, which forms a dense protective sod and is fairly drought resistant. It is also very useful for safe water disposal on roadsides. Tifton Bermuda grass, an American variety of couch grass, is also under trial here and is proving superior to our local couch for soil conservation work. It was developed at Tifton, Florida, and is a very vigorous grower. In those areas which are too dry for subterranean clover, barrel medic is giving good results. Lucerne has its place also, although it grows in clumps and does not give the complete ground cover that sod forming grass and legumes afford. This means that it has limitations when used alone in such exacting situations as grassed waterways. Nevertheless, its qualities of drought resistance, heavy production, fertility building and ability to utilise profitably large amounts of water render it very useful. It is valuable for sowing on land that is gently sloping or flat and which has to receive large quantities of run-off water. It then receives what amounts to a periodic irrigation and the response is very satisfactory. It is extensively used in soil conservation work, especially in crop rotations to afford continuous cover, and is also included in many of the pasture mixtures.

Viewing the position generally, although many men in this State have recently become grass conscious primarily because of soil conservation work, they are developing their interest in grasses and pasture management because of the many advantages which can result. A better understanding of the use of grass will lead to its wider utilisation in the general farming programme. There is every indication that in addition to controlling erosion and giving more stability to the land, a wider use of grass will have other important effects and far-reaching economic advantages on the production side. It gets us away from the practice of one crop farming which exploits the soil, increases erosion, lowers fertility and lowers crop yields. The development of grassland farming offers a feasible way of diversifying farming. It can improve production from the land generally, increase crop yields, maintain fertility and save labour.

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LAND USE FACTORS IN THE CONSERVATION OF STEEP GRAZING LANDS IN THE CENTRAL HIGHLANDS

BY

L. A. H. McCaffrey, B.Sc., Soil Conservationist.

SINCE 1946, when the Soil Conservation Service began its programme of post-war expansion, the quickening tempo of conservation activity has continued to produce far reaching changes in concepts of land utilisation in this State.

At the moment, a stage has been reached in which we are re-orienting our use of the land towards soil stability and sustained fertility; the aim to-day can be summarised as efficient land husbandry. This stage is being carried through, firstly, by stabilising advanced erosion by mechanical measures and, secondly, by rational land management.

It is to be expected that the urgency of quickly overhauling the damage of decades has given impetus to the mechanical aspects of soil stabilising; they have the merit of comparatively quickly application and success. Yet, more fundamental are the methods of wise land management. These may only need minor mechanical aids, and a moment's thought proves how well a maintained vegetative cover supplies soil surface protection, promotes sustained production and is a veritable soil structure improver. It is a *sine qua non* in the concept of land husbandry.

On this basis it is of particular interest to consider methods of conservation in the hilly to mountainous grazing country of the central highlands. This land is important for its wool production and equally important as the catchment of the Macquarie River immediately above the Burrendong dam site, *i.e.*, the eastern Wellington, Mudgee, Hill End and Sofala districts.

The steep and rocky nature of the landform places great emphasis on the non-mechanical methods of soil conservation and supplies a good opportunity to consider what methods may be adopted to stabilise current erosion and promote the concept of soil husbandry on steep purely grazing areas.

THE NATURAL ENVIRONMENT OF THE HILLY LANDS.

Highland farm environment may be considered in two ways—one featuring its participation in the general overall qualities of climate, land-form and soils, and the other dealing with the particular individual qualities of the property itself.

Compared with more westerly country, the highlands have the more genial rainfall and temperature regime. Rainfall is usually effective throughout the year—though two to three months dry times are not unusual. Average falls of rain vary from 24 to 27″ per annum, rising to thirty inches and over on plateau uplands at 3,000′. With this latter land, this article is not concerned. Winter temperatures are well down, *e.g.*, mean minima at Mudgee of June, July, August are 35.6°, 34.1°, and 35.4°F. There is no marked seasonal drought, but heavier sporadic storm rains are commoner in summer than in winter.

Topographically, the land enjoying these climatic conditions is of alternating steep ridges and valley type with from 200′ to 1,000′ relative relief from valley floor to ridge top and predominant slopes of over 25%. Low lying arable and sloping land is relatively limited, being most extensive near a river or a major tributary creek.

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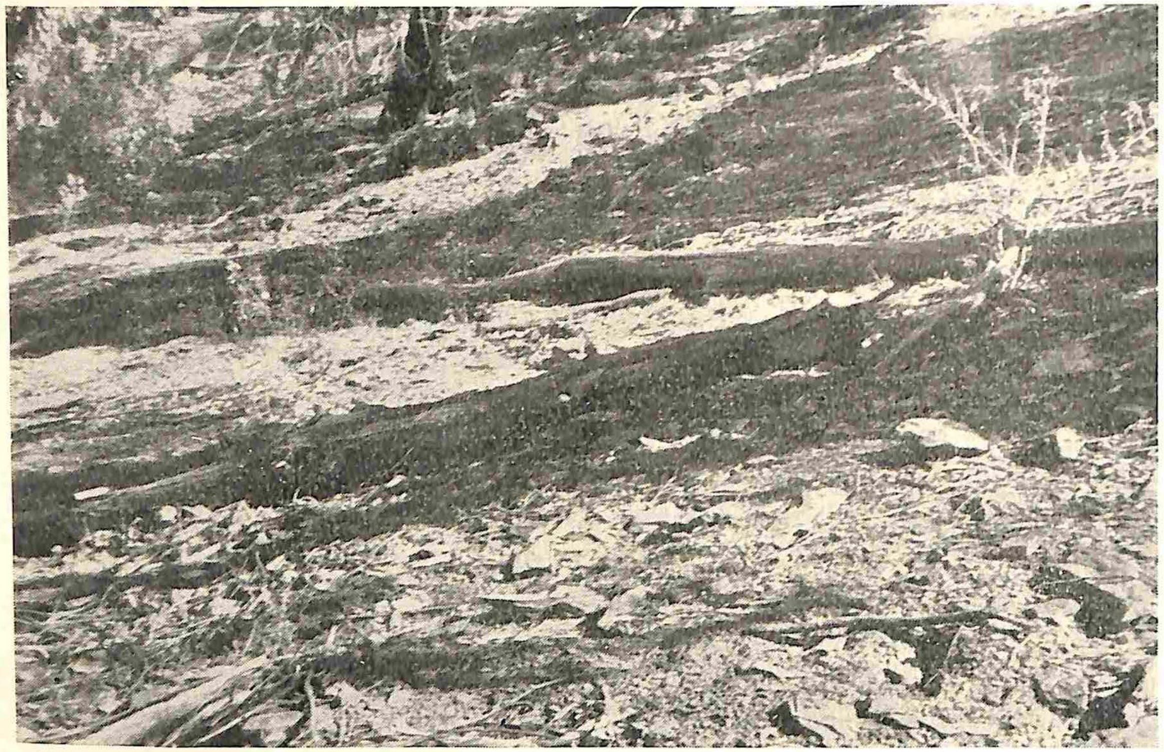

Fig. 1.—The destruction of surface litter following recent clearing. The early stages of sheet erosion are already apparent.

Under such conditions, the most widespread rock, a Silurian slate-diorite complex produces a shallow, rocky, skeletal soil on the steep slopes. On the lower country the arable soils are grey-brown to grey-podsolic, of rather variable natural fertility.

Pastures are dominated by a spear grass, wallaby grass, wire grass association (*Stipa-Danthonia-Aristida spp.*), the latter becoming dominant where soils are coarser and sandier in texture. This association is joined on the rougher ridges by tussocky poa (*Poa caespitosa*) and kangaroo grass (*Themeda australis*). The following genera are also widespread: *Bothriochloa, Chloris, Panicum* and *Enneapogon*. Annual legumes consisting of clovers and medics, *e.g., T. glomeratum, T. arvense, M. minima* are likewise widespread.

Appreciable areas of Devonian strata, mainly mudstones and limestones, occur and form some of the most rugged country to be found in the central highlands. Soil fertility is somewhat higher in this country especially on the lower slopes; much the same pasture species as above are present except for a decrease in the *Aristida* component and a rise in the amount of *Danthonia*. *Themeda australis* (kangaroo grass) is widespread on infrequently grazed rough country.

Superimposed on these differences are the variations from property to property and these have a profound influence on the type of land use. Aspects of slope, for example, influence pasture composition by their alignment relative to the path of the sun. Northerly aspected slopes are frequently dominated by a *Stipa-Aristida* association since these slopes are hotter and dryer. Southern and south-westerly slopes are better grassed with a *Danthonia* dominant association and good herbage.

More obvious differences occur in the amount of arable bottom land and in local fertility variations, as through the presence of a basaltic residual or sandstone outlier. Most properties have only portion of their area as effective grazing; some are too rough and rocky to support the better grasses.

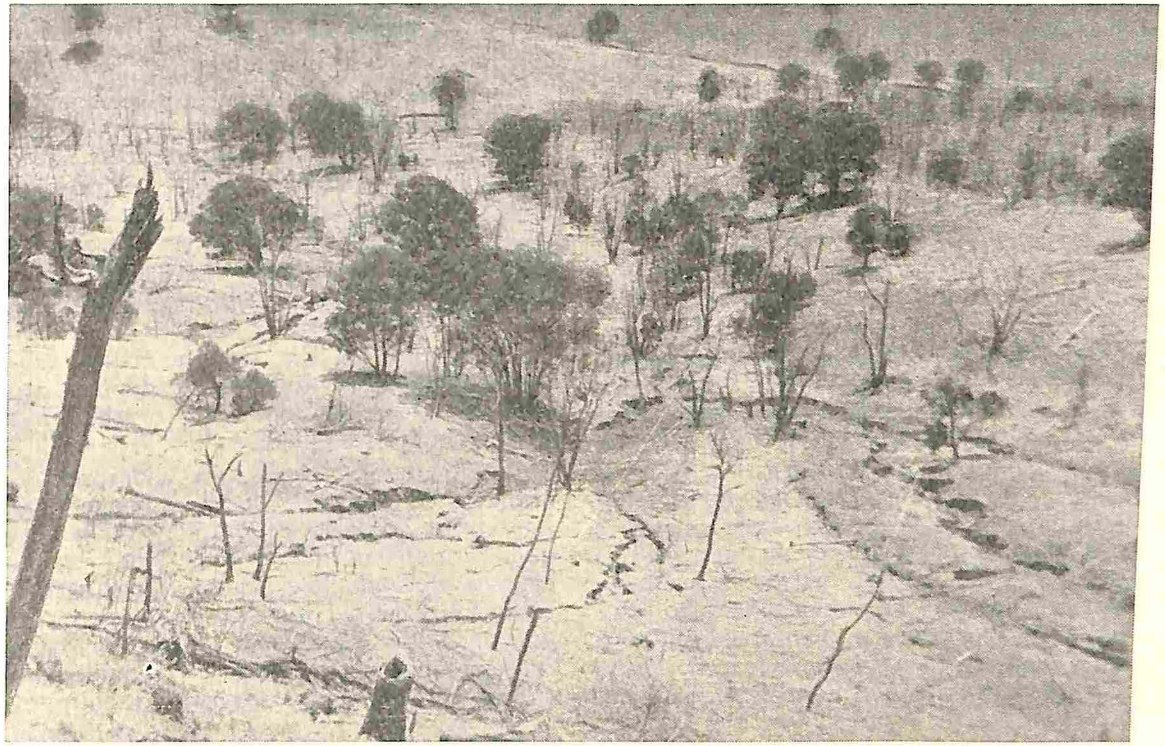

*Fig.*2.—Rabbit infestation and failure to adjust stocking rates to land class leads to serious erosion on these steep lands.

Fig. 3.—Sheet and gully erosion in a critical stage. Land usage is in need of urgent adjustment.

The relative influence all these factors have upon the present and potential land use of a property need careful consideration by the landholder. If a more "intensive" use and management is to replace the present "extensive" system, each acre needs scrutinising as to how best it can be improved.

THE PRESENT LAND USE AND EROSION POSITION.

Ever since the development of the Australian merino, the steep grazing lands have been extensively utilised for wool growing. To-day this breed accounts for 80 to 90 per cent. of all sheep in the area. Properties with substantial acreages of better land favour Corriedale and other dual purpose sheep. Pasture improvement either by sown grasses and legumes or by topdressing natural grasses with superphosphate is unusual—lucerne is the commonest and is grazed and cut for hay on alluvial country. Oats are grown to some extent to give winter grazing whilst an occasional millet or maize crop is grown for summer feed. However, the majority of landholders carry out summer grazing upon dry pastures and feed hay or grain should rain be scarce, so that stocking rates are maintained.

Most property areas fall between 1,000 and 3,000 acres; few are over 10,000 acres. Pasture Protection Board figures show average stocking rates at about $\frac{3}{4}$ sheep per acre. Rates for smaller properties in these ranges frequently reach or exceed one sheep per acre. Stocking rates for the larger properties are generally lower, varying between $\frac{1}{2}$ and $\frac{3}{4}$ sheep per acre.

The nature of the terrain makes rabbit extermination difficult; paddocks are large, so that the population of this pest remains high throughout.

Gully and sheet erosion are widespread—probably 80 per cent. of all drainage lines are in an unstable condition; the largest gullies are found where hill side run-off courses through low lands. Catastrophic erosion is localised, with the worst examples occurring on very steep slopes of from seventy per cent. upwards, denuded of timber and over populated with rabbits.

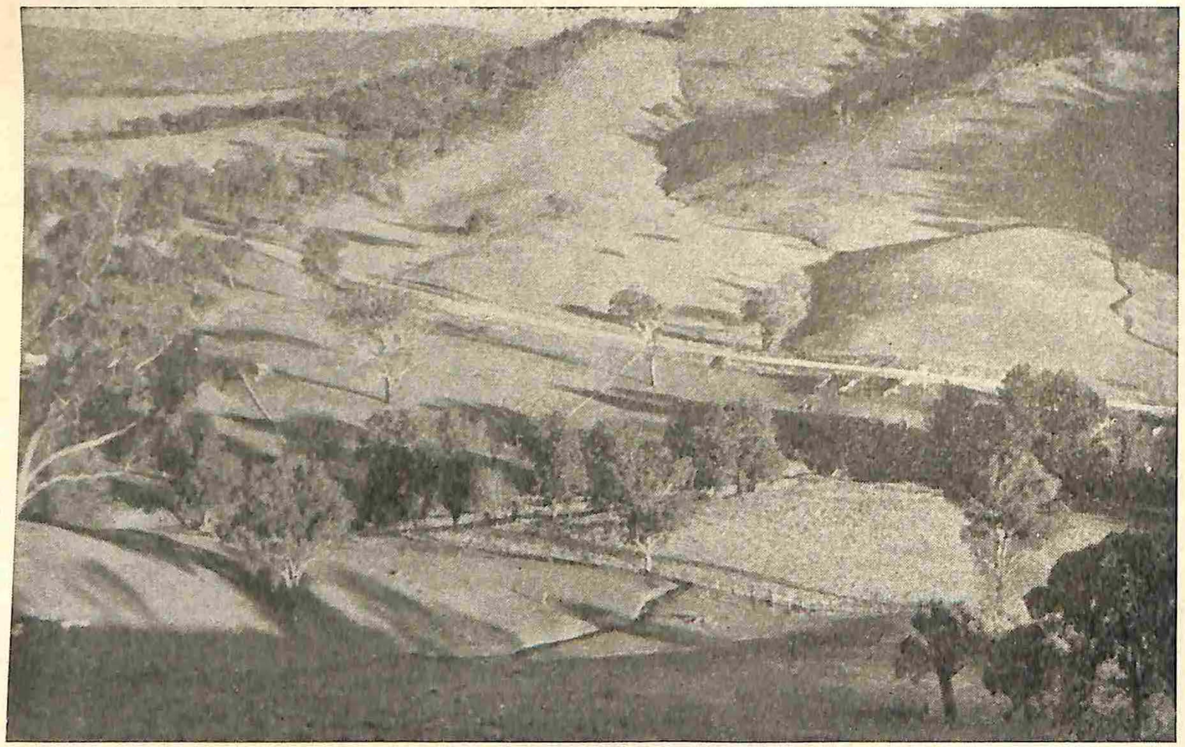

Fig. 4.—An excellent sown pasture (right foreground). This land has been fenced separately and acts as an absorption area for run-off and erosional material from the steeper land.

WHAT CAN BE DONE?

Publicity given to the erosion problem has not been lost upon holders of these hilly lands, but many are in a quandary, wondering what means of conservation should be adopted. They realise that widespread moved earth installation can be ruled out over most of their property and, being used to an "extensive" outlook on land management, tend to regard any other methods, insofar as they know them, as impracticable.

In the ensuing lines some suggestions are made which may help to clarify the husbandry concept as applied to this steep grazing country.

PASTURE IMPROVEMENT AND SELECTIVE FENCING.

Pasture improvement should be the basis of successful conservative grazing. Practically every property in the steep country has some land favoured by topography and soil for the establishment of denser and more productive pastures. Even slopes of up to 20 per cent. may be utilised in this climate provided the soil is reasonable; establishment is aided markedly by the installation of run-off conserving structures such as pasture furrows. All creek fringing lands and low slopes come into this category, and these do not usually require furrowing. Subterranean clover, perennial rye, lucerne and phalaris have already demonstrated their capacities in such conditions with yearly applications of super. Top dressing of natural pasture with super, without introduction of new species, has been found effective. Better results, however, are obtained with introduced species.

Improved country needs to be fenced so as to permit satisfactory control of grazing. Improved low land enables the landholder to reduce grazing pressure on the steeper lands and allows systematic spelling to encourage pasture growth. Following recovery, a shift of land use to include a greater number of cattle and less sheep is a wise move, and paddocks may be grazed in rotation.

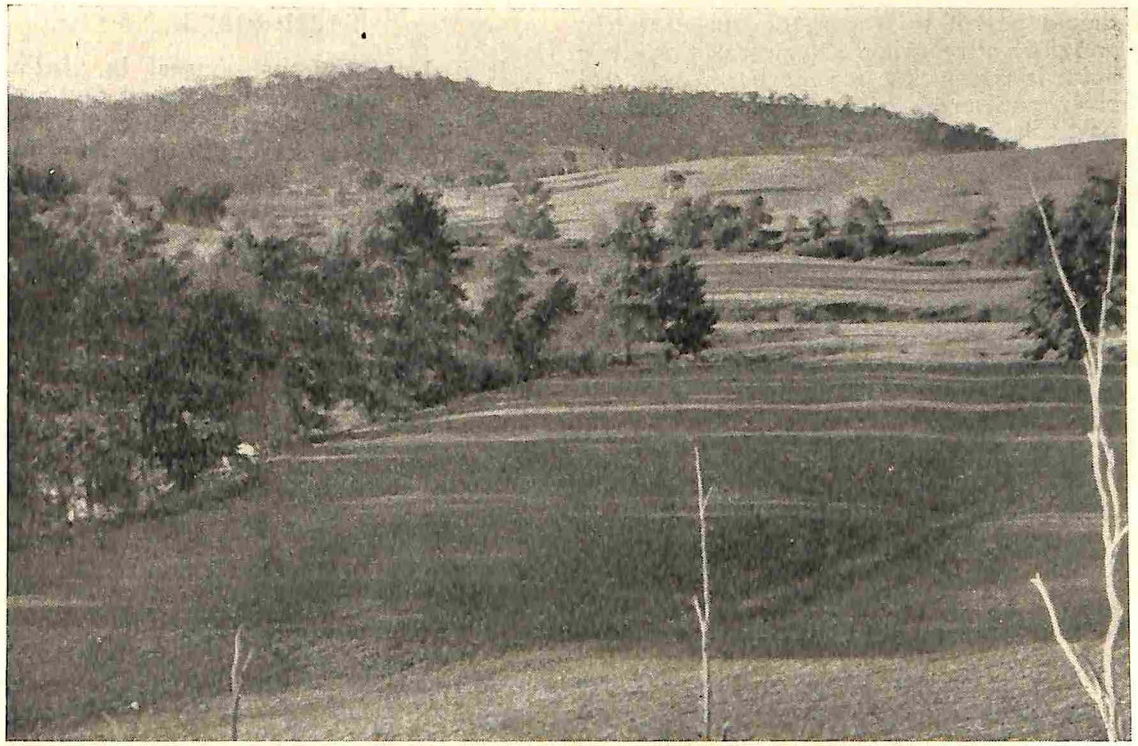

Fig. 5.—Wise land usage on lower slopes in the Cudgegong district.

Again, consideration of the farm environment must cause the landholder to treat different steep land in different ways. Very steep and rocky land or very poor country needs to be segregated, fenced, left in timber or, if cleared, grazed very lightly. Steep land already badly eroded should be fenced completely to exclude all forms of stock.

An overall reduction in stocking of critical high country results in a denser and better balanced pasture, which in time means greater fleece weights and at least equal income. Improved lower country provides better breeding facilities and additional income from fat stock.

FODDER CONSERVATION.

Properties with reasonable areas of bottom land should always have part of this country under fodder crop; oats have an advantage as a cover crop for pasture mixtures containing summer growers. Where cultivation extends into slopes operations should be carried out on the contour. In all cases, where drainage lines intersect arable lands, a natural or sown grass waterway strip should be left to dispose of run-off safely and prevent scouring. Neglect of this latter point is responsible for much soil loss and river and creek siltation and should be particularly guarded against.

RABBIT CONTROL.

If fodder conservation is the grazier's best immediate answer to drought, the rabbit factor through overgrazing is one of drought's greatest allies. Failure to control this pest can nullify other good aspects of the individual's management and there can be little doubt that stringent control does simplify the maintenance of soil stability. The fact that smaller sized netted paddocks mean better rabbit control dovetails well with other aspects of management as regards rotational grazing. Rocky areas, difficult to attack, should be fenced out.

AFFORESTATION.

Very steep land, unless of obvious fertility and capable of sustaining good grass growth, is better for its covering of timber, and furthermore should be kept free from stock. Insurance against soil movement in this class of country is provided principally by its natural surface litter of leaves, bark, fallen branches, etc., which impedes the speed and concentration of surface run-off. To allow stock free access to timbered country means in time, destruction by trampling of this surface litter and very high risk of erosion.

DIVERSIFICATION OF WATER SUPPLIES.

The commonest means of watering in steep country is by dams and this is often the only feasible means. Very often only one major dam is used to each paddock. In the hot summer months this leads particularly to over stocking and trampling, causing denudation and risk of sheet and gully erosion. Grazing can be made more equitable where dams are multiplied and so placed that thirsty stock do not have to travel execessive distances and to only one point in the paddock, thus losing condition and constantly using the same series of tracks with risk of gullying. The dams can also serve the purpose of stabilising existing gullies.

FARM ROADS.

It is by no means unusual in grazing country to observe both incipient and well advanced gully erosion through badly sited farm roads and tracks. In many cases tracks have followed the valleys in pre-automotive days, keeping a line close to the watercourse for easier travelling. All such tracks have subsequently eroded. All such valley roads should be sited away from the watercourse, and keeping to the harder country where possible. Roads on undulating lower slope country are better located on the contour. Cross alignment of roads, especially on long slopes leads readily to gullying of wheel tracks. In general, where slopes need to be ascended at right angles or at a cross alignment, through the very rocky nature of the ground, the lengths of these sections should be short and follow hard ground.

CONCLUSION.

It needs to be stressed that the involvements of each aspect of land management unite and are mutually assistant, so that if one method is worthwhile, other wise land

use techniques will reinforce the benefit to be obtained. It is impossible, for example, to improve pasture and yet not fence to obtain its maximum effect. It is only a short step further to consider segregating other land categories and correctly adjusting their use. The methods for more scientific and intensive management involve certainly an expenditure of money, but it is money well invested. The expenditure can be gradual and spread over several years.

Our steep grazing lands are, in their present state of productive capacity, being overtaxed and the resultant soil wastage is both an effect of the present land use process and a cause of even more rapid future deterioration.

Conservation of soil resources, together with maintenance of productive capacity, can only be achieved by a land management which allows these high grasslands to recover and to improve in quality.

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