SOIL CONSERVATION SCHOOL FOR LOCAL GOVERNMENT ENGINEERS

THE problem of erosion on public roads and damage due to excessive run-off is one of increasing importance to Local Government bodies throughout the State.

In an endeavour to tackle this aspect of erosion and arrive at effective control, arrangements were made for Engineers specialising in the field of Local Government to have a working knowledge and a practical appreciation of the factors causing erosion and to view some experimental roadside erosion control measures; with this object in view a school of instruction was held at Wagga Soil Conservation Station during late October, 1949. Some forty-five Local Government Engineers from various parts of New South Wales attended the school, together with a Senior Engineer and a number of District Engineers from the Public Works Department.

The school was under the chairmanship of the Senior Soil Conservationist, Soil Conservation Service. Lectures on many aspects of erosion control were delivered by officers of the Service. Each lecture was followed by stimulating discussions.

Opportunity was taken to make field inspections of soil conservation operations on the Wagga Soil Conservation Research Station and erosion control works on the adjacent roadside of the Sturt Highway and the Wagga-Albury trunk road. A number of private farms in the Wagga and Junee districts, on which soil conservation demonstration works were in progress, were also inspected.

The question of roadside erosion was dealt with at length. It was pointed out that much damage to roads is caused by the concentrated run-off from adjoining lands under various systems of land tenure. Further, the safe disposal of water from road culverts through private property adjoining was explained and fully demonstrated by examining cases in the field. The effect of altered land use and mechanical

Fig. 1.—Local Government Engineers inspecting soil conservation work at Wagga.

control works on land was fully demonstrated to the school in lecture hall and in field inspection. It was pointed out that the correct use of vegetated disposal areas and restricted grades in banks and disposal drains could be used to good effect and the results obtained would be of a more permanent nature than those obtained by the construction of special structures.

Soil conservation works on private lands are carefully designed so as to obviate concentration of water on the roadside. Landholders were assisted by the Service to control run-off and reduce its quantity and velocity before reaching the road. The ways in which the Service assists landholders to carry out control works on their properties with their own plant and equipment or by way of the Plant Hire Scheme were fully discussed.

Soil Conservation Service officers are at all times available to Local Government bodies to assist and advise their staff in dealing with erosion problems.

The school stimulated widespread interest amongst the Engineers, and the view was expressed by those attending that they would now be able to approach erosion problems from a different angle.

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SOIL CONSERVATION IN THE RIVERINA

BY

L. W. SMITH, H.D.A., H.D.D., District Soil Conservationist.

IT is now a little over ten years since the first country officer of the Soil Conservation Service commenced investigations in the Riverina and South-western New South Wales, and as a decade provides a useful time unit, it is the purpose of this article to briefly summarise the experiences met and to take stock of advancements made over the period 1940 to 1950.

POSITION IN 1940.

Although the Soil Conservation Act was passed in 1938, it was not until late 1939 that the nucleus field staff of the Soil Conservation Service was appointed. Of this staff one officer was located at Wagga early in 1940 to investigate broadly the soil erosion position in the Riverina and South-western New South Wales and to assist landholders where possible with their soil erosion problems.

Investigations from 1940 to 1942 were directed mainly along four lines:—

1. An Erosion Survey which formed part of the Erosion Survey of New South Wales [1].
2. An Erosion and Land Use Survey of the New South Wales portion of the Hume Reservoir Catchment [2].
3. Collection of all available data and observations of soil erosion and storm-water run-off in the area.
4. Initial investigations and field trials on private properties of the behaviour of known erosion control measures.

It is unfortunate that the heavy demand on personnel caused by the war more or less brought these investigations in the Riverina to a standstill, although much of the information being collected at the Cowra Research Station, which continued to function during the war, was found to be applicable to some parts of the Riverina.

RAPID EXPANSION SINCE 1946.

It was not until late 1945 or early 1946 that investigations recommenced with the establishment of the Wagga Soil Conservation Research Station and the development of strategically situated Demonstration Areas.

These two phases of activity allowed the collection of data from both controlled research and practical experience at the same time and by the end of 1949 not only is soil conservation theory fast approaching an advanced stage but also the Service is providing a tremendous amount of help to the landholders, a large number of whom are now actively engaged in controlling erosion by both vegetative and mechanical means.

A rapid expansion in staff commenced in 1946 and at the end of 1949 the works staff had increased from one officer to nine, together with the necessary plant and labouring staff in addition to the small Research Station staff.

DIVISION OF THE DISTRICT INTO ZONES.

In common with the findings of similar investigations in other parts of New South Wales the investigations in the Riverina clearly showed that to make general recommendations for large areas of the State without regard to local conditions of soils, climate and land use was extremely dangerous. At the same time, however, the information gathered showed that the erosional behaviour of soils, the behaviour of control measures and the application of wise land use practices might be similar for fairly large areas provided that the basis of classification of these areas was one of soils, climate, vegetation and land use.

The Riverina Soil Conservation District has been subdivided into several zones, the classification of each being based on vegetation, climate, soils, erosional behaviour of soils, application of control measures and land use.

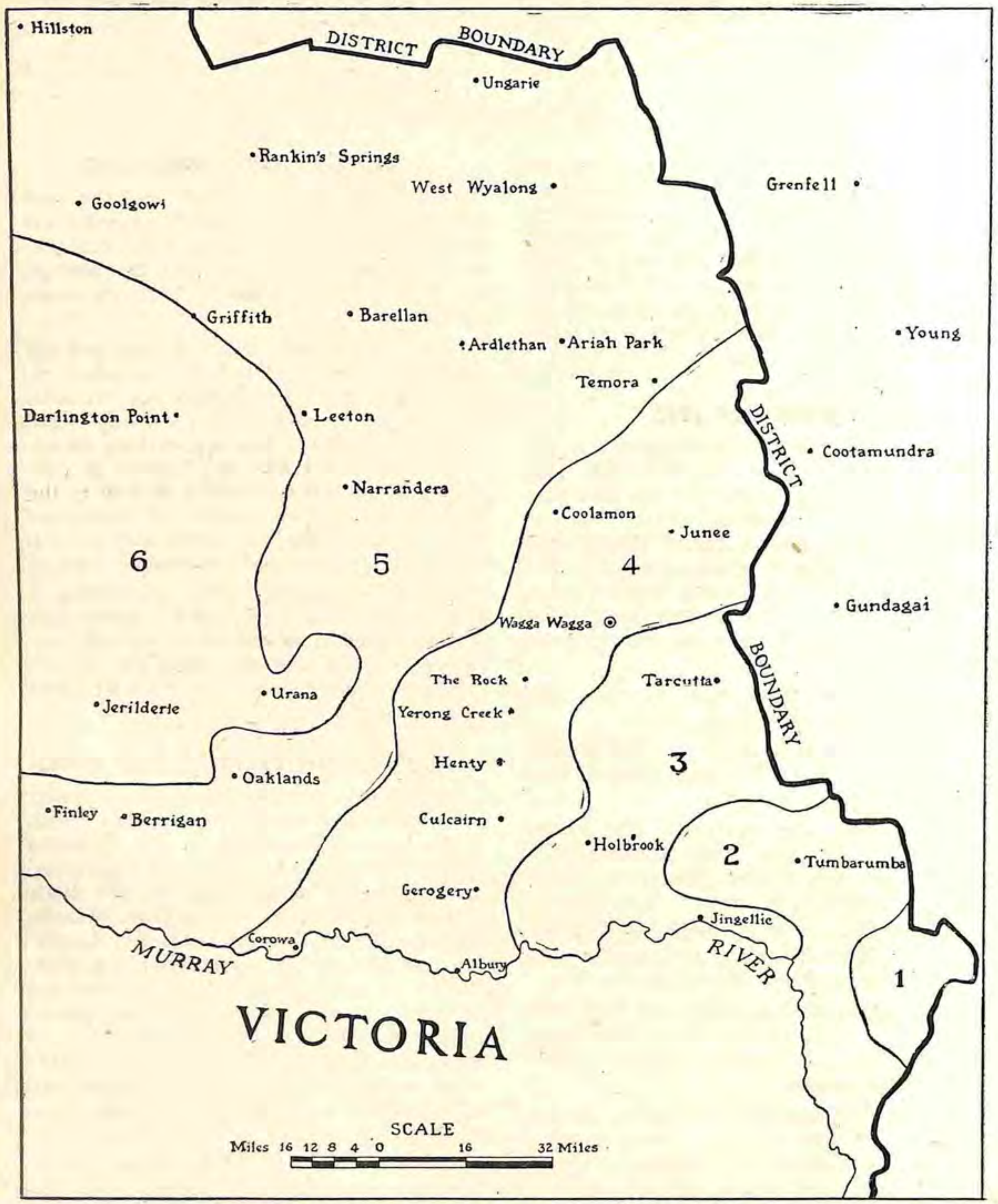

Fig. 1.—Zonal Map of Riverina Soil Conservation District, N.S.W.

These zones have been defined in Fig. 1 and reference to Table I will show the close relationship of vegetation, soils and climate.

It has also been found that erosional behaviour and the application of erosion control measures bear a close relation to vegetation, soils and climate, and the subdivision of the district in this manner is convenient for discussions on the trends of land use and erosion control which have shown up in the past ten years.

ZONE No. 1.

Although not very large in area this zone is of tremendous importance to Australia, being part of the vital catchment areas of the Hume Reservoir and Burrinjuck Dam, which play such an important part in the water conservation schemes of Eastern Australia. Together with the neighbouring catchments of the Snowy River the value of these areas as efficient catchments has been given great prominence recently following the commencement of the Snowy-Murrumbidgee-Murray diversion schemes for further water conservation and development of hydro-electric power.

The catchment efficiency of these areas is very high. There exists high rainfall with annual snow, high mountain swamps, soils of high water-retaining capacity, good vegetative cover and relatively gentle topography.

Being subject to snow in the winter months these areas are used mainly for summer relief grazing mainly under "Snow Leases" and "Permissive Occupancies." Considerable attention has been given during the period under review to ensure that this type of land use does not affect adversely the efficiency of the area as a source of water supply.

ZONE No. 2.

Although the greater part of this area is steep, inaccessible and mainly still under heavy forest, the gentler and more accessible areas such as the headwaters of Tumbarumba and Mannus Creeks, have been cleared for grazing and agriculture.

Under very favourable rainfall conditions pasture improvement in these areas has been developed at a very rapid rate; such exotic species as subterranean clover, red clover, perennial rye grass and Phalaris have been sown over extensive areas together with regular liberal topdressing of superphosphate.

The trend in the past ten years has been very wisely to concentrate on the improvement of the better quality areas rather than further clearing of the inferior ridges. The better areas develop very quickly while the inferior hills and ridges are slow to develop good grass cover after clearing and may suffer severely from sheet erosion during this vulnerable period. Again, wise landholders now realise the value of the Peppermint (*Eu. dives*) as a valuable natural crop for the production of high quality Eucalyptus oil. The wise use of this valuable species for this purpose by cutting and coppicing on a three to five year rotation provides a payable land use without depreciating the catchment area to any extent.

The particularly dense ground cover obtainable by adopting pasture improvement on the better class areas can be regarded as equally as good as dense forest from the soil conservation aspect.

With some few exceptions associated with old mine workings and roadside drainage the erosion position is not generally serious in this zone. It is to be expected that these conditions can be preserved mainly by wise land use; sound management and soil conservation programmes in this area should generally be considered under the following headings:—

1. Forest Management.
2. Bush Fire Control.
3. Rabbit Control.
4. Grazing Management.
5. Pasture Improvement.
6. Minor Mechanical Control Measures.

ZONE No. 3.

Most of the better class and more accessible areas in the zone have been cleared for grazing or agriculture and although the zone does not enjoy as high a rainfall as Zone No. 2, the practice of pasture improvement, using subterranean clover and other exotic species, together with liberal annual topdressing of superphosphate, is very successful.

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Fig. 2.—Typical contour furrowing near Ladysmith in Zone 3.

Clover Leyland Rotation.—Where the topography is suitable for cultivation, such as in the Holbrook and Tarcutta districts, there is a general wise trend to adopt a subterranean clover leyland system in rotation with winter cereals (wheat and/or oats). Under this system the clover is usually seeded with a cover crop of oats and the clover allowed to develop for a five to seven year period, when it is cropped to wheat then sown to oats on the wheat stubble and returned to clover leyland. This clover leyland (5 years) wheat-oats rotation is proving very profitable in these areas where adequate cultivation country is available and is a very desirable soil conservation practice. Under this system also the clover swards appear to benefit considerably.

Those who have commenced this rotation have experienced some difficulty in stubble cropping to oats without burning the wheat stubble. It is to the credit of some of these men, however, that they are taking the initiative in overcoming this problem and developing ways suitable to their own land and plant to avoid stubble burning. Many ingenious methods to overcome this problem have been evolved, mostly quite successful; amongst the best are the use of the tandem disc harrow-drill without tynes-disc harrow combination, and a disc harrow-drill without tyne-culti-packer roller combination. The roller used in this latter combination is the usual type of subsurface roller with multiple V-shaped wheels forming the roller.

The clover is usually topdressed with superphosphate in the leyland period.

Mechanical Erosion Control Measures.—Some serious erosion is occurring in this zone and Soil Conservation Demonstration Areas have been developed in the Holbrook and Ladysmith districts. Experience gained in these Demonstrations and in other field works in this area has shown the value of some mechanical measures in this zone.

Contour pasture furrows have achieved excellent results as a means of reducing the frequency of run-off across unstable eroded

Fig. 3.—A contour farming scene near Junee in Zone 4.

areas, and also as a means of controlling sheet erosion on hillsides and assisting the development of good pasture cover.

The use of dams, diversion banks and grassed waterways for controlling deep bottomland gullying has also been successful where such measures are applicable.

As the areas subjected to cultivation are not frequent in this zone, and, as the frequency of fallow is low, the application of terraced systems of graded banks is limited usually to special cases. Where necessary, however, good grassed waterways should be provided for bank outlets. Fortunately, the climate in this zone generally allows the rapid development of adequate cover on these waterways.

Diversion and graded bank work in this zone is usually graded up to 0.5 per cent., but the minimum possible grade is usually designed.

The design of such measures has been discussed frequently in previous issues of this Journal.

The soil conservation programme in this zone should be considered under the following headings:

1. Rabbit Control.
2. Bush Fire Control.
3. Grazing Management.
4. Pasture Improvement.
5. Crop Rotation.
6. Contour Pasture Furrows.
7. Diversion Banks (graded) and Grassed Waterways.
8. Roadside Erosion Control.

ZONE No. 4.

This zone forms a transition stage between the eastern grazing areas and the more typical wheat growing areas of Zone 5.

Wheat growing was predominant up till the end of last decade, but during the period under review there has been a marked change in the land use practice in this zone. Although for somewhat different reasons in the northern portion to the southern portion there has been a general realisation that single crop farming of wheat with frequent fallow was responsible for a rapid decline in soil fertility and increase in the frequency of erosion damage. With this realisation a gradual improvement in land use methods has developed, and now it is generally realised in this zone that successful wheat growing cannot be continued indefinitely without diversification to include the grazing of livestock.

The zone has two distinct sections, namely, north and south of a line drawn approximately from Mangoplah to Osborne through Yerong Creek. Land use practices differ and each will be considered separately.

Northern Section.

The heavy infestations of skeleton weed in this part of the zone has been largely responsible for a radical change in general land use over the last ten years or so. The old single crop farming rotation of wheat, fallow and even wheat-oats-fallow, together with the burning of stubble, is gradually dying out. Fortunately, skeleton weed has a high summer feed value and allows diversification to include sheep grazing. This has fostered a shorter fallow and a general tendency to less cropping and longer leyland. Subterranean clover and Wimmera rye grass are successful temporary leyland pastures and are gradually finding favour with a consequent reduction in the amount of oats grown on stubble land.

Wheat, Leyland, Fallow Rotation.—Probably the most successful soil conservation rotation yet developed in this area for the comparatively small mixed farmer is the wheat and/or oats-leyland-fallow rotation. The leyland, if sown to sub. clover and Wimmera rye grass with the wheat, and topdressed, provides excellent grazing and reduces the necessity for large areas of grazing oats. Smaller areas of oats may be grown either on fallow or leyland as part of the cereal phase of the rotation.

One large landholding company in the Marrar district is practising clover-leyland farming more typical of the southern section of the zone, but this has not yet spread to the smaller holdings.

Mechanical Erosion Control Measures.—Serious erosion is widespread in this northern part of the zone, and there is probably no area in the Riverina Soil Conservation District requiring more intensive mechanical erosion control measures than the Wagga, Coolamon, Rannock, Marrar and Junee areas. Soil Conservation Demonstrations have been developed at Coolamon, Junee, Milbrulong and Sebastopol, and a great deal of general field work has been undertaken. A wide range of mechanical measures is usually necessary, including pasture furrows, graded banks, grassed waterways and storage dams. Fortunately, the climate allows a reasonably rapid development of cover on grassed waterways if stock are excluded in the establishment period. Bank work is usually graded up to 0.5 per cent., but the lowest possible gradients are usually applied.

Contour pasture furrows have proved of particular value to reduce run-off from pasture areas above cultivation paddocks.

Southern Portion.

Skeleton weed has not infested this part of the zone to the same extent as the northern portion. Nevertheless, a radical change in land use practices is occurring with the same object of less crop and more stock. Experiments on clover-leyland farming at Rutherglen Experiment Station, Victoria, have assisted in fostering this change and this Station has published very interesting figures on the success of these rotational methods.

Clover-Leyland Farming.—Briefly, the most successful application of this method of farming cereals is to sow subterranean clover with a cereal cover crop and allow it to become well established, then to crop wheat twice or wheat followed by oats and again retire to clover-leyland for four to seven years. Fallow is reduced to the minimum possible period and clover-leyland is topdressed with superphosphate.

The reduction in total annual cereal production is more than offset by the high stock-carrying capacity of the leyland and the reduction in cost of cereal production by minimising the fallow.

The further adoption of these methods is strongly recommended for soil conservation purposes in this zone.

Mechanical Erosion Control Measures.—Soil erosion is not as widespread in this part of the zone as in the northern portion.

Fig. 4.—Serious damage resulting from uncontrolled erosion in eastern Riverina.

However, Demonstration Areas have been developed at Munyabla, Burrumbuttock, Jindera and Albury.

Generally speaking, the same measures as recommended for the northern portion apply, but if clover-leyland farming is adopted, the intensity of application of these measures will be greatly reduced.

Soil conservation programmes for both portions of the zone should be considered under the following headings:

1. Rotation of crops and stubble conservation.
2. Grazing management.
3. Pasture improvement.
4. Rabbit control.
5. Pasture furrows.
6. Grassed waterways.
7. Contour cultivation and graded banks.
8. Gully control.
9. Roadside erosion control.

ZONE No. 5.

This zone is one of the most concentrated wheat growing areas in the State, and although, as in Zone No. 4, there has been the same trend for less wheat acreage and more stock in the past ten years, this does not appear to have reduced the total wheat production appreciably in the main wheat-growing districts such as Temora.

It will be seen by Table I that there is a wide range of vegetation types and climatic conditions in this zone. The more western areas and the Mallee areas suffer by wind erosion in addition to the widespread water erosion of the more undulating eastern areas. Both problems have a common basic need—the conservation of protective cover.

The variable and somewhat unreliable seasonal conditions make it difficult to recommend a set rotation practice for the wheat growers of this zone, but the old wheat and fallow or wheat-oats-fallow rotation is fast disappearing in favour of a wider rotation with leyland. This usually follows a three or four-year pattern with one or two seasons of leyland between the cereal and the fallow. The important point that has been generally realised is that any rotation which fosters stubble burning is a major factor in depletion of soil fertility and a cause of soil erosion. The length of the leyland is usually governed by the size of the holding and the condition of the stubble and leyland cover. If stubble cover is poor following a poor crop or is blown away by wind, it is desirable to recrop immediately as there is no quicker way of covering old cultivation ground in this zone than with a cereal. On the other hand, a good stubble cover may remain adequate for three or four years.

Ball Clover and Wimmera Rye Grass Ley land.—Ball clover (*Trifolium glomeratum*) is fortunately widespread in this zone, throughout which in general rainfall is inadequate for successful subterranean clover development. It is also fortunate that it thrives under rotational cultivation, probably on the residual value of the superphosphate used with the cereal. The seeding of Wimmera rye grass with the cereal results in a well-balanced leyland with ball clover and the rye grass thriving under rotation conditions.

Although not very widely practised yet, some outstanding carrying capacities for the Temora district leylands have been reported by topdressing the stubble to encourage naturalised clovers.

Not only has this proved an economic proposition but it has rendered possible a longer life of well-covered leyland and minimised erosion.

Mechanical Erosion Control Measures.—There have been some interesting trends also in the approach to mechanical erosion control measures.

Most early mechanical control measures followed the early type of graded bank with gradients up to as high as 1 per cent. Some serious outlet scours followed this practice as grassed waterways were, at that time, not widely known. Grades of banks have now been reduced greatly. In fact, work on Demonstration Areas at Mirrool, Ardlethan and Temora has amply demonstrated the value of level diversion banks and absorption banks with or without grassed waterways, even on arable lands. Waterways take a longer period to establish in this zone than in Zone No. 4.

Advantages of Level Banks.—Although usually applied at less vertical intervals than graded banks, the level banks have the following advantages:—

1. They do not rely to the same extent on the cover of the waterway for permanent success and as the establishment of waterway cover is a longer process in these climates this is a big factor.
2. Greater retention of rainfall for use by crops and pastures.
3. Suit all soil types in the zone.
4. General design is simpler and can be laid out more rapidly.
5. Installation of the bank is not dependent on the establishment of waterway cover. Banks and waterways can be designed and formed at one period of operation. The banks can be used closed ended while the waterway is establishing with a reasonable degree of safety and when the waterway is satisfactorily covered, the bank may be opened into the waterway if required.

Contour Cultivation.—There is probably no where else in the Riverina Soil Conservation District that contour cultivation has been so widely accepted as in parts of this zone, and in the Ariah Park district in particular. As a measure of erosion prevention where the degree of erosion is not too severe, this method of cultivation is very successful. Some enthusiasts in the Ariah Park district mark their contour plough lines out at 4 feet vertical intervals in the early leyland period with a disc plough. The plough furrows then act as a system of contour furrows during the leyland period, retaining moisture and reducing run-off. The subsequent fallowing is done on the contour from these guide lines.

Natural Grassed Waterways.—A keener appreciation of the natural function of grassed depression is now being shown in this zone and farmers, particularly those adopting leyland rotations, are gradually making adequate grassed natural waterways to conduct run-off safely.

Each year sees another leyland paddock broken up with a grassed reserve for water disposal. This is a practice which should be given greater consideration in some other zones.

Consideration of soil conservation programmes in this zone should be made mainly around the following points:—

1. Rotation of crops and stubble conservation.
2. Grazing management.
3. Rabbit control.
4. Diversion banks (level).
5. Level absorption banks.
6. Pasture furrows.
7. Grassed waterways.
8. Gully control.
9. Windbreaks and farm woodlots.

ZONE No. 6.

This zone is more closely associated with Western New South Wales than other zones of the Riverina Soil Conservation District.

Topography is mainly level to gently undulating and the land use mainly grazing.

Although not very widespread, some serious wind erosion occurs and in common with the control of water erosion, the conservation of protective cover is the main method of erosion control.

The treatment of scalds and other matters in connection with wind erosion in this zone has been discussed in previous issues of this Journal[3].

A Question Answered.

Probably the most common question that is asked when discussing the development of soil conservation activities is: "Are the farmers and graziers actively undertaking soil conservation work or do they passively regard the danger as something inevitable to be passed on to posterity?"

A survey of the reactions of the landholders over the past ten years may answer this question.

At the end of 1942 or early 1943 approximately sixty landholders were recorded as having sought some measure of assistance from the Soil Conservation Service in the Riverina.

At the end of 1949 the number recorded as requesting assistance was over 400 and additional requests are being received at the rate of approximately 100 a year.

This is a very encouraging answer to the question and it is felt that we can confidently look forward to very satisfactory results by the end of the next decade.

References:
(1) Kaleski. Soil Conservation Journal, Vol. 1.
(2) Smith. Unpublished—1943.
(3) Beadle. Soil Conservation Journal, Vol. 4.

TABLE I.
Natural Factors of Zones.

Zone.	Vegetation.		Soils.	Altitude.	Rain-fall.	Topography.
	Formations.	Dominant Species.		feet.	inches.	
1.	Alpine Eucalypt Forest ...	Snow Gum (*Eu. pauciflora*), Mountain Ash (*Eu. gigantea*).	Skeletal	Over 4,000	40–60	Ridges and hills.
	Alpine Grassland ...	Snow Grass (*Poa Scaespitosa*) ...	Peaty over Skeletal ...	Over 4,000	40–60	Undulating.
2.	Wet Eucalypt Forest ...	Snow Gum (*Eu. pauciflora*) Mountain Ash (*Eu. gigantea*), Mountain Gum (*Eu. Dalrympleana*), Messmate (*Eu. radiata*), Ribbon Gum (*Eu. viminalis*), Eurabbie (*Eu. bicostata*), Apple Box (*Eu. Stuartiana*), Broad Leaf Sally (*Eu. camphora*), Black Sally (*Eu. stellulata*).	Skeletal	3,000–6,000	40–60	Mountainous.
	Eucalypt Forest	Stringybark (*Eu. macrorrhyncha*), Peppermint (*Eu. dives*), White Gum (*Eu. maculosa*), Long Leafed Apple (*Eu. elaeophora*).	Skeletal (inferior) ...	2,000–3,000	30–40	Hilly (dry sites).
	Deforested Areas (Grassland).	Kangaroo Grass (*Themeda* Sp.) Snow Grass (*Poa* sp.), White Top (*Danthonia* sp.) and improved pastures of exotic species.	Greys, grey-browns and red-brown loams	2,000–3,000	30–40	Undulating to hilly.

Zone.	Vegetation.		Soils.	Altitude.	Rainfall.	Topography.
	Formations.	Dominant Species.		feet.	inches.	
3.	Eucalypt Forest	Stringybark (*Eu. macrorrhyncha*), Peppermint (*Eu. dives*), Red Gum (*Eu. Blakelyi*), Red Box (*Eu. polyanthemos*), Apple Box (*Eu. Stuartiana*), Scribbly Gum (*Eu. Rossii*).	Skeletal and grey to grey-brown loams.	1,000–2,000	25–30	Hilly to mountainous.
	Eucalypt Woodland ...	White Box (*Eu. albens*), Red Gum (*Eu. Blakelyi*), Red Box (*Eu. polyanthemos*), Yellow Box (*Eu. melliodora*), Apple Box (*Eu. Stuartiana*), Iron Bark (*Eu. sideroxylon*).	Grey, grey-brown to red-brown loams.	800–1,000	20–25	Undulating to hilly.
	Cleared Areas (Grassland)	White Top (*Danthonia* sp.), Corkscrew (*Stipa* sp.), Red Grass (*Bothriochloa* sp.), Kangaroo Grass (*Themeda* sp.) and improved pastures of exotic species and cultivation.	Grey, grey-brown to red-brown loams.	800–1,000	20–25	Undulating to hilly.
4.	Eucalypt Woodland (mainly cleared).	White Box (*Eu. albens*), Red Gum (*Eu. Blakelyi*), Yellow Box (*Eu. melliodora*), Grey Box (*Eu. microcarpa*). GRASSLAND: White Top (*Danthonia* sp.), Corkscrew (*Stipa* sp.) Windmill (*Chloris* sp.), with improved pastures of exotic species and exotic annuals and cultivation.	Grey-brown to red-brown loams.	800–1,000	20–25	Undulating to hilly.
	Pine–Eucalypt Woodland (mainly cleared).	Cypress Pine (*Callitris glauca*), Yellow Box (*Eu. melliodora*), Grey Box (*Eu. microcarpa*). GRASSLAND: White Top (*Danthonia* sp.), Corkscrew (*Stipa* sp.), Windmill (*Chloris* sp.), with improved pastures of exotic species and exotic annuals and cultivation.	Red-brown loams ...	600–800	20–23	Undulating.
5.	Pine–Eucalypt Woodland, Eastern phase (mainly cleared).	Cypress Pine (*Callitris glauca*), Yellow Box (*Eu. melliodora*), Grey Box (*Eu. microcarpa*). GRASSLAND: White Top (*Danthonia* sp.), Corkscrew (*Stipa* sp.), Windmill (*Chloris* sp.), with exotic annuals and cultivation.	Red-brown loams ...	600–800	18–20	Level to undulating.
	Pine–Eucalypt Woodland, Western phase (mainly cleared).	Cypress Pine (*Callitris glauca*), Bimble Box (*Eu. populifolia*), Mallee Box (*Eu. Woollsiana*), Bull Oak (*Casuarina* sp.), Belah (*Casuarina* sp.). GRASSLAND: Corkscrew (*Stipa* sp.), White Top (*Danthonia* sp.), Windmill (*Chloris* sp.), with annuals and cultivation.	Red-brown loams ...	400–700	15–18	Level to undulating.
	Mallee	*Eu. oleosa*, *Eu. dumosa*. GRASSLAND: White Top (*Danthonia* sp.), Corkscrew (*Stipa* sp.), Windmill (*Chloris* sp.), annuals and cultivation.	Red-brown sands and loams.	400–600	15–17	Level to undulating.
	Dry Eucalypt Forest ...	Hill Gum (*Eu. dealbata*), Ironbark (*Eu. sideroxylon*).	Skeletal	400–1,000	15–20	Rough hills and ranges.
6.	Eucalypt Woodland ...	Red Gum (*Eu. rostrata*), and/or Black Box (*Eu. bicolor*).	Grey and brown clays and clay loams.	400–500	15–17	Level, subject to flooding.
	Grassland	White Top (*Danthonia* sp.), Windmill (*Chloris* sp.), Corkscrew (*Stipa* sp.).	Grey and brown loams	400–500	15–17	Level plains.

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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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PART II. MASS MOVEMENTS OF THE SOIL SURFACE IN THE MONARO REGION (continued).

II. SLIPPAGE MOVEMENTS.

(1) SLUMPING.

Slumping occurs in all tracts of the Monaro, being favoured by high soil moisture contents, severe frost action, steep slopes, and exposure of the soil surface by overgrazing, burning and clearing. In all areas where slumping has been observed, accelerated soil creep, solifluction, and wind and water erosion are also active.

Importance in Natural Processes.—Natural slumping is not important on the Monaro except in earthflows and sometimes in stream and gully widening. Slumping of gully walls and stream banks is usually accompanied by caving, both processes frequently being hastened or induced by human interference.

* In this number, Mr. Costin concludes his article. The earlier portions of the article appeared in this Journal, Vol. 6, Nos. 1 and 2, 1950.

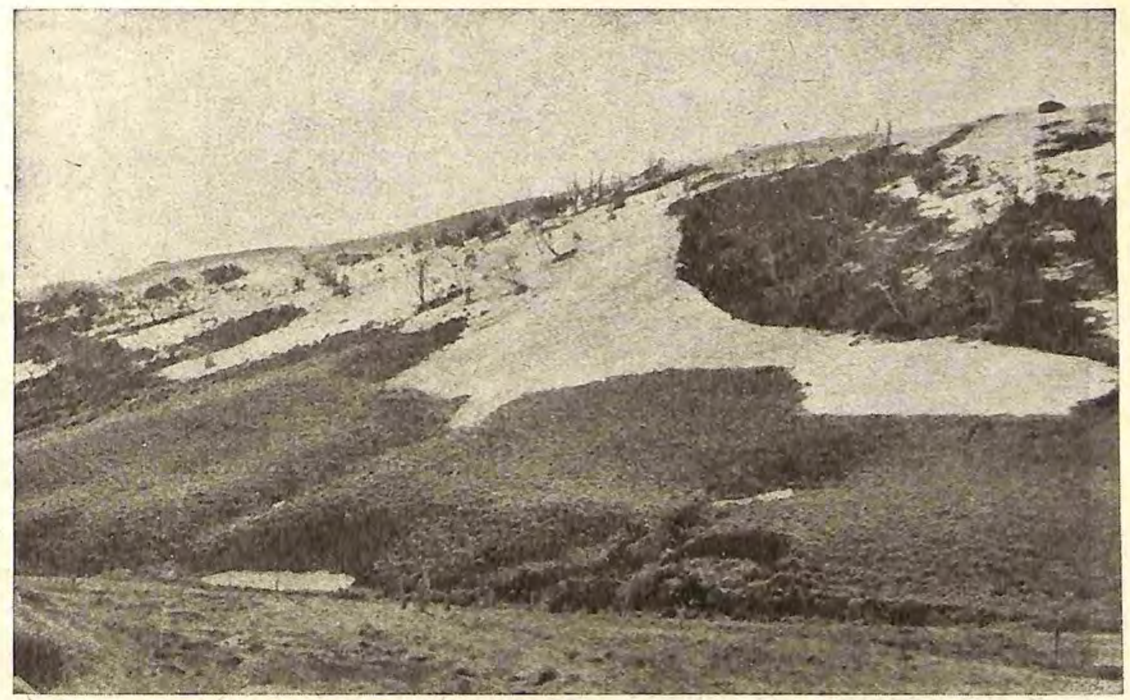

Fig. 1.—A typical spring scene in sub-alpine tract showing way in which melting of snow is retarded on shady aspects. Note solifluction terracettes, and slump scar near base of slope.

Fig. 2.—Close-up view of Fig. 1, showing accumulation of snow on small slump scar (right hand corner of photograph) and in bare soil pockets between solifluction terracettes.

Fig. 3.—Close-up view of slump scar and associated terracettes shown in Fig. 1.

Fig. 4.—Lateral coalescence of bare slump surfaces in subalpine tract by further mass movements between the original slumps.

Importance in Accelerated Erosion.—Particularly on steep, overgrazed slopes of the subalpine tract the development of solifluction terracettes (in which minor slumping is also involved) is frequently accompanied by larger slump movements. In the bare, depressed soil pockets separating individual terracettes, snow tends to accumulate. With the spring thaw the soil frequently becomes so lubricated by snow water that, in the absence of a continuous vegetative cover, slumping commonly takes place. Both lateral and vertical coalescence of slumps may occur, and in this way large slump surfaces are exposed (figs. 1, 2, 3, 4). Some of the most serious slumps in the subalpine tract have occurred on steep, shady slopes where burning and overgrazing have replaced the climax snow gum woodland by a disclimax grassland of snow grass. Here it is considered that the destruction of trees has resulted in a less uniform accumulation of winter snow and consequently in the acceleration of soil mass movements.

The recession of stream banks and gully walls by slumping, usually following undermining by frost or water erosion, has also been hastened by human interference (figs. 5, 6).

Control of Accelerated Slumping.—The control measures recommended are those previously discussed in connection with soil creep and solifluction. Where slumping has occurred on the steep slopes of the subalpine tract, on which trees have been killed, the encouragement of natural tree regeneration is particularly recommended.

(2) CAVING.

Usually acting in conjunction with slumping, caving is also a major process in the recession of stream banks and gully walls. It is especially active in soils possessing a columnar or prismatic structure. While slumping may occur without undercutting, the latter process always precedes caving movements.

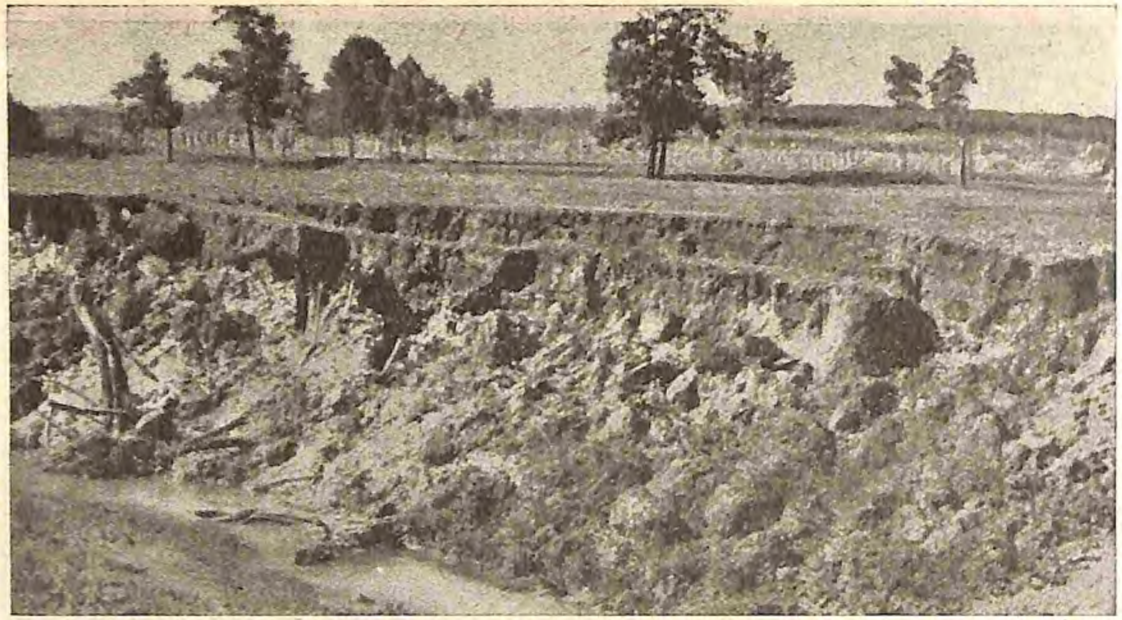

Fig. 5.—Recession of stream bank by slumping. (Photo by U.S.D.A.)

Fig. 6.—Recession of stream bank by caving. (Photo by U.S.D.A.)

Fig. 7.—Gully widening and recession hastened by frost action and caving in soils of the alpine tract.

Importance in Natural Processes.—Natural caving occurs almost universally along the banks of creeks and rivers as the result of undercutting by water action.

Importance in Accelerated Erosion.—The greater fluctuations in stream flow following clearing and overgrazing have probably hastened the recession of stream banks by undercutting and caving (fig. 6).

Of greater importance on the Monaro, however, is the role of caving in accelerated gully widening and recession. In the alpine and subalpine tracts caving usually results from undermining by frost action, and in the montane and tableland tracts from undermining by water erosion.

At alpine and subalpine levels exposed gully walls are vigorously attacked by frost during the spring, autumn and summer months. Owing to the partial protection from needle ice erosion afforded by dense root development in the A1 horizon, and by the greater abundance of stones and gravel in the BC, the relatively unprotected A2 and B horizons of exposed soil profiles are more rapidly eroded resulting in the undercutting of the surface soil. Saturation of the overhanging surface soil causes the formation of tension cracks along which caving occurs. In the Kosciusko area lateral gully recessions approaching three feet per annum have been observed (figs. 7, 8).

No less serious are the caving movements resulting from the undermining of gully walls in the montane and tableland tracts. The deep, vertical gullies, which are such a typical erosion feature of the fossil laterites of the Monaro, have been intensified by caving movements facilitated by the prismatic and columnar structures of the pallid and mottled horizons of these soils. In marked contrast is the erosion pattern of the prairie soils, chernozems, and chocolate soils, the highly self-mulching properties of which prevent undermining and caving and result in gently sloping gully walls (figs. 8, 9).

Control of Accelerated Caving.—In the montane and tableland tracts caving movements may be minimised by the standard methods of gully control.

Fig. 8.—Recession of roadside cutting in sub-alpine tract, due to vigorous frost action followed by caving of the undermined surface soil.

Fig. 9.—Broad gully in prairie soil of montane tract, the self-mulching properties of which prevent caving movements and the formation of vertical gullies such as are shown in Fig. 10.

In the alpine and subalpine tracts, however, where frost is the major undermining agent, the prevention of caving is a more difficult problem. Sinces the exposure of any vertical section of soil immediately initiates caving movements, every effort should be made to preserve the natural vegetative cover.

(3) DEBRIS SLIDE.

Debris slides are of widespread occurrence on steep slopes of the alpine, subalpine, montane, and sometimes tableland tracts. At alpine and subalpine elevations the debris slide scars are sometimes deep and narrow, suggesting that these slides were probably accompanied by rapid flowage movements characteristic of debris avalanches.

Importance in Natural Processes.—Although natural debris slides are an important geomorphological agency in the mountainous areas of the Monaro, the majority occurring in recent years have been favoured by human interference.

Importance in Accelerated Erosion.—In many parts of the Monaro the severe forest fires of 1939 left soil surfaces in an exposed, unstable condition. These fires were followed by heavy rains which resulted in many debris slides, as for example on the steep, granitic slopes of the Lower Snowy River.

In the Kosciusko area small debris slide scars are sometimes found on steep slopes where accelerated solifluction and slumping are active. Although some of these slides were instigated by natural undercutting due to stream action, their occurrence was undoubtedly facilitated by unfavourable human interference (fig. 11).

Control of Accelerated Debris Slide Movements.—The man-induced debris slides of the Monaro can be minimised by the prevention of forest fires and overgrazing.

Debris Fall, Rock Slide and Rock Fall.—Natural debris falls, rock slides and rock falls are important pedogenic and geomorphological processes occurring in mountainous areas of the Monaro.

These processes have not been affected by human interference.

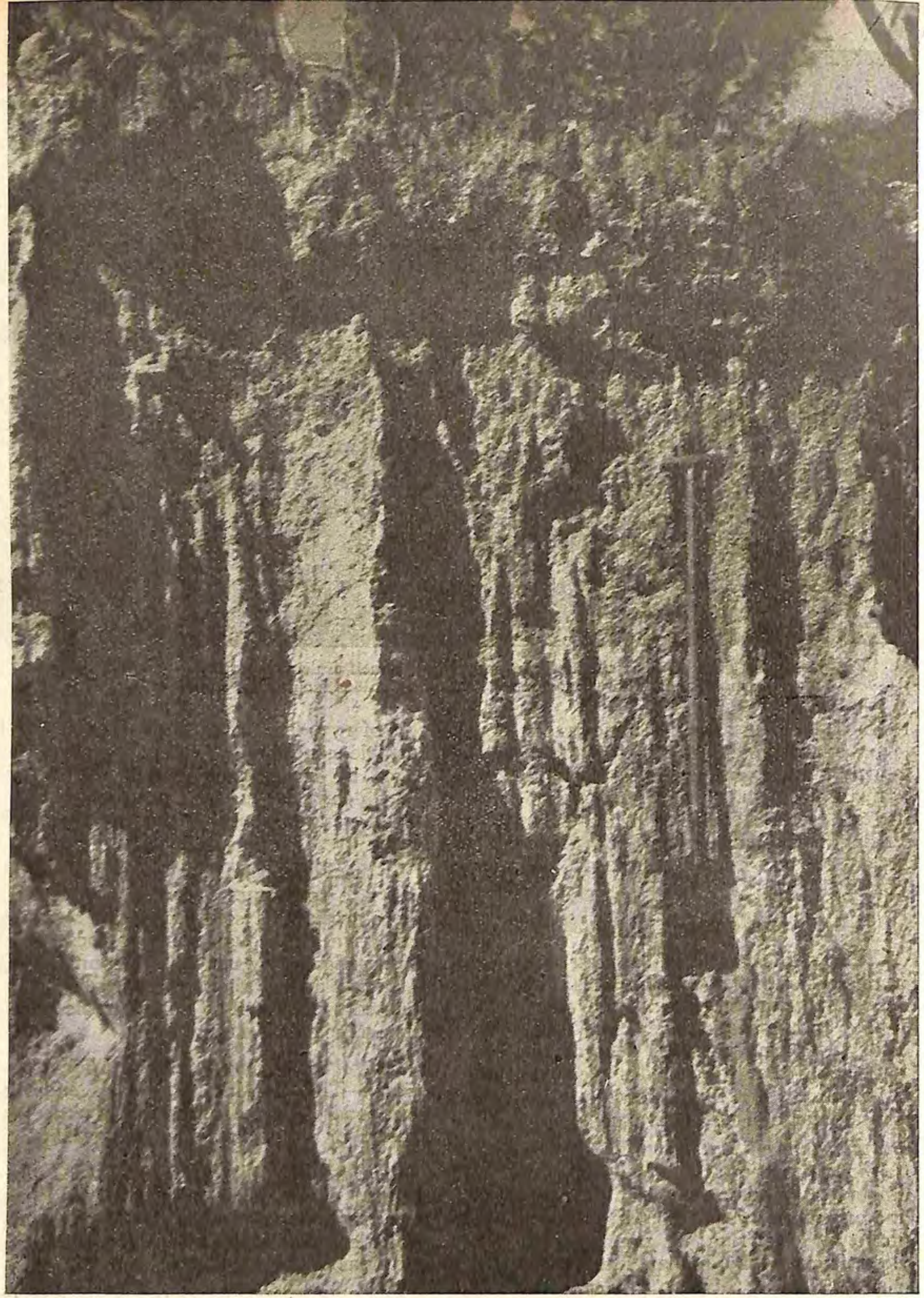

Fig. 10.—Deep, vertical gully in fossil laterite of tableland tract, showing columnar structure of mottled and pallid horizons which facilitates caving movements.

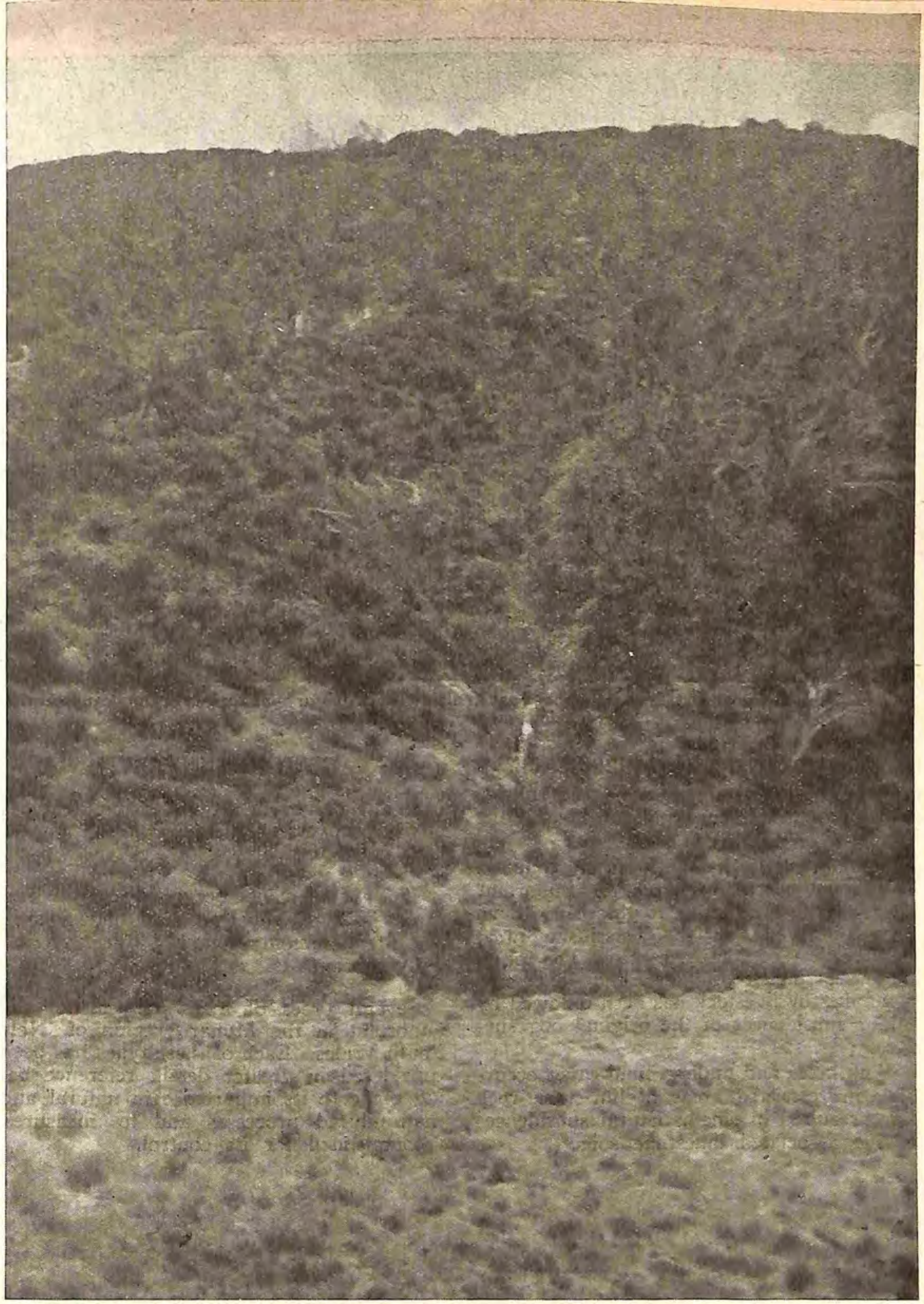

Fig. 11.—Partly vegetated scar of debris slide in subalpine tract. This slide was probably instigated by undercutting due to stream action; and judging from the narrowness of the scar near its base, may have been accompanied by flowage movements characteristic of debris avalanches.

Fig. 12.—Subsidence of surface of raised bog peat in alpine tract, due to humification of the peat following over-grazing and trampling by livestock.

(III) MOVEMENTS BY SUBSIDENCE.

Neither natural nor man-induced subsidence movements are important on the Monaro.

Mining activity has been largely confined to alluvial operations, and no important cases of subsidence due to this cause have been observed. In the Kosciusko area, humification of localised raised bog peats due to artificial draining and excessive trampling by livestock has been followed by minor subsidences of the original bog surfaces (fig. 12).

Sink holes and underground caves occurring in restricted areas of limestone rock have resulted in small, natural subsidences of the associated limestone soils.

GENERAL SUMMARY.

In the preceding article the major types of mass movement affecting the soil surface have been considered.

These movements occur by slow and rapid flowage, slippage, and subsidence, and are commonly followed by sheet and gully erosion.

Several types of mass movement are important in the Monaro region of New South Wales. Each of these types has been considered in greater detail, reference being made to its importance in natural and man-induced processes and to measures recommended for its control.

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EROSION CONTROL IN THE BINGARA-GRAVESEND DISTRICT

BY

J. Stewart, B.Sc.Agr., District Soil Conservationist.

THE nature of the topography and the characteristics of the soils in this district have provided a most interesting study, and although the area is relatively small it has presented some peculiar problems. The erosion damage is as severe as, or perhaps worse than, on any comparable area in New South Wales. The location of the area is illustrated in Fig. 1, and includes the Bingara Shire and the southern portion of the Yallaroi Shire.

SOILS.

The geological formation is mainly of Devonian and Carboniferous sediments, chiefly shales and cherts with interbedded limestones and tuffs, overlaid in isolated places with Jurassic sandstones and very limited areas of Tertiary basalt. The influence of the sandstone and basalt is negligible except for their effect on topography as the hard remnants cap the high hills and are responsible for the steep slopes on the upper part of many of the small catchments.

The soils derived from the Devonian and Carboniferous series are of similar types. The A horizon is a reddish-brown loam which lacks a stable crumb structure so that it becomes compacted by rain and sets hard when dry. Its depth in virgin soils ranges from 6 to 12 inches. The B horizon is a brown clay with a high lime content which is frequently evidenced by nodules. It disperses almost completely when wetted, and cracks and crumbles when dry. Its depth is generally 3 to 5 feet, but it may be as much as 12 feet in some places.

VEGETATION.

The most widespread tree species is Silverleaf Ironbark (*E. melanophloia*), with White Box (*E. albens*) in the eastern section and Bimble Box (*E. populifolia*) in the western section. There are scattered areas of Cypress Pine (*Callitris robusta*) and Wilga (*Geijera parviflora*) with some Kurrajong (*Brachychiton populneus*), Bull Oak (*Casuarina Luehmanni*) and Boonery (*Heterodendron oleafolium*) throughout. On low-lying areas Yellow Box (*E. melliodora*) occurs, and along the main creeks and rivers there is River Red Gum (*E. rostrata*) and River Oak (*C. Cunninghamiana*). Hop Bush (*Cassia eremophila*) is found on stony areas, and Cotton Bush (*Kochia aphylla*) is a widespread shrub on overgrazed land.

Queensland Bluegrass (*Dicantheum sericeum*) is the dominant grass species. Other major species are Corkscrew (*Stipa setacea*) and Windmill Grass (*Chloris truncata*). Plains grass (*Stipa aristiglumis*) is confined to the alluvial black clays.

A wide variety of herbage plants are found, the principal ones being Trefoils (*Medicago* spp.), Crowsfoot (*Erodium* spp.) and Tarvine (*Boerhaavia diffusa*).

RAINFALL.

The annual average rainfall ranges from 26 inches at Gravesend to 29 inches at Bingara. The seasonal distribution is shown in Table 1 for the mean monthly rainfalls during 48 years of record at Warialda. Included in this table are the mean monthly rainfalls for 55 years of record at Wagga, in the Riverina. These figures are interesting from a comparison of both the similarities and the differences.

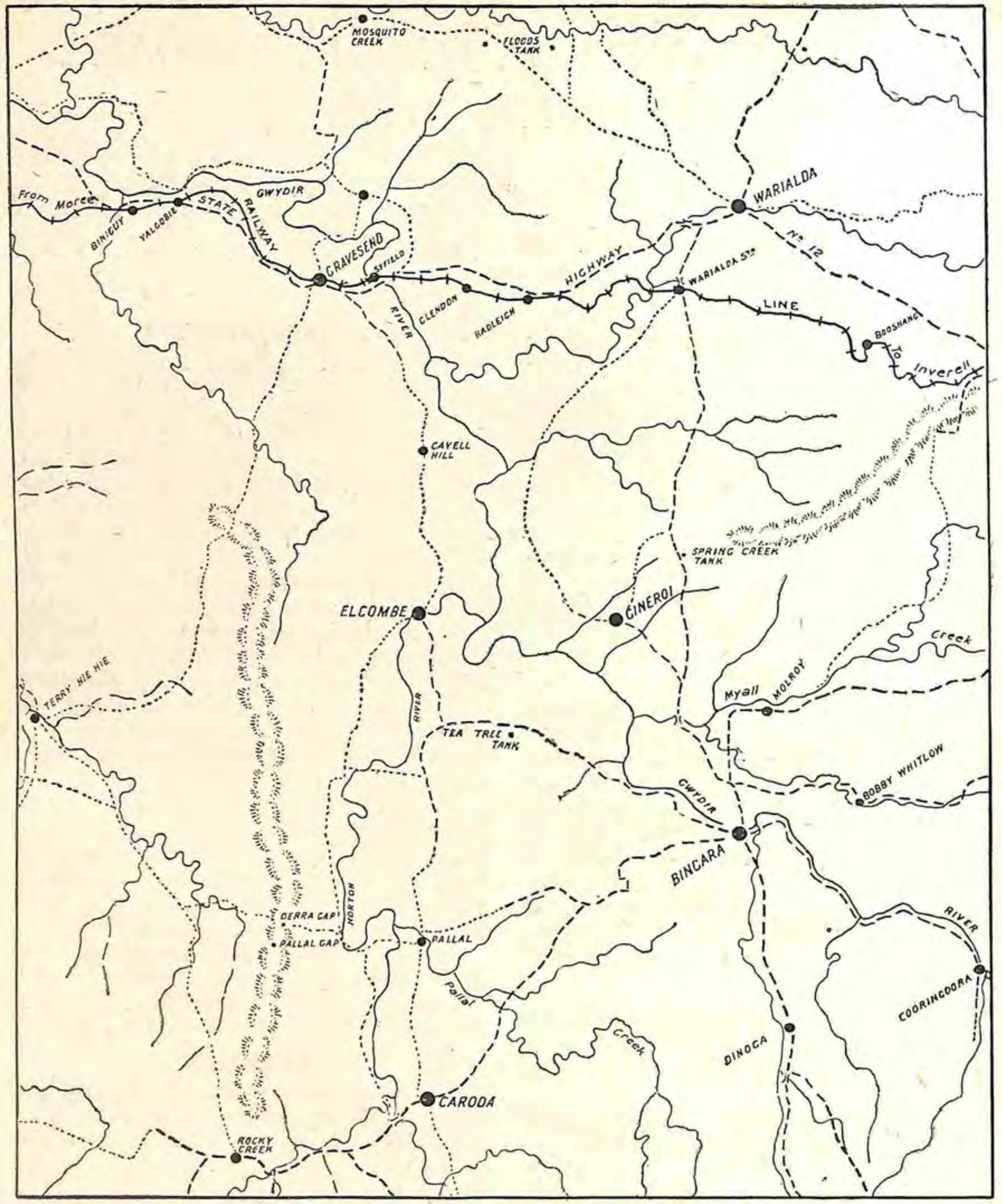

FIG. I

SCALE

MILES 0 1 2 3 4 8 12 MILES

Railways —+—+— Roads — — — Tracks ....

TABLE I.

	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Total
Warialda	1·63	1·85	2·16	1·78	1·75	1·88	2·06	2·34	2·88	3·39	2·91	2·73	26·36
Wagga	1·58	1·91	2·74	1·89	1·99	1·90	2·03	1·56	1·42	1·41	1·36	1·65	21·44
Difference	—0·05	+0·06	+0·58	+0·11	+0·24	+0·02	—0·03	—0·78	—1·46	—1·98	—0·55	—1·08	...
	Total difference April–October, Wagga 0·93 in. Higher.							Total difference November–March, Warialda 5·85 in. Higher.					
	Average monthly difference, Wagga 0·13 in. higher.							Average monthly difference, Warialda 1·17 in. higher.					

There is some similarity between the soils of the Wagga District, developed upon Silurian sediments, and the soils of this district, but the rainfall characteristics give rise to a totally different erosion problem. There is very little difference in the rainfall between the two districts from April to October, but a big difference in the rainfall from November to March. By far the greater portion of the total of 14.25 in. falling at Warialda during these five months is derived from thunderstorms with high intensity falls for short periods.

EROSION DAMAGE.

Cultivated Land.—The principal cultivated crop in the area is wheat, and the soil preparation for sowing leaves a loose bare fallow during part of the period of summer storms. The compact nature of the surface horizon of the soil renders it resistant to erosion when undisturbed, but, when left loose by cultivation, run-off and soil losses are high because the compact soil under the loose cultivated layer has a low absorption rate. Sheet erosion continues to remove the "A" horizon until it is reduced in places to a thickness of less than 3 inches. When this stage is reached the next ploughing breaks through into the friable subsoil which is highly erodible. The next storm produces devastating results, cutting gullies up to 3 feet deep in a matter of minutes. One case has been observed where a paddock of 79 acres was sown as a complete block in June, 1948, and by November of the same year there were twelve gullies too deep to be crossed by harvesting machinery; the paddock was harvested in thirteen sections. It is often stated by local landowners that erosion has only occurred within the last ten years. It is true that obvious gullying has become serious only recently, but insidious sheeting has paved the way over the past fifty years, and subsequent gullying has been unusually rapid.

Once a gully has formed it spreads rapidly both laterally and by head cutting. The friable subsoil sloughs away, undermining the firm surface soil which collapses. Fig. 2 shows the typical vertical edge of a gully down as far as the "A" horizon, the more gentle slope of the sloughing "B" horizon and the undermining action of the overfall.

In addition to sheet erosion by water, there is considerable wind erosion caused by the squalls which almost invariably precede the summer storms. When a squall passes the soil is usually dry, and as the air in the squalls is extremely turbulent large amounts of dust are lifted from bare fallows.

An important contributing cause to erosion on cultivated land in this area is the lack of useful vegetation on leyland. The native and naturalised grasses do not volunteer readily, the surface becomes almost bare and the run-off from retired cultivation land is high.

Grazing Land.—The seasonal growth of pasturage in this district is extremely variable and this has resulted in severe periodic overgrazing. The occurrence of good seasons and droughts is unpredictable, and they may occur at any time of the year. Unless a consistent policy of reserved stocking is practised, when a drought develops and the owner should reduce his stock numbers, he finds that his neighbours are doing the same thing and he can sell only at a heavy financial loss. The stock are then held in the hope that rain will fall, but when there is

Fig. 2.—Gully head showing scalded surface, firm "A" horizon, sloughing "B" horizon and undercutting overfall.

no rain the land is grazed bare and the perennial grasses are killed. The position is aggravated by rabbits. The next rain not only gives a high proportion of run-off and heavy soil loss, but permanent damage has been done to the perennial grasses and bare hard patches appear which are very slow in revegetating. Reserved stocking is essential to maintain perennial pasture species in such climatic areas as these.

The reason for this slow revegetation; where reserved stocking has not been practised, is that the bare soil is compact and absorbs water very slowly. Investigation has shown that after three storms which precipitated a total of 3.85 inches of rain over four days the penetration on scalded areas was less than 2 inches. The exposed soil dries out in two or three days and any seedlings that may have begun to germinate cannot survive unless rain falls again in that time. Scalded areas commonly comprise 10 per cent. and may be as much as 60 per cent. of grazing land. They tend to make overgrazing cumulative by reducing the area actually growing pasturage.

The bare areas are subject to wind erosion and sheet erosion by water, and gullying proceeds with the same rapidity as on arable lands as soon as the subsoil is exposed by stock tracks or concentration of run-off.

CONTROL MEASURES.

Cultivated Land.—The tendency of the surface to become compact, together with the low absorption rate, renders it essential to construct graded banks and carry out farming operations on the contour; it appears impossible with our present knowledge to reduce and control run-off by any other means alone. Landowners on these soils are becoming convinced that construction of graded banks and contour farming are as much a normal and essential part of crop production as cultivation and sowing.

Farming practices also require alteration to improve soil texture and increase water absorption. Continuous cropping with its attendant evil of burning stubble should be eliminated. The great difficulty to be overcome in developing a crop rotation with temporary leyland pasture is that suitable

Fig. 3.—Waterway damaged by storm of 3·06 inches after sowing, before cross-checking and straw mulching.

pasture plants are not known. The winter growing annuals, such as ryegrass and clover which can be sown conveniently under the wheat crop and which are so valuable in southern districts, are a failure here because they are germinated in the leyland by late summer rains and almost invariably killed by hot weather in the autumn. The summer growing giant Panic and liverseed grass show some promise but cannot yet be recommended with certainty. However, considerable protection is gained by eliminating stubble burning and incorporating the stubble in the surface soil. This practice increases absorption of water and offers some obstruction to wind erosion.

Waterways present a most difficult problem. Whenever possible undisturbed natural grass should be sought. A waterway should only be graded as a last resort as the subsoil may be exposed. Although the subsoil is quite fertile it is liable to break into gullies even after a grass cover is established. Good cover has been established on graded waterways by sowing wimmera ryegrass and Rhodes grass in the autumn and straw mulching with Queensland bluegrass carrying seed. The sown species give protection for 12-18 months and by that time the native species become established. As a further protection during establishment it is necessary to build level soil checks at intervals so that they drain through gaps left in the waterway banks. By leaving the gaps where graded banks will discharge when the waterway is established, the banks are then readily connected to the waterway. A waterway damaged by a storm immediately after sowing is illustrated in Fig. 3. Checks were built across the waterway before re-sowing and no further damage has occurred even though it has been subject to several worse storms than the one which caused the damage.

Grazing Land.—The problem of controlling grazing so that perennial grasses are not eaten out during drought is not readily solved. Pasture growth is not regularly seasonal, but dependent on the incidence of rain. Some of the natural pasture plants may provide feed at any time of the year, and to adjust stock numbers would require anticipation of the season's rainfall. Consistent reserved stocking and conservation of fodder is a solution, provided that the common error is not made of increasing stock numbers on the false assumption that stored fodder increases carrying capacity.

In some districts stored fodder does increase carrying capacity by providing for a regular annual seasonal shortage, as for example the New England winter. But in the Bingara-Gravesend district stored fodder must be regarded as purely a safeguard against unpredictable drought.

As the bare scalded areas reduce the effective pasture area and are focal points of erosion, they requite attention to restore the grass cover. As pointed out earlier, these areas are hard and they dry out too quickly for seed to germinate. Breaking the surface slightly to permit penetration and straw mulching to prevent rapid drying are effective. Both can be achieved at once with any tyned implement by scratching the surface first and then raking grass straw from adjoining grassed areas.

Pasture furrows used in conjunction with mulching the bare patches are valuable in reducing run-off, but their value is soon lost if the scalds are not revegetated. Rabbits prefer to feed on young seedlings in the open, and destruction of the pest is essential to establish grass on the scalds.

CONCLUSION.

Erosion can be effectively controlled in this district by application of the methods outlined in this article, but observation and investigation is proceeding to discover if the techniques can be improved. Increase of the absorption rate by improved soil texture, the introduction of better waterway grasses than the native species, and the development of suitable pasture plants for leyland in rotation with cereal cropping are the immediate pressing problems requiring solution.

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

PART IV.

BY

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Asst. Engineer.

In Part III of this article (Vol. 6, No. 1), it has been shown that in recent studies of the soil erosion process, W. D. Ellison and O. T. Ellison, of the United States Soil Conservation Service, made a new approach to the problem.

Their approach is based on the proposition:

> "Soil Erosion is a process of detachment and transportion of soil materials by erosive agents."

The main erosive agents are (I) Raindrop Splash, (II) Surface Flow (Run-off).

These erosive agents combine within themselves the powers to (*a*) detach and (*b*) transport soil materials.

1. The forces of Raindrop Splash play a major part in "detaching" soil particles from their moorings in the soil mass.

2. The forces of Surface Flow play a minor part in "detaching" soil particles from their moorings in the mass except in gullies or channels where concentration was possible.

3. The forces of Raindrop Splash play a minor part in "transporting" soil particles by splashing and re-splashing them in one direction.

4. Surface Flow has the greatest ability in "transporting" soil particles which have been first detached by some other force; the impact force of falling raindrops, for instance.

The transporting ability of Surface Flow will be described in this Part.

Transportation by Surface Flow or Run-off.

It is usual to believe that Surface Flow, or run-off, is the sole erosive agent, its effect depending on whether or not the soil over which it flows is in a condition liable to erosion.

This common belief is based on the observation that the occurrence of erosion is *always* accompanied by the occurrence of run-off.

For this belief to be true, however, it must be possible to demonstrate that whenever run-off occurs erosion always follows.

The facts, however, are otherwise. Very often, little erosion arises from high run-off and much erosion from comparatively little run-off. (See Table I).

The reason for this must be sought in some other force acting in conjunction with run-off.

FORMS OF SURFACE FLOW.

Surface flow during a rainstorm may move across the land surface in several forms.

First, it may move across broad surfaces that have no perceptible channels, as a shallow sheet of water; in this case it is referred to as sheet flow or pre-channel flow because sooner or later the sheet flow will begin to concentrate into a channel or channels.

Second, it may move in rills, gullies, or valley channels in which case it is referred to as rill flow, gully flow, or generally as channelised flow.

SHEET FLOW.

When broad sheets of water move across land in pre-channel stages, the velocities of translation will seldom develop sufficient soil suspending capacity to move appreciably large amounts of soil.

But when the energy of turbulence is imparted by the action of falling rain drops, its soil suspending capacity increases considerably as also its soil transporting capacity.

The soil transporting capacity thus imparted varies widely with raindrop size and velocity of impact.

Under certain conditions the turbulence imparted was observed to cause coarse sand and small gravel to be moved by surface water which was barely flowing.

In one series of observations, the following note was made in regard to a small plot free of rills and gullies:

> "It was observed that raindrop impact under certain conditions, would move stones as large as 10 m.m. in diameter when they were partially or wholly submerged in water; when raindrops would strike these stones, the stones would rise and frequently they would move some distance downslope. Where there was surface flow, this would assist the downhill motion even though the surface flow acting alone would not move them."

More recent observations demonstrated further outstanding effects. It was observed that soil-bearing water flowing more than half an inch deep at a velocity greater than a quarter foot per second deposited soil on a city pavement at each place where it flowed under a parked motor car.

Each of these deposits conformed exactly to the shape of protection afforded by the car above it. Between parked cars, where splashing raindrops continued to churn flow, there were no deposits whatever.

CHANNELISED FLOW.

Raindrops bombarding water surfaces in shallow channelised flows may often increase their transporting capacities by several hundred per cent.

This can be strikingly demonstrated at the lower end of run-off plots. When the run-off leaving a plot is high in silt content, an intercepting trough along the lower edge may fill very quickly if covered to keep out falling raindrops. But when the cover is removed so that raindrops strike the surface, no deposit will be made in the intercepting trough and even deposits already in the trough may be removed.

TABLE I.

Soil Losses Corresponding to Run-off.

Wagga Research Station Experimental Plots—December, 1947, to October, 1949.

	Pasture Mixed.	Lucerne.	Land Retired.	Wheat.	Leyland.	Fallow.
Run-off (inches)	7.06	10.21	6.26	12.91	9.44	11.41
Run-off (per cent. of rain) ...	16.7%	24.3%	15.0%	30.7%	22.5%	27.2%
Soil Loss (tons per acre)	0.7	1.34	0.6	10.9	0.6	30.0

Although the Run-off from Fallow is very little more than from Leyland, the Soil Loss from Fallow is nearly 50 times as much as that from Leyland.

Although the Run-off from Wheat is more than the Run-off from Fallow, the Soil Loss from Wheat is only one-third as much as that from Fallow.

EFFECT OF LENGTH OF SLOPE ON SOIL LOSS DUE TO RUN-OFF.

Soil loss which is due principally to the transportation process tends to decrease with each increase in slope length during a rainstorm.

If a slope is only 4 ft. long, then an average of only 2 lb. ft. of soil transportation energy is necessary to remove each pound of soil from the slope.

But if the slope is 400 ft. long, an average of 200 lb.ft. of soil transportation energy

Fig. 1.—In this field most of the top soil is removed from the upper reaches of the slopes where surface flow is a minimum. This is typical of fields where splash erosion is active, and manifests itself in the form of sheet erosion on upper slopes.

Contrast this with Fig. 2 where gully erosion is most active near the foot of the slopes.

is required to move each pound of soil from the slope.

Accordingly, 100 times more transportation energy is required to move one pound of soil from the 400 ft. slope than is required to move one pound from the 4ft. slope.

In practice, however, this increase in energy requirements will usually be more than offset by the energy of water concentrated within gullies.

Outside gullies, however, no such water concentrations occur and where there are no gullies in a field, soil loss per unit of area will usually decrease with each increase in slope length.

Another factor which operates to cause soil loss per unit of area to decrease with each increase in slope length is the matter of soil transportation when rain ceases. Transportation on field surfaces almost ceases when raindrops stop falling and soil, in suspension at the time rain ceases, will be deposited. The longer the slope, the greater will be the quantity of soil so returned (by deposition) to the field after rain ceases.

Both factors will operate to cause soil loss from a field to vary inversely as the slope length.

This relationship will cause subsoil to appear first through the topsoil near hill tops and soil loss per unit area is then greatest on the shortest slopes and least on the longest slopes.

Gully erosion tends to reverse these relationships due to concentration.

EVALUATION OF TRANSPORTATION HAZARD.

The actual amounts of soil transportation on a field cannot be measured usually.

But the total amounts that are available for transportation can be evaluated. This evaluation would represent the maximum transportation hazard present in given circumstances. The transportation which actually occurs will then be some proportion of the maximum.

The equation for determining this hazard can be expressed:—

T^1_1 = function of (T^1_2, T^1_3)..... (1)
where T^1_1 = the pounds-feet of soil transportation, or the maximum transportation hazard that exists on the bare open field.

T^1_2 = the transportability of the soil or the capacity of the soil to be transported.

T^1_3 = the transporting capacity of the surface flow or the capacity of the surface flow to move soil by transporting it.

The upper indices are used to differentiate the equation from the transportation hazard equation for raindrop splash which was given in Part III.

TRANSPORTABILITY OF THE SOIL (T^1_2).

The transportability of a soil particle in flowing surface water will depend mostly on its shape, density and size.

Shape is important in the case of large dense particles. Round-shaped particles will be rolled over more freely than particles with projections and broad flat sides.

Density will affect the suspension process and the settling rate of a particle that has been set in motion.

The distance particles are floated each time they are splashed into suspension depends on their rates of settling.

The rates of settling may possibly be used as an index of a soil particle's transportability. This aspect has yet to be explored.

But, in addition to rates of settling, experiments employing surface flows stirred by splashing raindrops will be necessary to determine relative transportabilities of different soil materials under conditions of field performance.

These results would then need to be referenced to settling rates, if a practical procedure can be established.

However, it seems unnecessary to introduce a standard soil when testing a soil's transportability in surface flow. It would suffice to standardise the capacity of the surface flow and the surface over which the soils are transported. It is believed that after these two factors have been standardised along with a method of injecting the soil into the surface flow, the pounds-feet of soil transportation can be used without conversion, as representing the relative transportability of a soil.

The standard surface should not be smooth. Roofing paper covered with coarse sand and pebbles should suffice. It is essential that the surface will be (1) easily duplicated, (2) similar to a soil surface, and (3) permit recovering of all the transported materials at the points of deposit.

In standardising the surface flow, it will be necessary to use surface flow bombarded by raindrops.

If we wish to test transportation in deep channels, the raindrops may not be necessary but, on open field surfaces, the raindrops often increase the amount of transportation by several hundred or even several thousand per cent. Outside of gullies, practically all of the transportation occurs under the influence of falling raindrops.

Decreases of soil loss resulting from increases of slope length will tend to be greatest on soils of low transportability and least on soils of high transportability.

The degree of slope of land can have a definite influence on soil transportability. For example, if a soil is so highly transportable that it is carried in continuous suspension, practically all of the soil that is detached may be transported on very gentle slopes and further increases of slope may have little or no effect in increasing soil losses. But, if a soil is of a very low transportability, such that many of its particles must be dragged and rolled along, each increase in slope may cause considerable increase in soil loss.

The effectiveness of erosion control practices will depend considerably on a soil's transportability.

If a soil is so highly transportable that it is carried in almost continuous suspension, small ridges, depressions and small

Fig. 2.—On this soil the gullies increase in size as they approach the bottom of the slope. This could be caused by the flow not being fully charged and its detaching capacity may then continue to increase as the gully flow moves downslope. Contrast this with Fig. 3 where the gullies tend to be of uniform size from top to bottom of slope.

straws and stems of plants on the surface will impede soil movement very little.

But if the soil is of very low transportability, these surface irregularities may greatly retard soil transportation.

Soil transportability must be determined therefore before we can fully interpret soil loss measurements and design most effective control practices.

If a run-off plot from which soil loss is measured is very short, the transportation factor is at a minimum and the detachability of the soil may limit rates of soil loss.

This would be the case in a round plot only 3 inches in diameter:—

As length is increased a length may be reached at which the transportation factor becomes the control that limits soil loss.

If the soil is of low transportability, the shift will occur on much shorter slopes than if it is of high transportability.

Certainly, we cannot extrapolate from short plots where detachment factors limit losses to large fields where transportation factors limit losses.

If subsoil on one hillside is exposed much farther downslope than that on another hillside of equal slope and under equal use and treatment; the one with subsoil appearing lowest on the hillside may be assumed to have the most highly transportable soils.

TRANSPORTING CAPACITY OF SURFACE FLOW (T^1_3).

The soil transporting capacity of unit width of surface flow will depend on three principal factors (1) the velocity of translation which controls the velocity at which materials are moved across the surface, (2) the depth of the flow, as the product of this depth and velocity will determine the volume of flow per unit of width, and (3) the capacity of flow to suspend soil materials, as this factor will limit the soil content of the flow.

Transporting capacity may be expressed by equation.

$$T^1_3 = \text{function of } (V^2/2g,\ d,\ D_3) \quad \ldots\ldots\ldots (2)$$

where $\frac{V^2}{2g}$ = velocity head

d = depth of flow

D_3 = the capacity of falling raindrops to impart turbulence to the surface flow (this will be proportional to its capacity to hold soil materials in suspension).

If we were testing the transporting capacity of water applied as surface flow in flood irrigation work, the splashing raindrops would not be introduced but the entire amount of water used would then be applied at the top of the slope. In the case of rain irrigation, the water is applied all over the field and practically all the soil transportation outside of gullies occurs during rainfall with raindrops and drip from plants bombarding the surface of flow and producing turbulence.

In transportation experiments, the T^1_3 factor may be held constant for any one experiment or a group of experiments by regulating the release of flow at the upper end of a plot and by regulating the release of raindrops from above the path of the flow of water.

In the course of a series of experiments designed to evaluate T^1_3, each of the factors $V^2/2g$, d and D_3 must be manipulated as independent variables that are held constant for the duration of an experiment.

On soils that are of very low detachability, and very high transportability, an increase in the transporting capacity of surface flow may cause little, if any, change in soil tonnage loss. But on soils of high detachability and low transportability, an increase in the transporting capacity is almost certain to increase tonnage losses.

As a result, we may assume that erosion control measures which reduce the transporting capacity of surface flow will be most effective in reducing tonnage losses from fields having the least transportable soils and least effective on the fields having the most highly transportable soils.

OTHER FACTORS AFFECTING SOIL TRANSPORTATION.

Most of the factors that affect the transporting capacity of surface flow do so through their effects on the energy factors.

These effects on energy factors ($V^2/2g$ and D_3) are caused by such things as stems of plants that retard velocities, increases in slope or channel elements that increase velocities, contour ridges and terraces that divert, and dams that impound water and thereby reduce the flow energy.

But in addition to their indirect effects of changing the flow energy, two other factors will have a direct influence on soil movements. These are: (1) slope, and (2) surface irregularities.

Slope.—If a soil is of such low transportability that the particles are transported by dragging or rolling across the surface of a field, very much less energy may be required to move them down steeper slopes. Therefore, there will be more transportation on steeper slopes even though the transporting capacities of flow are equal on different slopes. Accordingly Equation (1) will then read:—

$$T^1_1 = \text{function of } (T^1_2\ T^1_3 \text{ slope}) \quad \ldots\ldots\ldots (3)$$

Surface Irregularities.—These may have an outstanding effect on transportation of soil particles of low transportability and less effect on soils of high transportability. Accordingly, this factor must also be considered in evaluating T^1_1 which may now read:—

$$T^1_1 = \text{function of } (T_2\ T_3 \text{ slope surface}) \quad (4)$$

It would not be a difficult matter to set up experiments where these factors are varied one at a time and the effects on transportation of soil determined.

In the first stages, the factors of slope and surface should be standardised for evaluating the factors of T^1_2 and T^1_3. When these have been evaluated, then the factors of slope and surface can be varied and the effect of these variations measured.

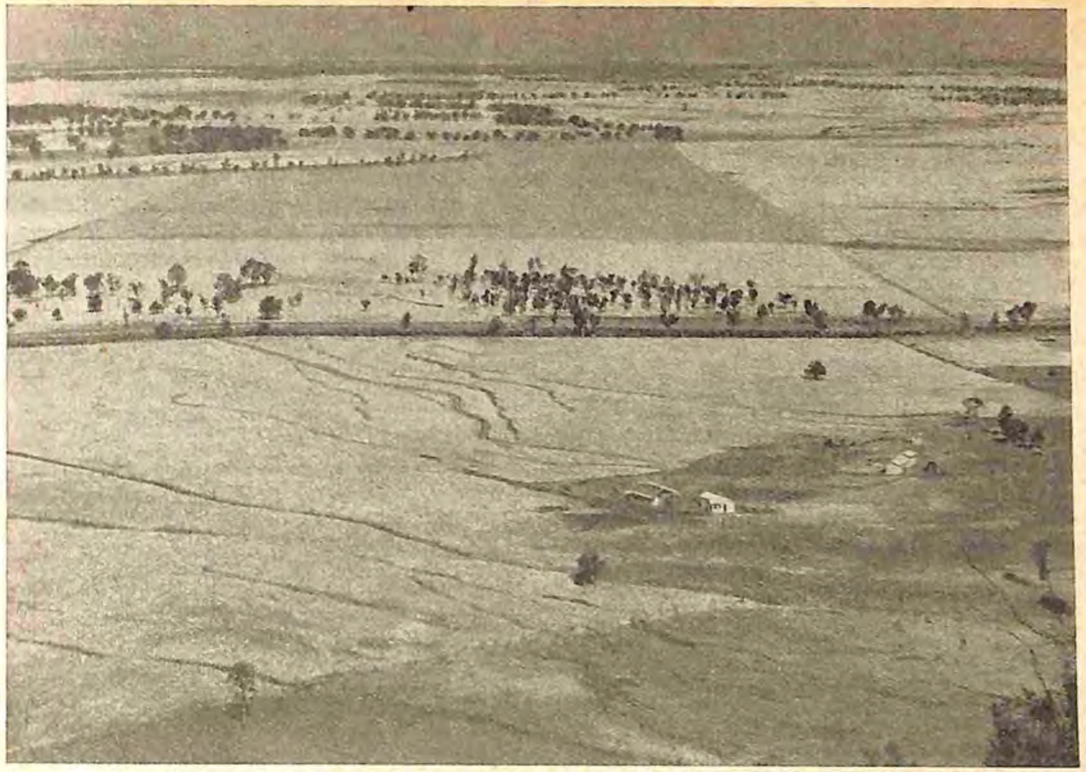

Fig. 3.—This soil is of high detachability and many gullies have developed. A characteristic of these gullies is that they tend to be of about uniform size from top to bottom of slope. This may indicate that the flow is charged to the limit of its transporting capacity all the way from the hill top to valley bottom and the transportation factor limits erosion.

In conditions where considerable depths of flow have been reached, the factor D_3 and the factors of slope and surface irregulatrities may decrease in importance, but in the opinion of the Ellisons, the depths at which these factors cease to be important are much greater than is normally found on more than 95 per cent. of sloping fields during rainstorms.

Because of this, they believe that new types of transportation experiments, on the lines of the foregoing discussion, will prove to be of great value when working with problems of soil transportation by surface flow.

CONCLUSION.

The studies conducted by the Ellisons have provided a practical means of evaluating erosion hazards and the effectiveness of control measures.

The main erosion hazards are:—

1. Detachment Hazard due to Raindrop Splash in tons per acre.

   It represents the tons of soil particles detached or separated from their original position in the soil mass by the impact force of falling raindrops. The evaluation disregards soil particles which are resplashed and is confined only to first separations. The evaluation represents the erosion taking place ON a field as distinct from soil removed FROM the field as soil loss.

2. Detachment Hazard due to Surface Flow in tons per acre.

   It represents the tons of soil particles detached or separated from their original position in the soil mass by the dragging, rolling or abrading force of owing water.

The evaluation disregards what happens to the soil particles after they have been detached.

This evaluation also represents the erosion taking place ON a field or channel as distinct from soil removed FROM the field or channel as soil loss.

3. Transportation Hazard due to Raindrop Splash in tons feet per acre.

It represents the soil loss following movement of soil particles splashed and resplashed in one direction by the impact forces of falling raindrops aided by wind and slope.

It is expressed by the product of tons moved and distance in feet of movement in a given direction.

4. Transportation Hazard due to Surface Flow in tons feet per acre.

It represents soil loss following movement of soil particles detached and transported in one direction by surface flow.

It is expressed by the product of tons moved and distance in feet moved in one given direction.

Both detachment and transportation hazards can be evaluated for circumstances where no control measures have been applied or for circumstances including the effects of control measures.

By wise application of appropriate erosion control measures, the risks of soil erosion through detachment and transportation of soil particles can be reduced to any predetermined low level.

GRASSLANDS AND CONTROL OF EROSION

BY

R. E. HERRINGTON, Dipl. Hort. (Qld.),
Soil Conservationist.

In the past the emphasis on land use in Australia, as in most pioneering countries, has been towards the more efficient, but often wanton, exploitation of the potential wealth of the soil. There has been a tendency to regard the virgin fertility, built up over the centuries, in the light of a perpetually regenerating phenomenon capable of maintaining production for ever; whilst migrant farmers, used to high rainfall efficiency and temperate climates, attempted unsuccessfully to introduce the familiar methods of their homeland, without realising that quite different principles and techniques were involved.

This pioneering phase of agriculture is gradually passing, its faults underlined by falling production and accelerated soil erosion, that unmistakable symptom of past land misuse.

The Soil Conservationist is primarily concerned with the prevention of this deterioration of the soil, and, having full regard to the economic factors involved, he develops a land use policy designed to maintain and consolidate the stability he achieves. Experience has shown the urgent need of new species for this work, and for a wider knowledge of the new concepts involved.

THE SEARCH FOR BETTER PLANTS.

Various bodies have, in the past, brought new species into Australia, among them the various State Departments of Agriculture, Acclimatisation Societies, the Universities and Agricultural Colleges and the Plant Introduction Section of the C.S.I.R.O., but these introductions have mostly been undertaken for their value as a cash crop or for grazing. The testing of promising species among these for the more specialised needs of erosion control can now be undertaken. Plants are sought for establishment on the exposed subsoil of earthworks and graded waterways and on erosion scalds, or which will build up the soil texture and fertility and reduce run-off and soil loss.

Introduction of new species from abroad tends to be restricted somewhat in scope by the limited distribution of homoclimes of our problem areas. On the other hand, however, this very difference in environment sometimes results in quite unexpected successes. The widespread use of subclover and *Phalaris tuberosa* in Australia and the comparative insignificance of these species in their native state is an outstanding example of this.

Introduction of native pasture species from other districts may not hold very much promise unless breeding or selection is undertaken. It is unlikely that a species would not have migrated to all areas suited to it, prior to white settlement, even if only as a minor component of the then existing pasture mixture. Changes in environment, brought about by the clearing of timber and a recession from the climax grassland, accelerated by overgrazing, rabbits and bushfires, do not, however, exclude such possibilities, and further study of this possibility is desirable.

On the other hand, the trial of acclimatised exotics outside their recognised limits of use may be well worthwhile, and has in fact already proved of inestimable value. Examples of this may be seen in the successful use of lucerne for dryland grazing in the low rainfall areas of the State, and in the use of kikuyu and Rhodes grass for erosion control work in areas much further west than had previously been thought possible. The use of improved strains of subclover for waterways in southern N.S.W. in areas outside the present subclover belt is also likely to prove worthy of further investigation, whilst new strains of medics and clovers may provide a better legume component for much of the western grazing lands.

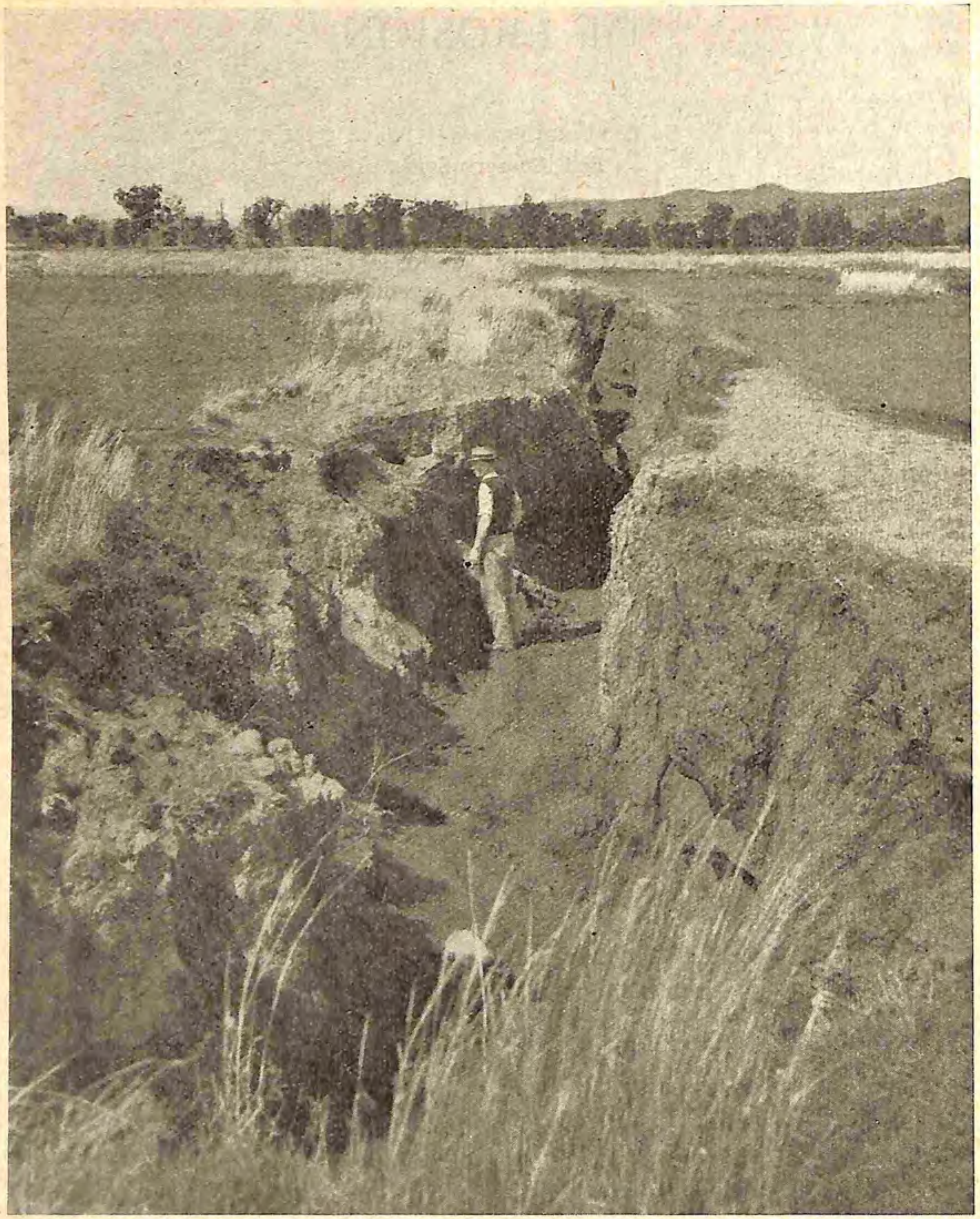

Fig. 1.—Destruction of pasture cover is often a primary cause of erosion.

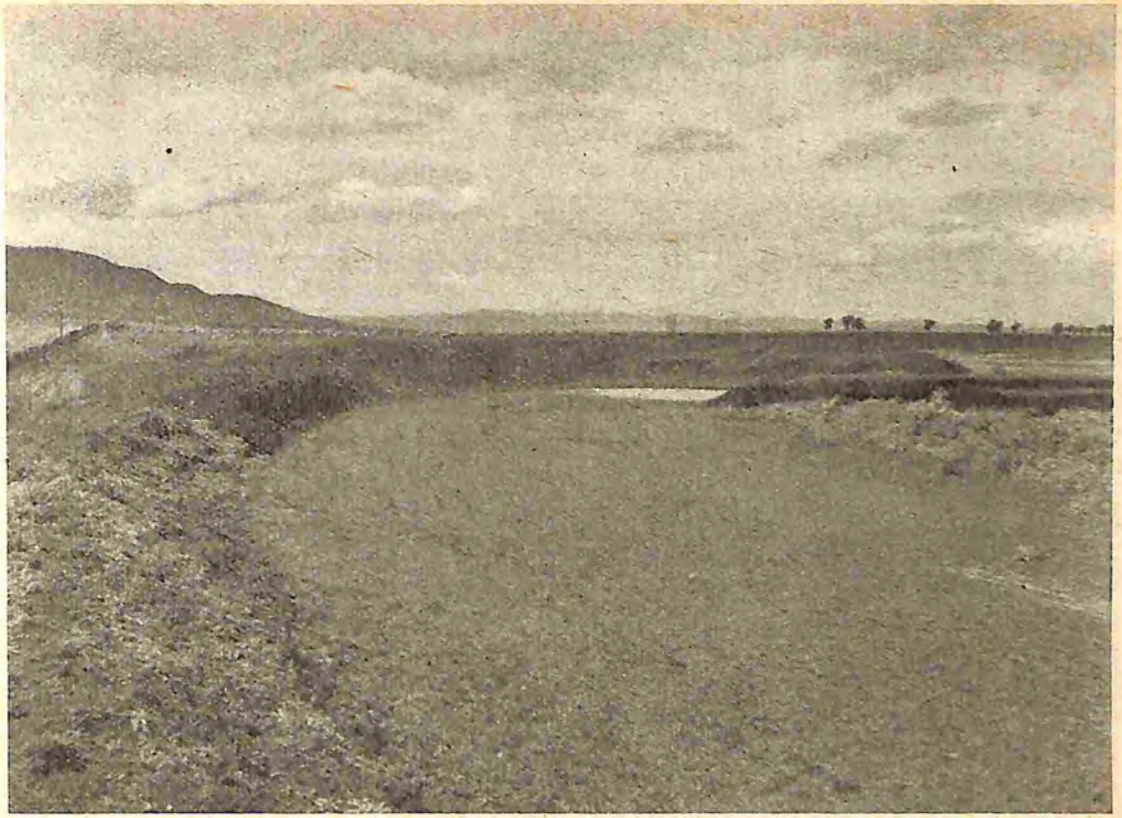

Fig. 2.—Newly established grassed waterway in the Manilla district. Additional suitable species are necessary for this type of work.

The selection and breeding of native and introduced species might also yield promising strains for erosion control work, but this programme requires the expenditure of much time and labour and remains essentially a long-term solution.

MODIFICATION OF THE ENVIRONMENT.

Much deterioration of grazing lands may be checked or lessened simply by changed management, and in the extensive grazing areas of the State this is often the most practicable method of control. Sometimes it will be necessary to reduce stocking rates, but often good results may be obtained by subdivision, provision of dispersed water supplies to allow of more equitable grazing, deferment of grazing of each paddock in rotation to encourage free seeding of palatable species, and seasonal reduction of stocking at critical periods by disposal of surplus and aged stock off shears, regardless of market conditions. All these and other similar practices will assist in re-establishing better pasture conditions irrespective of whether other remedies are also applied.

Investigations have shown that, in some parts of the State, a deficiency of one or more of the many elements required for satisfactory plant growth has been responsible for the adverse results sometimes obtained with plants which would appear, from their behaviour elsewhere under similar climatic conditions, to be quite suitable. For instance, the failure of subclover in many parts of the Southern Tablelands, even when topdressed with superphosphate, has been found to be due to the non-availability of molybdenum. The application of two ounces of sodium molybdate per acre with superphosphate has often resulted in a remarkable improvement in the clover sward.

It is also self-evident that the amount of moisture in the soil, and available to the plant, is dependent upon the percentage of

Fig. 3.—Vigorous growth of grass along a diversion bank in the Hunter Valley shows the value of preventing excessive run-off.

actual rainfall which penetrates into the soil and is not lost by run-off or surface evaporation. The retention of all rain where it falls may well be the equivalent of an increase of several inches in the annual rainfall, and plants which previously suffered from a deficiency of soil moisture might then grow with success.

Furthermore, in revegetating banks and waterways it is to be expected that these works will, in their early stages at least, be required to carry run-off water. In other words, the plants which constitute the protective cover will receive irregular irrigations to supplement the natural rainfall.

As the land returns to its former stable state these run-off irrigations will decrease in volume and frequency, but this loss of irrigation capacity should not prove as serious as it may seem at first sight. This may be explained by two complimentary tendencies. Firstly, the heaviest run-off producing storms can usually be expected during the summer months at a time when the ground cover of the pasture is at a minimum and the run-off into the waterways is greatest. Secondly, as the erosion control practices take effect and ground cover and soil stability improve a less efficient waterway sward is able to deal adequately with the smaller run-off flows.

CONCLUSIONS.

The retention of as much rainfall as possible on his property should always be both the immediate and ultimate aim of every farmer. One of the cheapest and most satisfactory ways of achieving this is by the establishment of good pasture, while a long-term land-use plan for arable paddocks should always include a ley period in the rotation. Any grazing or ley period, even a stubble ley, is a considerable improvement upon a cash crop-fallow rotation.

Improvements along these lines, and by the use of new species or different methods of agriculture to increase the efficiency of the ley, will convert more and more farmers to a system of conservation farming, but

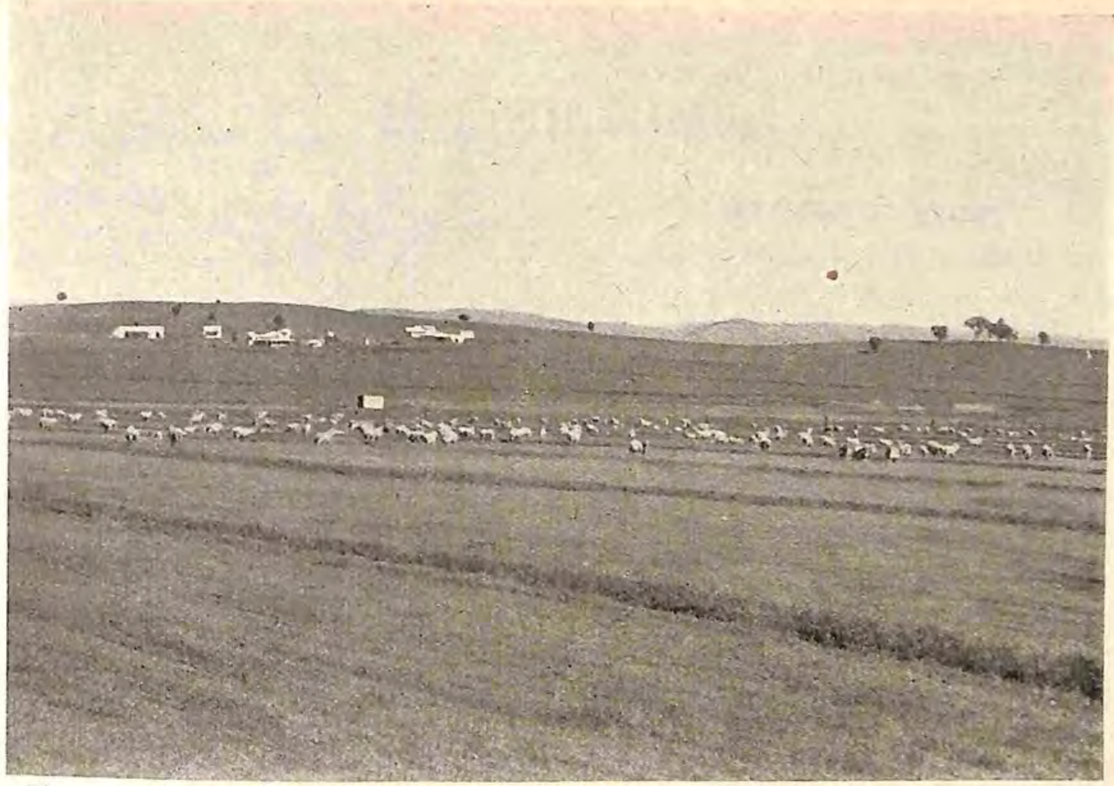

Fig. 4.—Conservation farming brings stability to agriculture. Eroded wheat land under ley pasture at Wellington.

however much emphasis is placed upon the control of erosion in being, and on the construction of major earthworks, the responsibility for conserving the soil does not begin there. Prevention is always more effective than the cure, and a Soil Conservationist is interested in the land use of farms which, while not displaying the development of deep gullies or bare areas of sheet or wind erosion, are already suffering soil loss, or are exposed to loss by injudicious farming practices. On such properties the introduction of a ley rotation in cultivation paddocks, the retirement of areas unsuited for arable farming to permanent pasture, contour ploughing, the sowing of improved pastures, top-dressing and pasture renovations, lighter stocking rates and other changes in land use may well save the farmer and the nation large sums of money in future reclamation and loss of production potential.

Conservation farming is a way of life. If the farming practices of the past are resumed on a treated property it can only be a matter of time before conditions become even worse than they were before. Mechanical control of erosion, however well designed and constructed, is never a substitute for good management. It is a means to an end, affording the farmer an opportunity to introduce a land use programme designed to restore the lost physical structure and organic fertility to his land. In this programme grass must play a major role.

BOOK REVIEW

"ROAD TO SURVIVAL."

A PROVOCATIVE book on conservation has appeared in William Vogt's "Road to Survival". This is a book which covers many aspects of the question left untreated by other authors. It steps beyond the bounds of a purely technical discussion and seeks to show man as part of his total environment, what he is doing to that environment on a world scale and what that environment is doing to him. Following upon this general diagnosis, Vogt suggests various approaches to the problem of refashioning our civilisation to conformity with the laws on which its habitat runs.

His opening chapter is stimulating in the extreme. Taking people from various walks of life and from various climes, he illustrates the stunting of life and the frustration of human needs that is caused by the failure of man to understand the simple facts of his relation to the natural world. He further demonstrates the global interdependence of men, and shows that the loss of natural resources is not merely damaging to the local landholder, but vitally affects the lives and living standards of all men everywhere. Thus he deplores the disproportionate influence of "the urban mind" in the affairs of government and of nations, and states that the assumption that man lives in a vacuum, independent of his physical environment, will always be leading us to false and unrealistic economic and political solutions.

He suggests that the acceptance of a bio-equation would help us to clear our thinking and may help to regulate the forces which bemuse leaders. His simple generalisation is that—

> C = B:E. C stands for the carrying capacity of any area of land. In its simplest form this represents its ability to provide food, drink and shelter; in the case of human beings it finds complicated expression in civilised existence. This carrying capacity is the resultant of the ratio between the other two factors; B, the biotic potential or the ability of the land to produce plants for shelter, food and clothing; and E, the environmental resistance or the limitation that any environment, including the part of it contrived and complicated by man, places on its productive ability.

This appears at first sight to be platitudinous, but when one examines the current conceptions of what constitutes the ruling forces in the world, one recognises that the veneer of civilised, industrial man has overlain this basic fact and obscured it. How many historians have interpreted the rise and fall of nations, the causes of wars and depressions in terms of the way plants and their habitats have been treated?

Vogt then proceeds to describe the cycle whereby man derives his energy from the earth. He explains in simple terms the photosynthetic process in which our existence rests, and how its operation may be modified by differing "environmental resistances". He speaks of the physical bounds imposed by climate, relief and soil type, and shows their interrelation with biotic factors such as insects and man. He develops the theme of man raising the environmental resistance by various abuses of natural law —*e.g.*, by over-grazing thereby lowering "carrying capacities," exhausting resource capital and bringing about degradation and misery. He also uses statistical examples to show the mounting population pressure on the land, and quotes the old Chinese proverb, "one hill cannot shelter two tigers".

Our era is the age of discovery. We have set ourselves at the centre of the universe and have reached out to explore and to subdue. Now, the recognition must come that man, too, is living within ecology and must comply with its laws by managing his resources on a sustained yield rather than an extractive basis, and by controlling the population pressure which may otherwise force him over a precipice.

Vogt attempts an analysis of the culture patterns which have inspired our land use. He speaks of the dominance of the idea over the activity, and the necessity of bringing our ideas into touch with the laws of nature. One of the strangest lacunae in human cultural development is the absence of understanding of man's relationship with his physical environment. The task of bringing about this understanding is the foremost one. Most conservationists would probably agree that while the unsolved technical problems of erosion control are important, the greatest problems arise from the operation of human wills and traditions —from conservatism and prejudice, from selfishness and ignorance, from inherited attitudes towards the land, and from economic systems which may force men to adopt certain practices.

The author regards "industrial man" as "the great illusion." He asserts that the industrialisation of the New World has only been purchased by the export of much irreplaceable resource capital; that the development of secondary industry has exerted greater pressure on the land by the creation of artificially high living standards which bear little relation to the ratio of population numbers to replaceable national resources; that industry has brought about declining productivity per acre. It is difficult to accept Vogt's remarks *in toto* and apply them directly to our economy, except insofar as one recognises that the source of real wealth lies primarily in the land, and that industrialisation cannot indefinitely postpone an ecological Judgment Day.

The preliminary analysis is concluded with an enunciation of the principles of land use. He writes in simple terms which should have appeal for the layman. The limitations of patterns of rainfall and the development of soils and of plant communities are described, and an introduction to the complex system of checks and balances which hold these factors in a dynamic tension is given. It is shown how readily this system may be thrown out of gear, its resultant being displayed in declining crop yields, the invasion of inferior species into a pasture, the deterioration of soil structure, in increased flood peaks, and finally in the displacement and loss of the soil. This is the path to destruction; the road to survival lies in the understanding of the delicate mechanism surrounding this tension, and the adjusting of the land utilisation pattern to its requirements for each catchment area.

Vogt then proceeds with a conservation survey of the five continents. As can only be expected, a task of this nature leads to much oversimplification and generalisation when confined to the space of a popular volume. However, it is more recent than other surveys, and the writer appears to have travelled widely and had access to valuable data. His method is to look for information regarding a country's original resources, and to measure these against the present situation in terms of water table heights, flood levels, soil fertility, stock carrying capacities and crop yields, timber and wild life resources, and, of course, the extent of soil erosion. Living standards and population numbers are further related, and the whole integrated by reference to the cultural and political environment.

His conclusions are not heartening. Apart from isolated cases, the whole of the New World and part of the Old are shown to have drunk deeply of their most precious assets. One is lead to the simple conclusion that man has moved into a quite untenable position by protracted and wholesale violation of certain natural laws, and that in consequence his very survival is threatened. The path to reconstruction lies in looking for the order, the principles within the seeming chaos, and adjusting our lives to it.

It is from this point forward that Vogt's book is disappointing. He has laid an excellent foundation in revealing the situation and by developing the "idea" which must find a central place in our culture. The difficult task of working out the implications of the idea in concrete situations, and the implementation of such revolutionary proposals in our society remains. He suggests that the first step is of diagnosis; the collection of detailed information covering the many aspects of the relationship of human beings to their various environments. Having defined the problem the solution then rests on three things: research, education and action on the land.

What this volume lacks in logical development is compensated for by the pungency of its expression and the appeal of its vivid word pictures. While one may question some of Vogt's conclusions, the book is a thought stimulating work which should be read by all who are concerned by the growing severance of man from the earth and the disastrous consequences which ensue. (*Road to Survival,* by William Vogt. Victor Gollancz Ltd., London, 1949.)

L. R. HUMPHREYS, B.Sc.,Agr.,
Soil Conservationist.

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FOREWORD

BY

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

THE interest of the New South Wales farmer and grazier in soil conservation is growing very rapidly. A remarkable degree of voluntary co-operation has been extended by land-owners to the Soil Conservation Service.

Since our work has been extended from the Soil Conservation Stations on to the privately owned lands during the last few years, we have never lacked for willing farmer co-operators. Demonstrations were established in many districts, and the coverage is being gradually extended to cater for most of the eroding portions of the State. In almost every case the land-owner voluntarily extends conservation methods to the remainder of his property at his own expense. To inspire this confidence, the methods demonstrated necessarily have to be sound and especially applicable to the local conditions.

Although soil-saving structures are largely used by the Service, the foundations of our work, as I have stressed from the inception, are based on conceptions of correct land use and the utilisation of vegetative cover. The grazing, rotational and cultural practices we advocate cater for the restoration and maintenance of the soil itself, and farmers working with the Service are taught conservation farming with a view to their lands being used in such a way that they are protected and their productivity maintained.

To this end the farm planning and survey for design of water disposal, storage, banking or pasture furrowing is provided free of charge. For the major earth-moving works the large plant of the Service can be hired by farmers, when available, at reasonable charges, the work being done by the Service operators and plant and the cost being borne by the farmer. Farmers are rapidly taking advantage of this facility to a remarkable extent in the districts where work has been demonstrated.

Financial assistance is also available under the Advances Scheme. Advances can be arranged at a low rate of interest to cover the cost of essential soil conservation work, whether such work is done by the farmer himself, by private contractor or by the Soil Conservation Service.

Other farmers in the district see the work done on private farms under our "Plant Hire" or "Advances" Scheme and on our Research Stations. They observe and discuss the planned land use and the application of conservation farming practices to pasture and crop lands as well as to hilly lands. Our experience is that the majority of these men then wish to co-operate with the Service. The response is so great that in those mixed farming districts where the Soil Conservation Service work has been developed the man who is not yet prepared to join in is the exception. Under any of these schemes the land use and the cropping or grazing practices are discussed between the land-owner concerned and the Soil Conservationist and the details are mutually agreed upon to meet the needs of both farm and farmer. The object of conservation farming is to achieve safe and stable lands with profitable and permanent production.