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FOREWORD

BY

E. S. CLAYTON, H.D.A.,
Commissioner, Soil Conservation Service.

PRESENT-DAY farmers are widely realising that fire is one of the greatest enemies of the soil. Continuous use of fire on the surface of the land will rapidly destroy it. Although it had to be used extensively in the pioneering stages in rural development in Australia, the up-to-date present-day farmer avoids fire like the plague.

On improved pastures fire should never be used. It burns up the organic material on the surface which otherwise would rot down, enriching the soil and improving its waterholding capacity. Fire injures the more nutritious grasses and clovers and adversely affects the useful biologic activities in the surface few inches.

Humus, earthworms, helpful bacteria and other organisms are active often only in the first few inches of the topsoil. These are killed by fire.

Instead of burning crop residues, stubble and general weed growth, wherever possible all suitable vegetative material should be returned to the soil, either by incorporating it or leaving it dead on the surface as a mulch and a protection for the surface.

In earlier years stubble-burning was universal in New South Wales. Even to-day some books still contain this antiquated and unfortunate advice. New disease-resistant varieties of wheat, the widening of crop rotations by farmers and improved methods and machines for dealing with straw have enabled farmers to discontinue the harmful practice of burning stubble.

Progressive farmers in practically every district in New South Wales have turned away from the burning of stubble and are evolving methods of dealing with crop residues. Methods will, of course, vary with the district and the individual farmer's requirements. Mr. W. Giles, of Temora, has evolved one of the most successful methods for his particular conditions. Stubbles are not burnt and he encourages the growth of ball clover, which is grazed until the land is to be cropped again. By this time the stubble has completely broken down on to the surface. The system practised at Temora and in the southern parts of the State, however, will not meet all the requirements of the northern and north-western parts of New South Wales. Here the greatest need is improved machinery for carrying out cultural operations whilst still leaving the straw on the surface.

Fire in the timbered country in the mountains and on the catchment areas is equally disastrous as on the farming and pasture lands. It injures and even kills trees and burns the forest floor and the humus near the surface. The loss of timber is serious as in the recent great Gippsland fires when millions of feet of Alpine Ash were killed. The effect on the catchment area, however, is also disastrous. Not only is the ground cover burnt, but the precious moss and peat beds also suffer. These moss beds are the most valuable waterholding features in the high alpine catchments and should be protected at all costs.

Rains following fires in the mountains carry away great quantities of surface soil. Siltation of storage dams is the inevitable result. All too often the stockman has started fires in the open forest mountain catchments to burn the old grass and rubbish to make green grass next season. The fire runs through the hills till rain extinguishes it. The stockman gets his bit of grass, but it costs the country many thousands of pounds in destruction of timber, impairment of the catchment area and siltation of the storage. Fire causes greater damage to a catchment area than any other single factor. The damage can hardly be estimated.

To get the water into the soil is the great need of a catchment. The soil itself is the great storage, and anything which impairs its capacity to absorb water is injurious. Anyone who understands a little about the composition of the soil must oppose the burning of it.

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SOIL CONSERVATION ON THE CENTRAL TABLELANDS—RYLSTONE DISTRICT.

BY

J. D. Colclough, H.D.A., Resident Soil Conservationist, Burrendong Catchment Area.

CONTAINING as it does the source of the Cudgegong River and providing for a considerable distance the catchment for the upper reaches of this river, the district centred on Rylstone forms an integral portion of the catchment area of the Burrendong Dam, preliminary work associated with the construction of which is now being effected below the junction of the Cudgegong and Macquarie Rivers.

The topography of the area under discussion varies from undulating to steeply hilly and mountainous, being bounded on the southern and eastern extremes by the main dividing range and subsidiary offshoots from this range.

Soil types in the district are variable, ranging from light-coloured to light sandy loams with areas of light clay soils, and heavier red loams of basaltic origin on the basalt caps and slopes of the more steeply rising hilly country; scattered areas of brown to black soils are to be found in the more secluded and not extensive river flats immediately adjacent to the Cudegong River.

The average annual rainfall taken over a period of sixty years is 24.74 inches, and the mean monthly averages over that period vary between 2 inches and 3 inches with the heavier predominance in the summer months.

VEGETATION.

With the exception of areas on the hilly to mountainous ranges, which are densely timbered, the district has been extensively and apparently judiciously cleared, with a substantial number of shade trees remaining; predominate timber types are White and Yellow Box on the better soil types, with some Applebox in the more favoured situations, and Gum and Ironbark-Stringybark association on the mountainous areas—numerous Kurrajong are to be found on the basalt caps and slopes of the hilly country.

Predominate native species of grasses are corkscrew and *Danthonia spp.* with wire grass much in evidence on the poorer soil types of a loose sandy nature—naturalised clovers are very evident.

Excellent stands of kangaroo grass are to be seen on fenced railway areas, indicating that this palatable and nutritious grass is indigenous to the area and presumably was widespread at one time, but, apart from these stands on fenced and unstocked areas, its presence in the district is indicated by isolated plants in inaccessible parts of grazing and cultivation areas.

Very extensive areas of red grass are to be found throughout the district, and it is suggested that the dominance of this grass in the grazing areas is a legacy of consistent overstocking and very high rabbit infestation, with the consequent reduction of the ability of the more palatable and therefore more useful species to compete with it. This gives an indication of the general stocking policy over an extended period in relation to the erosion problems experienced in the district.

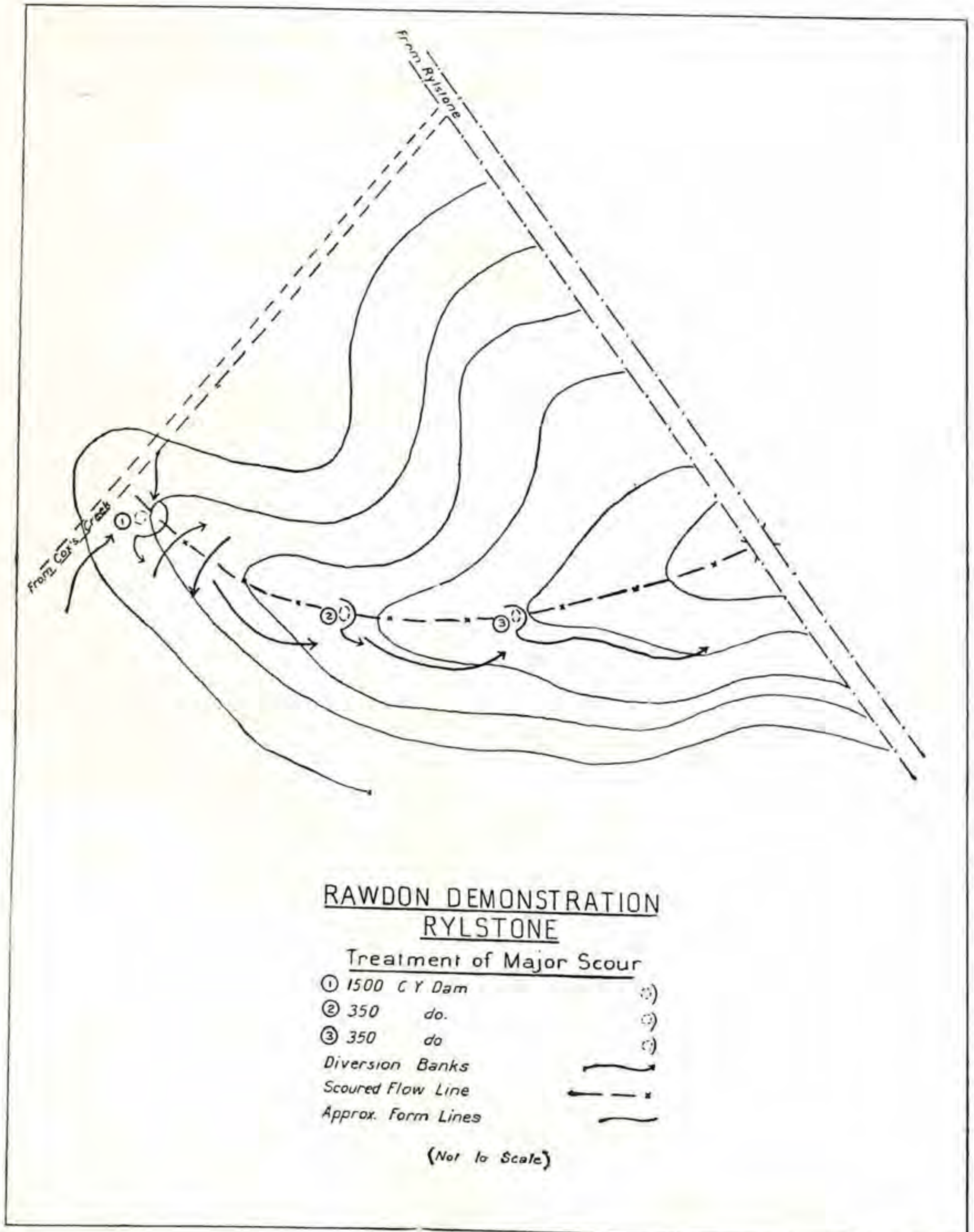

Fig. 1.

Of the introduced pasture species, subterranean clover, associated with Wimmera rye grass, is well established in the more favoured areas especially towards the higher country on the Glen Alice road, while lucerne is grown successfully throughout the district.

The major land usage in the district is the grazing of sheep both for wool and fat lamb raising with cultivation of the arable areas confined to the growing of fodder crops or in the preparation of the land for the establishment of permanent or semi-permanent pastures. Beef cattle and horses are also carried in conjunction with sheep or as the major industry in certain areas.

Rabbit infestation throughout the district is very high and will be extremely difficult, in certain instances almost impossible, to overcome due to the cover provided by the densely timbered mountainous areas and the lack of more intensive subdivision of the larger grazing areas. The position is further aggravated by the shortage of fencing materials for the repair and replacement of fences.

It is considered that this high rabbit infestation is one of the major contributing causes of the serious erosion problems in the district.

EROSION.

The general erosion problem encountered is basically similar to that in the majority of other areas in the Central Tablelands where serious sheet erosion of arable and grazing lands is widespread and has culminated in extreme scour of natural flow lines due to the concentration in these of the excessive run-off from the sheeted and denuded catchments.

Treatment of these eroded areas by the usual combination of mechanical controls and wise land usage, as recommended by the Soil Conservation Service, is possible in the majority of areas seriously affected and has been demonstrated to be most effective in the mitigation and control of erosion and subsequent revegetation of eroded areas in the Rylstone district. The application of these controls is more difficult on the very striking instances of extreme sheet erosion which are evident in parts of this district, where complete hillsides are bare of vegetation of any kind due to the sheeting of all topsoil from the area with the often seriously scoured subsoil totally exposed. As these areas are located mainly on hilly country of extreme slopes of a broken nature, it will be appreciated that reclamation work by the application of mechanical controls is not at all times practicable.

Extensive scoured gully systems exist in the district, with overfall exceeding 6 feet in depth, rapidly heading back from the downstream end of large catchments; control in these areas is not simplified by the fact that, in the majority of cases experienced, the catchments are up to several hundred acres in extent, contained in the single large paddock and including mountainous tracts of densely timbered country. The topography of this country is invariably such that diversion, either temporarily or permanently, of the water flow, during treatment of the gully head, with the normal dam diversion bank combination as applied to less extensive catchments, is not fully practicable and additional methods of treatment usually have to be adopted. These include top-dressing with superphosphate to induce increased vegetal cover and increase absorption, rational stock control and rabbit eradication.

CAUSE OF EROSION.

The basic cause of the erosion problem is to be found in the policy of consistent overstocking, overcropping or continuous cropping of areas too steep for such practices. Combined with the very high rabbit infestation, these have resulted, in the former instance, in the denuding of pastures with consequent decreased absorption and resistance to surface water flow and in the latter to a reduction of soil fertility and a similar decrease in the absorptive power of the soil and its resistance to the increased surface water movement resulting from this combination of erosion-producing factors.

DEMONSTRATIONS.

The policy of the Soil Conservation Service in allocating priority to soil conserving works, designed in the ultimate to reduce siltation in major water storages, has resulted in the installation of two major

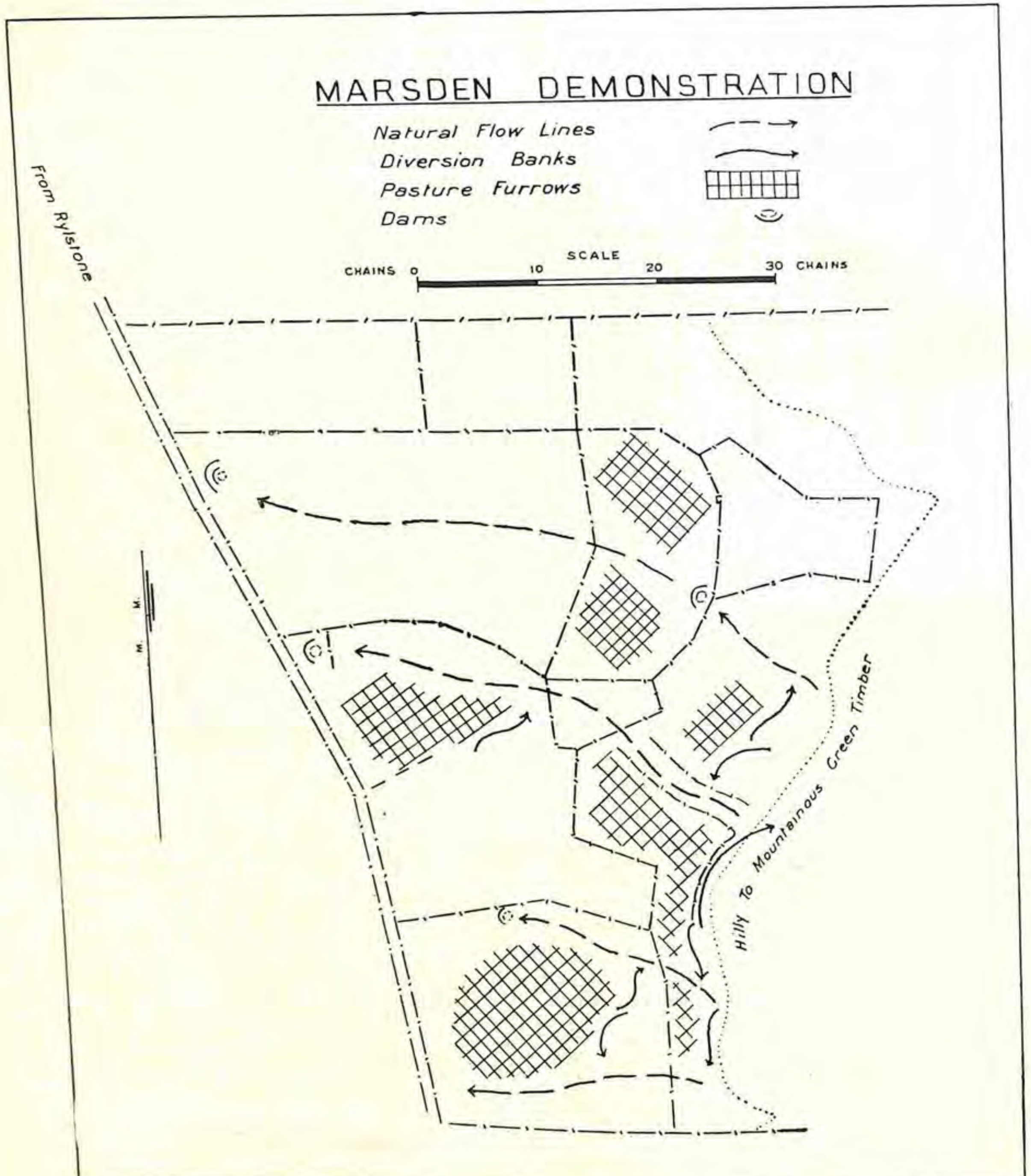

Fig. 2.

demonstrations with ancillary minor demonstration of soil conservation methods, in this Rylstone sector of Burrendong Catchment Area.

Rawdon Demonstration.

This demonstration, the original soil conservation demonstration in the Rylstone area, is located on the property of Mr. J. Kerr, "Rawdon," Rylstone, and is situated 2 miles from Rylstone on the Lue Road.

The demonstration is subdivided by Cox's Creek Road and includes 350 acres of pasture furrowed lands, the furrows constructed with the ripper-grader-terracer combination, on a 2 feet vertical interval, on undulating country of an open nature.

Treatment of a scoured natural flow line causing siltation of a culvert on the Lue Road was also effected by the construction of a series of dams and diversion banks in the flow line, thus demonstrating the possible treatment of similar areas, referred to previously in this article, where major scoured areas exist, with extensive gully systems heading back, in areas where treatment with normal routine conservation controls is not possible or practicable; application of this type of control may also be made to the reduction of damage caused by excess roadside run-off through arable or grazing areas.

The topography of this particular flow line is such that it was impossible to divert completely excess water flow from it and it was thus necessary to carry this flow along its environs, preventing as far as possible water movement on the scoured portion of the flow line. The problem was further complicated by the excess run-off from the Cox's Creek Road, on the downstream side of which the scour is located.

Treatment of the scour was effected by pasture furrowing all that portion of its catchment it was possible to so treat, to reduce water movement by increased vegetal cover and consequent increased absorption.

One major holding dam of 1,500 cubic yards' capacity was then positioned immediately below the road at the head of the scour and a series of diversion banks formed below this dam to divert its overflow from the scoured area to two minor dams of 350 cubic yards' capacity positioned in badly scoured portions of the flow line, the overflow from these being similarly diverted and finally spread on a stable well grassed area at the lower end of the flow line.

The scoured area was then cross ripped following the breaking down of the scour side walls and sown to a pasture mixture of which Rhodes grass was a predominate inclusion.

The object of this demonstration was to show the improvement possible with a combination of mechanical controls (to reduce surface run-off and increase absorption) and top-dressing of pastures with controlled moderate stocking and rabbit eradication, in the regeneration of the pastures on the area generally and the reclamation of a badly scoured area.

It must always be appreciated that the immediate application of these "follow-up" practices on the completion of mechanical control installations is essential to ensure the success of the treatment and unless these practices, which may include top-dressing, re-seeding, retiring of areas from use for specified periods where possible, rational stocking and rabbit eradication, are so applied the mechanical treatment will be only partially successful and the revegetation and regeneration of the area delayed indefinitely.

This system of control was further demonstrated in a modified form when applied to a small catchment area, with a major scour to an 8 feet overfall, rapidly heading back from the downstream end of the catchment, on "Northam" minor demonstration, Rylstone. In this instance, the complete catchment, with the exception of the actual flow line, was pasture furrowed and a 500 cubic yard soil saving dam and 5 chain diversion bank to control the overflow from the dam, were constructed immediately above the scour; thus, by "beheading" it, its progession along the flow line was stopped and subsequent regeneration of vegetation was possible.

Marsden Demonstration.

A second major demonstration in the district was completed on the property of Mr. S. R. Jackson, "Marsden," Rylstone, situated along the Glen Alice Road approxi-

Fig. 3.—An absorption bank well up the slope at Rawdon Demonstration.

Fig. 4.—A diversion bank takes surplus water to dams.

mately 9 miles from Rylstone on the extreme south-eastern boundary of this section of the Burrendong catchment.

The topography of this area, situated at a higher altitude, varies considerably from that experienced at Rawdon and Northam; these latter are of an open, undulating nature whereas the Marsden area comprised undulating land rising fairly steeply to the mountainous, densely timbered country of the main dividing range which forms the south-eastern extreme and falls away steeply to blind natural gully lines of great depth on the west, the whole area being completely surrounded by mountainous, broken country.

The erosion problem encountered was, in the first instance, that outlined previously as being a typical form in this district, *i.e.*, extensive scald of steep hillsides of extreme slopes, and, in the second, the control of the excessive run-off from the adjacent densely timbered mountainous country.

The normal treatment of this latter country to prevent the concentration of run-off on the lower slopes was impossible, due to its mountainous broken nature, therefore, it was decided, in the design of the demonstration, that all this excess water flow be confined where possible to well-grassed natural flow lines, leading in most instances to large dams for stock watering purposes, and provision made to ensure the maintenance of these flow lines in a stable state by fencing them to exclude stock and top-dressing with superphosphate to induce increased vegetal cover.

Rabbit control on the more accessible areas is effected by fencing out the mountainous country from which it is almost impossible to eradicate the rabbit and thus confine these pests to this area; the possibility of this action increasing the erosion hazard due to the concentration of the rabbits in one area has not been overlooked, but it is considered that attention to ensure stable flow lines on the lower slopes capable of handling any additional run-off will lessen the possibility of any damage to these areas.

The construction of a series of major diversion banks of adequate capacity to divert excess run-off from their respective catchments to the selected flow lines, was effected as far above scalded areas as it was practicable to operate heavy plant—the scalded areas were then treated by cross ripping and the formation of pasture furrows.

Following construction, all work was immediately sown to an oats, Wimmera rye grass, subterranean clover mixture broadcast with superphosphate and the areas fenced to ensure stock control.

Treatment of the extensive scalded areas on extreme slopes was carried out by cross ripping the area, working uphill until it was impracticable to operate heavy plant any higher and then forming level absorption banks above the ripped areas—these latter areas were then sown as previously outlined following the construction of pasture furrows. These pasture furrows were formed with the road-plough on the extreme slopes and the grader ditcher on the lesser slopes.

On more undulating areas showing little or no erosion, pasture furrows were formed with the ripper-grader-ditcher combination with the object of assisting the establishment of subterranean clover.

Excellent stands of subterranean clover had been established on Marsden and these have been successful in stabilising minor scours on the more accessible slopes, but the use of heavy earthmoving equipment was essential in the further establishment of this clover on the eroded areas of the more extreme slopes.

To date results on this demonstration have been extremely gratifying, good vegetal cover has been established on all treated areas and the demonstration has shown adequately the benefit to be gained by immediate co-operation and "follow-up" of mechanical treatment with vegetative methods of stabilisation.

CONCLUSION.

By the extension of the methods applied on these demonstrations, modified to suit their respective cases, it will be possible to apply generally suitable and successful mechanical control works to the mitigation of the erosion problems existing in the Rylstone district; also it will be possible, particularly, to treat to a varying degree,

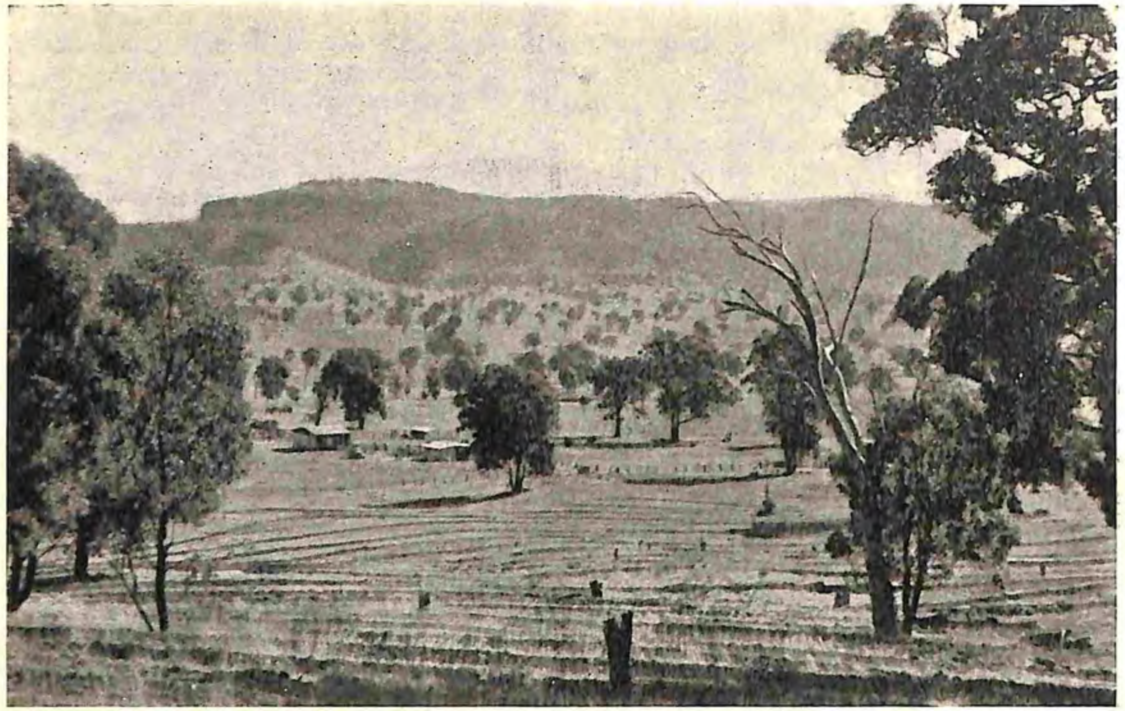

Fig. 5.—Pasture furrows help increase the absorptive capacity of grassland.

Fig. 6.—A small dam plays an integral part in water disposal at Rawdon.

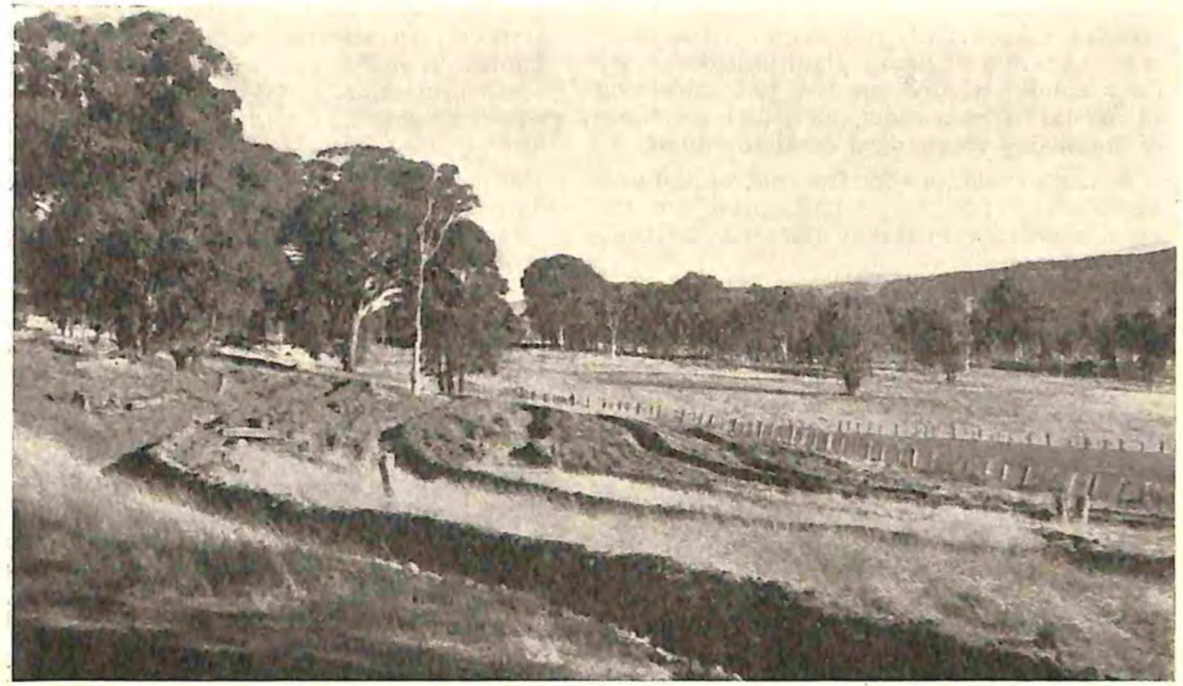

Fig. 7.—Pasture furrows at Marsden Demonstration check run-off.

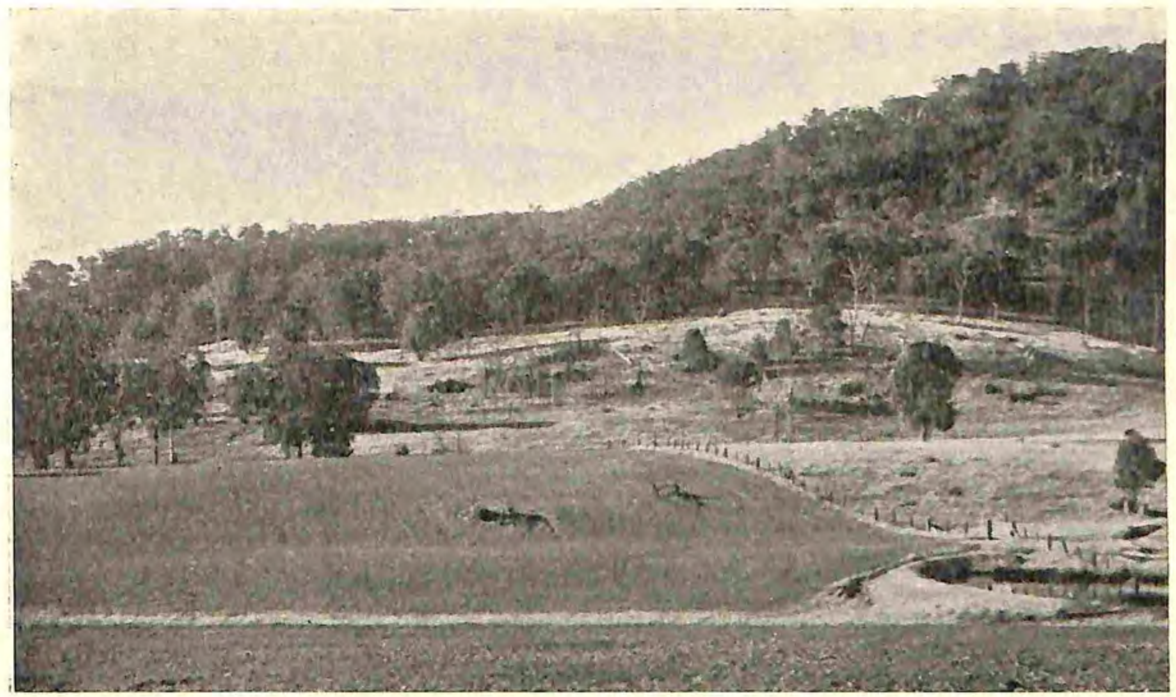

Fig. 8.—A newly constructed dam at Marsden.

extensive sheet erosion on extreme slopes which are apparently too steep for the practical operation of heavy plant and which, by their condition, prevent the re-establishing of vegetal cover without the added assistance of stabilising mechanical erosion controls.

Recommendations for the control and prevention of further deterioration in the erosion position in this district may be summarised as follows:—

(1) Controlled and moderate stocking —this will also entail more intensive methods in the subdivision of large grazing areas.

(2) An intensive rabbit eradication programme—a further reference may also be made to more intensive subdivision to aid this programme.

(3) Top-dressing of natural pastures with superphosphate which respond readily to such treatment in this area. Failure to appreciate the fact that the increased vegetal cover resulting from this treatment does not justify increased heavy stocking will only lead to overstocking and a repetition of the vicious circle with denuded pastures and consequent erosion the major components.

(4) Introduction of improved pasture species in suitable areas to allow of a more intensive system of land usage and soil protection.

(5) An appreciation of the fact that adjacent to mountainous, densely timbered areas provision must be made at all times for stable, well-grassed natural flow lines or constructed waterways to carry the excess run-off from these areas through the lower, more productive and more vulnerable country with a minimum of possible damage.

Finally, the stabilisation of all large catchments is entirely bound up with the improvement of these areas either by mechanical or vegetal soil conservation measures, or by a combination of both, to ensure the maximum possible absorption on the lower more undulating areas.

Emphasis at all times should be placed on control by improved methods of land usage in this district, which lends itself readily to such methods, with a minimum application of mechanical control and this mainly of a reclamatory nature.

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FARM WOODLOTS FOR SOIL CONSERVATION.

BY

R. Powles, B.Sc.

THE development of woodlots on farms presents a new concept of land utilisation in New South Wales. From the earliest days of settlement the basis of land occupation has been the cultivation of the land for the growing of crops or the raising of pasturage to feed livestock. To achieve these ends, widespread deforestation has taken place and, in common parlance, the ring-barking and killing of trees has been deemed synonymous with land improvement. As a result, we find that the retention of a belt of timber specifically for woodlot purposes is practically non-existant and, in fact, on a large percentage of farming properties there is now a noticeable lack of trees, insufficient even to satisfy shade and shelter requirements. On such properties as have retained a belt of timber we find, in most cases, that it is restricted to land completely unsuited to any other form of land use and, even there, is open to unrestricted grazing and not managed for forestry purposes.

It is therefore apparent that a changed outlook to the place of trees on a farm is required before the establishment of farm woodlots can become a generally accepted practice.

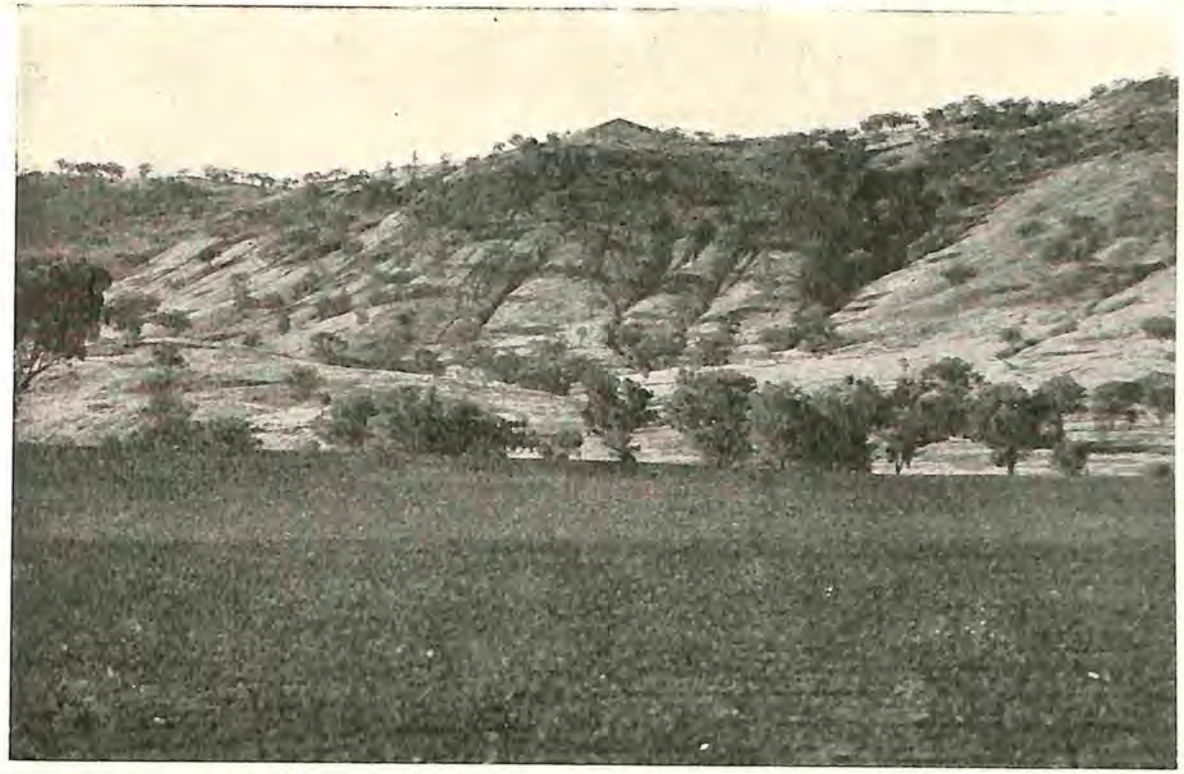

Fig. 1.—Severely gullied hillside—Manilla District. This class of land should be reforested.

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FARM WOODLOTS IN U.S.A.

Although excessive deforestation is now a serious problem and a major cause of soil erosion in most countries, not every country has so completely excluded trees from a place on the farm as we have. In U.S.A., for example, no less than 139,000,000 acresof land, or 14 per cent. of the total land area in farms, is classified as farm woodlots, the average area on individual farms possessing woodlots being 43 acres. By no means does all this large area represent rough land suited only to the growing of timber, but no less than 33,000,000 acres of woodlots has been classified as land suited for agriculture, while a considerable area of the remainder is suitable for grazing by livestock.

Naturally, much of the woodlot area is in a rundown condition and not managed on sound forestry lines, but the figures indicate that there is a large area of land on farms, at present under timber, that could be cleared for farming pursuits. No figures are available for similar timbered land on New South Wales farms, but the extent of such land now under timber that would be suitable for farming is certainly not great.

Apart from this area of timbered land on American farms, a survey has also indicated that there is an area of 12,000,000 acres of abandoned cultivation land and gullied areas on which the only profitable land use would be reforestation, that there is 18,000,000 acres of unprofitable pasture that should be returned to woods and, on the great plains, there is a need for 3,500,000 acres of shelterbelts to provide protection from wind and prevent wind erosion. In all of these three categories there is a similar urgent need in New South Wales for the establishment of farm woodlots for soil conservation purposes.

EROSION POSITION IN N.S.W.

Widespread and damaging soil erosion by water is evident throughout the sloping cultivation land and the hilly grazing lands of New South Wales. The erosion survey undertaken during 1941-43 disclosed that severe and extensive gully erosion was taking place on 560,000 acres of land. On that area erosion is so severe that production is seriously affected, in some cases the land having been thrown out of production. Additionally, gully erosion was found occurring on 19,300,000 acres, and unless soil conservation measures are applied this large area will become as seriously damaged as the former area.

The survey additionally indicated that within the central division of the State severe wind erosion had occurred on 620,000 acres and moderate wind erosion on 11,900,000 acres. The survey did not extend to the western division where it is known that far greater areas are subject to this type of erosion.

The figures quoted above give some indication of the extent of erosion in New South Wales. In combating this problem the Soil Conservation Service uses a wide variety of vegetational and mechanical measures designed to increase the cover of soil-protecting vegetation, to hold up the flow of run-off water and allow it to soak into the soil and to reduce the velocity of wind at ground level. The overall requirements for farm woodlots for soil conservation have not been determined, but the erosion problem, as indicated, is of such extent that woodlots can, and should, play an important part in soil conservation practice.

PLANTING OF ERODED AREAS.

The severely eroded areas of the State present a special problem in erosion control. Although certain parts can be safely returned to their former land use after the adoption of extensive mechanical soil conservation measures, much of the land must in future be subjected to a less exacting type of usage.

Considerable areas are in such a condition that their future use as cultivation or grazing land is out of the question, and the most

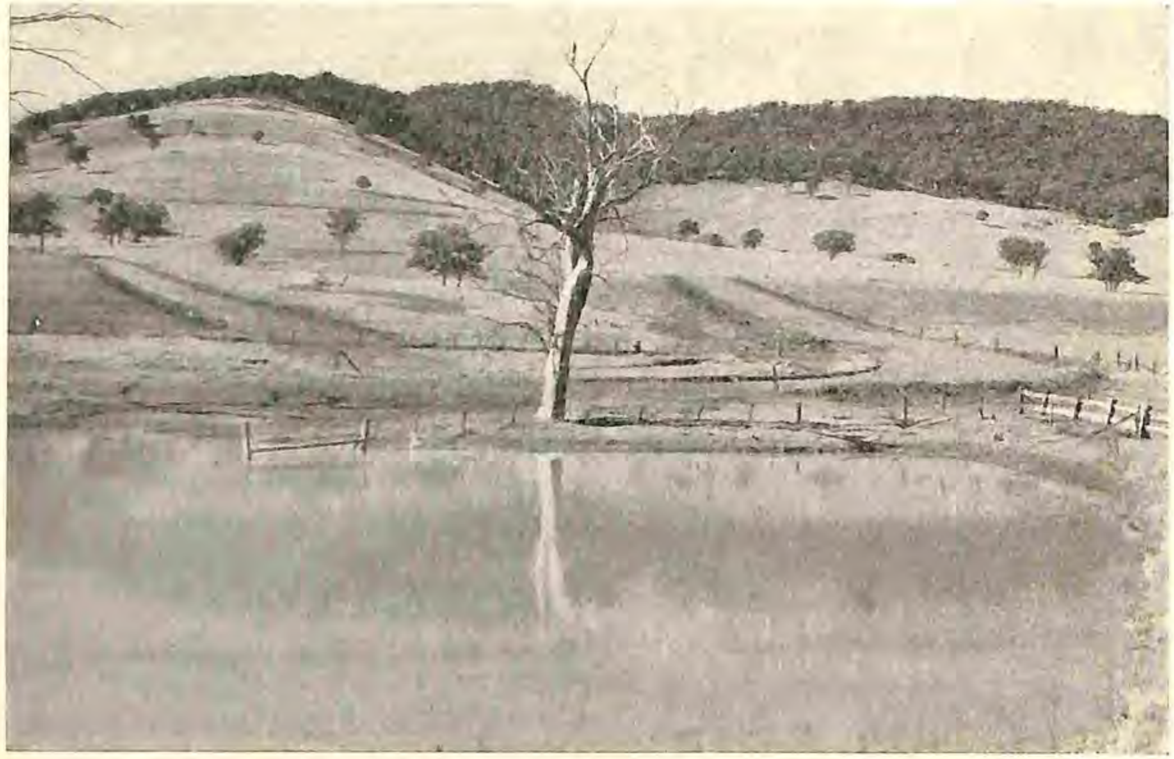

Fig. 2.—Wise land use with steep slopes retained as woodlot for soil conservation.

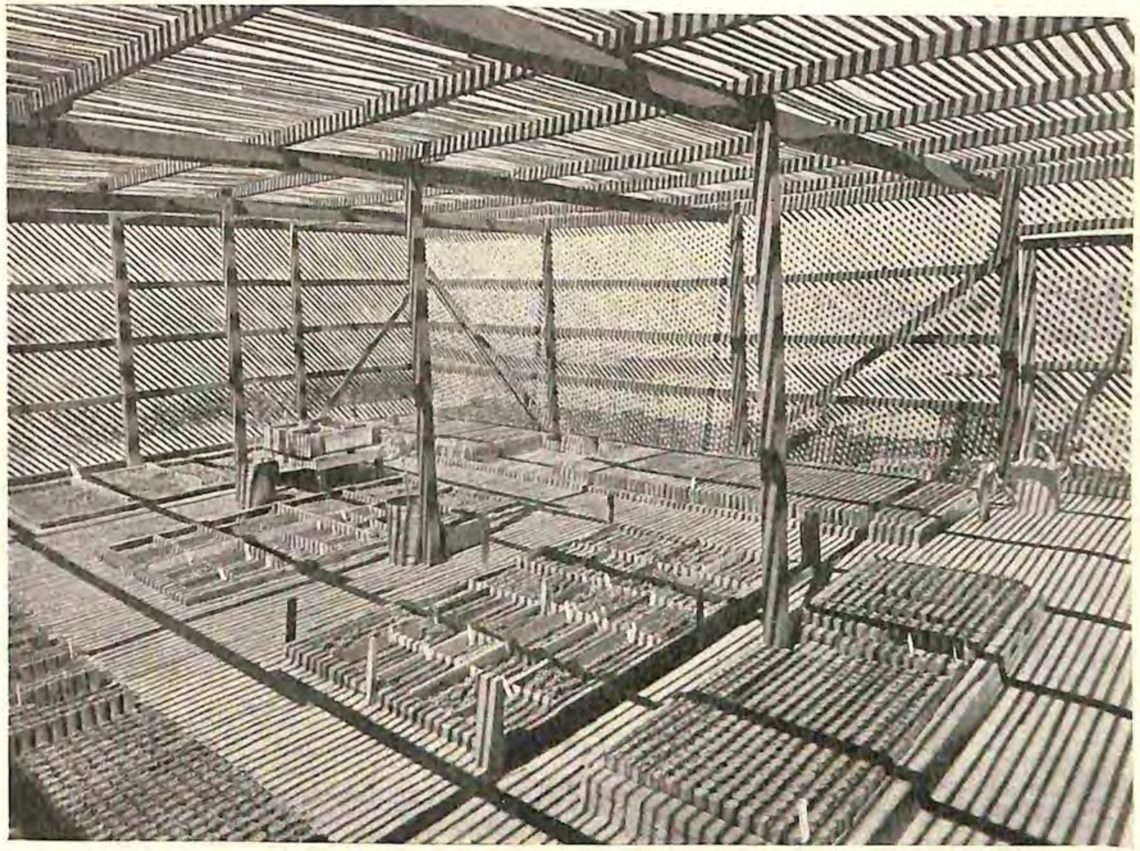

Fig. 3.—Interior of shade house. Cowra Soil Conservation Research Station Nursery.

profitable use to which the land can be put is to be planted to trees and managed as farm woodlots in the interests of soil conservation. Tree roots will bind the soil and, with a gradual development of forest conditions, run-off and erosion will be controlled and land reclamation take place.

Trees may also be used to prevent excessive siltation of river beds, dams and reservoirs. Planted across the channel of intermittently flowing watercourses that periodically discharge large quantities of silt, they can be effective in slowing down streamflow, thereby causing deposition of sediment at that point and preventing siltation further downstream.

In U.S.A. considerable progress is now being made in the establishment of new woodlot plantations for soil conservation purposes. During 1946, landholders co-operating with the Soil Conservation Service agreed to plant forest trees on 151,737 acres of land and trees were actually planted on 29,872 acres. Shortage of planting stock prevented a larger area from being planted.

REFORESTATION OF OVERCLEARED HILLS.

The unprofitable pasture land class is evident in many districts of New South Wales. In hilly coastal districts, tablelands and western slopes areas there are numerous examples of poor infertile soils on steep slopes that have been unwisely cleared; the soil-protecting forest cover has been replaced by sparse and unpalatable pasturage. As a result, sheet erosion is taking place generally, gully erosion is frequently evident and in special cases, particularly coastal districts, landslides occur after heavy rainfalls.

The development of farm woodlots for soil conservation is particularly applicable to this class of country. The land has been cleared for grazing and found unsuitable; reforestation then is the only alternative if a soil-conserving land use system is to be substituted. On many areas, especially in the higher rainfall regions, natural regeneration of native species is taking place; this should be conserved and allowed to develop. Other areas would require planting with suitable species.

Fig. 4.— Young woodlot 18 months after planting, Tamworth District.

WIND EROSION.

The third class of farm woodlots for which there is a definite need in New South Wales is in the provision of shelterbelts to provide protection for stock and buildings and prevent soil erosion by wind action. Wind erosion is normally thought of as a problem of the arid grazing lands and marginal wheat farming areas; that is the region where it is most prevalent but, during dry seasons, the area subject to active soil blowing extends much further east into districts that are normally not considered subject to this class of erosion. Thus during recent dry years quite severe wind erosion has occurred on farming land as far east as Tamworth and Harden and the need for farm woodlots or shelterbelts for soil conservation extends to those districts.

A particular need for tree-planting exists on unwisely cleared mallee lands that not only have been found to be unsuited for wheat production, but also have drifted badly during dry seasons. Frequent shelterbelts are necessary in this class of country to control sand drift.

Windbreaks and shelterbelts are also a definite need in tablelands regions, but their primary value in those areas lies in providing protection and shelter for stock and homesteads rather than in protecting against wind erosion.

This need for providing windbreaks is now being tackled in a comprehensive manner in the U.S.A. where, during 1946, the Soil Conservation Service were planning windbreaks for co-operating farmers at the rate of 1,300 acres per month, while planting was being carried out at the rate of 600 acres per month. Since then, with the expansion of nurseries to raise seedlings, the gap between the planning and the establishment of windbreaks and shelterbelts has been narrowed.

The extent of shelterbelts required for soil conservation purposes in New South Wales has not been estimated but, with the

Fig. 5.—Windbreak 3 years after planting—Wellington Soil Conservation Research Station.

large area involved extending from south to north across the centre of the State, it is apparent that the need must amount to many thousands of acres.

THE SOIL CONSERVATIONIST'S RESPONSIBILITY.

The starting point for interesting landholders in developing woodlots lies in farm planning. In its initial stage the landholder has to be convinced of the necessity for including what is a forest practice in the farm programme.

This work can best be undertaken by persons experienced in overall farm planning and who are able to determine the soil conservation requirements of each property The soil conservationist is particularly well fitted to undertake this work. He is experienced in viewing farms or creek catchments as a whole and determining the total requirements as to each type of soil conservation measure required. He also determines what adjustments in land use, if any, are necessary and, in this regard, must consider the establishment of farm woodlots for soil conservation purposes. In the first instance, the responsibility for developing an energetic farm woodlot for the soil conservation programme therefore rests with the soil conservationist.

At a later stage, especially if plantings of an extensive nature are undertaken, technical assistance on an entirely different level may be required by the farmer. His need then will be for technical forestry assistance to show him how to manage his woodlot according to sound silvicultural and forest management practice.

The primary consideration in all tree plantings undertaken from a soil conservation viewpoint is to plant those species that will provide the most effective soil protecting vegetation to the land. The growing of trees with a substantial market value is a secondary consideration but, naturally, whenever any extensive plantings are undertaken, this aspect must be considered. In addition to their soil conservation benefits and the protective sheltering influence on stock, crops and homestead influences, woodlots can produce valuable farm products for the future. These would include firewood, fencing timber, rough building timber and, in certain cases, poles and mill logs for sale to augment the farm income.

In furtherance of its policy of providing advice and assistance to the landholder in all phases of soil conservation activity, the Soil Conservation Service of New South Wales has established several small tree nurseries for raising trees suitable for planting on erosion control projects. The majority of these are used on works being undertaken by the Service, particularly in connection with its catchment area protection programme. Advice and limited assistance is, however, given to landholders prepared to undertake farm woodlot planting as a soil conservation measure.

References:—

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FACTORS INFLUENCING THE DESIGN OF GRADED BANKS IN BLACK CLAY SOILS OF BASALTIC ORIGIN.

BY

M. G. M. Woods, H.D.A., Soil Conservationist.

THE graded bank is the most used erosion control structure on the Inverell black clay soils of basaltic origin. In the Inverell districts periods of heavy rainfall and the self-mulching nature of the black soil limit the use of absorption type banks and pasture furrows.

The broad-based graded bank, with its wide-level channel, similar in design to the banks generally used and recommended in other districts, has been used. However, during the years 1947-1948, when several heavy storms and prolonged rainfall periods were experienced, it was found that the standard design was not entirely satisfactory.

In order that observations in the field could be supported by substantial evidence it was decided to make detailed surveys of three graded banks lying in front of the administration buildings at the Inversell Research Station. It was hoped that these surveys would give some indication of the change in outline and capacity of the banks, and, in addition, that some evidence would be obtained of the most serious defects inherent in the standard design.

This article records the results of these surveys.

METHODS OF SURVEYING.

The first survey of cross sections was made on the 27th of May, 1948. Each bank was surveyed at four points. One point on each bank was permanently located by using a line of sight between two fixed outside points. These points were the highest position on each bank. The other points were located by measurement at distancec of 20 feet, 40 feet, and 80 feet down the banks. Unfortunately the crests of the banks were not fixed to obtain downhill movement, but this was done when the second set of readings were taken on the 20th March, 1949. The true heights were obtained by levels taken from a bench mark.

CONSTRUCTION OF BANKS.

The three banks were constructed in the first week of February, 1948. The vertical intervals were: Bank No. 2, 6.5 feet; No. 3, 7 feet; No. 4, 7 feet; average slope 7 per cent. Each bank was constructed with an average grade of 0.5 per cent. The banks were then: No. 2, 594 feet; No. 3, 726 feet; No. 4, 660 feet, in length. In August-September the lengths of these banks were increased to: No. 2, 1,240 feet; No. 3, 1,520 feet; and No. 4, 1,500 feet.

CULTIVATION RECORD.

The cultivation record is indicated below; this does not include the area protected by the extensions of the banks. The full length banks carried water for the first time on the 12th February, 1949.

Cultivated with Sundercut 28-29 January, 1948.

Cultivated with Scarifier, 26th February, 1948.

Cultivated with Sundercut, 19th March, 1948.

Cultivated with Scarifier, 31st March, 1948, and 30th May.

Sown with Combine, 22nd July, 1948, and harvested end of November.

Disc-harrowed across banks and then on the contour, 20th December, 1948.

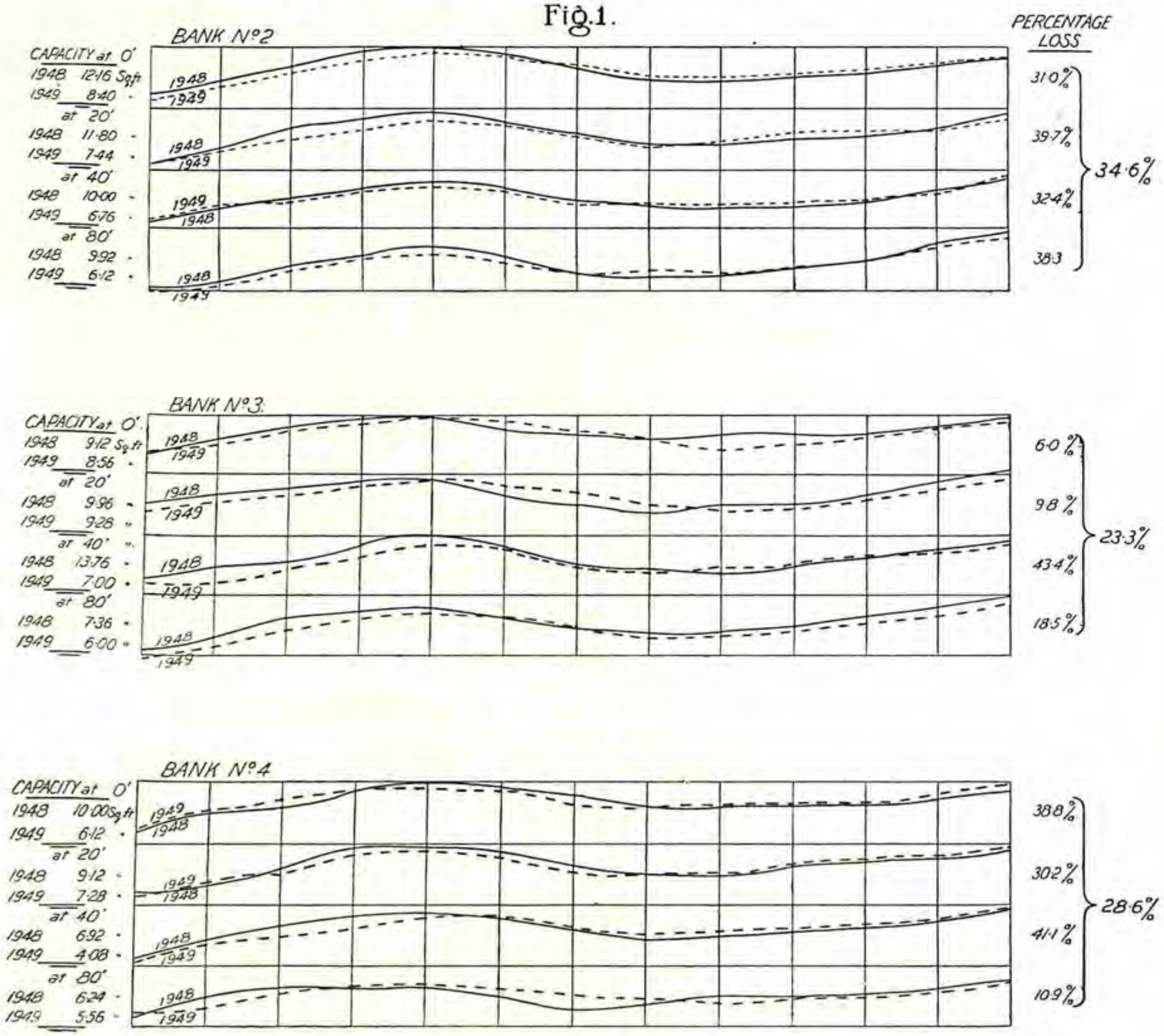
Cultivated with Sundercut, 5th January, 1949.

Cultivated with Disc-harrows, 3rd March, 1949.

INVERELL RESEARCH STATION

CROSS SECTION OF GRADED BANKS

Fig. 1.



RAINFALL RECORD.

The rainfall record is indicated in Table I. This details rainfall periods that produced runoff and soil loss.

TABLE. 1.

Rainfall.	Remarks.
28th February, 1948, 2.77 inches. Low intensity rainfall except 0.73 inches at over 2.0 inches per hour.	Soil loose after cultivation of 26th February. Banks carried good flow of water.
Total rain for February, 5.25 inches. Total rain for March, 1.60 inches. Total rain for April, 0.80 inches. Total rain for May, 2.10 inches.	
7-8th June, 1.97 inches. 0.30 inches at over 1.75 inches per hour.	This rain produced runoff and soil loss. Soil in fine condition.
Total rain for June, 4.22 inches. Total rain for July, 1.99 inches. Total rain for August, 1.51 inches. Total rain for September, 1.62 inches. Total rain for October, 1.49 inches. Total rain for November, 2.22 inches. Total rain for December, 2.33 inches.	No soil loss while area under crop.
8-9th January, 1949, 2.85 inches. Low intensity.	Runoff but little soil loss. Soil disced on 5th January and straw turned into soil helped to hold water.
Total rain for January, 3.27 inches.	
12th February, 2.33 inches. 2.0 inches at intensity of over 2.0 inches per hour.	Area disced 5th January and soil still open; some soil and water loss.
20-21st February, 3.34 inches. 0.47 at rate of 1.75 to 2.0 inches per hour. 0.56 at over 2.0 inches per hour.	From the storms of 12th February and the 20-21st February, water flowed over the entire length of the extended banks, the extended portions are in red soil.
Total rain for February, 6.81 inches.	This rainfall caused runoff and soil loss. The banks carried heavy flows of about 6 cubic feet per second but little evidence of red soil on the black is to be found.
10th March, 1.52 inches. Low intensity.	Little runoff.
14th March, 1.23 inches. All at over 2.0 inches per hour.	The soil was saturated and fine. Soil and water loss again took place. No red soil deposited on the black soil, indicating that the channels held most of the displaced soil.

RESULTS OF SURVEYS.

The comparison of results bears no relation to the position of the crest of each bank, but for convenience in graphing the banks and channels, the crests were plotted in the same position.

The percentage loss in capacity at each cross-section was determined. The results are indicated in Table 2.

TABLE 2.

Bank.	Percentage Loss.			
	Cross Sections.			
	0	20 ft.	40 ft.	80 ft.
No. 2 ...	31.0	39.7	32.4	38.3
No. 3 ...	6.0	9.8	43.4	18.5
No. 4 ...	38.8	30.2	41.1	10.9

The average capacity loss for each individual bank was: No. 2, 34.6 per cent.; No. 3, 23.3 per cent.; No. 4, 28.6 per cent. Average loss over all banks, 29.1 per cent.

OBSERVATIONS.

The first survey was carried out on 5th May, 1948, aproximately thirteen weeks after the banks were constructed and after the banks had been subjected to 9.13 inches of rainfall. The banks were constructed with a tractor and grader and had been cultivated three times before the 5th May. It was considered that the banks had had time to settle before readings were taken.

The cultivation given to each bank was the normal cultivation used on the average farm. The rainfall, although heavy and a little above average, must be regarded as falling within the average, or normal, expectancy.

The figures reveal a serious loss in capacity over a short period. This loss may be due to the following causes:—

1. A small degree of settling.

2. The effect of tyned implements which tend to smooth out graded banks. This is offset, however, by the use of a disc plough which throws soil back towards the crests of the banks.

3. Erosion of the banks. This may be of some importance. Apart from water erosion, dry weather fretting and crack development are contributing factors which do reduce bank height.

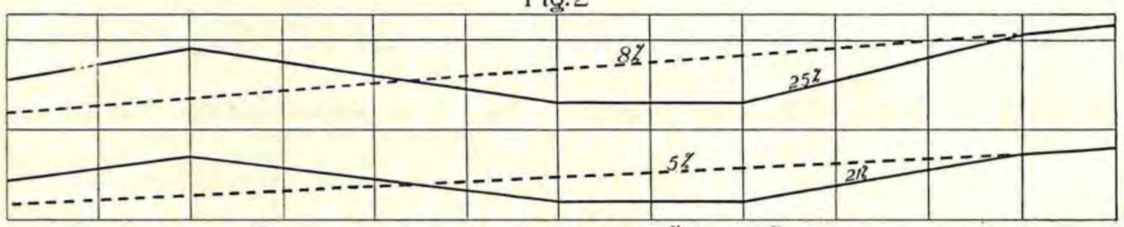
4. The effect of erosion in silting channels. This is the most important in the depletion of channel capacity.

In the graph for Bank No. 2 evidence of siltation at the batter edge of the channel is particularly noticeable. The tendency for this deposit to take place in all banks with steep batters is general on the Research Station in both black and red soils and is always associated with rill formation. It is obvious that water flowing over a steep batter can have its velocity greatly increased in the short distance of the batter. Now this water is flowing quickly into the channel, at right angles to the body of water flowing slowly along the channel, and where the flows converge silt is deposited. This deposit is initially on the batter side of the channel but it continues to move towards the bank,

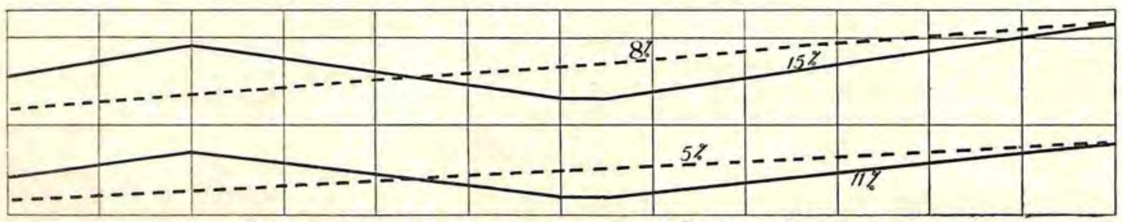
INVERELL RESEARCH STATION

CROSS SECTION OF GRADED BANKS

Fig. 2



Present cross sections on 5% and 8% slopes.



Proposed cross sections on 5% and 8% slopes.

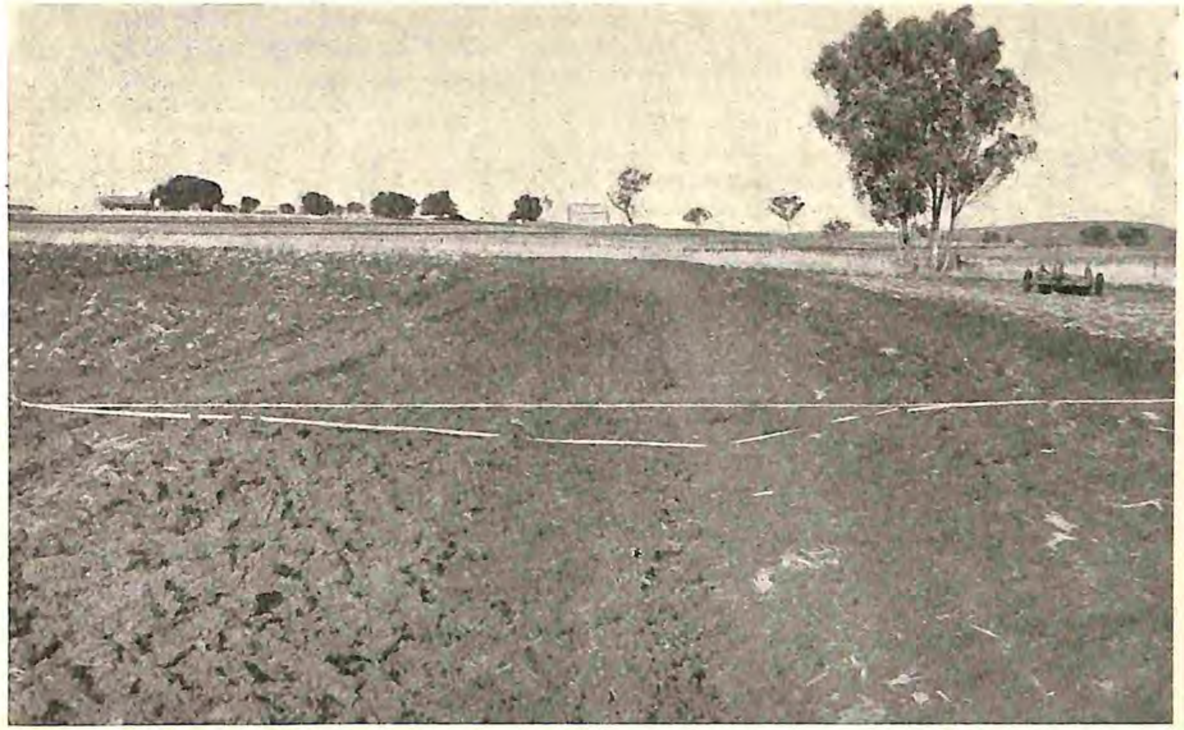


Fig. 3.—A graded bank on a 6 per cent. slope with gentle batter into the channel.

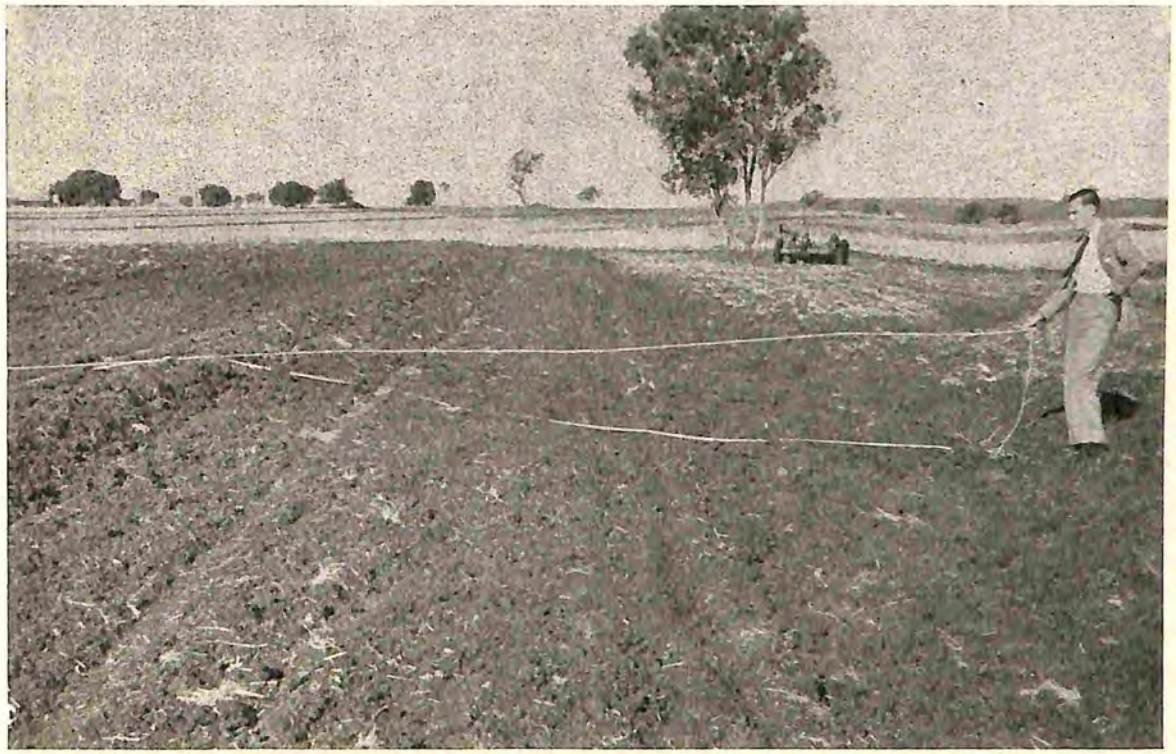


Fig. 4.—The gentle slope of the downhill side of a graded bank.

Fig. 5.—Cultivation presents no difficulties on the gently battered banks.

Fig. 6.—A graded bank on a 6 per cent. slope.

inevitably reducing its capacity and confining small flows in a narrowing channel closer to the bank itself. This tends to defeat the object of the broad channel.

CULTIVATION ASPECTS.

The black soil bank which has had silt deposited on it is not greatly improved by cultivation with a disc plough; certainly the bank height is improved, the channel is levelled out again (and its height increased), but the batter is again cut. It is evident that this process reduces the capacity of the bank and from the figures quoted above a loss in capacity of 25 per cent. or more in twelve months makes the permanence of a graded bank in black soil a question of frequent maintenance.

It must be remembered that black soil is difficult soil to work when it is damp, and for that reason alone it is essential that banks be made of sufficient size to withstand the average rainfall. It may not be possible to work channels for periods of from three to four weeks during a wet season.

CONCLUSIONS.

While it is not suggested that the final solution to the problems associated with black soil is known, it is claimed that at least some progress has been made in this direction. There are two main features that emerge for careful study. These are, the construction of banks that overcome or greatly reduce the siltation problem, and the construction of a bank easily cultivated, sown, and harvested with normal farm equipment.

The downhill side of the bank should be made on the least grade possible. For a bank of given height and quantity of soil the nearer the crest of the bank is to the channel, the less grade is produced on the downhill side. The distance between the crest and the inside channel is now determined by the width of the combine used for sowing and need not be more than eight feet for a ten feet combine or six feet for an eight feet combine.

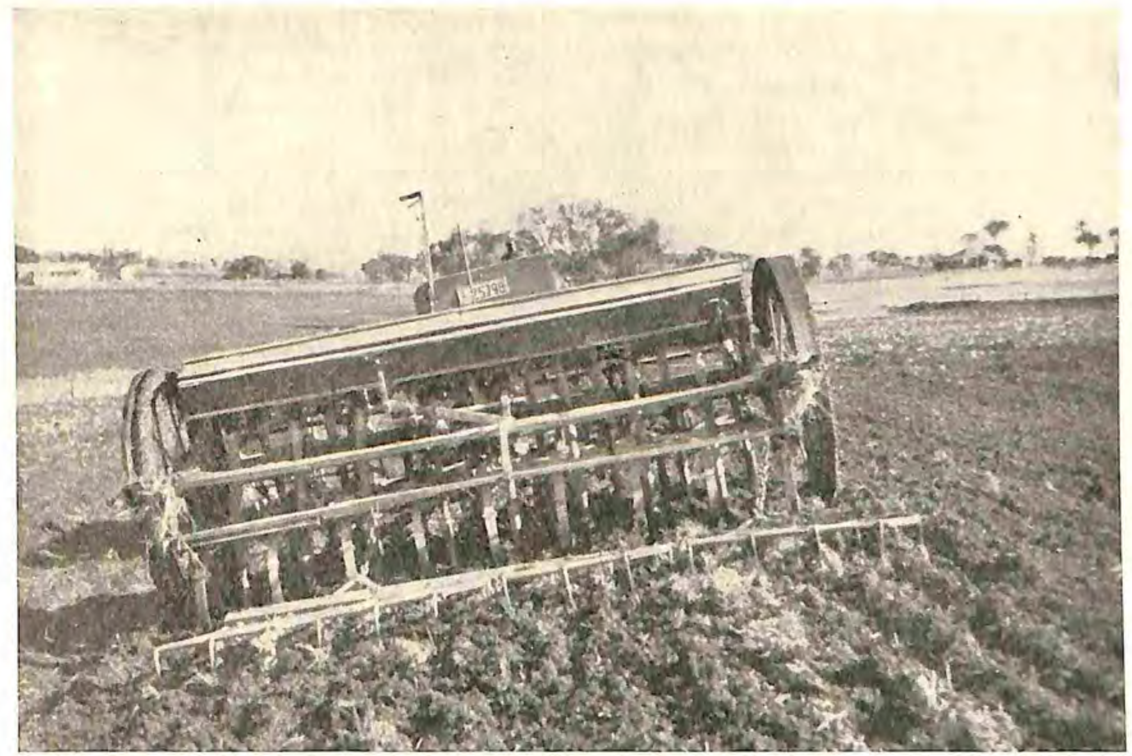


Fig. 7.—Sowing the downhill side of the bank with a combine. It is easy to cultivate banks of this construction.

The downhill side should be tapered out to merge gradually into the natural slope. There is no objection to a more or less flat section at the base of the bank as this tends to collect any soil loss by erosion from the bank side. The question of maintenance of a bank of this type is important; it is not difficult to throw soil towards the bank crest with a disc plough.

A natural conclusion to be drawn is that siltation can be reduced by the elimination of steep batters, and it should be realised that steep batters should never be cut in black soil. To achieve this a deep channel cannot be cut and the maximum depth of six to eight inches should be obtained in the two initial cuts with the grader.

The soil should then be moved from above these cuts so that the finished channel appears similar to that depicted in Figs. 3 and 5. Compare these with Fig. 4, a conventional type batter and note the reduction in grade on the batter. It is evident that this method of construction does not allow for a broad, level channel.

The argument in favour of a broad level channel is a substantial one, but its major defect of a steep batter does not justify its use on these black clay soils. Again, the narrower channel as illustrated will ultimately broaden following cultivation and the normal unavoidable soil movement into it; this is the reverse to the wide channel which becomes reduced in capacity through silt movement and which then becomes a confined channel near the bank.

The bank can be constructed by moving approximately half the required soil from the downhill side. This method of construction means that the soil is moved from a wider area than is usual, and the bank contains a good deal of top soil. However, construction does not take much longer as surface soil is easier to move and the blade of the grader is not used at acute angles to dig out the usually puggy deeper soil. A grader operator who has worked black soil will appreciate the advantages.

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SOIL EROSION AND SOIL CONSERVATION IN THE CONDOBOLIN DISTRICT.

BY

D. D. H. Godfrey, H.D.A., Soil Conservationist.

ALONG the Lachlan River and its tributaries the soil is a heavy grey clay supporting Black Box association. The main land utilisation is sheep grazing (fat lambs, wool, and some breeding) with some irrigation for lucerne growing (hay and grazing) and millet for drought feeding. There is some cultivation of wheat and oats.

To the south of the river the soils become lighter (light grey-brown clay loams to red-brown sandy loams) and support Grey Box association with some Bimble Box and Mallee in the east, becoming lighter still in the west supporting Bimble Box and Pine with more Mallee and some Gum and Ironbark. Land use is chiefly marginal wheat growing and mixed farming with more sheep and less cultivation to the west.

To the north of the river the soils are of a red-brown to brown loam nature and support mainly the Bimble Box and Pine association with some Mallee; Grey Box and Gum-Ironbark association also occur. The main land utilisation is wool growing with some marginal wheat growing.

In addition to the above some cattle and pigs are raised and pastured throughout the district.

The average annual rainfall recorded at Condobolin for the period 1891 to 1947 is 15.87 inches.

EROSION.

Although wind erosion is the main problem in the district, damage caused by water erosion, wherever the country is undulating, is often very severe.

The first signs that active erosion is taking place are as follows:—

(1) An increase in the area of bare ground between individual plants, *i.e.*, a reduction of the number of plants growing per unit area.

(2) A continuance of the above resulting in the appearance of small bare patches of ground (may only be a foot or so in circumference) and an increase in the size of bare patches (usually not noticed unless the extremities of the patches have been pegged, or marked in some other way).

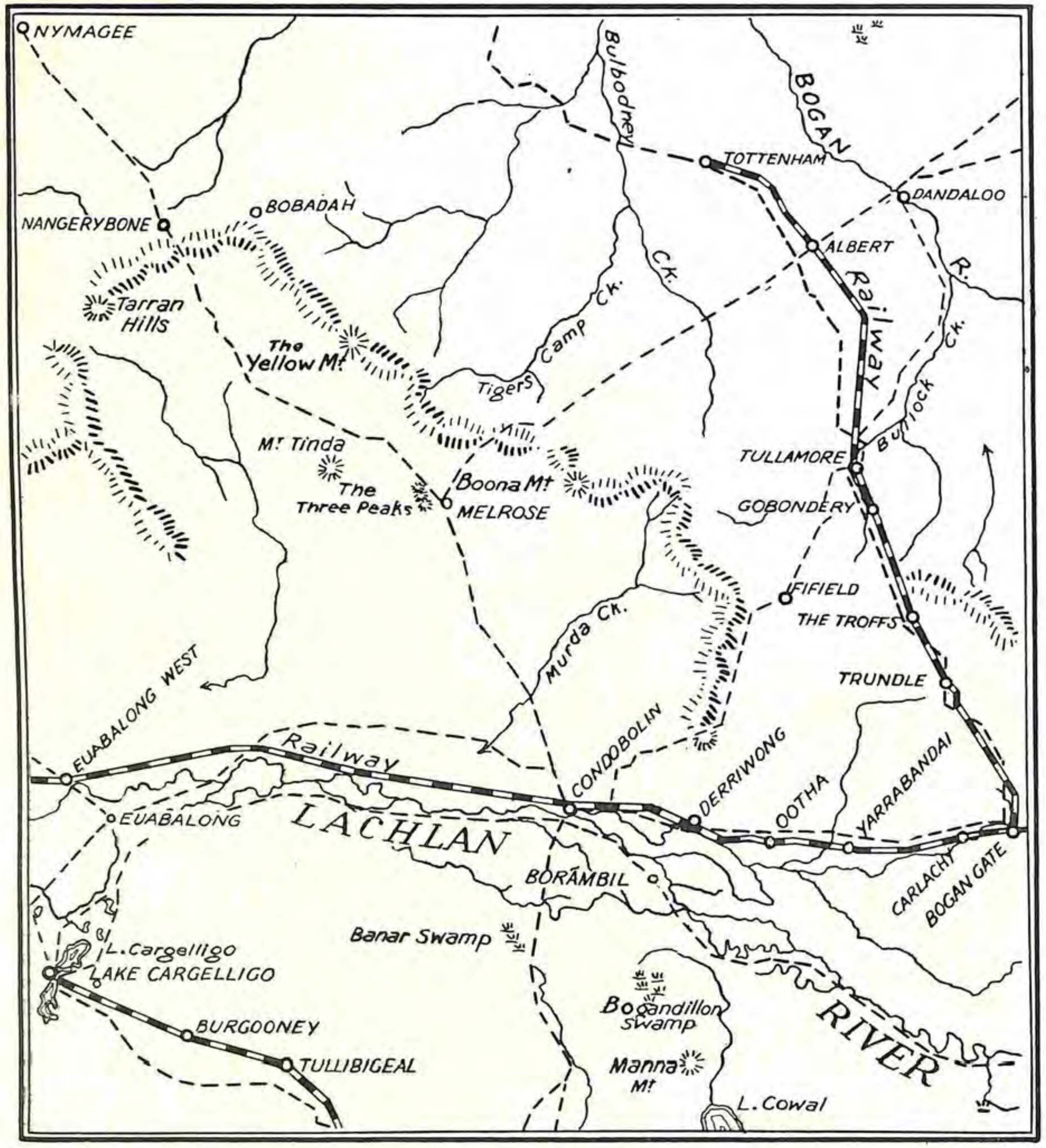
(3) The accumulation of silt against fences (especially rabbit-proof fences) and also the presence of sand and silt banked up against individual plants, logs, etc.

(4) The appearance of small rills or gullies; these may only be an inch or so in depth. This is usually the first warning sign on cultivation land where the first rills noticed may be up to 18 inches deep but are usually the depth of the last ploughing.

(5) Very often the warning signs of erosion are not noticed until the landholder realises the returns from his property, or portion of it, are not as high as experience tells him they should be. Hence a lowering of the productivity of the land may be the first sign.

After the above stages have been reached the signs become more pronounced as follows:—

1. The death of mature trees for no obvious reason. This is often caused by reason of the surrounding land being eroded to a bare condition. Under these conditions the required amount of water does not enter the soil and become available to the tree.



CONDOBOLIN DISTRICT

Miles 0 5 10 20 30 40 Miles

Railways ——— Roads - - - -

Fig. 1.

2. After a prolonged dry period it is often realised that the detrimental effect to the property has been greater than it was for a similar period, say, five years ago.

3. The increase in size and number of gullies. This occurs especially on cultivation land.

4. A definite lowering of productivity. Fewer head of stock can be run per acre and less per acre is being taken from cultivation land.

5. A definite increase in the amount of silt and sand built up against the windward side of fences, logs or any other obstruction.

6. The water in more or less permanent creeks, etc., starts to give out quicker than formerly.

7. An increase in the number of unpalatable, and often noxious, plants.

Very often some of the above signs that erosion is taking place may be concealed for a year or two by a dense sward of annual herbage produced in a flush or abnormal season. This is a very dangerous occurrence, as it is liable to lull the landholder into a false sense of security where erosion is concerned and has often been the cause of the cessation of erosion mitigation works and practices already commenced and, in some cases, has caused a temporary doubt as to expert ideas and practices. It must be remembered that when a flush season occurs the time is opportune to assist nature in reclaiming eroded land. The flush of annuals will not correct or reclaim eroded lands because the first hot dry wind will blow most of them away.

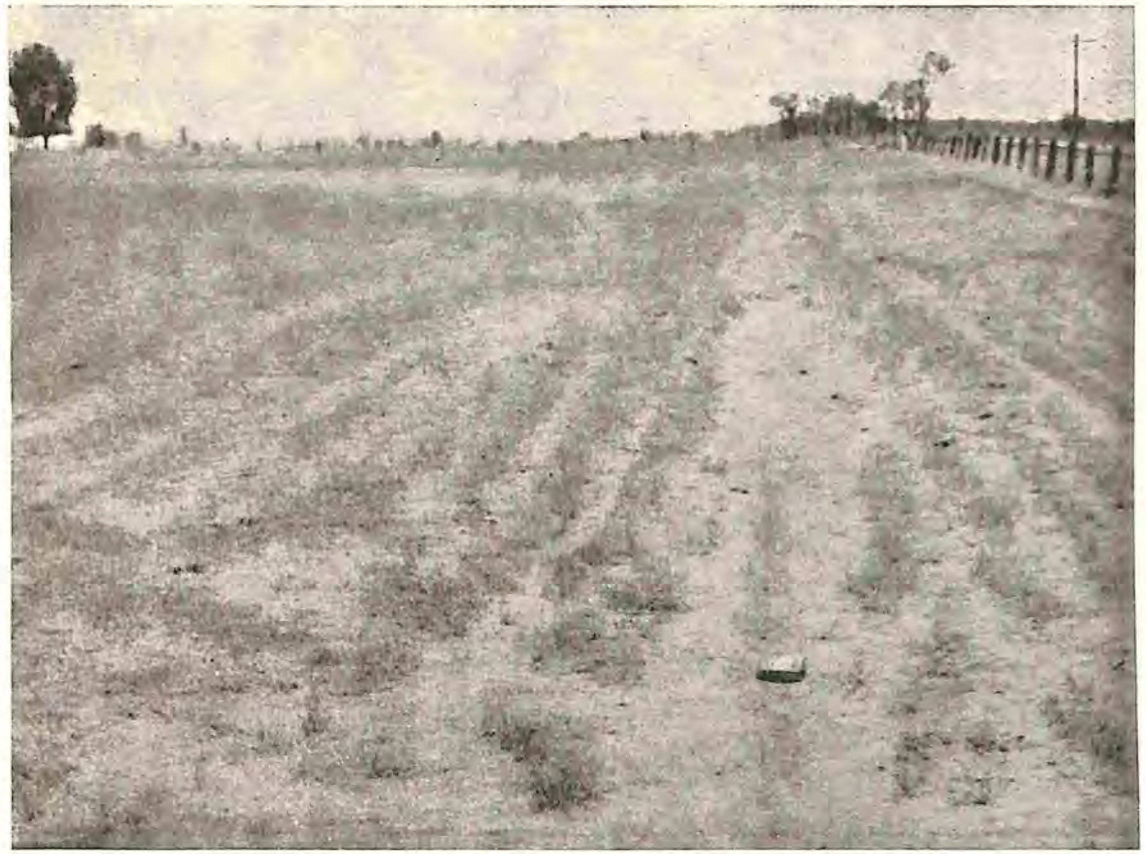


Fig. 2.—The first stages of erosion by water; 4-inch rills on gently sloping land cultivated up and down the slope.

CAUSES OF EROSION.

1. Overstocking.

The selective grazing habits of sheep quickly cause the deterioration of a pasture sward if overstocking is practised. The signs of overstocking are the disappearance of the more palatable grasses, especially our native perennial species, and an increase in the number of non-palatable species, such as rolypoly, wire grass (No. 9), galvanised burr, etc. Then appear small bare patches with consequent damage by wind and water erosion. Rabbits must also be considered and the present day shortages in labour and materials make this a very difficult problem; however, many landholders have demonstrated that this pest can be kept under control.

2. Overcropping.

The continued cultivation of the same crop on the same land year after year, or without an adequate rotation, the cultivation of excessive slopes, cultivation up and down the slope and the burning of crop residue all assist erosion.

3. Overclearing.

In the past large tracts of country were cleared in "a face" with no regard to the future timber supplies or effect on the soil. On country which has been overcleared wind velocities at ground level are noticeably higher than on timbered country. The roots of trees have a valuable binding effect on the soil; especially is this noticeable on the banks of waterways, creeks and rivers. It is interesting to note that of the winners of the Condobolin P.A.H. & I. Crop Competitions, which were held in this district some years ago, approximately nine out of ten grew their winning crops on land which was protected by natural windbreaks, in the form of belts of green timber, on the western and southern sides. It is an undisputed fact that the majority of the fat lambs, wool and cattle commanding the highest prices in the district have been grown, or at least topped off, on land which is well protected and sheltered by trees.

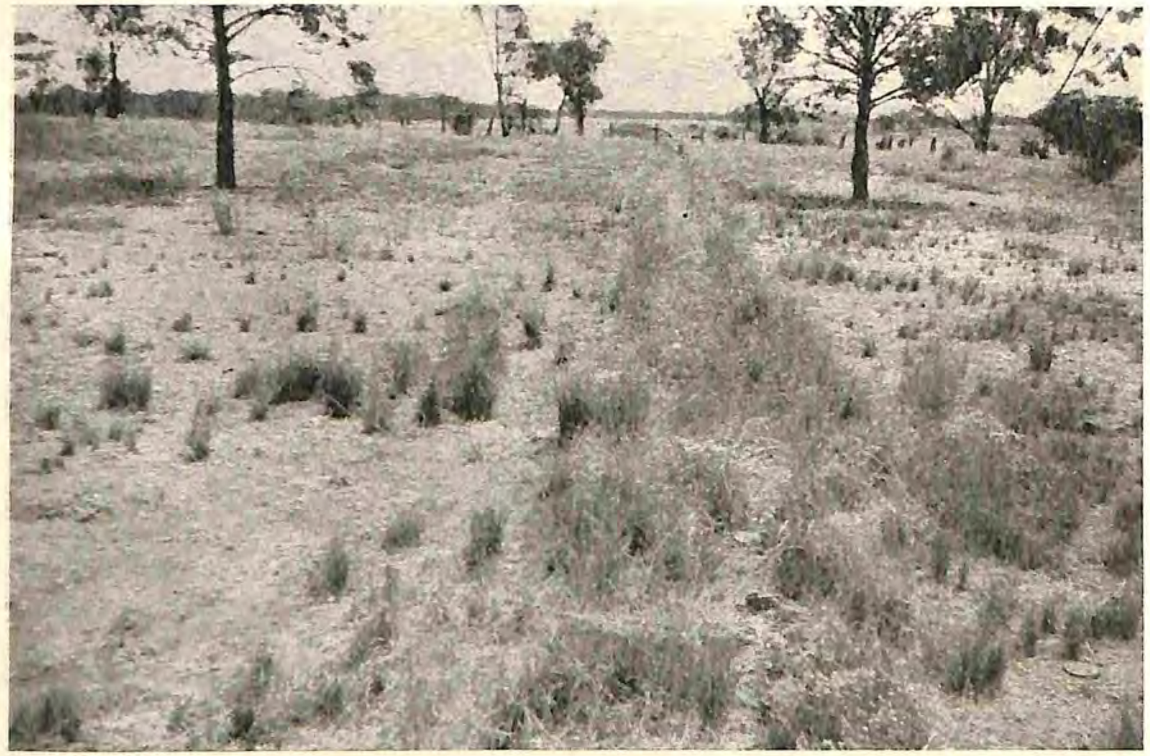


Fig. 3.—Excellent regeneration 2 years after pasture furrowing a severely eroded area in the Condobolin District.

4. Short Term Leases.

There are many instances in the district of land which has been repeatedly let on a short-term lease agreement (from one to four years usually) being in a very much worse condition as to erosion than the neighbouring blocks. This is sometimes brought about by high rentals but is usually the result of absolute exploitation of the land and a complete disregard of the future use and productivity, the argument often being "it will just about hold out until my lease expires."

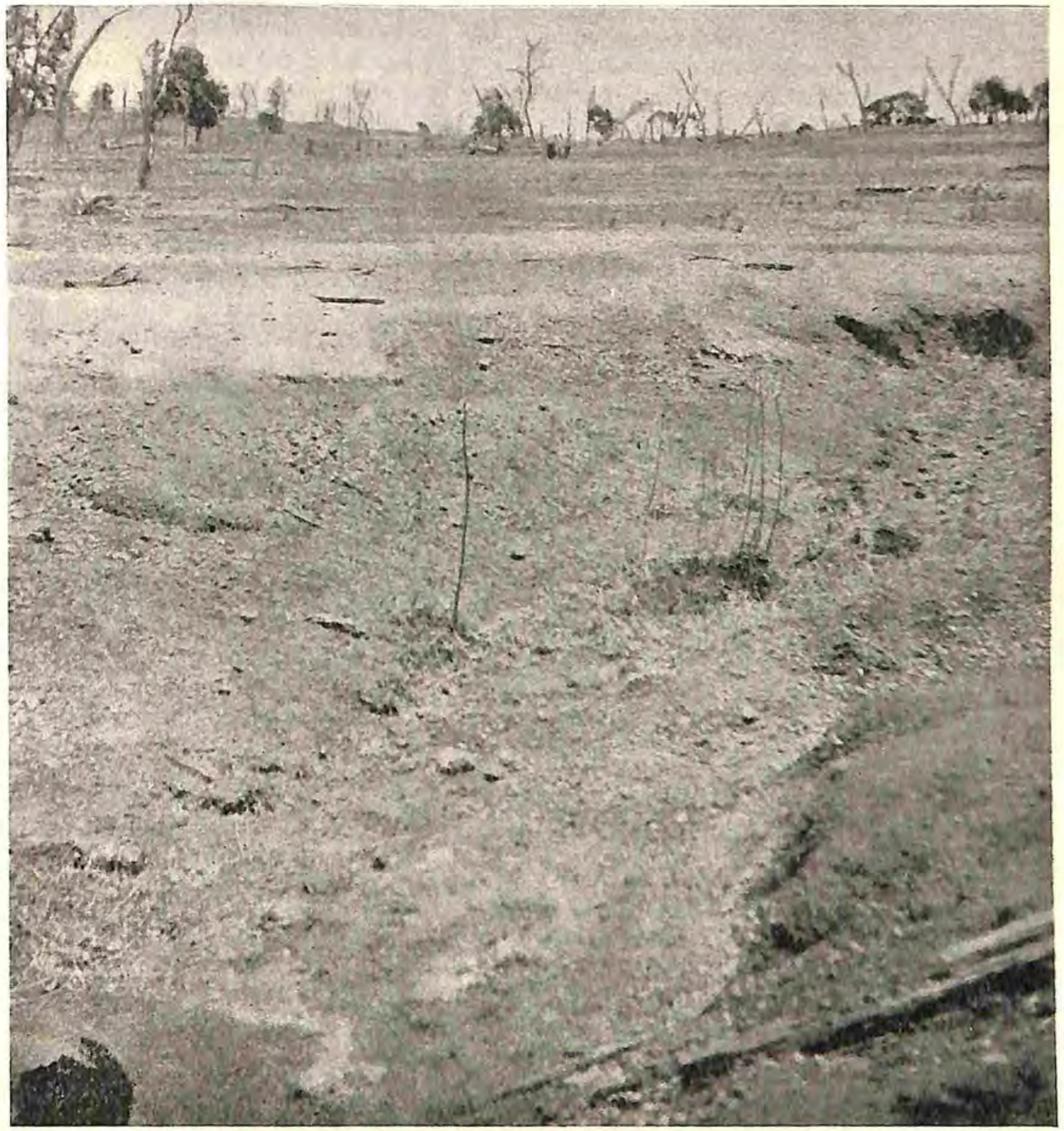


Fig. 4.—An overcleared and overgrazed hillside north of Condobolin, severely eroded.

5. Agistment.

This is really another consideration for inclusion under "Overstocking" and its indulgence very often gives the same results. Before accepting agistment the landholder will be well advised to carefully consider the possible effect on his own grazing land of the number of agisted stock it will be expected to carry. If too many, the resultant quick eating off of his grasses—even in a flush season—may seriously diminish the land's prospective seed supply and thus considerably deteriorate pastures for some years, even with careful future stocking.

To sum up, overstocking, overcropping and overclearing and the consequent expected erosion damage will result in:—

(i) Loss of effective rainfall—due to increased runoff.

(ii) A reduction of carrying capacity.

(iii) Lower crop yields.

(iv) A general lowering of production and consequent lower land values and increases in the maintenance costs of the property.

EROSION PREVENTION.

Extensive investigations and experimentation are progressing in this district with the object of finding still more efficient methods and practices of combating the foregoing problems, but there are some practices which have been proved sound and which are well worth consideration by every man on the land, and it must always be remembered that prevention is better than cure.

Most of our lands showed no signs of active wind or water erosion before clearing, stocking and cropping commenced. The scrub, trees and grass were a natural protection for the surface soil. In the same way, the establishment and maintenance of plant cover, either living or dead, constitutes our first line of attack on eroded areas and our first line of defence in erosion prevention.

Some of the measures which can be taken by every landholder to combat soil erosion, and which generally require no technical advice or assistance, are as follows:—

(1) Reserve Stocking.

Not only will an overstocked property be subject to soil erosion but it will require more labour, materials and money per acre to maintain—especially does this apply during drought periods.

(2) Conservation of Fodder.

This may be in the form of grain and/or hay (preferably baled). It also entails the care and maintenance of fodder trees and, in the more fortunate areas, the maintenance of an irrigation plant. Conserved fodder is the grazier's best insurance.

(3) Timber Preservation and Planting.

This is preferably done in the form of windbreaks in this district, running south-east and north-west or north and south, the prevailing and damaging winds being from the west and south-west The main purposes served by trees may here be listed as follows:—

(i) Windbreaks and shelter belts;

(ii) Shade and shelter trees, isolated or scattered;

(iii) Reserve supplies of fodder in times of drought;

(iv) The supply of timber and fuel for the holding, in addition to perhaps being a source of revenue by the sale of products;

(v) Screens round dams and tanks to prevent silting up by dust, and undue evaporation of the water;

(vi) A means of preventing soil erosion on slopes and along the banks of creeks and rivers;

(vii) A means of enriching worn-out and poor land;

(viii) Ornamental trees improve the comfort and appearance of the homestead; and

(ix) Bee trees.

(4) Adequate Firebreaks.

This also includes the active support of local Bush Fire Brigades. Fire can destroy not only the visible vegetation but may also effectively sterilise the soil for a period and so do infinitely more damage than the severest drought.

(5) Contour Cultivation.

Here also is included the avoidance of cultivation on over-steep slopes. Cultivation up and down an even gentle slope has the same effect as constructing an open drain from the top to the bottom of the slope in a straight line.

(6) Adequate Rotations.

In this district it is considered that the general minimum rotation for wheat growing should be wheat-layland-fallow-wheat and in most areas of the district it would be preferable to include another year of layland. Unfortunately the size of many holdings, especially south of Condobolin, makes these wider rotations impossible and in such cases the farmer will have to make very careful provision in his land use policy for the conservation of the soil.

(7) Retention of Trash.

The practice of stubble burning is injurious to the soil; fortunately not many farmers still persist in this practice. It is realised that on certain occasions it would be difficult to cultivate the land efficiently unless the stubble was burnt, but it is very seldom that these conditions arise, and it is well to realise that future erosion is being helped every time stubble burning is practised.

(8) Land Use.

Consider all land use and management practices in the light of absorption of as much water (rainfall) into the soil as is possible and providing the greatest possible soil protection against winds.

Fig. 5.—A level area a few miles west of Condobolin completely denuded of vegetation by excessive grazing. Wind erosion has commenced.

Fig. 6.—Different grazing rates illustrated on either side of the fence. Denudation of vegetation in the right hand area has resulted in surface drift.

SOIL CONSERVATION.

In addition to the foregoing broad practices and measures to combat erosion, considerable work of a more technical nature can be, and has been, carried out in the district. Briefly, this work includes—

1. Pasture Furrows.

Any grazing land, eroded or non-eroded, which has a definite slope is considerably improved by pasture furrowing. Many articles have already appeared in this Journal on the construction and laying out of pasture furrows.

Equipment so far found successful in this district for furrow construction includes the 69 road plough (also the modified pattern—see S.C.S. Journal, Vol. 4, No. 3 (July, 1948), page 104), the two-furrow reversible disc plough and a four-furrow mouldboard plough with either two or three mouldboards lifted up. When using an implement of more than one furrow it was always found necessary to load the plough, for extra weight, with bags of sand, a strainer post, etc. It has, however, been found that equipment used depended on the adaptation of the plant available to the landholder.

The checking of the furrows was found very important because of the generally light soils and their susceptibility to washing.

Although a practice which is not recommended, some landholders with moderately water-washed and wind-swept slopes of an even grade have obtained considerable success with pasture furrows laid out entirely by eye; the irregularities in some cases have been overcome by extra checking, but in one case no attempt was made to either take levels or check the furrows and, so far, very satisfactory results have been obtained, but it is problematical as to what will happen in the event of a heavy and concentrated fall of rain, as this has not occurred since their construction.

2. Use of Large Stock.

With regard to the more selective grazing habits of sheep, a few landholders have considerably reduced the numbers of sheep carried and replaced them with cattle on the approximate ratio of 1 beast to 10 sheep. This partial change over has been undertaken as a temporary measure, but over a two or three-year period, which included one very good season, the improvement in pasture swards has been considerable.

3. Increasing the Catchment Area of Excavated Tanks, etc.

Considerable success has been obtained with long drains of a gentle gradient (usually 0.25%) in two ways, namely:—

(i) By increasing the catchment area available to dams and tanks and so increasing the water supply on the property, and

(ii) by cutting off the headwaters of gullies and so protecting the lower country from water erosion.

In one case in particular run-off water was conveyed by means of a drain with a 0.25% fall, from the eastern and southern slopes of a hill round to the western slope and into a large dam which, prior to this operation, had never been more than half full of water. The result was a considerable increase in the value of the dam as a permanent water supply and also an almost complete protection of the lower slopes to the east and south of the hill from excess run-off water.

4. Gully Control.

Before a gully itself can be treated it is necessary to control the excess supply of water which is causing the gully. Work must, therefore, commence at the highest point of the local catchment area, or as high up as is practicable. Means of control successful in this district include—

(i) Pasture furrowing and drains of a gentle gradient, as indicated above.

(ii) Absorption banks. These are level banks placed as high as possible up a slope with the idea of holding up the flow of water sufficiently long for the majority of it to be absorbed into the soil and so diminish the quantity of water entering the gully proper.

(iii) Cutting off the gully head by means of a bank above it sloping outwards both ways. The area immediately below both ends of the bank must be closely pasture furrowed to stop the formation of other gullies.

(iv) Tapping the gully water and spreading it. This practice has so far not been proved conclusively successful in this district. It entails the construction of weirs across the gully and running off most of the water the gully carries by means of gently-sloping drains on either side of it; these drains empty onto either closely pasture-furrowed areas or else are zig-zagged down the slope so as to inclease the length of the catchment area and decrease the degree of slope, so giving the water an opportunity to enter the soil.

(v) The construction of weirs across the gully, tree planting on the gully banks and, finally, filling up the gully with rubbish of any kind. Weirs may be made from brush, timber, stones, wire-netting or concrete and their weakest point is where they join the gully banks. To relieve this weakness the weir must be notched, or made lower, at the top-centre, so as to give a waterfall effect, with adequate provision such as a bed of stones, etc., to safely receive the fall of water.

5. Graded Banks.

Quite a few attempts have been made by farmers in the district to construct graded banks and so a very brief discussion on them is warranted. The first and most important requirement for graded banks is a safe and non-erodible outlet for the excess water which will flow off the land as a result of the banks. Up to the present not a great deal of success has been achieved in the artifical vegetation of graded waterways in this district for climatic reasons. Furthermore, the importance in this district of retaining all available water on the land and preventing it from running off makes it unlikely that graded banks will achieve much success in these marginal arable areas. However, there are a few instances of banks being a moderate success; one case is on the property "Wilga Hill," where they were constructed some years ago and are doing an efficient job.

CONCLUSION.

Landholders are now realising that in the drier districts in particular it is unwise land use that brings about erosion, and that the easiest and most economical means of combating erosion is to prevent its occurrence by the implementation of a wise land use policy based on the ideas and methods outlined above. A land use policy with the aim of maintaining the productivity of the soil is the only way in which the landholder can be assured of lasting and constant returns from his property.

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MASS MOVEMENTS OF THE SOIL SURFACE

With Special Reference to the Monaro Region of New South Wales.

BY

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Soil Conservationist.

THE processes of sheet and gully erosion by wind and water action, and the importance of these processes in natural and accelerated erosion, have long been recognised. Inadequate attention, however, has been given to mass movements of the soil surface by flowage, slippage and subsidence, and to their significance in natural and accelerated erosion and in soil formation.

The purposes of this article are firstly to enumerate the main types of mass movement, and, secondly, to consider in greater detail those types which are important in the Monaro Region of New South Wales.

Mass movements in the United States of America have been studied intensively by Sharpe (7, 8), and less detailed discussions have been given by Ayres (-), Bennett (2), Emerson (3), Gustafson (5) and Krynine (6). Information concerning mass movements in New Zealand is obtainable from the reports of Zotov (9) and Gibbs and Raeside (4).

PART I. TYPES OF MASS MOVEMENT AFFECTING THE SOIL SURFACE.

Mass movements of the soil surface occur by flowage, slippage and subsidence. In flowage lateral movement of the mass is effected by continuous deformation without the formation of a slip surface; whereas in slippage lateral movement takes place by discontinuous deformation with the formation of a surface of weakness or slip plane. In subsidence there is little or no lateral displacement, and movement occurs only in a vertical direction. The primary distinctions between flowage, slippage and subsidence are illustrated in figure 2.

I. Flowage.

The rate of flow of the moving mass, and its moisture content (which may occur as water or ice), provide the bases for classifying flowage phenomena. Such a classification is shown in Table I (after Sharpe, 7).

Table I.—Classification of Flowage Movements.

Rate of Movement.		Moisture Content. Earth or rock plus ice.	Earth or rock dry or with minor amounts of ice or water.	Earth or rock plus water.
Slow Flowage.	Usually imperceptible.	Rock glacier creep. Solifluction.	Rock creep. Talus creep. Soil creep.	Solifluction.
Rapid Flowage.	Perceptible. Slow to rapid.		Rapid flowage movements rare.	Earth flow. Mudflow (four types).
	Rapid.	Debris avalanche.		Debris avalanche.

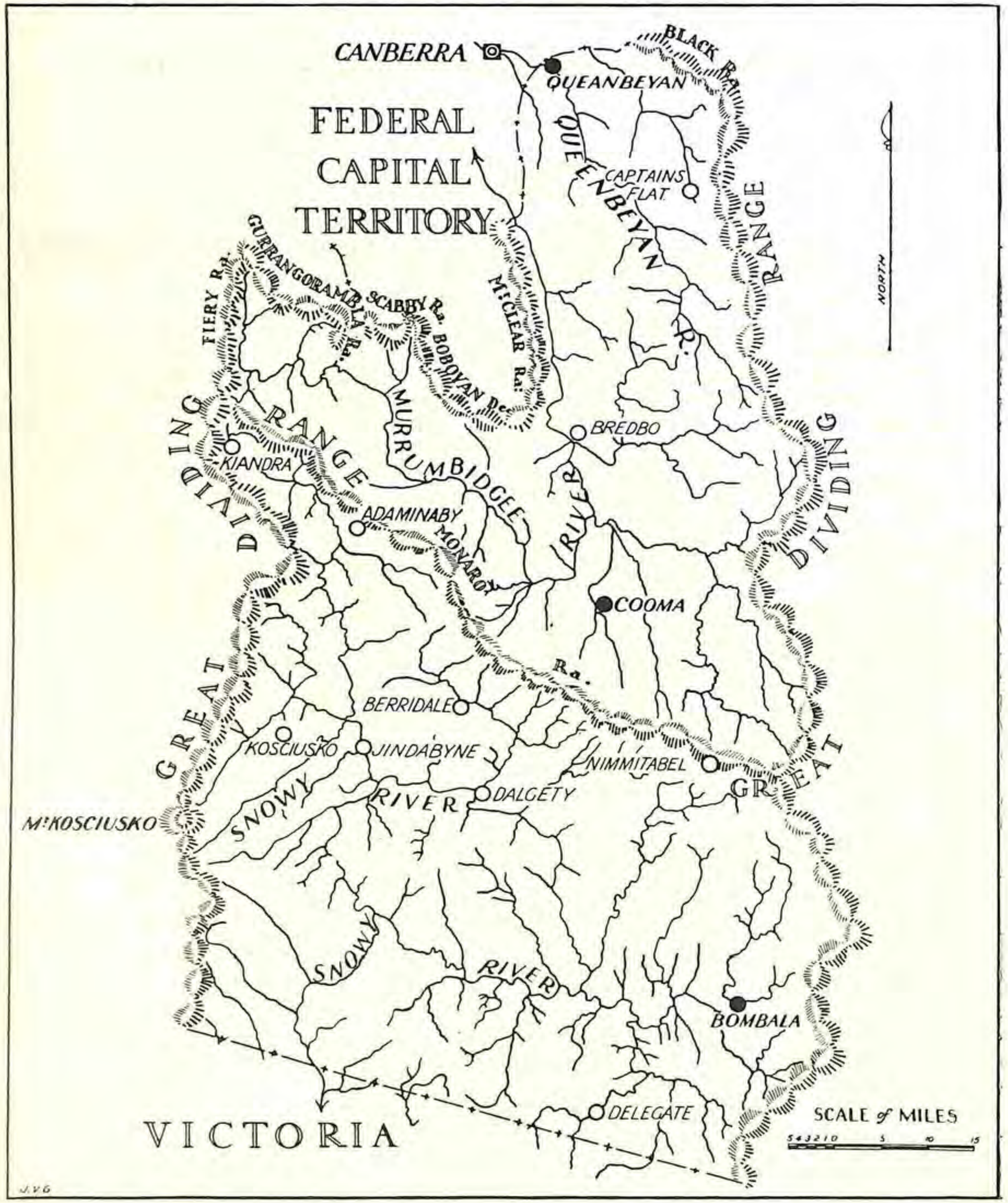


Fig. 1.—The Monaro Region of New South Wales.

A. SLOW FLOWAGE.

All forms of slow flowage may be defined as the "slow down-slope movement of superficial soil or rock debris usually imperceptible except to observations of long duration." (Sharpe, 7.)

1. *Soil Creep.*

Soil creep is the imperceptible movement of soil particles from higher to lower levels. The more familiar evidences of its occurrence include the greater depth of soil profiles near the bases than near the tops of slopes, the presence of a horizontal layer of stones or stone line within a soil, and the downslope leaning of posts and trees.

2. *Rock Creep.*

Rock creep is the imperceptible downslope movement of individual rock fragments, which may occur either at the surface of the soil or as floaters within the soil profile. The accumulation of rocks often found near the foot of a slope is partly due to this process.

3. *Talus Creep.*

Talus creep is the "slow downslope movement of a talus or scree, or of any of the material of a talus or scree." (Sharpe, 7.)

4. *Rock-glacier Creep.*

In subarctic, subantarctic and alpine regions, talus creep grades into rock-glacier creep, the action of which depends on the presence of a high ice content in the talus or scree. Rock-glacier creep may thus be defined as ice-controlled talus creep.

5. *Solifluction.*

Solifluction is a special form of creep occurring in materials of high moisture content which are usually subject to severe frost action.

B. RAPID FLOWAGE.

As its moisture content increases the soil or rock mass may become sufficiently fluid for rapid flowage movements to occur. In most cases rapid flowage is accompanied by more or less slippage which usually takes place near the head of the moving mass.

1. *Earthflow.*

The earthflow, which is the slowest of rapid flowage movements, typically involves both flowage and slippage, the former process occurring near the middle and base of the moving mass and the latter near its head. An earthflow is thus characterised by a sunken area near the head of the flow and a bulging near the base.

2. *Mudflow.*

While earthflows may occur anywhere on sloping ground, mudflows usually occupy such pre-determined channels as gullies or watercourses. Heavy, intermittent rains, or water suddenly released from rapidly-melting snow, may result in a viscous surface run-off of mud and coarser debris. These viscous materials may be carried into gullies and watercourses down which they flow in the same condition to be deposited as a fan on gentler slopes below. Sharpe (7) has distinguished three main types of mudflow, semi-arid, alpine and volcanic, with a fourth minor type resulting from the bursting of bogs.

3. *Debris Avalanche.*

The debris avalanche is the most rapid of flowage forms and is usually confined to steep slopes saturated by water from soaking rains or melting snow. It differs from a mudflow in that there is no lateral transport of debris from adjoining slopes, and in not being confined to pre-determined channels. Movement is initiated by slippage at the head of the avalanche, the track of which is typically long, deep and narrow.

II. Slippage.

The various slippage forms (including caving), which are popularly referred to as landslides or landslips, may be defined as the "perceptible downward sliding or falling of a relatively dry mass of earth, rock, or mixture of the two." (Sharpe, 7.) Slippage forms are classified in Table 2 (modified from Sharpe, 7).

TABLE 2.—CLASSIFICATION OF SLIPPAGE MOVEMENTS.

Rate of Movement.	Moisture Content.		
	Earth or rock, plus ice.	Earth or rock, dry or with minor amounts of ice or water.	Earth or rock, plus water.
Perceptible. Slow to rapid. Very rapid.	Slippage movements rare.	Slump. Caving. Debris slide. Debris fall. Rock slide. Rock fall.	Slippage movements rare.

1. *Slump.*

The slump, which is usually the slowest of slippage forms, may be defined as the "downward slipping of a mass of rock or unconsolidated material of any size, moving as a unit or as several subsidiary units, usually with backward rotation on a more or less horizontal axis parallel to the cliff or slope from which it descends." (Sharpe, 7.) Slump scarps are typically crescent-shaped with the horns of the crescent directed downslope, and may range in size from major displacements involving thousands of tons of material to the minor slumps often associated with the so-called stock terracettes.

2. *Caving.*

Caving movements differ from slumping (with which the former are often associated) in that the moving materials fall downwards and outwards without backward rotation. Caving most commonly occurs on a small scale, and is often preceded by the formation of tension cracks marking the lines along which separation subsequently occurs.

3. *Debris Slide.*

"Debris slides include all cases of rapid downward movement of predominantly unconsolidated and incoherent earth and debris in which the mass does not show backward rotation but slides or rolls forward forming an irregular hummocky deposit which may resemble morrainal topography." (Sharpe, 7.) With increasing moisture content of the sliding mass, debris slides grade into debris avalanches.

4. *Debris Fall.*

Debris fall may be defined as "the relatively free rolling of predominantly unconsolidated earth or debris from a vertical or overhanging cliff, cave, or arch." (Sharpe, 7.)

5. *Rock Slide.*

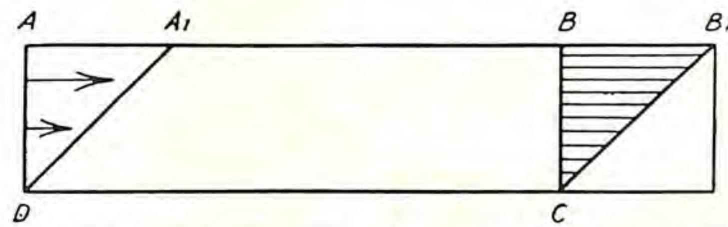
A rock slide is the "downward and usually rapid movement of newly-detached segments of the bedrock sliding on bedding, joint, or fault surfaces or any other plane of separation. (Sharpe, 7.)

6. *Rock Fall.*

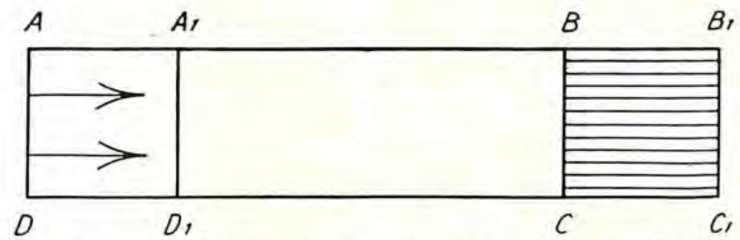
A rock fall is the "relatively face falling of a newly-detached segment of bedrock of any size from a cliff, steep slope, cave, or arch." (Sharpe, 7.)

III. Subsidence.

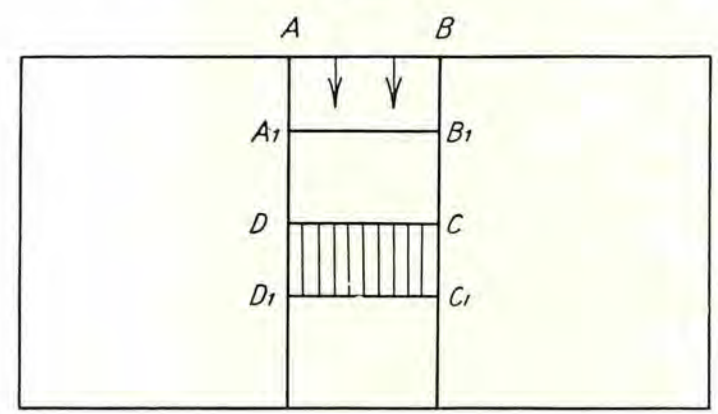
Subsidence, which usually occurs only on a small scale, is a relatively unimportant form of mass movement. Only vertical displacements are involved, and movements are limited to localities where underground support has been reduced either artificially as by mining, or naturally as by subterranean solution of limestone rocks.



Flowage – Movement by continuous deformation without formation of slip plane. Position of mass before flowage ABCD; after flowage A_1B_1CD.



Slippage – Movement by discontinuous deformation with formation of slip plane DD_1. Position of mass before slippage ABCD; after slippage $A_1B_1C_1D_1$



Subsidence – Movement in vertical direction without lateral displacement. Position of mass before subsidence ABCD; after subsidence $A_1B_1C_1D_1$.

Fig. 2.

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(*To be continued.*)

"ROSENEATH" DEMONSTRATION—INVERELL DISTRICT.

BY

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Soil Conservationist.

THE "Roseneath" Demonstration was undertaken to demonstrate control methods on the lighter types of red basaltic soil in the Inverell district, situated in the upper Far North-western Slopes of N.S.W. The area is portion of the property of Mr. J. H. Jackson, and is situated on the Gwydir Highway, between four and five miles east of Inverell. The property has been used for grazing for many years. The area in the demonstration includes three cultivation areas, a tract of timbered land, and grazing land. The cultivation areas have an interesting history, having been cleared and cultivated some sixty or more years ago. In recent times they were utilised for grazing only, and carried the usual grass cover. There was only minor erosion on these areas, but in view of the readily-erodible nature of the soil it was considered that control was essential to conserve the soil under subsequent cultivation about to be undertaken.

TOPOGRAPHY.

The area is part of the top of a ridge, rising some 200 feet above the level of the MacIntyre River to the south, and the Swanbrook Creek to the north. The Gwydir Highway at this point traverses the peak of this ridge, and Mr. Jackson's property slopes down to the river. On the slopes there has been sheet erosion caused by overstocking, and some gullying on the lower slopes. The slopes under the cultivation areas are too steep for cultivation and carry grass with occasional trees, until the vicinity of the river is reached, where alluvial, dark-coloured flats are found.

CLIMATE.

Situated some 2,000 feet above sea level, the climate is classed as temperate and the winters are sufficiently severe to cause the problem of winter feed to be a factor in farm and station management. The rainfall is well distributed throughout the year, but the summer period, December to March, is a dangerous one. During this time rain occurs in the form of thunderstorms and these storms usually have a short duration and a high intensity. These high intensity storms are the factors which have to be considered in the design of mechanical control measures; the Inverell Soil Conservation Research Station records show that a five-minute intensity of 4.5-5 inches per hour can be expected in at least two storms each year. These records are not sufficiently extensive as yet to be classed as definite, but as far as they go a minimum of two high-intensity falls have been recorded each year. The rainfall average is about 30 inches each year.

ECOLOGY.

The timbered country carries a regrowth of White Box (*Euc. albens*), this area having been cut over at some previous time and

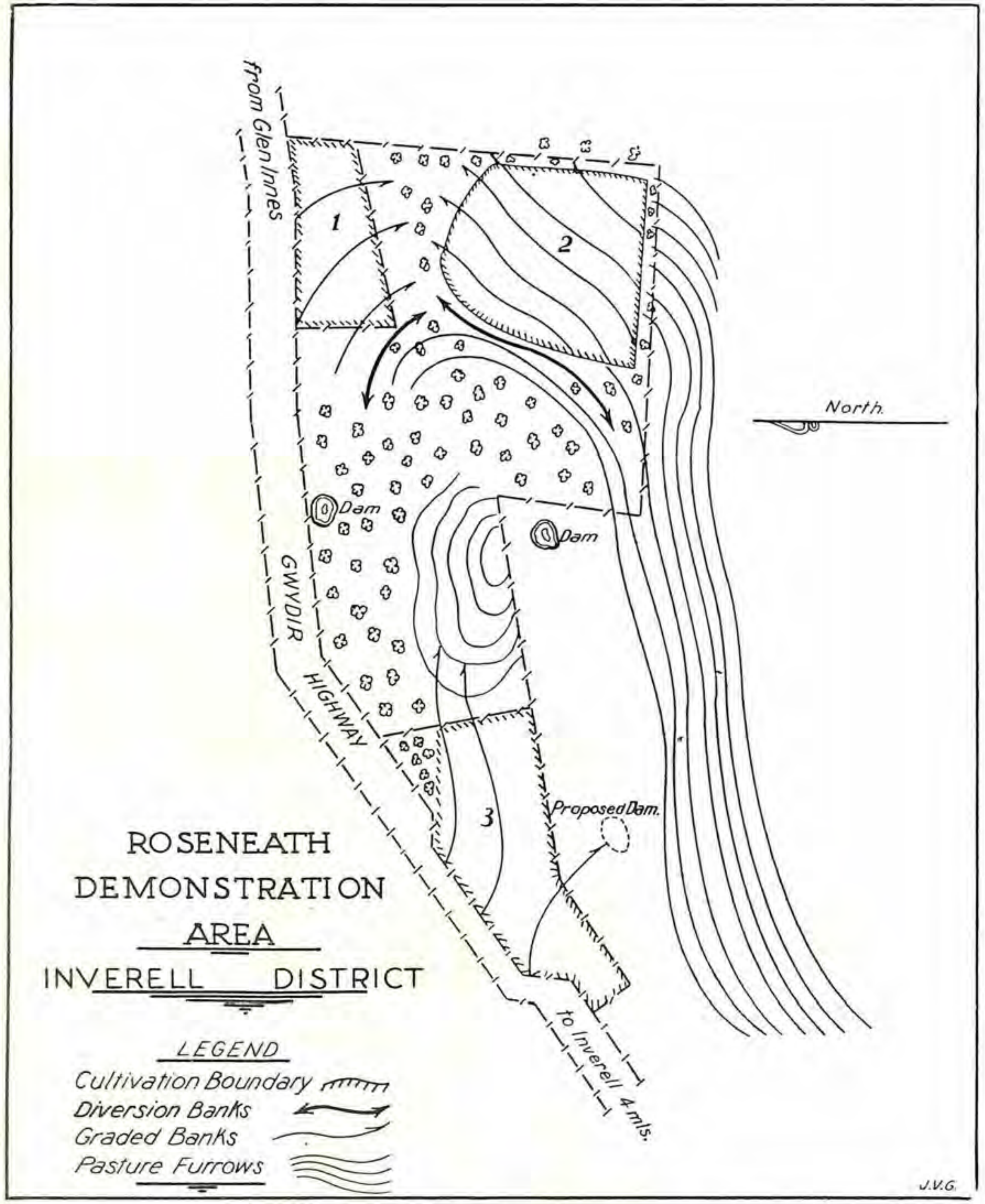

Fig. 1.

young trees have developed from seedlings and stumps. Some native apple trees (*Angophora intermedia*) occur on the area. An orchard was established on area No. 1, but only a solitary Almond tree now remains. A few specimens of Osage Orange trees (*Maclura aurantiaca*) survive near the site of a dwelling long removed and forgotten. The principal grasses in the pasture are Queensland Blue grass (*Dicanthium sericeum*) and Windmill grass (*Chloris truncata*), and the Trefoils (*Medicago spp.*) occur also. Couch grass (*Cynodon dactylon*) and *Paspalum dilatatum* can be found in favoured spots. The usual weeds of the district are found, such as Bathurst Burr (*Xanthium spinosum*), Darling Pea (*Swainsona galegifolia*), Sweet Briar (*Rosa rubiginosa*), but generally the area is in good condition.

CONTROL MEASURES.

Operations commenced in June, 1948, on areas Nos. 1 and 2 (see Fig. 1). No. 1 has an area of 11¼ acres, and No. 2 an area of 23½ acres. Just above the cultivation two diversion banks with a grade of 0.25% were installed to discharge on the grassed areas between these two paddocks. These banks provide protection against run-off from the timbered and grassed areas above. Broad-based banks on 0.25% grade were installed below at a vertical interval of 7.5 feet. Three were required on area No. 1, and five on No. 2, of which the three upper banks discharge into the area between the paddocks, and two discharge through a timbered headland into an adjoining pasture area. The timbered grassland above the banks was pasture furrowed. This section of the work was completed on 20th July, 1949, and the arable area sown to wheat two weeks later.

In December, 1948, following the harvesting of an oat crop on the third cultivation area, three broad-based banks were installed in this area and pasture furrows were installed on the top of the southern slope to mitigate sheet erosion on the lower slopes.

The two diversion banks above areas 1 and 2 (Fig. 1) handle any run-off from the timbered grazing country above the cultivation and are further reinforced by an area of pasture furrows along the edge of the timbered area. In these two areas eight graded broad-based banks with a total length of 7,100 feet were installed. On the cultivation area marked 3 on the sketch no diversion bank was required as the highway watertable protects this area to some extent and a farm road just outside the short western fence gives further protection. The short bank in this area discharges into a depression on the crest of the ridge and Mr. Jackson intends to instal a dam at the exit to provide stock water at this point. The three graded banks in this area have a total length of 3,200 feet. On the southern side of the area pasture furrows were installed down to a point low enough to check excessive run-off to the land lying further down the slope.

An interesting point in this demonstration is the absence of waterways, all bank exits being spread on the areas of timbered and pastured land. The topography allows this and banks discharge towards the north, south and east, which is somewhat unusual.

"Roseneath" demonstration is an object lesson in the prevention of erosion on an area at present only slightly eroded, this being a major objective of the Service, in addition to the treatment of those lands unfortunately eroded to a very serious degree.

LAND USE.

It is pleasing to be able to report that the wheat crops grown on the two treated portions gave very good results and the crops covered both banks and channels in a most satisfactory manner. Rainfall during the period was light and sporadic, and the value of the pasture furrows was shown in the remarkable growth of blue grass in the pasture furrowed area.

Many landholders are under the impression that control methods, such as graded banks, entail the loss of production area. The broad-based banks installed in cultivation areas in this demonstration are so designed that there is no loss of production area and both the bank and channel are sown in the same manner as the balance of the area. In fact, in this district, especially

Fig. 2.—One of the fallows of low slope beginning to erode immediately prior to the demonstration.

Fig. 3.—Soil Conservation Service plant at work on Roseneath, Inverell.

on the black soils, any area left out of cultivation would develop a great collection of strong growing weeds, such as Bathurst Burr, Mexican Poppy, and thistles of many varieties until such time as a cover of native grass could control the area, and this usually requires a number of years.

Mr. Jackson's property is utilised for stock rearing, cattle and sheep, and these cultivation areas will be used principally for the growth of wheat and winter feed which in this district is usually grazing oats. Up to the present no rotation on cultivation land is practised. Rotations are confined to an interchange of cereal crops, wheat followed by wheat until black oats become a nuisance, when grazing oats take the place of wheat for a few years. When autumn-sown crops fail, grain sorghums are sown in late spring or early summer. Sometimes lucerne is sown with wheat or oats and the area becomes a haymaking or grazing area for a period, but no regular rotation in the fullest sense of the term is practised.

Any rotation of crops must be suited to the soil, climate and farm economy of the district. It should embrace a period of temporary pasture of at least two years' duration. This period is of utmost importance in building up the crumb structure of the soil, the population of earth worms in the soil and increasing the humus content. All these factors increase the absorptive capacity of the soil, reduce run-off and mitigate erosion.

GENERAL.

The Soil Conservation Service at Inverell wishes to record their appreciation of Mr. J. H. Jackson's co-operation in this Soil Conservation Demonstration, the first in the Inverell District, on arable land.

Fig. 4.—Broad-based banks discharge into safe timbered areas.

Fig. 5.—Pasture furrows below the crest of the ridge check run off on slopes and protect the lower land.

Fig. 6.—The stimulated growth of native pasture in the pasture furrowed area.

A REVIEW OF SELECTED RESEARCH STUDIES IN THE U.S.A.

PART III.

BY

E. G. Connolly, A.M.I.E. (Aust.),
Assistant Engineer.

In Part II of this Review a new line of approach to the problem of soil erosion was described in some detail.

Studies in this direction are being conducted by W. D. Ellison and O. T. Ellison in the U.S.A. and were reported in "Agricultural Engineering," April to October, 1947.

This new approach has the outstanding merit of providing more precise and understandable means of dealing with soil erosion problems.

Many anomalies, and apparently contradictory results arising out of earlier experiments to explain observed phenomena, disappear when the same phenomena are examined on the basis that raindrop splash and surface flow are both responsible agents instead of surface flow alone.

The erosion hazard introduced by the detachment action of raindrop splashes and surface flow (run-off) was described in Part II (S.C.S. Journal, Jan., 1949), along with a means for evaluating and classifying control measures.

In Part III the transportation hazard introduced by the transporting activity of raindrops will be described, and finally in Part IV the transportation hazard introduced by the transporting action of surface flow or run-off.

TRANSPORTATION BY RAINDROP SPLASH.

It is not generally recognised that relatively large amounts of soil can be transported by the action of raindrop splashes acting alone without surface flow or run-off.

This fact explains why in many cases soil losses are relatively large despite the run-off being small.

Although, in a single splash, soil particles may not be splashed more than 3 to 5 feet away from their original position, the same soil particles may be resplashed many times in the same direction during a rainstorm. Thus, some particles may be displaced or transported a great distance away from their original position.

A favourable place for observing transportation by splash is on a large sand pile that is free of surface flow. The top of the pile will be lowered by splashing the sand particles downslope, while sand at the lower edge will be piled deeper and the pile made wider.

The results of this same process are apparent on small knolls and hummocks and along the crest of many hills.

In an experiment it was observed that considerably more than half the splashed particles were splashed in a downhill direction.

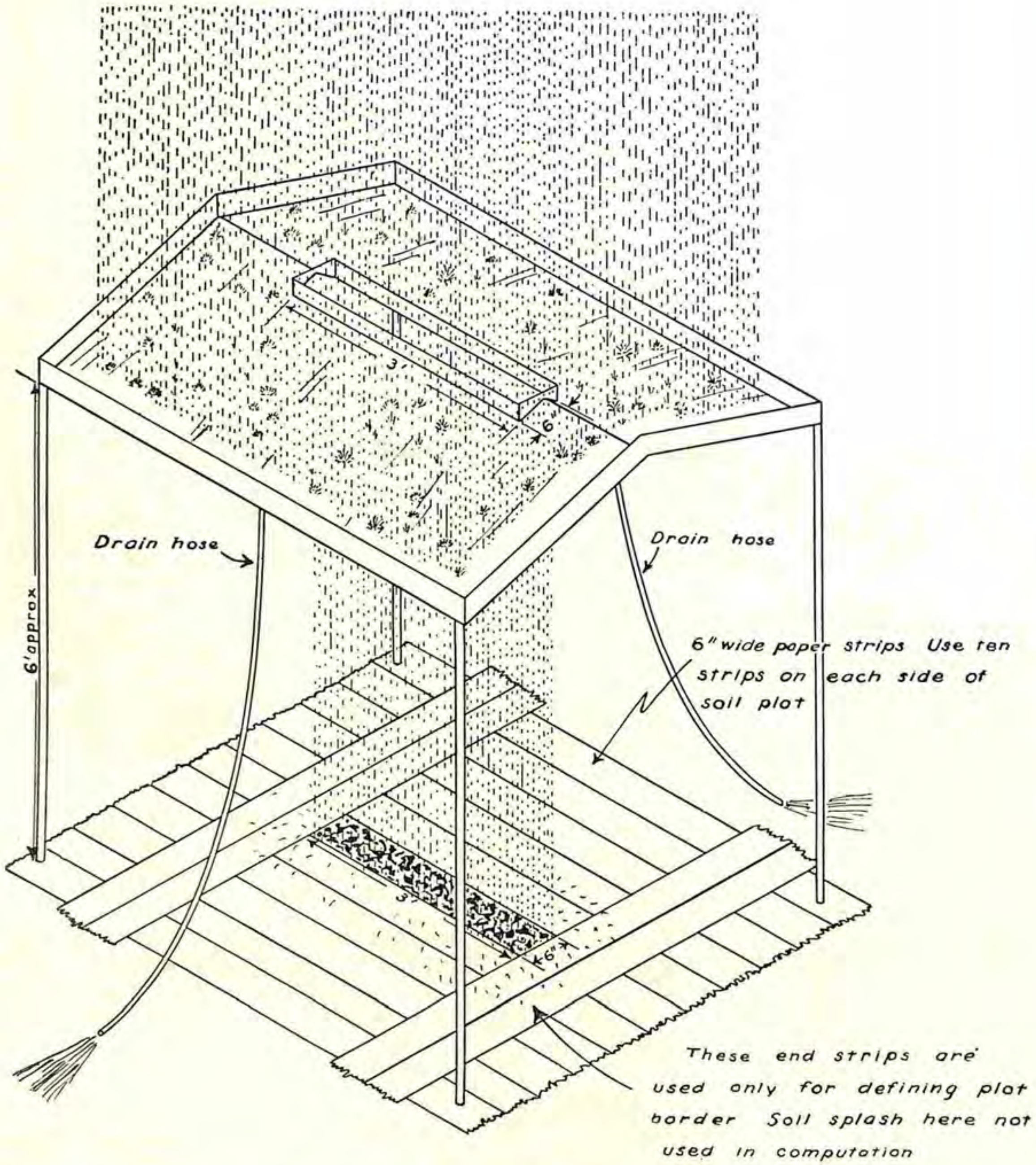

Fig. 1.—Equipment used in determining soil transportation by raindrop splash. (Reproduced from "Agricultural Engineering," August, 1947.)

Surface flow would tend to increase the amount of splash in a downhill direction by carrying the particles further.

Wind also could have an important effect in blowing the splashed particles in a particular direction—say downhill.

It would not necessarily follow, however, that a control measure designed to reduce the amount of raindrop splash would, at the same time, be sufficient to prevent transportation of the reduced splash to a safe level. If the transportation hazard remains high after the detachment hazard has been reduced, an additional corrective measure would be desirable to limit the transportation activity of raindrops to a safe level.

EVALUATION OF TRANSPORTATION HAZARD BY RAINDROP SPLASH.

In considering the transportation hazard we are concerned with the amount of soil in tons moved a distance in feet per acre of ground.

The amount and degree of movement of soil under the action of raindrop splash can be expressed by an equation:

T_1 = function of (D_1, T_2 and T_3) — [1]

where T_1 = The transportation hazard, and

T_2 = The transportability of soils expressed as relative values, to compare one soil with another in regard to distance of splash.

T_3 = The transporting capacity of the raindrops by splash action expressed as relative values, to compare the effect of varying rainfall characteristics on a standard soil.

D_1 = The soil detached by splash; it represents the quantity of soil per acre in transport by splash, or the amount of soil involved in the splash process.

This equation takes no account of the *direction* of transportation. It expresses only the total transportation occurring in *all* directions.

EVALUATION OF SOIL LOSS BY TRANSPORTATION IN SPLASH.

Soil loss would be considered when major movement in one direction takes place.

Slope and wind are two natural factors which, by giving direction to the splashes and increasing the movement in a particular direction will increase soil loss.

Surface condition and impediments to splash are two other factors which can be manipulated to counteract the effects of slope and wind.

The extent of soil loss by transportation in splash can be expressed also as an equation:

T_{loss} = function of (T_1, slope, wind)——[2]

Up to August, 1947, the Ellisons had carried out some exploratory studies of T_2 and T_3 and some effects of slope, but considered much more work was necessary before the functional relationships of factors in equation [2] can be evaluated.

TRANSPORTABILITY OF SOIL—T_2

Some tests were carried on at Coshocton, Ohio, in 1943 to determine the relative distances that different particle sizes would be carried by raindrop splashes.

A standard surface—smooth and level—was used and the distance that different particle sizes were splashed were determined by catching splashes on a plane that was level with the surface of the plot. The catch was made while applying simulated rainfall of known drop size, drop velocity, and rainfall intensity. See Fig. 1. It is necessary to use a narrow plot, and a soil plot six inches wide by three feet long is recom-

Fig. 2.—Splashes of soil and water on an area where the surface is 75 to 80 per cent. covered by vegetation. In addition to intercepting raindrops and thereby reducing the splash, these plants also intercept splashes and thereby reduce soil transportation. (Reproduced from "Agricultural Engineering," August, 1947.)

mended. The splashes moving out to each side of this plot should be caught in such a way that the pounds feet of transportation of each different soil tested can be computed. The catch can be made on narrow strips of oven-dried paper, weighed before the test. After the test these paper strips are again oven-dried and weighed and the amount of soil on each is multiplied by the distance in feet to obtain the foot pounds of transportation caused by the splashes. The results are to be expressed as relative values to compare one soil with another. Before making this comparison it will be necessary to make a correction for the amounts of soil splashed as T_2 is concerned only with relative distances.

There will be more soil splashed on those soils of high detachability than on those of low detachability. Because of this it is necessary to divide the amount of soil on each 6 inch strip of paper by the total amount of soil splashed before multiplying by distance of splash. For example: If there is a total of 10 lb. of soil splashed on the paper strips and, say, 2½ lb. of this is on each of the strips that join the plot on each side, the pounds feet of transportation will be $((2\frac{1}{2} + 2\frac{1}{2}) \div 10) \times (\frac{1}{2}$ ft.$) = \frac{1}{4}$. This ½ ft. distance is figured from the centre of the 6 inch plot to the centre of the 6 inch paper strip.

TRANSPORTING CAPACITY OF THE SPLASHES—T_3.

The transporting capacity of the splashes may be obtained with the same rainfall simulator and plot arrangement as was recommended to obtain T_2 values of the soil. This can be done by using standard soil (sand) on the plot, and by varying rainfall characteristics from one test to another. The foot pounds of transportation of the standard soil will be proportional to the transporting capacity of the splashes.

THE D_1 FACTOR IN THE TRANSPORTATION EQUATION.

Methods of evaluating this factor were given in Part II of this Report (January, 1949).

Having determined the transportability of the soil, and the transporting capacity of given rainfall splashes, the other dimension needed to define the amount of transportation is the quantity of soil involved in the splash process. This is represented by the D_1 factor, and it will vary from one soil to another, as well as from one rainfall to another. It will also vary with soil covers which impede the falling raindrops.

THE SLOPE FACTOR IN THE SOIL LOSS EQUATION.

To evaluate slope, the experimental set-up used for evaluating T_2 and T_3 may be used. In this work the plot surface will be sloped and the splashes will be caught at different elevations. The up and down splashes will be caught at elevations corresponding to projections of the surface slope. The upslope splash expressed in foot pounds is then subtracted from the corresponding downslope splash to determine the nett effects of slope on transporting soil downhill by the splash process.

THE WIND FACTOR IN THE SOIL LOSS EQUATION.

No measurements have yet been made of the effects of wind, and the equipment used in evaluating the other factors of the transportation process does not seem suitable for working with wind. New techniques will be needed.

SURFACE CONDITIONS AND IMPEDIMENTS TO SPLASH.

Differences in surface conditions that will have considerable effect on the direction of splash may be caused largely by differences in contour ridges. By making contour ridges very close together, such as on each crop row on a hillside, most of the splashes from the uphill sides of these ridges may be directed upslope. This will tend to modify the effects of slope and wind by giving direction to the splashes at the point of origin.

Fig. 3.—This photo. illustrates falling raindrops (the long vertical lines) and splashing particles of soil and water (the curved lines). (Reproduced from "Agricultural Engineering," August, 1947.)

It should not be necessary to run experiments to evaluate the effects of these ridges, but computations should be made based on the percentage of splash that will be directed uphill.

Fig. 2 shows splashed particles of soil and water on an area where the soil is 75 to 80 per cent. covered and protected by vegetation. The full height of this view is from 14 to 15 inches. Most of the vegetation is 4 inches to 8 inches high, and in the figure one can see that some of the splashes move considerable distances *horizontally* over the tops of the plants. All of these splashes contain some soil, and they originated at the ground surface and not from plant leaves. The leaves of the plant are not rigid enough and the water films on the leaves are not sufficient to cause many splashes to be thrown upward from their surfaces.

The very large leaf in the left background shows particles of soil that were deposited there by the splashes. These particles will soon be washed down by the falling raindrops.

We cannot determine how much soil is splashed merely by examining plant leaves and other objects above the ground because the splashed soil does not usually remain there during the storm, but it is usually washed down at about the same rate that it is splashed up.

The impediments to splash are composed of such things as stems of close-growing crops, either in drilled rows or broadcast. These will intercept the moving splashes and restrict distances of their travel.

Methods should also be devised for computing the effects of these, although some experiments may be necessary to test the validity of assumptions on which the computations may be based.

It is interesting to compare Fig. 2 with Fig. 3 in which the raindrops fall on bare soil.

SOIL TRANSPORTATION BY SURFACE FLOW.

Flowing surface water is usually the major transporting agent when erosion is caused by rainfall.

A means of evaluating the transportation hazard due to surface flow will be described in next issue of this Journal.

(To be continued.)