# SOIL EROSION IN RAIN SHADOW AREAS OF THE UPPER BURRINJUCK CATCHMENT

BY

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THE treeless downs of the Monaro on the southern highlands of New South Wales are of average elevation of nearly 3,000 feet. Soon after discovery by Captain Currie in 1824 a rapid introduction of sheep and cattle took place and pastoral pursuits still remain the most important industry of the district. The fact that abundant feed was available without the necessity for clearing influenced this early stock movement.

As early as 1885 the Cooma Pastures Protection District supported 31,000 cattle and 830,000 sheep. In 1947 there were 36,000 cattle and 1,050,000 sheep on the same area.

### TOPOGRAPHY.

That portion of the Monaro which forms the upper Burrinjuck catchment is bounded on the east, south and west by the Great Dividing Range which rises to heights in excess of 5,000 ft. Within this boundary are the undulating, hilly and steep treeless downs. These downs take the form of a basin with the mountains forming the lip (Fig. 1).

### RAINFALL.

Rainfall on the Monaro can be divided into three classes:—

(a) western influences causing winter falls in the form of snow as well as rain on the highlands to the west;

(b) local influences in the "rain shadows", *i.e.*, the lower areas between the mountain ranges, causing summer storms of high intensity and short duration and

(c) eastern influences on the coastal divide resulting in higher summer precipitation.

Owing to the barriers formed by the surrounding mountains, the main precipitation occurs before reaching the Downs resulting in a regular decrease in annual averages as we progress to the centre (Figs. 2 and 3). Thus the western and eastern influences have only a limited effect on the annual rainfall of the rain shadow areas, the main precipitation being in the form of high intensity summer storms. The average annual rainfall of the Downs varies from twenty-four inches at Rhine Falls and Countegany to as low as seventeen inches at Chakola in the centre of the rain shadow.

### VEGETATION.

The distribution of vegetation through the region is complex owing to the variation in rainfall, temperature and soil type. From the mountainous sub-alpine tracts covered in snow gum (*Eucalyptus niphophila*), the associations descend through the wet and dry sclerophyll forests, tall woodland and savannah woodland to the dry grasslands of the Downs.

It can be assumed that the original association on this latter area consisted of an even distribution of wallaby grass (*Danthonia spp.*) and spear grass (*Stipa spp.*), but owing to the stock factor the *Danthonia spp.* have gradually disappeared leaving corkscrew grass (*Stipa scabra*) and tall spear grass (*Stopa bigeniculata*) dominant with the wallaby grasses and kangaroo grass (*Themeda australis*) as subordinate species. Tussocky poa (*Poa caespitosa*) also occurs but is confined mainly to flood plains and moist flats in the comparatively dry regions.



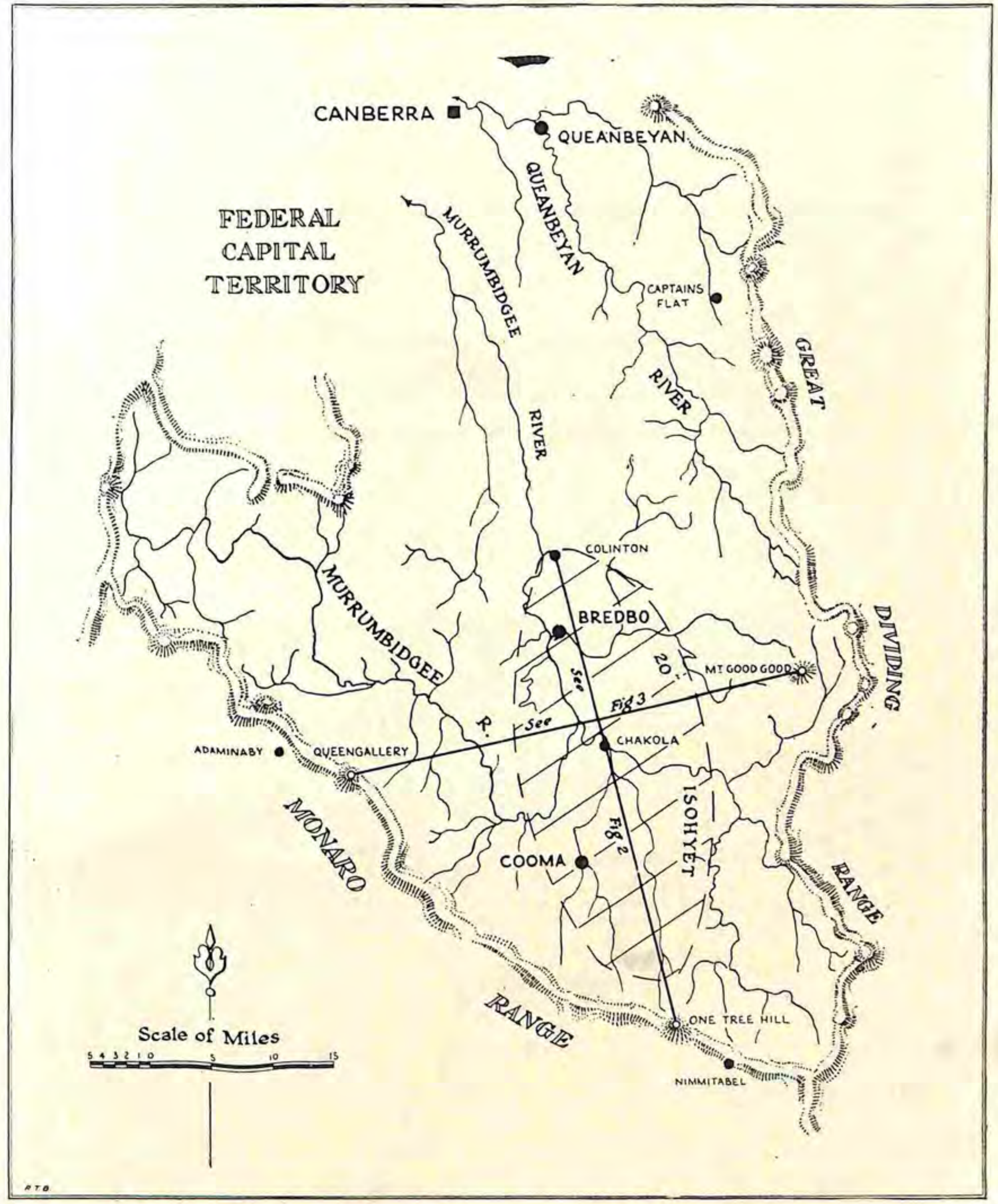


*Fig. 1.*—Upper Burrinjuck Catchment Area.

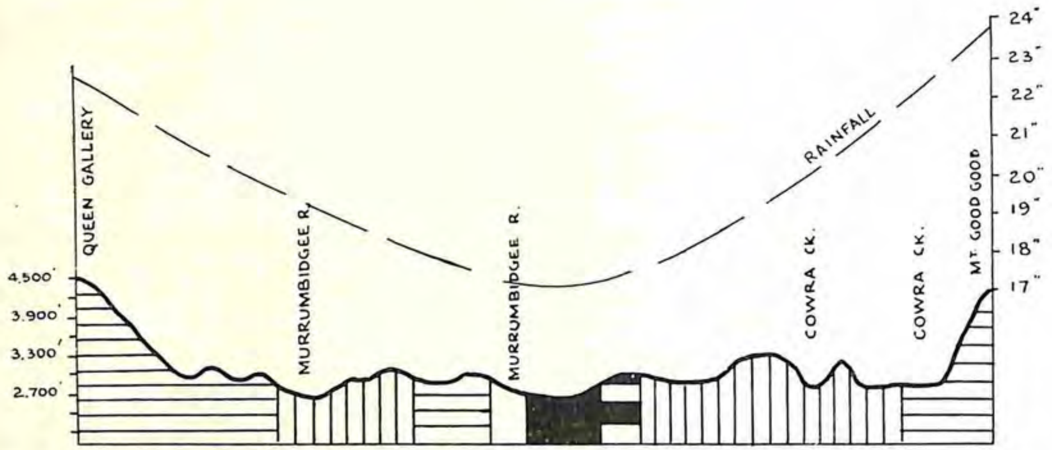


*Fig.* 2.—Showing the effect of topography on rainfall and the effect of both on erosion pattern.

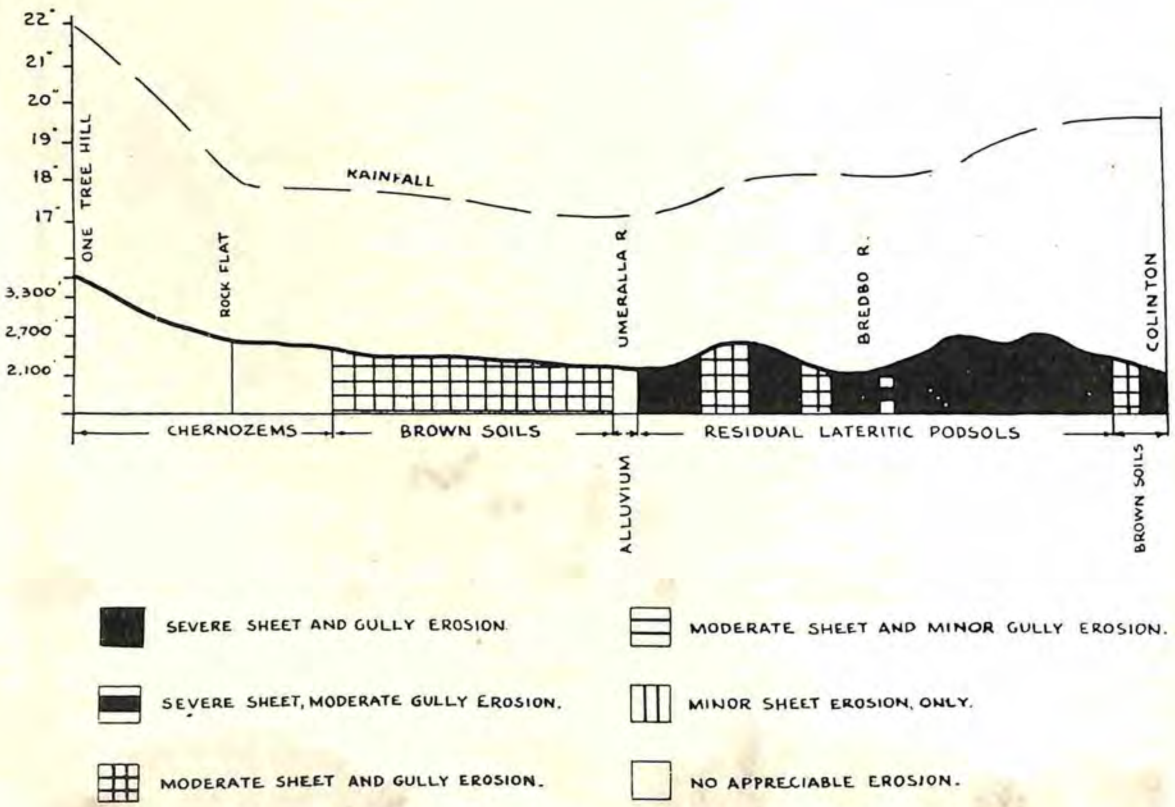


*Fig.* 3.—Showing the effect of soil types on erosion pattern.



## SOILS.

The soils within the catchment can be divided into four main classes with other types protruding in small deposits. Basaltic chernozems are present in the low rainfall areas south of Cooma, while brown soils of light texture form the main soil type over the rest of the district. Present within this type, however, are residual lateritic podsols in the centre of the rain shadow belt and alluvium along the flood plains of the main streams. (Fig. 3).

## PAST LAND USE.

Figures quoted above indicate that a relatively high stocking rate has been maintained through the region for at least seventy years. The sudden drop in stock numbers during all drought years is evidence that overstocking and little fodder conservation has been practised from the time of first settlement (Table 1). Space does not permit full stocking rates to be shown but those used are indicative of the effect of drought on stock numbers. No doubt other factors, such as disease, have had an effect on stock population but a correlation of annual stocking rates and climatic conditions shows that drought is the most important influence.

TABLE I.

*(Showing Section of Statistics of Livestock Numbers on the Monaro, indicating Effects of Droughts on Sheep Population.)*

| Year. | Nos. of Sheep. | Rainfall. |
|---|---|---|
| | | inches. |
| 1885 | 835,587 | 17.01 |
| 1894 | 874,215 | 22.21 |
| 1895 | 724,341 | 11.19 |
| 1900 | 802,971 | 26.26 |
| 1902 | 616,693 | 15.75 |
| 1914 | 1,086,864 | 19.80 |
| 1915 | 585,308 | 12.40 |

One factor leading to overstocking is the practice of holding large numbers of stock on freehold land in the lower country in

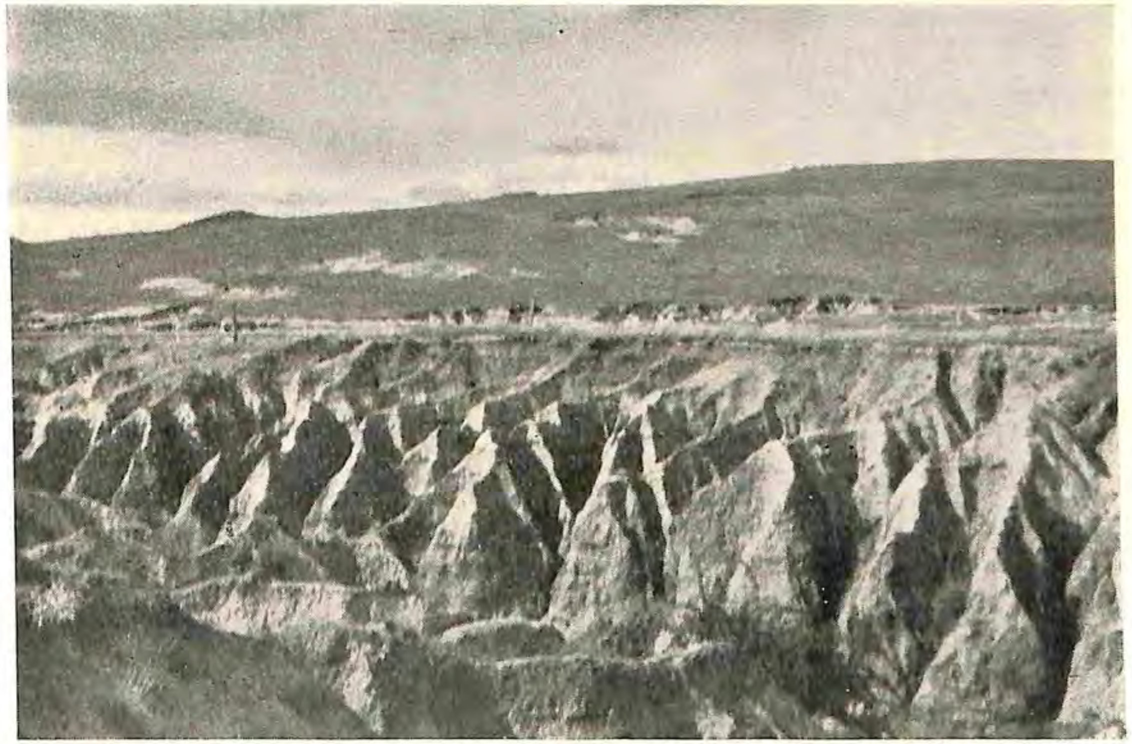

*Fig.* 4.— Gullies such as this discharge tons of silt into the Murrumbidgee River after each rain.

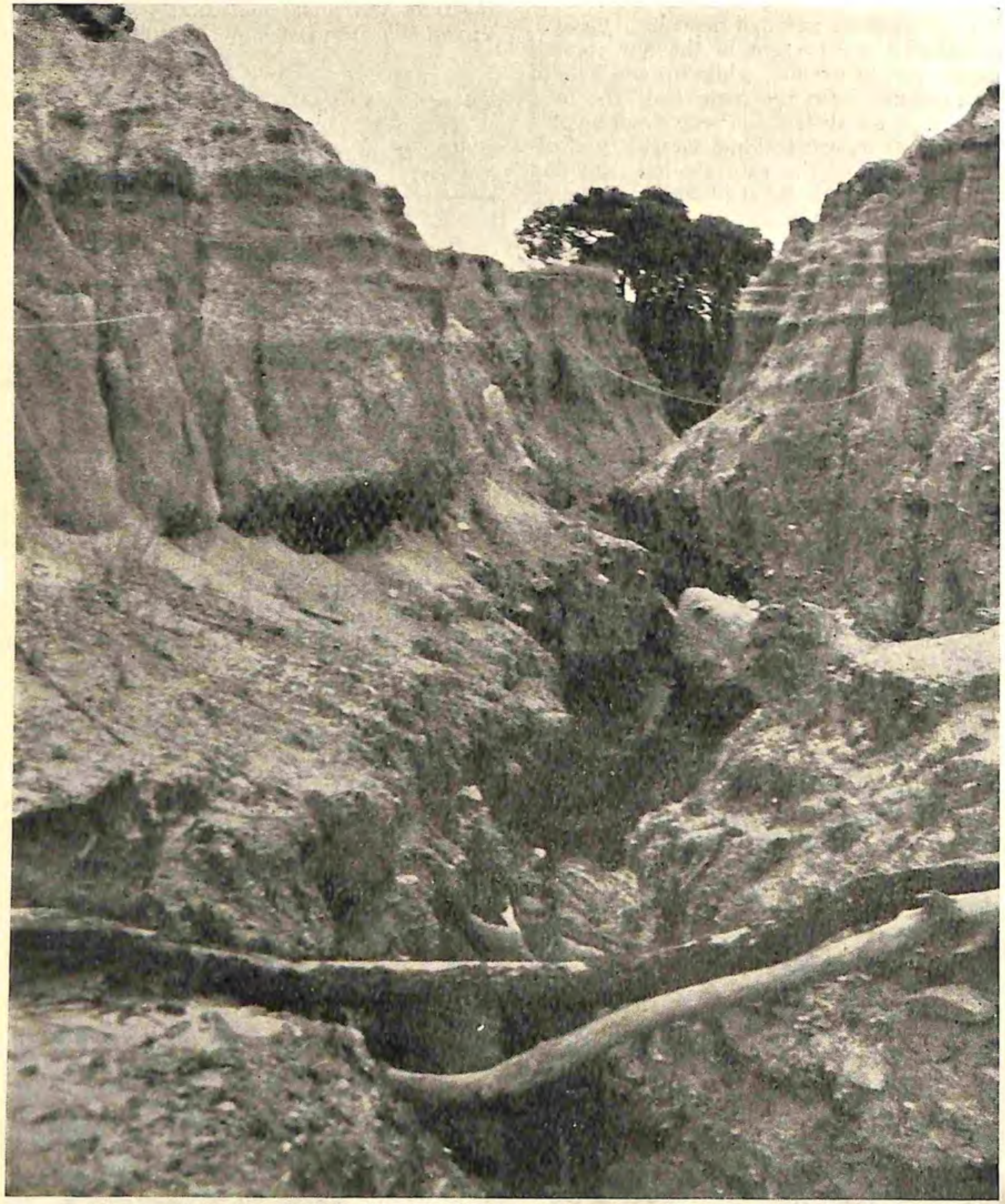

*Fig.* 5.—A typical scour in the rain shadow areas on lateritic soils of the Monaro.



conjunction with summer grazing in the alpine and sub-alpine tracts. Grazing in the mountains is available during the summer months only and the period of overstocking of the lower lands of the Monaro occurs during the cold, winter months when little or no growth takes place.

Most river flats have, at some stage, been utilised for the growing of lucerne for fodder. Owing to recent economic developments, many lucerne flats have been allowed to deteriorate until only short-lived annuals, such as barley grass (*Hordeum leporinum*) survive. The resultant shortage of conserved fodder has had severe repercussions, causing heavy stock losses during late snow falls, or under dry conditions such as in the spring of 1951.

## EROSION DAMAGE.

Accelerated erosion in the rain shadow areas has been initiated by man's disregard of the natural ecological balance. The degree of erosion that does occur, however, is influenced considerably by the other factors discussed earlier, namely, topography, rainfall, vegetation and soil type. Of these factors the first three are closely related and, although erosion patterns do vary with these influences, the greatest variation occurs with changes in soil type. For this reason erosion classification, for purposes of this article, will be correlated with soil types and the other variables will be discussed as secondary influences. (Fig. 3).

(a) On the basaltic chernozems of the Monaro grasslands little erosion is evident. Apart from isolated areas where rabbit infestation is high and overstocking has been practised erosion is confined mainly to gullying of the main watercourses. The self-mulching qualities of the soil allow early sloughing of the gully walls, resulting in a U-shaped channel and quick regeneration.

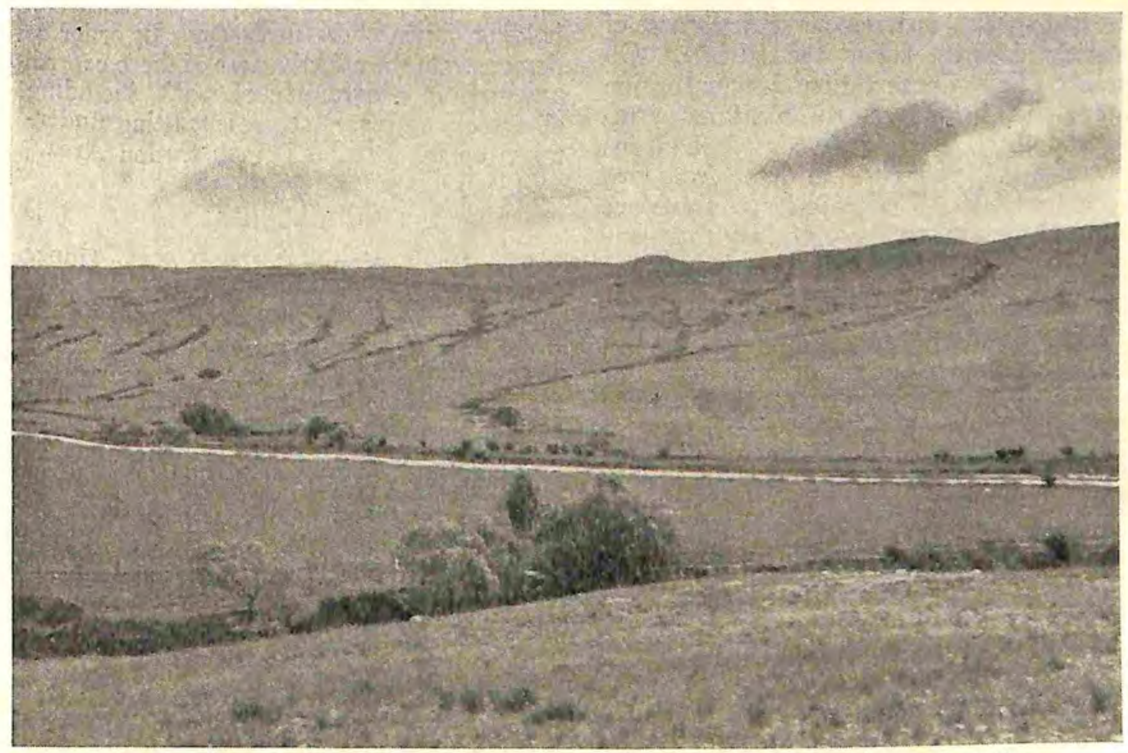

*Fig.* 6.—View of Bredbo Demonstration site before commencement of control works.

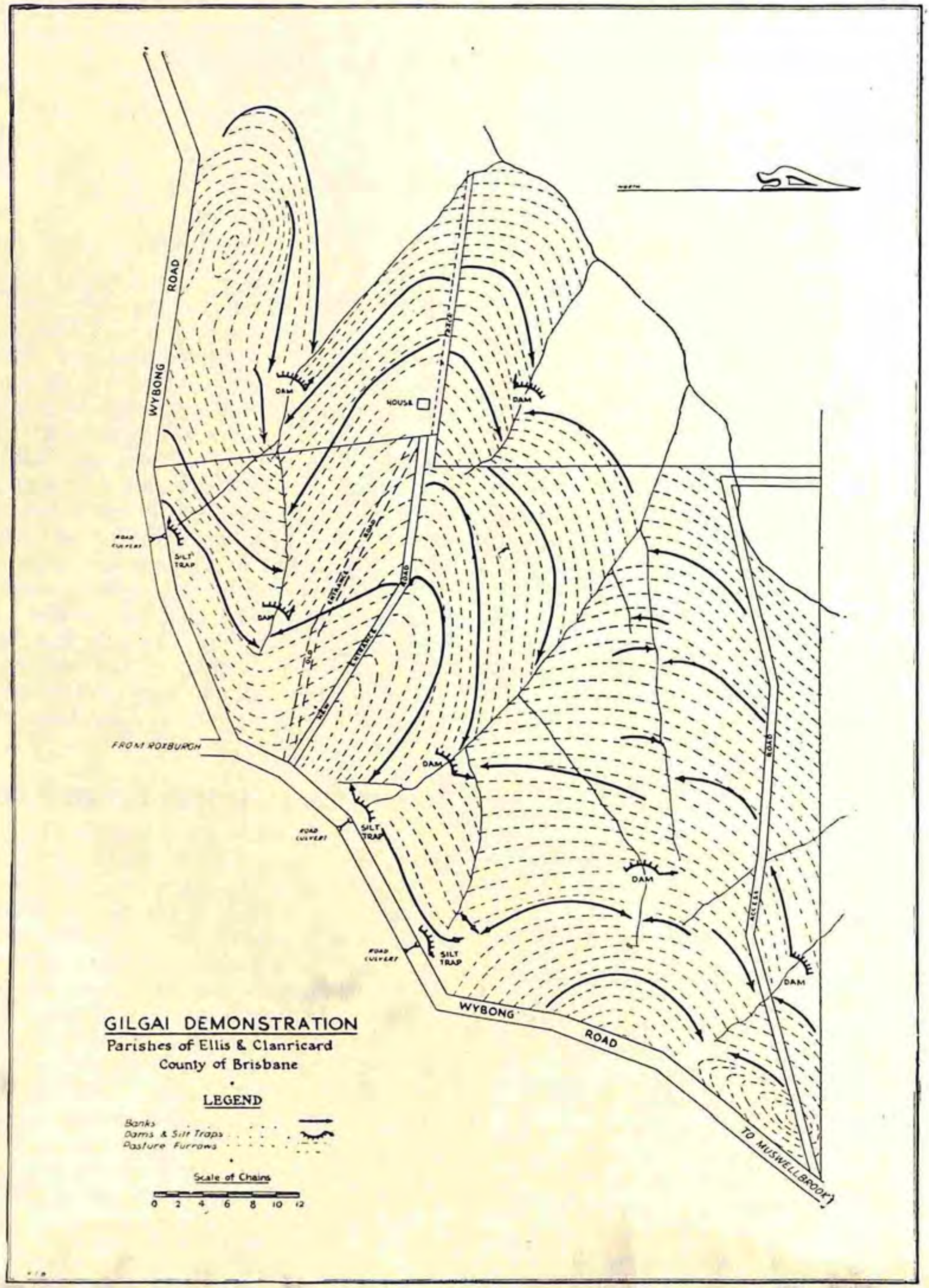


*Fig.* 1.



*Fig.* 2.—A dense growth of Rhodes grasses following ripping, furrowing and sowing formerly " scalded " areas.

*Fig.* 3.—A gully on " Gilgai " prior to treatment. Discharge from the roadside was the cause.

*Fig.* 4.—The gullied area shown in Fig. 3 after stabilisation by silt dam construction and outlet via a vegetated waterway.

The water was taken into the property from the road at three points. This inflow was steadied by the use of silt traps at each point, just inside the property. The water was run from the silt traps to the graded banks by means of short waterways, strip sodded with kikuyu sod.

Six dams of varying capacities were constructed to dispose of excess water and also act as controls for active gully heads. All outlets of banks and dams were sodded with kikuyu, also small amounts of sodding were placed in gullies used in the water disposal system. All the scalded areas were ripped on the contour and seeded with Rhodes grass and liverseed grass or Wimmera rye grass and subterranean clover as appropriate to the area and the spring and autumn sowings respectively. The whole sown area was topdressed with superphosphate.

## CONCLUSION.

This very seriously eroded area was quickly stabilised by the mechanical and vegetational measures employed, demonstrating very clearly that the serious erosion problems in this area can be controlled by appropriate soil conservation measures which can be adopted practically and economically by all landholders. Much of the mechanical work necessary in this district can be carried out with the heavier type of farm equipment, where available, and special earthmoving equipment may be hired for the major mechanical work which is necessary to support the vegetative regeneration. Wise land usage by conservative stocking rates and elimination of rabbits is an essential also in this type of work. The facilities of the Soil Conservation Service are available to assist landholders throughout this district.

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# SOME FACTORS INFLUENCING INFILTRATION INTO SOILS UNDER NATURAL AND ARTIFICIAL RAINFALL

BY

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PERHAPS the most fundamental problem in agriculture is the question of conserving water, not only to lessen erosion and to mitigate flooding but also to maintain sufficient moisture in the soil for the best crop growth. It is necessary to recognise the factors affecting infiltration, to know which may be altered and how it may be done to produce greater intake of water. The discussion of the variables pertinent to infiltration is set out under the following headings:—

1. Rainfall characteristics.
2. Soil surface covering.
3. Soil characteristics.

## RAINFALL CHARACTERISTICS.

These characteristics are intensity, drop size and velocity. There are very few figures on infiltration under natural rainfall, nearly all the work being carried out with artificial rainfall simulators. Results obtained with these simulators may be criticised on the grounds that the artificial rain is similar to natural rain neither in intensity nor drop size nor in the variability of these two factors. This criticism may not be so very important as the "rainfall" usually used is of high intensity and of large drop size which compares with the high intensity-large drop size rains which produce high run-off. Also the surface seal formed by the beating raindrops is formed in the first few minutes of the rain and any lessening in intensity afterwards is not going to affect greatly the infiltration rate.

A number of attempts have been made to determine drop size and velocity of waterdrops and raindrops. Lenard measured the velocity of drops of diameters 1.28-6.36 mm. by catching them in a fan blast. He measured drop sizes by catching the drops on absorbent paper. Schmidt measured the velocity of drops of diameters 0.4-3.5 mm. with two discs mounted one above the other. The upper disc had a small sector cut in it through which the drops passed to be caught on absorbent paper on the rotating lower disc. Mache studied drops photographically as did Laws([a]) in 1941. A resumé of Laws' method and results is given below.

He presents measurements of the velocity of fall of waterdrops of sizes ranging from 1.25-6.00 mm. diameter falling in still air from heights of 0.5 metre to 20.0 metres. A few measurements of raindrop velocity are also reported. His method of measurement is shown in Figure 1.

A collimating lens was placed at its focal length from the centre of the camera lens. There was a conical casing on the camera side of the lens to shield against the light. The shutter timing device was a single phase 1/150 h.p. synchronous motor turned at 30 r.p.sec. on a 60-cycle alternating current. The chopper disc was made from a water stage recorder chart, $11\frac{1}{8}$ inches diameter, 16 sectors cut $\frac{1}{4}$inch from the rim, each sector measuring 1 inch x $\frac{7}{8}$ inch. The disc was painted black. Exposure was 2 secs., f.8, Afga Super Pan Press developed for maximum contrast.

The image of each drop appeared as a pair of broken lines due to highlights on either side of the drop. Velocity was determined by measuring the distance between drop images and by knowledge of the timing. The diameter could not be determined by this method due to the highlights, but was

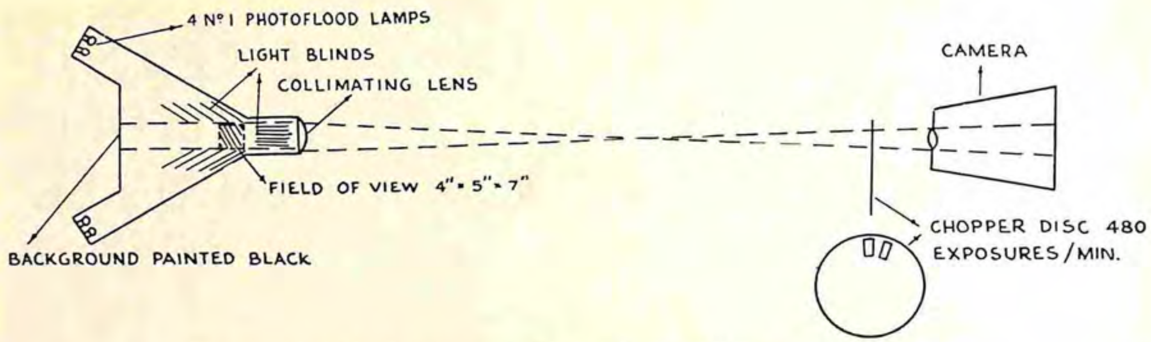


*Fig.* 1.—Method of measurement of velocity of falling water-drops.

determined by either weighing a counted number of drops or by weighing and drying drops into flour (Bentley [1]). Table I below shows the results obtained from falling drops. He has obtained a good fit between drops falling 20 metres indoors and raindrops when diameter x velocity is plotted. He has obtained velocities fully 15 per cent. greater than those obtained by Lenard and Schmidt.

TABLE I.

*Velocity after a Given Height of Fall for Drops of Various Diameters.*

H = Height.

| Dia. | 0.5 | 0.75 | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 | 4.0 | 5.0 | 6.0 | 8.0 | 20.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.25 | 2.65 | 3.15 | 3.52 | 3.97 | 4.21 | 4.43 | 4.56 | 4.80 | 4.85 | 4.85 | 4.85 | 4.85 |
| 1.50 | 2.76 | 3.26 | 3.64 | 4.18 | 4.50 | 4.82 | 4.99 | 5.25 | 5.39 | 5.47 | 5.51 | 5.51 |
| 1.75 | 2.84 | 3.34 | 3.74 | 4.34 | 4.73 | 5.10 | 5.31 | 5.64 | 5.80 | 5.92 | 6.08 | 6.08 |
| 2.00 | 2.89 | 3.40 | 3.83 | 4.47 | 4.92 | 5.29. | 5.55 | 6.91 | 6.15 | 6.30 | 6.53 | 6.58 |
| 2.25 | 2.93 | 3.45 | 3.91 | 4.57 | 5.07 | 5.44 | 5.74 | 6.14 | 6.42 | 6.63 | 6.90 | 7.02 |
| 2.50 | 2.96 | 3.50 | 3.98 | 4.65 | 5.19 | 5.57 | 5.89 | 6.34 | 6.67 | 6.92 | 7.22 | 7.41 |
| 2.75 | 2.98 | 3.54 | 4.04 | 4.72 | 5.28 | 5.69 | 6.02 | 6.52 | 6.89 | 7.16 | 7.50 | 7.76 |
| 3.00 | 3.00 | 3.58 | 4.09 | 4.79 | 5.37 | 5.80 | 6.14 | 6.68 | 7.08 | 7.37 | 7.75 | 8.06 |
| 3.25 | 3.02 | 3.61 | 4.12 | 4.85 | 5.45 | 5.89 | 6.25 | 6.82 | 7.35 | 7.56 | 7.96 | 8.31 |
| 3.50 | 3.03 | 3.64 | 4.15 | 4.90 | 5.52 | 5.98 | 6.35 | 6.95 | 7.40 | 7.73 | 8.15 | 8.52 |
| 3.75 | 3.04 | 3.66 | 4.18 | 4.95 | 5.58 | 6.06 | 6.44 | 7.07 | 7.53 | 7.88 | 8.31 | 8.71 |
| 4.00 | 3.05 | 3.67 | 4.21 | 4.98 | 5.63 | 6.12 | 6.52 | 7.17 | 7.65 | 8.00 | 8.46 | 8.86 |
| 4.50 | 3.07 | 3.70 | 4.24 | 5.05 | 5.72 | 6.24 | 6.66 | 7.36 | 7.85 | 8.21 | 8.70 | 9.10 |
| 5.00 | 3.09 | 3.72 | 4.27 | 5.11 | 5.79 | 6.33 | 6.77 | 7.50 | 8.00 | 8.36 | 8.86 | 9.25 |
| 5.50 | 3.10 | 3.74 | 4.29 | 5.16 | 5.85 | 6.40 | 6.86 | 7.61 | 8.11 | 8.47 | 8.97 | 9.30 |
| 6.00 | 3.10 | 3.75 | 4.31 | 5.20 | 5.90 | 6.46 | 6.94 | 7.69 | 8.20 | 8.55 | 9.01 | 9.30 |

D = Diameter in mm.; H = Height of fall in metres; V = Velocity in metres/second.

Actual photographs have been made of drops by Edgerton and Killen [2]. These are very good photographs and show that drops are not tear-shaped but oblate at their terminal velocity of fall. From Laws' results the height required by a drop to reach 95 per cent. of the terminal velocity of fall may be determined. (Table II).

TABLE II.

*Height to reach 95 per cent. of T.V.F.*

| Drop Size. | Height. |
|---|---|
| 1mm. | 2.2 metres. |
| 2mm. | 5.0 ,, |
| 3mm. | 7.2 ,, |
| 4mm. | 7.8 ,, |
| 5mm. | 7.6 ,, |
| 6mm. | 7.2 ,, |



*Fig.* 2.—A dense cover of native grasses on 25% slopes on the hill lands of the Station.

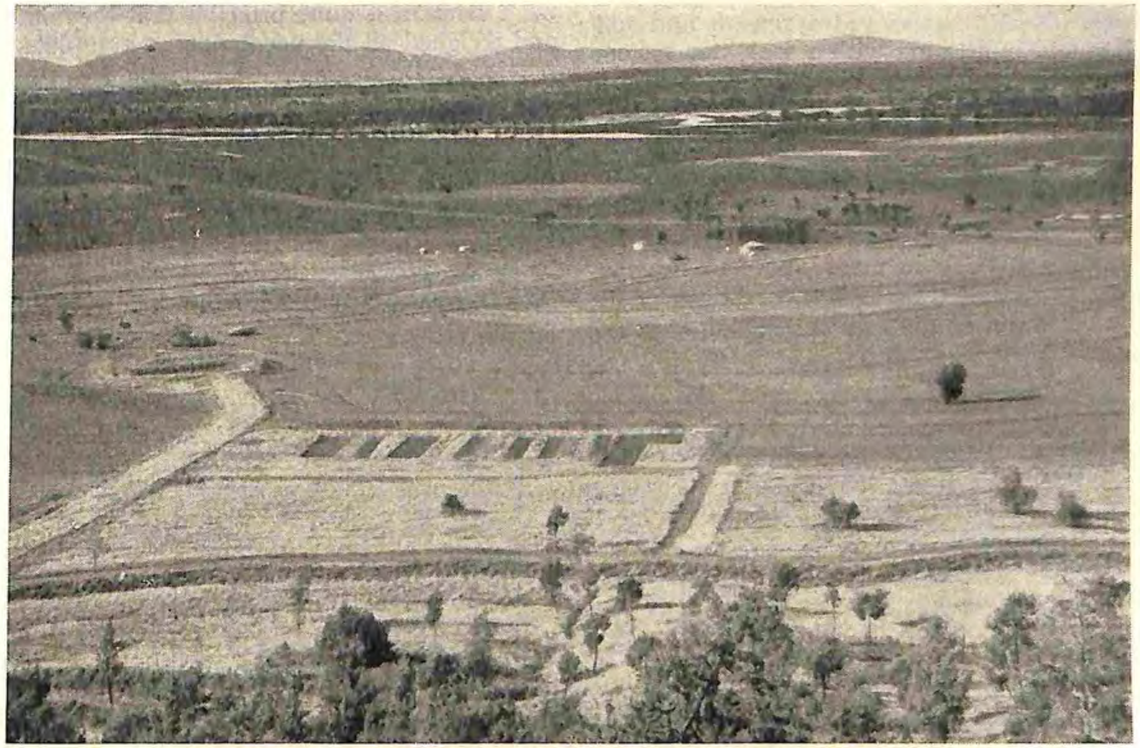

*Fig.* 3.—A heavy cover of Rhodes grass on steep land with lucerne and wheat paddocks below. Gunnedah Research Station.

Drops of 5 and 6 mm. size take less height than 4mm. drops, 3 and 6mm. drops are equal. This also holds for 98 per cent. of the terminal velocity of fall. This fact is related to overshooting of the terminal velocity of fall, due to changes in shape not occurring concurrently with changes in velocity, the time being required for a given relative air velocity to produce the final drop shape corresponding to that velocity.

From Laws' results the velocity of a drop falling from a given height can be determined. Also they show that there is good agreement between velocities and drop sizes of artificial and natural rain after falling 20 metres.

However, rainfall is a factor that cannot be controlled directly; in any case it seems that intensity of rain or drop size may be one of the lesser factors influencing infiltration. A surface seal on the soil surface is formed rapidly under the impact of raindrops and causes the infiltration rate to drop. Higher intensity storms cause this seal to be formed more rapidly, but the time required to produce the seal would very likely decrease at a decreasing rate with increased rainfall intensity. Neal([5]) measured a run-off and soil loss and infiltration with a sprinkler system on a 2-inch depth of Putnam silt loam in a soil tank 12 feet by 3.63 feet (1/1000 acre). He found that infiltration was not affected by rainfall intensity. He means apparently the final infiltration rate, for he states that the percentage of run-off increased as the rainfall intensity increased, but at a decreasing rate, which, under the conditions of his experiment, is the same as saying that the percentage of infiltration decreased as the rainfall intensity increased, but at a decreasing rate.

Although the rainfall or its characteristics cannot be predicted or altered, its effects can be modified by attention to the two other factors influencing infiltration; namely, the soil itself and its covering. The manipulation of these two variables is discussed in a general manner under their respective headings later in this article.

## SOIL SURFACE COVERING.

A covering of living and dead vegetative material increases infiltration by preventing the pounding action of raindrops, by increasing the time in which the raindrops reach the ground, and thus spreading the time in which infiltration can occur, and by improving the surface condition of the soil.

Smith and Leopold([7]) used a 12-inch by 30-inch rain simulator in 1942 on the Pecos River watershed and showed a highly significant positive linear correlation between final infiltration rate and vegetal density. They do not state how the density was measured, but, on the small plot sizes they were using, it is quite probable that they cut and weighed all the vegetation on the plots.

Osborn([6]), using a rainfall simulator in 1951, found that soil protection was correlated with either weight of cover or completeness of the cover. Table III shows results from 18 plots on a deep, fine textured, slowly permeable soil of the Edwards Plateau. The results are grouped and averaged by the range condition class of the cover and compared with the plot with the maximum cover.

TABLE III.

*Water Loss from Edwards Plateau Deep Upland, averaged by Range Condition Classes.*

| Range Condition Class. | Number of Plots. | Total Cover per Acre. | Effectiveness of Cover. | Water Applied 20 Min. | Water Lost from Plot. |
|---|---|---|---|---|---|
| | | Pounds. | Per cent. | Inches. | Per cent. |
| Best plot ... ... | 1 | 8,378 | 99 | 2.18 | 0 |
| Good ,, ... ... | 6 | 4,569 | 87 | 1.98 | 30 |
| Fair ,, ... ... | 3 | 2,131 | 83 | 1.91 | 48 |
| Poor ,, ... ... | 7 | 697 | 55 | 2.01 | 65 |
| Bare plots ... ... | 2 | ...... | ... | 2.13 | 46 |

One of the bare plots was in the fair range condition class, the other poor.



*Fig.* 4.—Stubble smoke out on the plain, while the Research Station tractor pulls a disc over stubble.

He also states that amount of cover on the ground is more important than kind in protecting soil from raindrop impact. Although there was some variation between plants of different growth habits, these differences were mainly due to different capacities to produce volume of cover.

From the foregoing, it can be seen that it is necessary to keep the ground covered as much as possible, especially during the period of greatest expectation of high intensity rainstorms. It was thought once that clean cultivation, with the consequent production of a "dust mulch", was necessary to keep down weeds and grasses, which reduced soil moisture through transpiration. However, under this system, the soil surface structure was broken down by rain, with eventual increased erosion and decreased infiltration.

To produce as much cover as possible, it is necessary, in the first place, to recognise the land use classes; namely, cultivate soil on flat and gently sloping land, grazing lands on the steeper slopes and purely forest usage on the steepest hills. The grazing areas can be kept covered by pasture improvement and judicious grazing, which covers rotation of paddocks, not overstocking, fodder conservation and controlling the rabbits. It is impossible to generalize on the practices for cultivated portions, due to the diversity of crops grown, except that it may be stated that mulching of some sort, more recently by sub-surface tillage, would apply in many cases.

## SOIL CHARACTERISTICS.

The characteristics affecting infiltration are reviewed under the following headings:—

(a) Antecedent soil moisture.

(b) Surface condition.

(c) Texture.

*Antecedent soil moisture.*—Smith and Leopold([7]), in their previously mentioned article, showed that soil moisture is as important as any other factor in governing rate of infiltration. Neal([5]) concluded, on Putnam silt loam, that the infiltration varied inversely as the initial soil moisture. The effect of soil moisture on infiltration has been studied at great length in irrigation practice, where it can be regulated to some degree and is of paramount importance in determining how much and when water should be applied.

*Surface condition.*—Ploughing or cultivation has a marked effect on initial absorption, due to the large spaces produced, but not so much on the final figures. This is distinct from a soil that has been harrowed and is in a very fine condition with a smaller percentage of large aggregates. Going a stage further, a hard packed surface would shed practically all water falling on it. Breaking up of scalded patches in the south-west and west of New South Wales has increased infiltration and encouraged pasture growth. A broken soil surface offers resistance to the flow of water, thus reducing its velocity and increasing infiltration. Also the numerous large spaces and clods increase the time for the formation of the surface seal. The effect is magnified if the ploughing or cultivating is carried out on the contour so as to produce a series of ridges to dam up the water for a longer period than if the ploughing is not done on the contour.

*Texture.*—In general there is a decrease in infiltration rate with increase in clay content of the soil. Smith and Leopold[7] found that the rate of infiltration showed a highly significant negative correlation with the dispersion ratio, amount of dispersed clay and silt plus clay. The 5$\mu$ clay showed a significant negative correlation with the final infiltration rate. The dispersion ratio is a ratio used by Middleton[4] in 1930, and expresses the ratio, as a percentage, of silt plus clay obtained by dispersion by hand-shaking, to the total silt plus clay obtained by mechanical analysis.

The decreasing infiltration rate due to increasing clay content may be brought about by washing of soil colloids into the pore spaces of the soil, swelling of the soil colloids and by the very size and shape of the colloids themselves. Clay particles are crystalline with a platy or rod-like form and being small they can be packed much more tightly than silt and sand and by this close packing reduce the pore space of the soil and hence the infiltration rate.

The saturating cations can have a marked effect on the behaviour of the clays and consequently on the infiltration. Where calcium is the dominating saturating cation, granulation of the clay occurs, producing a relatively greater pore space than if sodium is the dominant cation. The sodium ions peptise

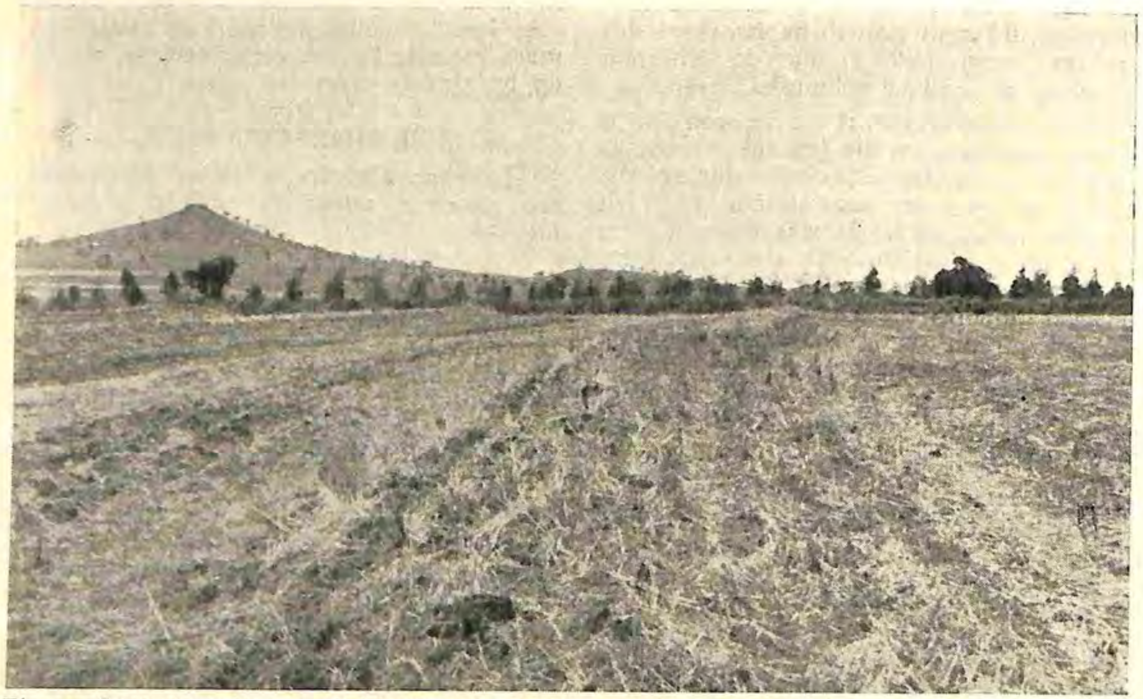

*Fig.* 5.—Contour working, graded banks and retention and incorporation of stubble, instead of burning, on Gunnedah Soil Conservation Research Station.



the clay, reduce granulation and, by corollary, decrease the pore space and the infiltration. In the Punjab irrigation ditches have been sealed by treatment with sodium ion. In general, it should be the aim in agriculture to keep or produce a calcium clay, especially on the heavier types of soil.

## SUMMARY.

This discussion has dealt with the problems of obtaining an artificial rain which approaches natural rainfall, has presented the conclusions of some workers on the effect of surface cover on infiltration and pointed out some of the physical and chemical properties of soils which influence infiltration. There has been also a very general reference to agricultural practices which would increase infiltration.

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# SOIL EROSION IN THE CAMDEN DISTRICT

BY

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THE Camden District, situated some forty miles from Sydney, is one of the oldest agricultural districts in Australia. Originally the main industry was wheat growing to provide grain for the infant colony and large tracts of steeply undulating country were put under the plough, the cultivation being done with bullock teams working up and down the hills on the old square system with which the early English settlers were so familiar. The old half-chain lands can still be seen to this day, many of them being now marked by severe gullying.

However, due to the serious attacks by wheat rust and the discovery and opening of the safer and more extensive western wheatgrowing areas, which followed the crossing of the Blue Mountains in 1813, there was a change during the middle years of the last century to horticulture—mainly vegetables—and dairying to supply the Sydney market.

Despite the fact that the average annual rainfall is in the vicinity of 30 inches, the district does not lend itself climatically to dairying as well as most coastal areas with a similar annual rainfall. This is due to the fact that the rain is of summer and autumn incidence, when nearly all of the annual rainfall is received, while the winter and spring months are usually dry and the small showers accompanied by severe westerly winds. These quickly dry up what scanty moisture is available, rendering it ineffective. Pasture growth is therefore brought to a standstill and grass cover dried off by heavy frosts. The result is a sharp decline in milk producing capacity of the pasture. Extensive grazing is prevented to a large extent by the small areas of the majority of holdings. This in turn necessitates continuous and intensive cropping to produce sufficient fodder—mainly oats during the winter and saccaline and Japanese millet in the summer.

The lack of suitable bottom land in most cases has forced dairymen to extend cultivation to the slopes, many of which are too steep for safety. This condition is further aggravated by the practice of using the same land for the same crop almost year after year without thought of resting the land or returning, at least in part, the nutrients which have been taken from the soil by the cereal fodder crops. Combined with overstocking, such practices have led to the serious erosion of the middle and upper slopes throughout the district.

## FACTORS INFLUENCING EROSION.

The major factors influencing erosion are—

1. Soil—including type, condition, and other physical properties.

2. Rainfall—particularly the incidence and intensity.

3. Management—the general farming and stocking procedures which either encourage or discourage the growth of an adequate and continuous vegetative cover.

The three are inter-related but are discussed separately.

## SOILS.

Erosion is governed by physical rather than by chemical properties of soil, though these latter can and do affect some of the physical characteristics. A chemically poor soil will not permit the growth of an adequate vegetative cover, the roots of which markedly affect the physical condition of the soil. Structure, texture, water holding



*Fig. 1.*—Portion of a bare cultivation paddock on a steep slope in the Camden district showing the first s age of rill erosion.

capacity and infiltration rate are the most important physical characteristics from the erosion aspect.

Usually structure and texture operate together. A well structured soil with poor texture will not be liable to erode as quickly as one which posesses neither of these qualities, or one which has good texture but poor structure. The structure of a soil is the way in which it will crack and break down under natural drying out. It is known to farmers generally as tilth and is one of the most important properties of the soil in that it influences aeration, moisture, heat, permeability, and water holding capacity as well as liability to erosion. In turn, it is governed by the presence of colloidal matter such as clay and humus materials which bind the finer particles into aggregates. Perhaps the best test of structure is the test for water stable aggregates.

In this light, the soils of the Camden District cannot, for the most part, be regarded as having a good structure, as they nearly all tend to pack down hard after rain, even when cultivation has produced good surface aggregation, which must be regarded therefore as artificial.

These soils are generally of poor structure and have a fine texture, both due to a very high percentage of clay. This derives from the parent material, Wianamatta shale, a sedimentary rock formed from clays deposited slowly in a former lake or coastal lagoon. As a result, the soils are subject to severe surface sealing by the fine clay particles.

### *Types of Erosion.*

Five main types of erosion occur in the Camden district—sheet, rill, gully and wind erosion, and mass land movement.

(a) *Sheet erosion.*

Sheet eroded areas occur widely throughout the district on both cultivation and pasture land where the surface soil is unprotected. Usually sheet erosion is associated with a shallow surface soil overlying a heavy subsoil or hard pan produced by continual ploughing to the same depth.

Susceptibility of the soils in the Camden district is due to the presence of clay close to the surface and a deficiency in organic matter.

Erosion of this nature is demonstrated by the accumulation of material along the fence lines or wherever run-off has been slowed down. This is the first stage of man-made erosion, and if the warning signs are neglected, serious damage soon follows.

(b) *Rill erosion.*

A further step beyond sheet erosion, is the development of small rills which occur in more or less parallel channels. These are not very deep, and in the early stages can be removed by ploughing. Rilling becomes evident mostly on sloping land which has been cultivated with the slope, and is especially prevalent on sloping areas sown to row crops such as peas. Overgrazed pasture and fallow land are also subject to rilling, and, if neglected, or if ploughing with the slope is continued, serious gully erosion soon develops. Rill erosion is the danger sign and it is at this stage that control measures can be employed most economically; a change in farming methods adopted more easily, and further damage prevented without much inconvenience. It is better to farm on the contour at this stage than to wait until large gullies develop.

(c) *Gully erosion.*

Provided the trend is not checked in the earlier stages, this, the final stage in the degeneration of arable land, can quickly engulf large areas resulting in the complete loss of production from the land so affected. Gullies generally develop up the slope from the lower boundaries of the paddock where the run-off has reached its maximum erosive capacity, and their spread can be very rapid due to undercutting and lateral collapse, until an intricate pattern of continuously collapsing gullies develops.

Large areas of the arable and pasture land of the Camden district have gone out of production due to widespread gullying.

(d) *Wind erosion.*

Is not widespread but does occur on the limited area of light sandy soils and also on the crests of hills of heavy soil areas.

(e) *Mass land movements.*

During the last few years the phenomenally wet seasons have caused a number of landslides which have damaged fairly large

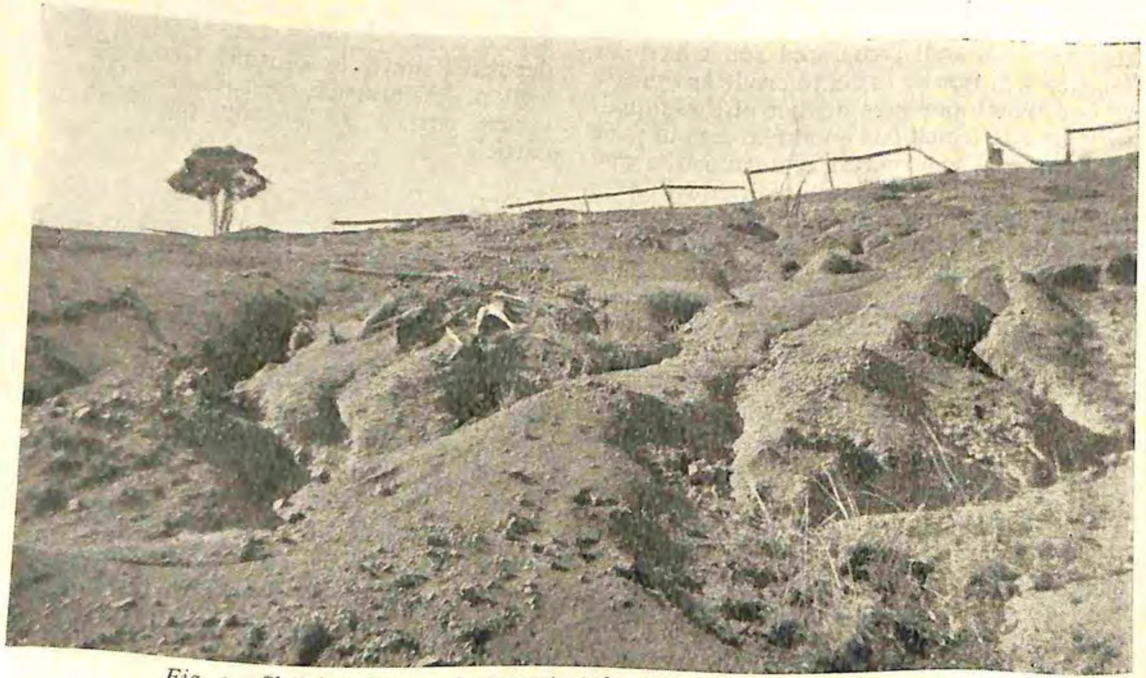

*Fig.* 2.—Showing damage to unprotected cultivation land on steep slopes.



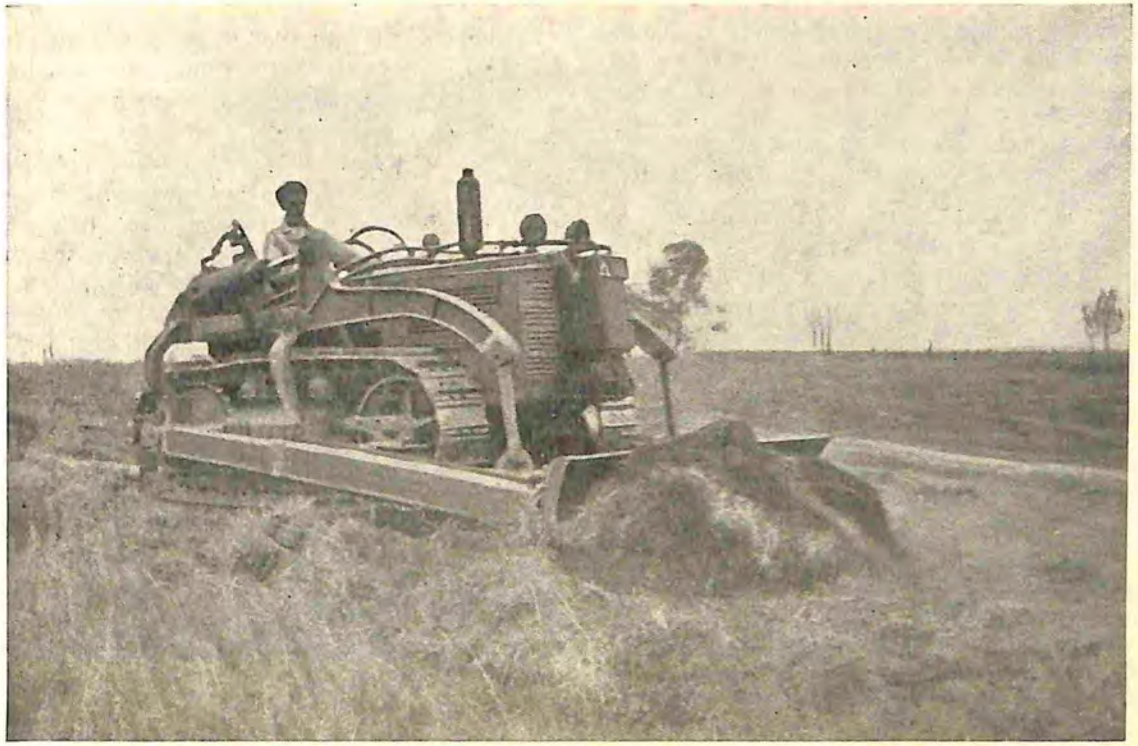

*Fig.* 3.—Reclamation of eroded land. The first stage is by bulldozing soil into gullies.

*Fig.* 4.—Heavy equipment preparing land for soil conservation work.

areas of sloping land. However landslides as have occurred of late appear to be less serious than they would seem at first glance as the vegetative cover has not been removed, though broken, and should recover with the return of normal years if kept free of stock to ensure recovery.

## RAINFALL.

Rainfall is not the cause of soil loss, but rather is it one medium by which soil is lost. Soil which is in good condition with a good structure and absorptive capacity should be able to take up almost all the rain which falls on it. Soil on which there is a good vegetative cover should also remain stable under any rainfall. It is only where the soil has lost its cover or is in a poor condition that erosion is likely to occur.

On paper, Camden appears to enjoy a good rainfall, as its average annual rainfall is approximately 30 inches. This is shown in Table I. One would therefore assume that the district could carry dense cover of the better type pasture plants, including such species as white and subterranean clover and the soft grasses such as perennial rye and Wimmera rye grasses. However, the greater part of the rainfall is received during the first part of the year in late summer and autumn, while the winter falls are light and are accompanied by boisterous westerly winds which quickly dry out the surface to render the precipitation ineffective. Drought resistant species such as lucerne and *Phalaris tuberosa* are therefore favoured.

Being of the summer type, the rainfall usually comes in sharp thunderstorms in which the precipitation is of high intensity. Under such conditions the already depleted surface is in a particularly susceptible condition because of overstocking, or being bare in fallow for crops, or just following harvest. The surface is quickly compacted and there is quick run-off of silt-charged water to scour the land. Even where some cross slope working has been done, there still remain ready-made channels in the finish-out lines along fences, and it is here that the worst damage occurs. The only safe way to prevent erosion under such conditions is to farm sloping lands on the contour and where necessary incorporate a system of graded diversion banks to divert the excess water safely to a prepared, well grassed, waterway or natural disposal area and thence to dams, if required to increase farm water supplies.

TABLE I.

*Average Annual Rainfall—Camden District as Average of Ten Year Cycles.*

| Years. | Inches. |
|---|---|
| 1894-1900 | 29.45 |
| 1901-1910 | 22.47 |
| 1911-1920 | 31.94 |
| 1921-1930 | 30.14 |
| 1931-1940 | 30.42 |
| 1941-1950 | 29.95 |
| 1894-1950 | 29.06 |

TABLE II.

*Average Monthly Rainfall—Camden District as Average of Ten Year Cycles.*

| Years. | Rainfall in Points. | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Jan. | Feb. | Mar. | April. | May. | June. | July. | Aug. | Sept. | Oct. | Nov. | Dec. |
| 1894–1900 ... | 371.4 | 213.8 | 346.9 | 211.4 | 275.6 | 319.1 | 322.0 | 222.9 | 125.0 | 150.7 | 195.5 | 190.9 |
| 1901–1910 ... | 250.1 | 243.2 | 225.4 | 220.7 | 126.0 | 89.1 | 315.6 | 199.5 | 118.0 | 206.1 | 99.5 | 282.7 |
| 1911–1920 ... | 367.3 | 196.5 | 407.3 | 267.2 | 199.7 | 197.3 | 323.6 | 113.7 | 162.4 | 240.8 | 253.6 | 368.5 |
| 1921–1930 ... | 274.6 | 316.2 | 291.1 | 319.0 | 244.6 | 324.6 | 274.2 | 117.7 | 153.0 | 197.8 | 295.0 | 255.7 |
| 1931–1940 ... | 374.6 | 335.5 | 287.3 | 342.2 | 154.7 | 155.7 | 206.9 | 151.5 | 224.6 | 189.6 | 287.5 | 332.0 |
| 1941–1950 ... | 309.3 | 314.3 | 271.2 | 272.0 | 325.1 | 393.2 | 125.7 | 111.1 | 161.2 | 183.3 | 295.6 | 298.7 |
| 1894–1950 ... | 324.5 | 269.9 | 304.9 | 272.1 | 220.9 | 246.5 | 261.3 | 152.7 | 157.4 | 194.7 | 237.8 | 288.1 |



*Fig.* 5.—Camden land ruined by unchecked erosion.

The main problem with which we are faced is to ensure that most if not all of the rain which falls onto any given piece of land is retained there and not allowed to be lost. When the water is kept on the hills it is kept where it will do the most good, as not only will it permit the increased growth of pasture on the slope, but also on the lower ground due to the increased supply of mosture seeping evenly and slowly through the soil. As a result a progressive improvement in the density and effectiveness of the vegetative cover can be achieved.

## MANAGEMENT.

Under dairying conditions existing in the Camden district, management, or rather the lack of management, has an important bearing on the presence of erosion. Because of the small area of the average holding, and the associated climatic conditions, all the year round grazing is not economical in terms of milk production and so crops have to be grown to provide sufficient supplementary fodder. So great is the need for these crops, that paddocks are often put under the plough year after year without rotation, a procedure which seriously depletes the soil's fertility, already lowered by almost a century of continuous cultivation.

Very often sloping cultivation paddocks are left without satisfactory after-treatment thus leaving the soil susceptible to wash, especially where heavy stocking is employed to eat out what crop residue remains and cause compaction of the surface. In this way the soil is left bare, unprotected, and in condition conducive to accelerated run-off and erosion. However, if renovated either by mechanical or vegetative means, worn-out land can, by careful building up and manuring, still produce a good growth of pasture where it was not able to produce a good crop. This is one of the main reasons why rotational cropping and grazing have proved successful, because each paddock is spelled periodically and has its fertility built up by the addition of the animal manures, provided use is made of the pasture harrows to ensure the return is more or less uniform. This practice helps to improve the chemical and physical properties of the soil; it will minimise the risk of erosion; increase the soil's ability to absorb moisture and leave the soil in a better condition to respond to the use of superphosphate and lime as top dressings.

Improper management is largely to blame for the erosion of grazing land. Too often the protective cover of timber is removed from hills which are too steep to be grazed safely, and too often is overstocking and exploitive grazing practised. Unfortunately, this is the legacy of farms too small to be economically productive. Even the best of the native grasses will not stand consistently heavy stocking and soon give way to less valuable species. These in turn quickly thin out, especially on the hillsides and expose the soil. The result is that an excessive amount of water flows over the hill lands and over the pasture below and carries with it large amounts of clay material to seal the surface and suffocate the vegetation. In a short time these bare areas spread with great rapidity. Notwithstanding the abnormally good seasons we have experienced during the last few years the bare areas have spread to an alarming extent. A reduction in the stocking rate in the early stages can alleviate this state of affairs to some extent, when combined with rotational grazing or cultivation.

## METHODS OF CONTROLLING SOIL EROSION.

The control of erosion is possible by two means, (a) vegetative and (b) mechanical. The two are usually interdependent in this district.

(a) *Vegetative Control.*

The sole use of this method is better suited to areas with more favourable seasons than those experienced in the Camden district where there is always an element of climatic risk. Some measure of success may be obtained if the affected area is treated in the early stages before much soil has been lost, but recovery is a relatively slow process except in abnormal seasons. However, control by this method can be achieved in favoured areas which can be readily fenced off from stock. Under these conditions, treatment such as strip planting with couch or kikuyu grasses with liberal applications of fertiliser or farmyard manure does give good cover fairly quickly. The encouragement of vegetative cover is particularly satisfactory in small shallow gullies which still retain some moisture, but as these grasses produce their maximum growth during the summer and little or none during the rest of the year, they do not ensure a complete cover in a short space of time, nor do they completely stop the onrush of water over the area.

On the whole this method is not very satisfactory or effective under local conditions and should not be used alone when large areas are to be treated. The main disadvantage is that the run-off is not arrested and the grass can be covered by silt material and suffocated or else the roots or sods undermined and washed away.

(b) *Mechanical Control.*

The utilisation of this method entails the construction of contour furrows with an associated system of graded diversion banks to carry excess water from the area under treatment.

A quicker and more successful result is obtained for two reasons; firstly, excessive run-off is diverted and is prevented from causing damage, and secondly the level pasture furrows open up the soil giving better aeration, and hold all the water which falls on the area, thus retaining moisture where it is needed most. In this way the furrows are increasing the effectiveness of the rainfall. Under these conditions better type grasses can be introduced into the pasture.

Under Camden conditions pasture furrows are designed to have a capacity of one cubic foot per lineal foot. They are usually constructed on a vertical interval of two feet. Where, however, the degree of slope is gentle enough to permit it, vertical interval can be altered accordingly but it is the usual practice to adhere to two feet vertical interval if bare eroded land is being treated. Heavy earthmoving equipment is usually employed, but if the landholder constructs furrows with his own machinery, it is most essential that the furrows be surveyed to ensure they are as level as possible, otherwise serious damage is likely to result. Moreover, the furrows themselves should be checked at regular intervals with small blocks of earth thrown up with a shovel, especially on either side of small natural depressions and old gully fills. Treatment in this manner will protect any weak spots



*Fig.* 6.—Formerly eroded land protected by level pasture furrows. This area near Camden, once virtually useless, is now almost completely reclaimed.

by decreasing the volume of water which may escape through a break. Damage to lower furrows will be minimised as well.

The basic principle of soil conservation work is to check run-off at its source, namely the top of the slope. If it is not possible to do this, by virtue of another property being upslope from the area to be treated, the construction of surveyed diversion banks becomes necessary to dispose of the excessive flow of water in order to protect the underlying furrows. A satisfactory bank is one which has a grade of not more than 1 per cent. and not less than 0.5 per cent. However, in every case the bank must discharge into a well-grassed disposal area, such as a natural drainage channel or a carefully prepared waterway of level cross section.

Where the surface soil is hard and compacted, it is advisable to rip between the furrows to permit greater aeration and maximum penetration of rain. The area should be sown either immediately before the furrows are constructed, where a large area is under treatment, or during the operation when only the furrows and their immediately surroundings are sown. If, however, the area is cultivated and sown before furrowing, sufficient seed should be retained to sow along the furrows. Equally good results can be obtained from sowing along the furrows and on the ripped area after the furrows have been constructed, as the soil will fret down to cover the seed naturally to an optimum depth, particularly where small seed is involved. This grassing of furrows will greatly assist their consolidation and ensure maximum retention of moisture.

Because the main pasture growth occurs in the summer and autumn, the following mixture gives good results:—

6 lb. Rhodes grass
2 lb. lucerne
8 lb. Japanese millet.

The millet should be sown as a cover crop with 1 cwt. superphosphate per acre. From about late October appears to be the best time to sow this mixture and sowing can continue until January if necessary. Following rain there should be good growth produced during the summer and early autumn. To permit the grass to produce good cover, the area should be kept free of stock for a period of twelve months, including the exclusion of rabbits. Should the area be partly grassed before furrowing, this resting period need not be so long, provided it is given only light and well spaced grazings and is otherwise managed carefully.

A well balanced cover results from the lucerne and Rhodes grass which is itself a very valuable pioneer species in this district. The Japanese millet, being a relatively quick grower, will provide ample protection for the young shoots of the other two species. Once established, Rhodes grass can withstand fairly heavy grazing, with the proviso that it receives periodic spelling and is allowed to seed, which it does very freely and vigorously. This mixture has proved reliable in the reclamation of eroded land and, if stocked judiciously, will ensure good milk production. Another feature is the great bulk of feed produced, even when the pasture is kept fairly short; hence a good supply of humus can be returned to the soil periodically by the rotting down of the unused plant material, especially during the winter, to build up the organic matter content of the surface soil and also provide an excellent seed bed for other species which can be introduced later.

If a pasture is being sown in the autumn, the following may be used:—

2 lb. Wimmera rye grass

2 lb. subterranean clover

with 30 lb. oats and 4 lb. purple vetch as a cover crop and again 1 cwt. superphosphate per acre. However, as these species depend on good spring rains for satisfactory growth, a certain amount of risk is taken and, as the winter and spring are generally dry in the Camden district, the chances of failure are rather high.

It is very important to maintain the furrows in good condition to permit them to control run-off effectively. Once they have been consolidated, and the area well grassed, it will not matter if the furrows overtop occasionally during a severe storm.

*Fig. 7.*—Pasture furrows used to prevent the onset of erosion and increase cover.



However, continual furrow maintenance pays dividends, particularly where gullies have been filled or in very wet years. Areas should be fenced off from stock and rabbits to allow good pasture establishment; kept free of rabbits at all times; grazed carefully and spelled periodically, more particularly at seeding time.

## CONCLUSION.

Large areas of land in the Camden district have been rendered useless by severe sheet and gully erosion. This erosion is continuing on many properties and is adversely affecting land situated lower down the slopes. Control can be attained by vegetative and mechanical means. Where mechanical control is employed, re-sowing of the treated area must be undertaken and it is imperative that proper care and management of the earthworks be maintained to ensure complete protection. Whenever furrows do not work satisfactorily, the cause can always be traced to the lack of attention and repair. Regular topdessing with superphosphate is advised and applications of lime or dolomite should also be of assistance in preserving a good vigorous vegetative cover.

Careful livestock management and the elimination of rabbits are essential.

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## ERRATA

In Vol. 8, No. 1, there are errors in Table 1, page 32. The figures in this table should read:—

| | | | | | |
|---|---|---|---|---|---|
| 151 Ewes (about to lamb) ... ... | $1\frac{1}{4}$ | 8 June | 10 July | 33 | 6,237 |
| 23 Weaners + Bull ... ... | 7 | 20 Aug. | 21 Aug. | 1 | 168 |
| 23 Weaners + Bull ... ... | 7 | 22 ,, | 31 ,, | 9 | 1,512 |
| 2 Cows + 1 Calf ... ... | 8 | 28 ,, | 31 ,, | 3 | 48 |
| 148 Ewes + Lambs ... ... | $1\frac{1}{4}$ | 31 ,, | 10 Oct. | 40 | 7,400 |
| 41 Cows + Calves ... ... | 8 | 23 Oct. | 31 ,, | 8 | 2,624 |
| 88 Cows + Calves ... ... | 9 | 3 Nov. | 5 Nov. | 2 | 1,584 |
| ,, ,, ... ... | 9 | 8 ,, | 15 ,, | 7 | 5,544 |
| ,, ,, ... ... | 9 | 30 ,, | 1 Dec. | 1 | 792 |
| 175 Ewes + Lambs ... ... | $1\frac{1}{2}$ | 1 Dec. | 13 ,, | 13 | 3,406 |
| 127 Sheep ... ... ... ... | 1 | 13 ,, | 22 ,, | 9 | 1,143 |
| ,, ... ... ... ... | 1 | 29 ,, | 1 Jan. | 3 | 381 |
| ,, ... ... ... ... | 1 | 5 Jan. | 8 ,, | 3 | 381 |
| 200 Sheep ... ... ... ... | 1 | 12 ,, | 15 ,, | 3 | 600 |
| 79 Sheep ... ... ... ... | 1 | 19 ,, | 23 ,, | 4 | 316 |

On page 33, Fig. 5 should read Fig. 6, and vice versa.

On page 35, Fig. 2 should read Fig. 3.

On page 37, for Percentage Ground Cover (Total), $P<.05$ should read $P>.05$.

# BOOK REVIEWS

## WATER, LAND AND PEOPLE

BERNARD FRANK and ANTHONY NETBOY: New York, Alfred A. Knopf. Pp. 331.

AN interesting book on resource conservation has appeared in Frank and Netboy's "Water, Land and People".

It is not an arresting publication for those who have already delved into conservation literature; no new princpiles are enunciated nor are conclusions reached which are any more startling than many already published. However, it remains a well set out rationale for integrated watershed planning on the broad scale. Although written about the United States, it offers a challenge universal in its application. The book is attractively written, if flavoured with occasional hyperbole and rather dramatic presentation. This, of course, may be expected from authors possessing a strong sense of mission and a keen eye for converts. Nevertheless, the book is quite well documented and freely sprinkled with authoritative statistics.

Part 1 deals with "The Problems". It sets out various deficiencies and surpluses detrimental to national life. The lack of stable stream flow necessary for irrigation, hydro-electricity, urban supply and navigation; the damage attributable to floods; the deterioration of soil structure and fertility, of pasture and woodland; the declining fish and wild life population; these are all appraised and shown to be of great national moment. The relationship of watershed mismanagement to these and other ills is closely demonstrated.

One cogent example might be quoted briefly. Comparison is made between the adjacent communities of Farmington and Centerville in the State of Utah. These towns are situated at the base of the Wasatch Mountains, each below comparable drainage basins.

Farmington suffered so severely from floods over the period 1923-30 that the community became virtually bankrupt. Orchards and crops were destroyed, valuable land was despoiled, homes were smashed and public communications damaged. So great was the public outcry after the 1930 flood that a commission of scientists was appointed to examine the underlying causes of the catastrophe. The commission found "that the great bulk of the flood waters originated on areas near the mountain top where the plant and litter cover had been destroyed or reduced and the soil eroded and compacted".

Centerville, on the other hand, suffered no significant damage. Centerville Creek continued to flow clear and relatively steadily over the same period. Interpreting the warning signs correctly, the six hundred villagers had purchased or leased the upper watershed lands, kept cattle off part of the area until regeneration was effective, and arranged for light grazing only by the owners of the remainder.

Part 2 is entitled "Water Economics". It indicates the heavy expenditure necessary to meet the water needs of an expanding community. It is again emphasised that river and land programmes must be integrated if the costly mistakes of the past are to be avoided.

Part 3 considers various solutions offered by the engineer, the agrostologist, and the forester. The piecemeal and insular approaches adopted by some engineers meet with trenchant criticism. The authors maintain that the tendency is to deal with symptoms rather than causes, and that permanent conservation of natural resources rests fundamentally with the use of the land. The engineering achievements of TVA are indubitable, but the success of its land improvement programmes have been of a minor order in comparison.

Some of the drawbacks to the construction of large reservoirs are enumerated. It is pointed out that large scale interference with a river inevitably creates its own problems, e.g., the construction of a dam, effecting in consequence a reduced carrying capacity of a river, may induce serious sedimentation problems further downstream. The possible value of a reservoir must be evaluated not only in terms of the economic return expected but against the possible uprooting of communities, inundation of land and despoliation of fisheries.

The authors present a case for the establishment of a single authority for river basin development in any region. The internecine warfare between various governmental agencies over developmental plans for the Missouri Valley is illustrative of this point.

In conclusion, the authors appeal for a more synoptic view of resource conservation.

## SOIL EROSION IN NEW ZEALAND.

K. B. CUMBERLAND. Whitcombe and Tombs Ltd. Pp. 228.

"Soil Erosion in New Zealand", by K. B. Cumberland, will have many points of interest for the professional and lay conservationist alike.

As a geographer, Dr. Cumberland is peculiarly fitted to the pioneering task of a reconnaissance survey of soil erosion in the Dominion. His approach is that of a regional synthesis of the different elements which go to make up the totality of the landscape. Eight erosion regions are differentiated on the basis of varying geomorphic, ecologic, climatic, lithic, pedalogic and land use features. The author maintains that each region requires consideration as an entity, and that conservation methods particular to each must be found and adopted.

His reconnaissance indicates that soil erosion is of widespread occurrence and severity through New Zealand. The Dominion, even more than Australia, depends upon products of the soil for her economic and social stability. Secondary industry has developed to a lesser degree, and thus improverishment of the soil implies even greater consequences than in this country.

Many New Zealand erosion forms are common to Australia, although the emphasis may fall in different places. The cultural heritage of the two countries is similar, and the pattern of exploitative land use has formed in the familiar lines of over-clearing, burning, cultivation of excessive slopes, over-stocking and wasteful mining procedures.

Pasture and forest, rather than agricultural land, form the basis of New Zealand's primary industries, and thus her conservation problems rest largely with the former. Steep and precipitous topography, often coupled with high rainfall and relatively infertile areas, might well daunt the New South Wales Soil Conservationist, accustomed to more genial conditions. For example, coping with a three-day rainfall of 40 inches would be no easy matter. However, vegetative regeneration under these circumstances may be a simpler question than in some of the semi-arid regions of New South Wales.

Soil erosion in New Zealand occurs in a great diversity of forms, some regional combinations of which may be unique. Large areas are subject to mass movement of soil in different variations of flow, slump and slipping. In their more accelerated forms, these occur on land cleared of timber and subject to frequent burning. The magnitude of this problem is considerable, and the phenomenon would appear most difficult to arrest and counter.

The book is chiefly a descriptive study, and as such is an excellent addition to conservation literature. However, Dr. Cumberland concludes with an approach to conservation measures. These latter chapters reveal the magnitude of the research and investigation necessary before a co-ordinated attack on the grand scale can be made.

One affirmation the author makes, that a decrease in the sheep/cattle ratio is highly desirable, is well substantiated by New South Wales experience.

Appendices on the geologic, climatic, vegetal and soil characteristics which affect the incidence and morphology of soil erosion in New Zealand form interesting introductions to these subjects.

Dr. Cumberland's thesis is vividly and concisely presented. The terminology throughout is necessarily scientific, but the layman will find assistance from a glossary and from the excellent photographic illustrations.

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

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# FOREWORD

BY

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

SOIL conservation activities are designed primarily to prevent erosion and thereby achieve stability of the land used in farming and grazing, and stability of the streams and underground water resources. The practices and systems are designed to give full use of the available soil, pasture, forest and water resources within their natural limitations, but conserving these resources in perpetuity.

In the few years since the end of the war, two and a half million acres, covering sixteen hundred properties, have been stabilised by the owners in co-operation with the Soil Conservation Service. In addition, there are many areas treated privately apart from the Soil Conservation Service of which we have no record, but we know that these run into a considerable acreage.

It is indicative of the character of the rural Australian that, in this State, he has been prepared to expend his money and his time in the application of soil conservation practices to the lands in his care. This has been done primarily for the high objectives enumerated above, for in those years we did not advocate soil conservation for its effect of increasing yields. Nevertheless, soil conservation has had the effect of increasing yields and it is a very welcome by-product which will greatly assist in accelerating the application of the improved methods.

Some of the fruits of applied soil conservation are becoming increasingly apparent. For example, on wheat farms the retirement to pasture of those portions too steep or otherwise unsuitable for cultivation, and the proper treatment and protection of the remaining arable land, has resulted in maintaining the farm's production of grain. In many cases it has considerably increased it. The greater production of grain that is obtained on the smaller area of land gives a greater economy of production. Cultivation costs in particular are reduced. Also, under this system, fertility of the cultivated areas can be maintained and even increased. The advantages also extend to the livestock returns. Less land is devoted to cultivation and more to pasture. If this retired wheat land, together with the other pasture, is first treated with pasture furrows to retain the water and is sown to suitable legumes and grasses and fertilised as required, the returns from livestock will also be improved.

The same principle applies to the mixed farming areas on the tablelands and coast, where oats, potatoes, maize, sorghum, millets, lucerne, clovers, pastures, etc., are grown. Here full use should be made of soil conserving pastures and legumes in the rotation. There is a greater scope for use of rotations and strip cropping practices in these areas. Primarily designed for soil conservation, they also greatly increase stock yields. The soil improving effects of a few years under a good mixed pasture of grass and clover can be immediately recognised if a crop of potatoes or maize follows the pasture. Continual cropping to maize or potatoes depletes the soil and progresssively lowers the yields. A good rotation system, including pasture legumes and stock invariably improves the soil and increases crop yields.

Soil conservation practices applied to the pastoral areas have given the same beneficial results. Designed for protection of the soil by improvement of the vegetative cover, they have resulted not only in achieving this, but very soon also in improving the annual output of beef, mutton or wool as the case may be. I have the results of a ten year experiment in soil conservation in New Mexico, U.S.A. The land had been badly eroded as a result of overgrazing by sheep. After the gullies had been stabilised and the number of stock reduced by 50 per cent., the reduced number of sheep produced the same amount of wool and mutton per year as formerly. The mortality was previously



*16385—2

7.5 per cent., it is now only 1.1 per cent. The country is now building up whereas formerly it was deteriorating.

In our own country on the Soil Conservation Station in the Riverina the land had been badly eroded and run down, cultivation had been discontinued and the area was capable of carrying only approximately half a sheep to the acre. After treatment we cropped the best portions to wheat. In five years the yields rose gradually from twelve bushels to seventeen bushels per acre, and the greatly improved pastures enable us now to carry the equivalent of approximately two sheep to the acre over the whole area, including the area cultivated. In other words, this particular farm, formerly carrying half a sheep per acre over the whole area, now carries four times the total number of sheep, and in addition some of the area is cropped to wheat in rotation and yields about seventeen bushels an acre. This is an example of how food production can be greatly increased under soil conservation farming methods. Comparable results are being obtained by private farmers in many parts of N.S.W.

Likewise on the purely grazing areas, reserve stocking and wise land management, in addition to reducing erosion, have actually increased total yields of wool and mutton, improved stock health and reduced drought losses. Sir Frederick McMaster, following his "reserve stocking" and soil conservation policy, reduced the total number of stock on his property, "Dalkeith" at Cassilis. This resulted in an increase in the wool production per sheep and per acre. Stock health was excellent, drought losses disappeared; in fact, drought feeding was not necessary; the feed reserve was in the paddock. Erosion was completely controlled, the soil was protected by a good vegetative cover of grass and no bare soil could be found; weeds, including Bathurst burr, could not compete with the vigorous growth of the grass. Substantial rains are needed to bring any worthwhile response on the heavy dark soils of the Cassilis-Coolah-Merriwa area when they are overgrazed and bare of vegetation, but on "Dalkeith" even light showers of rain are useful and bring a green shoot in the dense perennial pastures.

Our results in this State show that the adoption of soil conservation farming methods will not only stabilise and protect the farming and grazing lands, but will improve yields per acre, increase livestock returns and greatly improve economy of production. There is no doubt whatever that the adoption of soil conservation farming methods can be one of the most potent factors in increasing food production in this State.

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# A SOIL CONSERVATION DISTRICT PROGRAMME

BY

G. R. Wiltshire, H.D.A., H.D.D., District Soil Conservationist.

THE Lachlan Soil Conservation District embraces a large area running from the cool well watered hilly Tablelands to the relatively flat semi-arid marginal wheat and sheep country on the fringe of the Western Plains. A soil conservation programme for such a district can be laid down in broad terms only. It is the purpose of this article to attempt to state these broad principles and in some measure to explain their application to various sections of this District.

## A GENERAL REVIEW.

The fact that rapid or accelerated erosion is taking place on lands which were formerly quite stable under their natural cover, can be taken as evidence that the land usage being practised is responsible, and it can be inferred that this land usage must be modified as the first step in any programme aimed at arresting the erosion.

There are several important reasons why man's use of the land in crop and stock production renders it more liable to erode:—

1. Under natural conditions the land is held stable by a protective covering of vegetation. This cover is partially or completely destroyed by grazing and cultivation leaving the soil less well protected against the erosive action of running waters and the blasting action of winds.

2. Reduction in vegetative cover leads to a reduction in soil organic matter and humus content. In consequence the soil does not absorb the water so rapidly; therefore a greater proportion of the rainfall runs off.

3. Surface litter impedes the flow of water giving it time to soak into the soil. Conversely, lack of vegetation and litter allows the water to flow off rapidly; thus it has less time in which to be absorbed by the soil and a greater proportion of the total rainfall flows off.

4. Any increase in the amount of flow immediately increases the velocity of flow and this in turn greatly increases its erosive power.

From the foregoing it can be deduced that cultivation or heavy grazing of the land, which necessarily reduces vegetative cover, not only reduces the power of the land surface to resist erosion, but it also builds up the destructive power of those forces which cause the erosion.

From an agricultural point of view, the above deterioration is paralleled by a general lowering of soil fertility. Lack of soil organic matter and a reduction in moisture content adversely affect the beneficial actions of soil micro-organisms. Plant foods which are normally abundant become less readily available, and crop and stock yields decline.

To reverse this depletion of plant cover and soil fertility, and thereby reduce soil erosion to safe proportions, a review of existing land usage is necessary, and in many instances mechanical means of control of run-off waters are required.

## THE TABLELAND SECTION OF THE DISTRICT.

Included in this section are those parts of the catchments of the Lachlan and Belubula Rivers east of a line joining Cargo, Woodstock and Boorowa. It consists generally of steep hilly country, much of it relatively inaccessible and heavily infested by rabbits.

*Soils of the Area.*

Residual soils of granite, slate, basalt and limestone origin are general throughout, with small local areas of alluvial soil to be found along the courses of the main streams. The granite and slate soils are generally

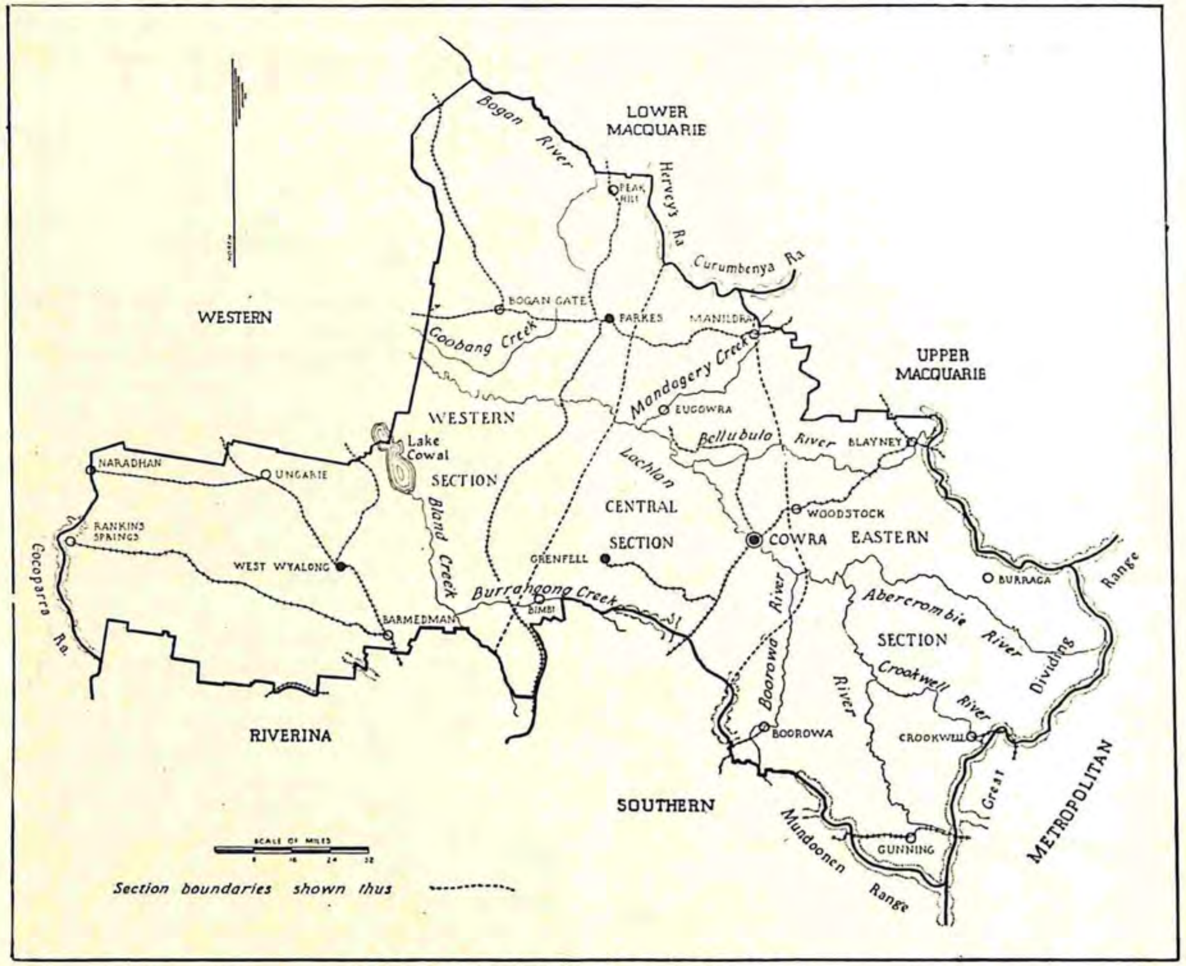


*Fig.* 1.—Lachlan Soil Conservation District.

podsolic in character, whilst those of basalt or limestone origin are deep rich clay loams with a dark red or black colour.

All of the residuals erode rapidly once vegetative cover declines. The alluvial soils are subject in flood time to surface washing and bank slumping which is usually caused by underground stream seepage. Another major hazard on these soils is their liability to be covered by coarse erosional debris which is washed from nearby hills by fast flowing waters.

*Land Usage.*

Grazing by sheep for the production of wool and meat is the major land usage, although some land is cultivated for the production of wheat and oats. Also some relatively small local areas are quite intensively farmed for the production of peas, potatoes, lucerne and vegetables, and in some cases orchards are established. These small areas are generally associated with the first-class soils of basalt and limestone origin.

Some areas are laid down to improved pastures and some are regularly topdressed, but the great bulk of the area is untreated native pasture, and in many cases there is considerable competition between sheep and rabbits for the available forage.

**General Soil Conservation Programme.**

*Wise Land Usage.*

The solution to the erosion problem of most of this area lies in the improvement of natural pastures by rabbit control, stock management and topdressing, combined with small areas of pasture furrowing.



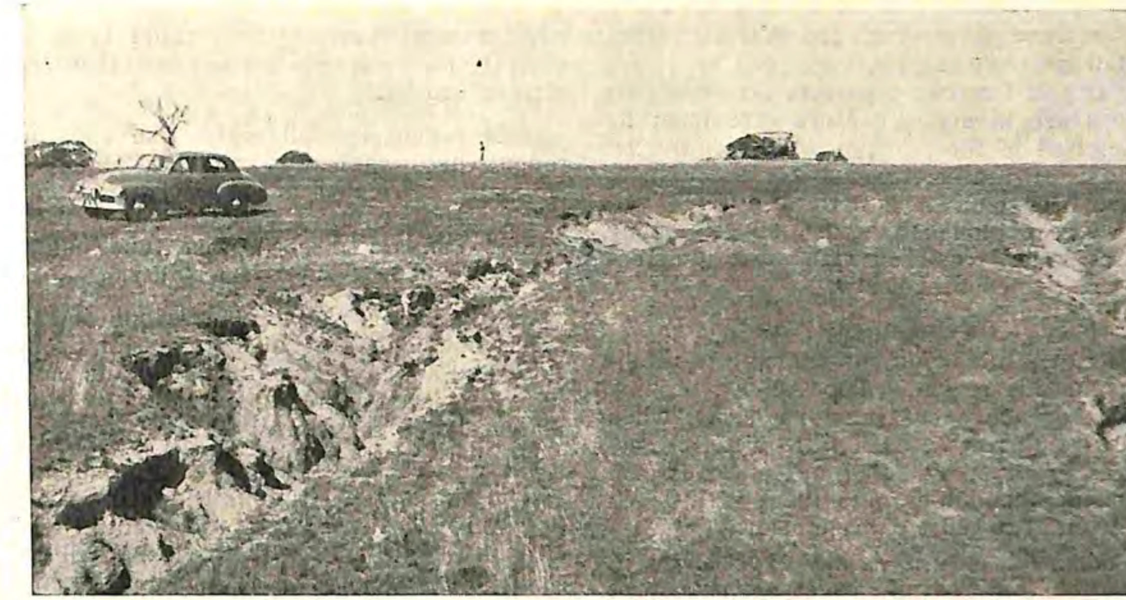

*Fig.* 2.—Cultivation paddock in the Carcoar district retired because of severe erosion.

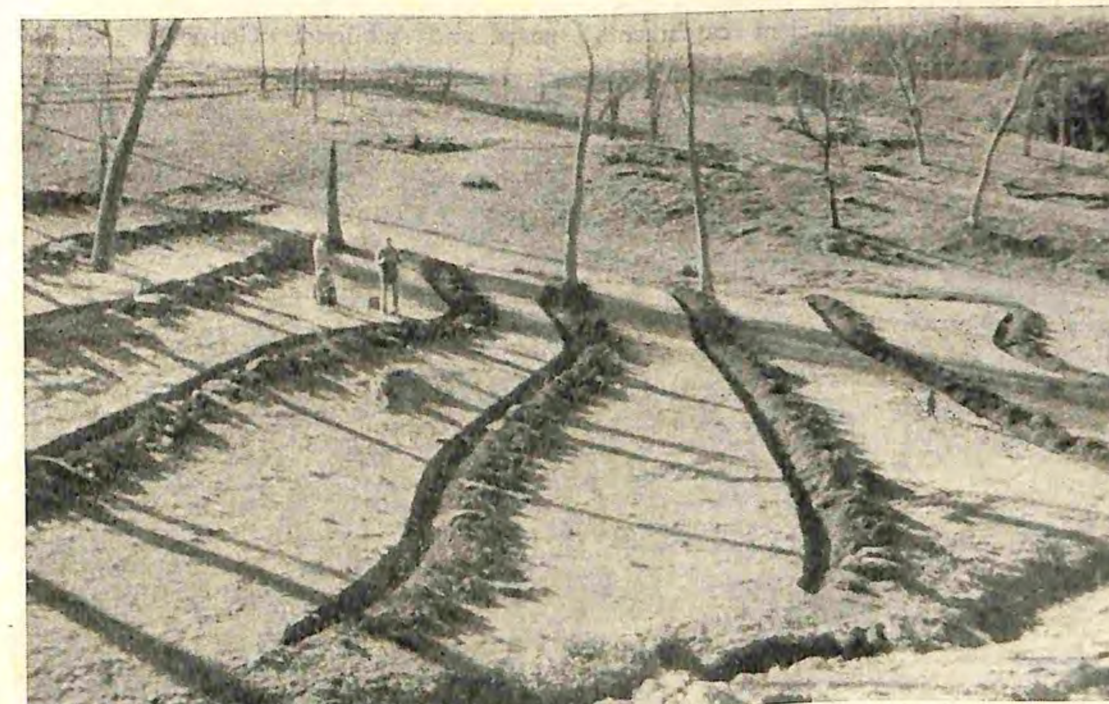

*Fig.* 3.—Pasture furrows on a steep hillside at Mandurama retain water and protect the fertile lower slopes.

On those areas which are cultivated wide rotations, including potatoes, peas, etc., with periods of temporary pasture between cash crops are necessary. More care must be exercised in the selection of the cultivated areas. In the past excessively steep slopes have been cultivated, natural watercourses have been ploughed across, and, in many cases, large areas shed water directly across the cultivated field below.

*Mechanical Control Measures.*

Pasture furrowing has immense possibilities in this region. Slopes above eroding areas or above cultivated paddocks, when pasture furrowed, shed little water. Pastures are thereby aided by improved soil moisture conditions, and there is little or no run-off to cause damage below.

Some difficulty is usually experienced in re-establishing pasture cover on bare sheet eroded areas. These revegetate much more quickly when stabilised by pasture furrows; in fact, the furrows are worthwhile even if their only use is in assisting this re-establishment of cover.

Diversion banks to convey damaging flows away to safe disposal areas can be used to great advantage in this region. Dams often have insufficient catchments while run-off waters which could be conveyed to them race down other watercourses causing erosion.

This region is well within the climatic range where waterways can be established. In many cultivated areas, at present unstable because of excessive slope, both graded banks and absorption type banks could be used to improve stability.

Cultivation on the contour is one of the surest methods of reducing run-off from cultivated areas. This method could and should replace the present method of ploughing parallel to the nearest fence.

Gully structures, tree planting along gullied areas, the straw-mulching of small sheet eroded areas, and the planting of unstable creek banks with trees must all be included in any soil conservation programme of this region.

## THE CENTRAL SECTION OF THE DISTRICT.

This section lies to the west of the Tableland area described above. It is a belt of country fairly well watered, in which grassed waterways can be successfully prepared and stabilised. Generally speaking,

*Fig.* 4.—Severe rilling caused by cultivation up and down the slope. Cowra district.



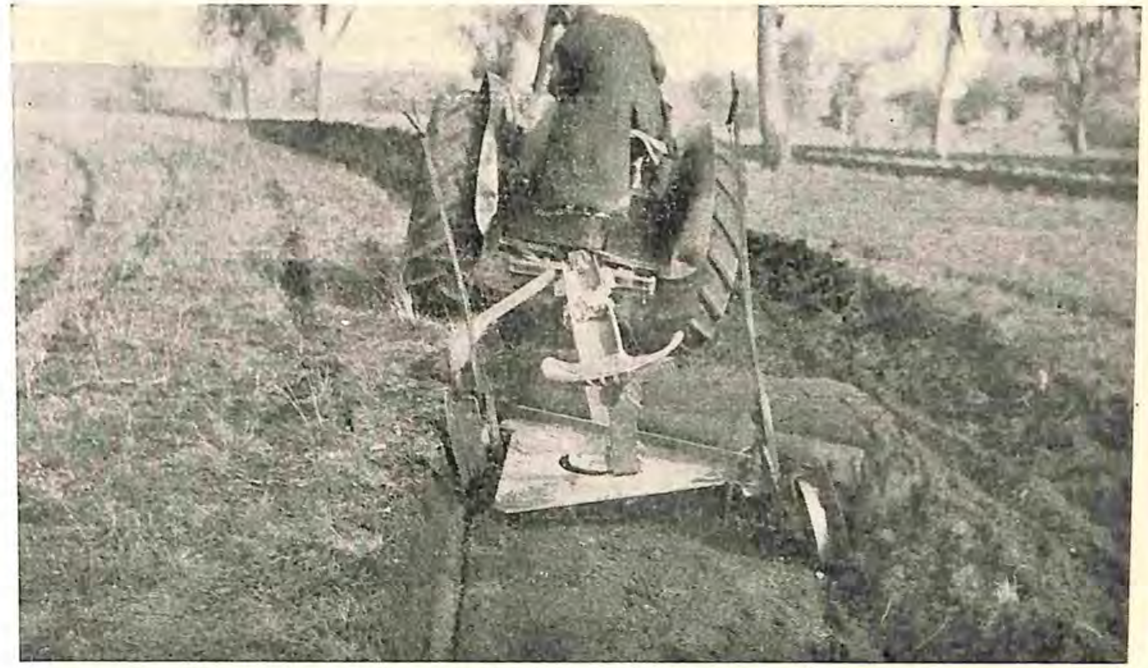

*Fig.* 5.—Constructing a graded bank with small plant. Cowra district.

the rainfall exceeds 20 inches and the area is bounded on the west by a line running from Bimbi in the south through Piney Range thence a little west to Eugowra to a point mid-way between Parkes and Manildra.

*Soils of the Area.*

Residual granite, slate, sandstone and basalt soils occur throughout with some alluvial soils especially along the Lachlan Valley. Also in some isolated areas west of the major topographical features aeolean soils are to be found. The residuals are podsolic in character in the eastern part, while Red-Brown Earths are common in the western parts. Red soils of basaltic origin also occur in some areas.

Considerable erosion is in evidence on most of the upland country, the natural flow lines being gullied in many areas and this erosion is extending very rapidly.

*Land Usage.*

A wide variety of land usage is found in this section, mainly because rich soils and a reliable rainfall render the lands suitable for many different lines of production. Mixed farming with wheat and sheep production is the main land usage; at present considerable emphasis is being placed on wool production, but in normal times this is one of the favoured fat lamb producing areas of the State.

Short term wheat rotations, stubble burning and heavy stocking with sheep have been responsible for the bulk of the present erosion problem. Rabbits generally are not as bad as in the Tableland section as the terrain is much less rugged and they are thus easier to control.

In some of the richer parts of the district, such as on the alluvial river flats, lucerne and vegetables are grown. These areas need only brief mention as generally they are not badly affected by soil erosion.

### General Soil Conservation Programme.

*Wise Land Usage.*

On cultivated areas the adoption of a wider rotation, including a period of clover-ley between wheat crops, so that the land is cropped not more frequently than once in every three years, is the first essential. It is quite apparent that a serious decline in the fertility of the soil is going on under the common wheat-fallow rotation.

Wide rotations, combined with wise grazing policies designed to maintain vegetative cover, should adequately protect the soils against erosion on the lesser slopes, provided run-off from above is kept off them. This policy does away with the necessity for stubble burning, as the old stubble rots and is returned to the soil before the new crop is sown.

On the steeper slopes the policy outlined above, combined with some mechanical control measures should prove successful, especially where waterways and graded banks are used.

The maintenance of soil stability and fertility on grazing areas requires the greater use of improved pastures, topdressing, correct stock management and rabbit eradication.

Special erosion control measures such as straw-mulching, tree planting, strip cropping and gully structures have their place within the general programme.

*Mechanical Control Measures.*

In this section, drainage type banks are the most important mechanical measures to be used. They have been developed for use on and above cultivated areas; it is quite likely that all cultivated lands having a slope in excess of about six per cent. will require the aid of graded banks if they are to remain undamaged, even if wide rotations are used. Constructed grassed waterways, grassed absorption areas and stable natural water courses can be used for suitable safe disposal of the run-off water. As an alternative to the above, absorption type banks can be used where a safe disposal of run-off is not available, but generally these banks are not favoured in this section.

Cultivation on the contour, either in conjunction with graded banks or on its own, is a practice which will be used increasingly as time goes on. It has a big effect in reducing run-off and it can be readily applied. Many farmers who have not the means to carry out a complete soil conservation programme can commence by adopting soil conservation rotations and by practising cultivation on the contour.

On grazing land the pasture furrow is the standard mechanical erosion control measure; these level furrows retain the run-off and increase absorption. There is an enormous scope for the use of these furrows on the hilly grazing country throughout this section.

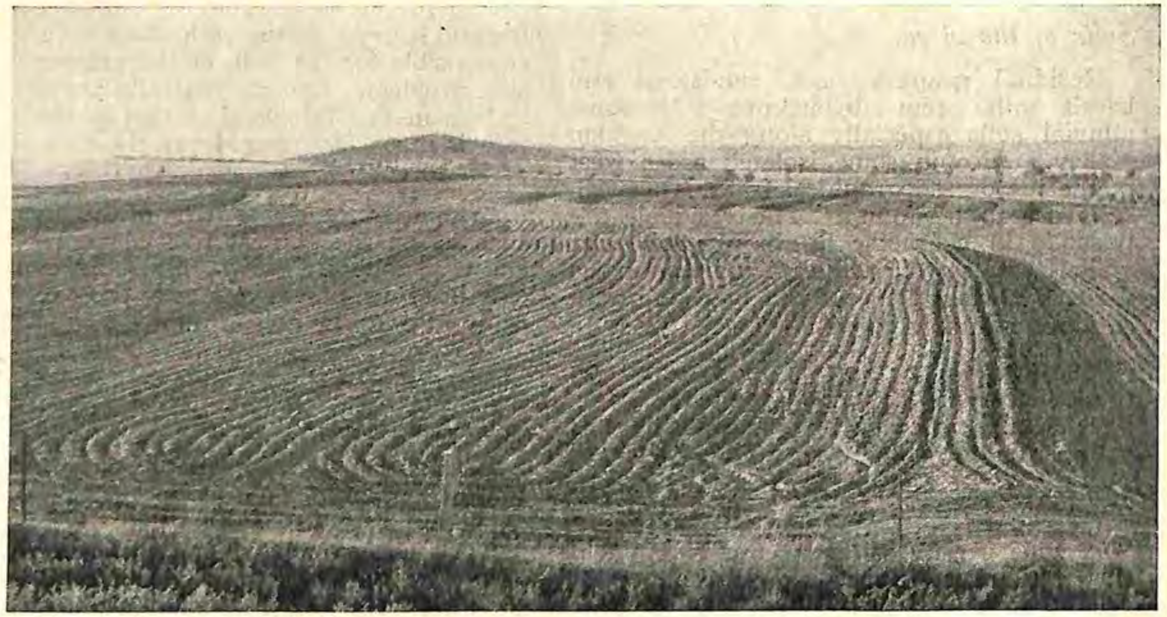

*Fig.* 6.—Land on the Cowra Research Station protected by crop rotation, contour cultivation and graded banks with a waterway in the foreground.



## THE WESTERN SECTION.

This section runs from the western boundary of the central section to a line from about Bimbi to Rankin Springs, then in a northerly direction through Lake Cowal and Ootha to Tottenham and eastwards to Peak Hill. This area includes the important wheat growing districts of Parkes and Forbes.

*Soils of the Area.*

These vary considerably in their origin; large areas of alluvial soils associated with flood plains of the Bland Creek, the Lachlan River and the Bogan River are found in the Marsden, Forbes, Yarrabandai and Peak Hill districts. Some residual limestone soils are to be found in the Parkes-Peak Hill area. Residual sandstone soils occur in widely scattered areas from Wyalong to the Lachlan Range in the Hillston district, while undoubtedly a considerable proportion of the soils west of the alluvium mentioned above is of aeolean origin.

Alluvium carrying a weeping myall (*Acacia pendula*) and belar (*Casuarina lepidophloia*) association, red-brown earths, carrying a cypress pine (*Callitris glauca*) and grey box (*Eucalyptus microcarpa*) association, and sandy brown mallee soils carrying mallee are the main soil types.

*Land Usage.*

Mixed farming for wheat and sheep is the main land usage, although a considerable area is devoted to grazing alone. Some cattle are run, but it is not regarded generally as being cattle country.

The alluvium of the Bland Creek and Lachlan and Bogan Rivers is excellent stock fattening country and is also used for wheat production, especially in the Quandialla area. West of this country, on red-brown soils and in the mallee areas, wool is grown and in recent years satisfactory wheat crops have been produced under the good seasonal conditions prevailing.

### Soil Conservation Programme.

*Wise Land Usage.*

The purpose of all soil conservation works in this area must be to increase the absorption of moisture by the soils, for two important reasons:—

1. As the proportion of rainfall absorbed increases, so the amount of run-off and subsequent erosion decreases.

*Fig.* 7.—Pasture furrows to check run-off on gentle slopes in the western section of the Lachlan District.



*16385—3

2. Lack of water is the greatest single factor limiting productivity in this region, and so any increase in absorption of water correspondingly increases productivity.

Wider cropping rotations based on the use of all available arable lands is of prime importance, although this presupposes the controlled clearing of large areas of land which are at present covered with standing timber. The utilisation of this arable land in many instances will allow the same area as formerly to be cultivated for wheat, but, instead of some areas being cropped every year or every second year, they need only to be cropped once in every three, four or possibly five years.

As wind erosion plays an important role in certain areas in this section, and its effect will become more evident as clearing proceeds, it is important that adequate wind breaks are left around paddock margins, and it is important that shelter areas for stock protection be left uncleared.

Improvement of soil organic matter and soil fertility by the use of pasture between crops and elimination of stubble burning is necessary to increase water-absorbing capacity, to improve fertility, and to give the soil resistance to the blasting action of the winds.

In the past, lack of suitable legumes has limited the scope of pastures to improve fertility in these parts, but the use of lucerne and some of the medics appears to have improved this position. It is clearly evident that where these legumes can be introduced, soil fertility, soil structure and water absorbing qualities of the soil are greatly improved.

On grazing areas, the management of stock and control of rabbits must be such that throughout the majority of years sufficient cover is maintained to ensure the seeding of desirable species, and to protect the soil against the blasting action of winds and from scouring by running waters.

*Mechanical Control Measures.*

Absorption type structures such as level banks, pasture furrows, or contour cultivation have their maximum value in this region as they reduce run-off and at the same time they increase soil moisture content.

As the development of prepared grassed waterways is very difficult in this climate the use of graded banks will be limited to areas where stable natural water courses are present, where they can be directed into water supply dams, or where the water can be spread on to flat or gently sloping grasslands. Where mechanical controls are necessary on cultivation lands, absorption type banks will generally be used.

On grasslands, pasture furrows have great possibilities. Quite apart from their considerable soil conserving value, their cheapness and efficiency in preventing runoff ensure their popularity with all landholders who are anxious to increase grassland productivity. In many instances the reduction of run-off from grasslands by the use of pasture furrows will so reduce erosion on cultivated fields further down the slope that good farming methods alone will be sufficient to ensure their stability.

## CONCLUSION.

Every different paddock has its own special features, and is therefore a different soil conservation problem, and the soil conservation programme for each must be worked out in the field; however, it is hoped that a study of the foregoing principles, together with the description of their broad application to the three separate sections of the Lachlan Soil Conservation District, will enable each farmer to understand, more readily, the most suitable programme for his particular area.

Soil erosion is very widespread and is very damaging and some landholders are inclined to view it as a hopeless problem incapable of solution. This is not the case. Many methods of control have been worked out and have proved successful. The application of these methods of erosion control, by landholders, aided by technical advice and other assistance from the Soil Conservation Service, has resulted in the commencement of a satisfactory district-wide soil conservation programme.

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# SALTBUSHES

BY

R. W. CONDON, B.Sc. Agr., Research Officer and Botanist, and G. H. KNOWLES, B.Sc., Soil Conservationist.

## INTRODUCTION.

THIS is the final article of a series dealing with saltbushes and related plants, and discusses the more important plants of this group other than the perennial saltbush, which was the subject of the original article in this series. The second article in this series dealt with the bluebushes and some of the more important of the copperburrs. In introducing this final article, a discussion of the relationships between these groups of plants would be appropriate.

The saltbush genus *Atriplex* contains about thirty known species in Australia and also occurs in other parts of the world (notably Arizona, U.S.A.). The genus falls within the family Chenopodiaceae which is a family of considerable importance to agriculture and industry generally, and to the grazier of western New South Wales in particular. This will be seen from the following table in which the more important genera of this family are set out.

1. Genus *Beta*—beetroot, sugar beet, silver beet.
2. Genus *Rhagodia*—the berry saltbushes (7 species).
3. Genus *Chenopodium*—fat hen, the goosefoots and other weed plants (18 species).
4. Genus *Atriplex*—the saltbushes (30 species).
5. Genus *Bassia*—copperburrs, poverty bushes, etc. (31 species).
6. Genus *Kochia*—bluebushes, cotton bush, and many smaller species (24 species).
7. A number of other genera common to western N.S.W., including samphires, saltworts, etc.

The saltbushes, with one exception, are all herbaceous plants, and most provide good fodder for stock in country with a saline character, although many species are relatively unpalatable. Characteristically, the flowers are inconspicuous and the male and female parts of the reproductive systems appear in different flowers though these may occur on the same plant. The flowering parts are unattractive to insects and birds and consequently pollination is ammophilous, *i.e.*, pollination by wind; the resulting fruiting body consists of two modified leaves containing only one seed. The saltbush counteracts this by the production of a large number of fruiting bodies. The leaves are flat and usually alternate and the whole plant is mealy in appearance, giving the varying shades of grey peculiar to this group of plants.

## DISTRIBUTION AND OCCURRENCE.

The saltbushes enjoy a wide distribution throughout New South Wales, particularly in the West, where they are rarely absent from any pasture, although they may often be inconspicuous. They are most common in the typical saltbush country of the Hay-Ivanhoe plain and in the "Gibber Downs" of the West Darling district. In these areas the soil is heavy in texture—loams, clay loams, and clays—and it is this habitat which is preferred by the saltbushes. Accordingly, they are common throughout the areas of heavy soil adjacent to rivers, creeks and lakes.

However, they are also common on the sandier soils of the scrub country, and on some extensive areas in the West Darling. On the Mundi Mundi plain the saltbush becomes the dominant form of vegetation on the sandy soils. Although the group as a whole is wide in its distribution, many species are limited to the better rainfall areas, while others are confined to particular soil types, *e.g.*, mallee or bitter saltbush (*At. stipitata*) and *At. vellutinella*, which are found only on sand dunes or deep sand drifts.

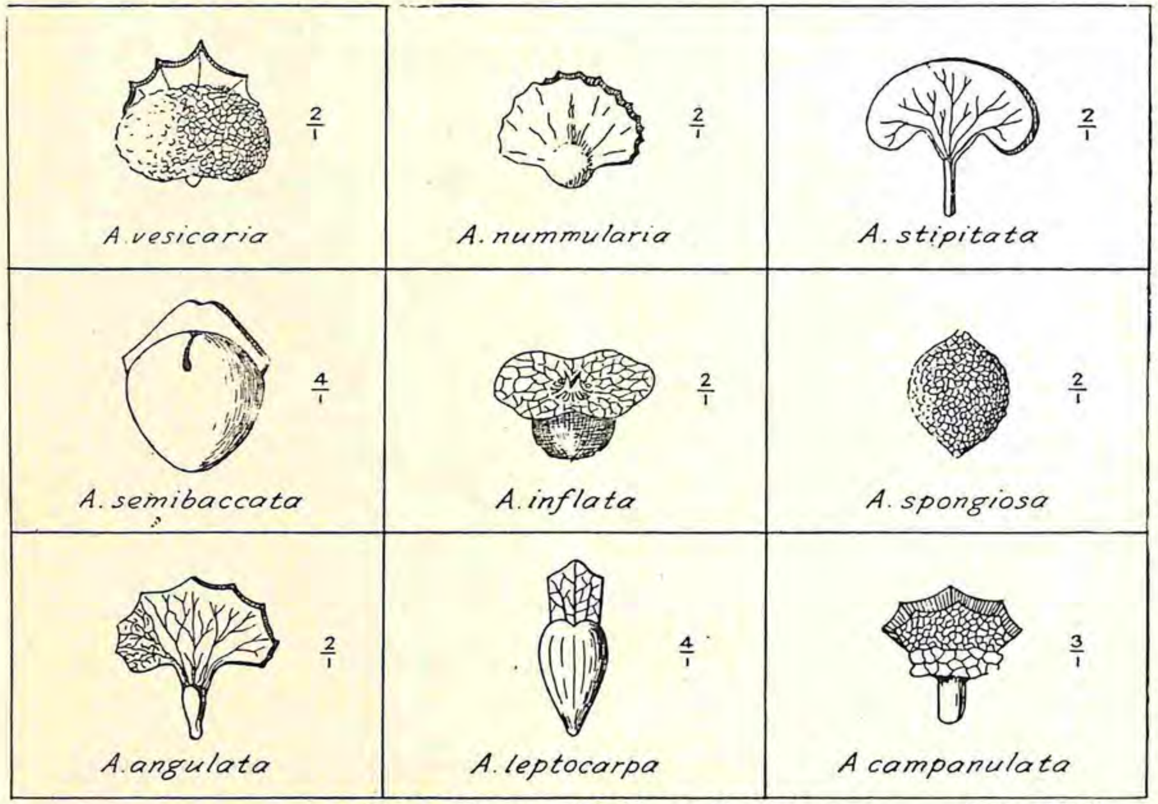


*Fig.* 1.—Diagram of fruiting bodies. (After *Black*).

Although these plants make their greatest development in areas receiving a greater portion of its rainfall in the winter (the southern half of the State), they make their most vigorous growth during the summer period, and their drought resistance is such that they will continue to provide green feed when all other herbage has dried off. This is due, generally, to the development of an extensive root system which is able to tap reserves of moisture too deep for other plants to utilise. They also have other means of resisting drought (described in the article on perennial saltbush), which enables them to withstand the arid climate of western New South Wales.

The high salt content of the leaves makes them relatively unpalatable, but they are of high nutritional value, and their greatest value is when the periodic droughts reduce or remove other feed. The annual saltbushes differ from most annual plants in that they have a long growing season (from early winter to late summer). Providing they have cool conditions, they will germinate at any time of the year. Summer germination is, however, rare. On the other hand, most annuals have a definite growing period, generally a very short one, and if rain does not fall at the appropriate time they fail to appear.

A number of the more important species have been chosen for a more detailed description.

**Old Man Saltbush** (*Atriplex nummularia*).

With the exception of the perennial saltbush, this is the most important of the *Atriplex* species. Commonly known as old man saltbush, or more correctly giant saltbush, it is not to be confused with the old man saltbush of South Australia (*Rhagodia parabolica*), which has a red berry for its fruiting body. *Atriplex nummularia* is a tall shrub generally 6-10 feet high, and may have a diameter of 12 feet when fully grown. It has a life span of 20-30 years. The adult plant is many-stemmed, due to the fact that



the young plant branches freely from the base. The leaves are rounded, $1\frac{1}{2}$ inches in length, and may be shortly toothed. The fruiting body is from $\frac{1}{4}$-$\frac{1}{2}$ inch long and wide, and the plant may produce so many fruits that the weight of them causes the branches to touch the ground. No doubt it one time formed a dense scrub over large areas but it is now relatively uncommon, though clumps are found dotted throughout the west. It is usually found in depressions in the western plains or on small islands of sand, but it may occur in any area. It prefers loamy or clayey soils, but it will thrive on any soil, acid or alkaline, and it is not unusual to find massive plantings of the species as hedges. It is extremely hardy and very palatable though it is usually accepted that it is a last resort for sheep. Dead leaves are eaten by sheep during drought but large stock will eat it at any stage.

**Flat-topped Saltbush** (*Atriplex inflata*)—(previously known as *At. halimoides*).

This is an annual plant which may live up to fifteen months under favourable conditions. The extremely hot dry summer of the interior is generally sufficient to kill it. It is a bushy shrub, pale bluish-grey in colour, generally about 1 foot high and 1 foot in diameter, though under favourable conditions it will often exceed these dimensions. In West Darling districts, however, it generally makes poor growth and is killed off when about 6 inches high during the long dry spells. The fruiting bodies are flat-topped and about $\frac{1}{4}$ inch in diameter, the two fruiting leaves being distended to form a bladder containing the single seed. The male and female flowers are found on the same plant, the male flowers being found in terminal clusters and the female flowers in the lower portion of its branches. The leaves are more or less diamond shaped, broadly toothed and about $\frac{1}{2}$-1 inch long.

Its distribution is not limited, and it is found throughout the western plains and throughout the perennial saltbush pastures, on loams and clayey loams, but usually in depressions. It can be looked upon as a sign of degeneration of the pasture, being relatively unpalatable but of special value on account of its bulk.

The short life of *At. inflata* is a disadvantage, for, although the community may present a good cover during the winter months, it usually dies off during the following dry summer. This species is proving of special value in scald reclamation work due to its copious seeding, easy dissemination and ready germination.

**An Annual Saltbush** (*Atriplex pseudocampanulata*).

This is a small bush, somewhat similar in shape, size and colour to flat-topped saltbush, but may be distinguished from this species by the smaller leaves, arranged in whorls around the thin stems, and by the distinctly different fruiting bodies. It is light bluish-grey in colour. The fruiting body is small, and somewhat fan-shaped, with a slight curl. Its fruit is very similar to that of *At. campanulata* (described later) but it lacks the appendages present on that species. The leaves are oval to rounded, $\frac{1}{4}$-$\frac{1}{2}$ inch in length. Like flat-topped saltbush, this species has a life span of about fifteen months under favourable conditions, but it is generally killed off by prolonged dry conditions.

It is found throughout the Hay-Ivanhoe plains and, though relatively uncommon in the natural pastures of this region, it can always be found growing thickly on those parts of scalded areas receiving a plentiful supply of water. It is found chiefly on clay loams and loams, preferring the heavier soil types, and is common along the heavy soils of the Darling River, being rarely found on the light soils. The species is moderately palatable and provides good feed after rains due to its ready germination, and consequently it is one of the first plants to be eaten by stock after the breaking of a drought.

Like flat-topped saltbush it is proving particularly valuable in scald reclamation, seeming to spread more rapidly and germinate more readily than that species.

**Spongy or Pop Saltbush** (*Atriplex spongiosa*).

This is another annual species very similar to flat-topped saltbush, but generally smaller. It is a small bush, generally 6-12 inches high and 1-$1\frac{1}{2}$ feet in diameter, a very

*Fig.* 2.—Flat-topped saltbush (*At. inflata*) helping to colonise a ploughed scald.

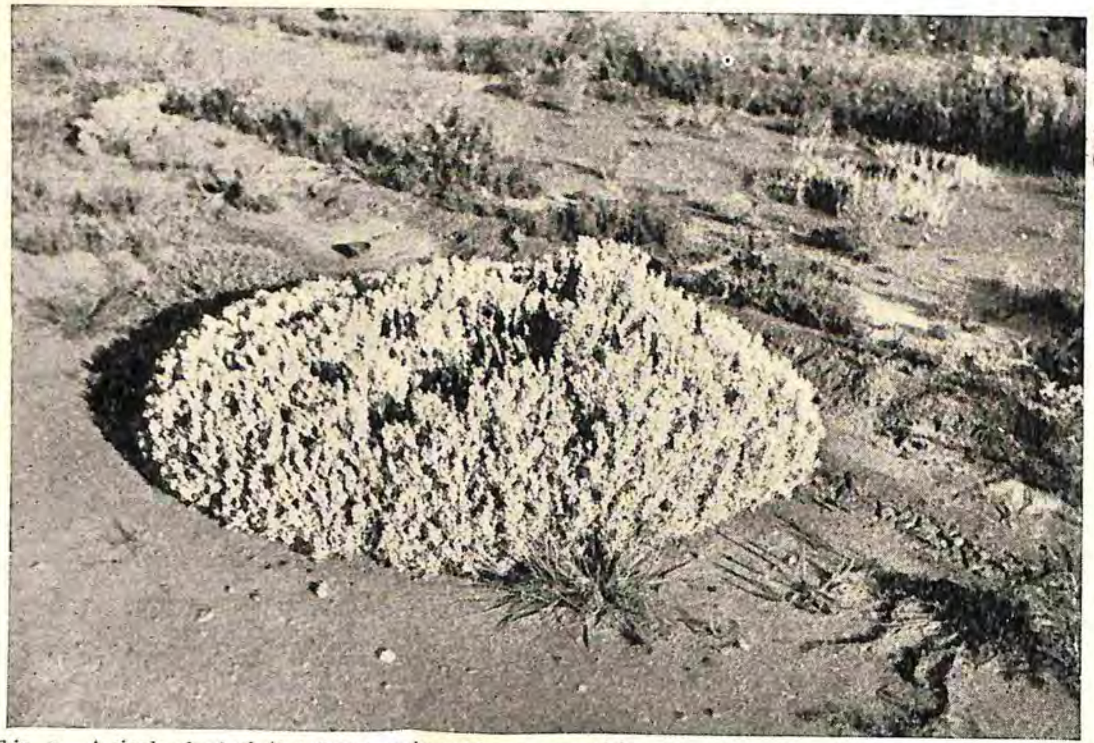

*Fig* 3.—A single plant of *At. inflata* growing without competition. It is 4 ft. in diameter and seeding heavily.



pale greenish-grey in colour with large rounded leaves about 1 inch in diameter and generally more fleshy than *At. inflata.* Its common and scientific names are derived from the fruiting body, which is lemon-shaped, spongy and ¼-½ inch in length, often having a pinkish or reddish tinge. It is relatively short-lived, rarely living longer than 6-8 months, even under favourable conditions.

It is found generally along the water-courses in the Western Division, particularly in West Darling and on the treeless plains, but may extend into the sandy country. It prefers alkaline soils, but it has also been found on sand dunes whose surface is neutral or slightly acid. It is very palatable to stock, both green and dry, but it is not widespread, due to the fact that, though it seeds prolifically, the seeds germinate only sparingly.

**An Annual Saltbush** (*Atriplex angulata*).

Another annual species similar in appearance and colouring to the preceding, being a low bush about 6-9 inches high, up to 1 foot in diameter and with a very pale greenish-grey colour. The branches are weaker than most other bushy species, and it is almost creeping in habit. The leaves are rounded, about 1 inch in diameter and broadly toothed. The fruiting body is, however, easily recognised, being flat, fan-shaped, with a distinct "handle" enclosing the seed, the leaves of the fruiting body being about ½ inch in width. It generally lives a little longer than pop saltbush, its lifespan being twelve months under favourable conditions. Like the preceding it produces seed at an early age.

It has a wide distribution throughout West Darling districts, rarely occurring to the eastward, and together with flat-topped saltbush, is the most frequently found annual saltbush in the saltbush country of this region, generally preferring the lighter soils. It is being tested for its value in scald reclamation work and is showing promise.

**Mallee or Bitter Saltbush** (*Atriplex stipitata*).

This is another perennial species probably living for 2-4 years. It is a small grey shrub, growing about 2 feet in height with very little foliage compared with most saltbushes. Leaves are generally oblong in shape from ½-¾ inch long. The fruiting body is easily recognisable, being similar to

*Fig.* 4.—Slender-fruited saltbush (*At. leptocarpa*) after sowing on ploughed scald.

that of *At. angulata* but more kidney-shaped, rounded on the back, flat, and up to ½ inch across. The kidney shape of the fruiting body gives rise to a further common name, namely "kidney saltbush".

This species is limited in its distribution by soil type, growing only on scrub country, in deep sandy soils (mallee), or hard loams. It is very common on hard, stony, sheet-eroded ridges throughout the Cobar district, where it represents an early stage in the recolonisation of such areas. It is unpalatable, the bitter taste of the leaves acting as a deterrant to stock.

**Diamond-berried Saltbush** (*Atriplex semibaccata*).

This is widely known as "creeping saltbush". There are two distinct forms of this species. One is a perennial bush, living for 3-4 years, blue-grey in colour with narrow leaves from ½-1 inch long on woody stems, standing from 1-1½ feet high. The fruiting body is always "dry", as distinct from the fleshy, succulent fruit of the creeping type, more or less diamond-shaped and about ⅛-¼ inch in diameter. It appears to be confined to the heavy river soils in the central west of N.S.W., and is often associated with myall (or boree) trees. It is very palatable, probably one of the most palatable of the saltbushes. It has proved valuable in assisting scald reclamation in the central west, but makes little progress under the drier conditions further west.

The second form of this species is widely known throughout the better rainfall areas of the State. It is of prostrate habit, forming a thick green mat about 2-3 feet in diameter, but under good conditions, with little competition, will readily form mats up to 6 feet in diameter. It is generally regarded as biennial. The leaves are greenish or bluish above but mealy-white below, up to 1 inch in length and usually toothed. The seed is enclosed in two diamond-shaped reddish-coloured fleshy appendages about ⅛-¼ inch long. It prefers loams and clay loams, and often it is found on scalded surfaces in the form of mats and appears to colonise them quite well. It is found throughout the west where it is regarded as one of the best of the saltbushes, being capable of growing on very hard soils.

It is a prolific seeder, the seed germinating freely and spreading rapidly. It is quite palatable to stock and provides good feed during droughts.

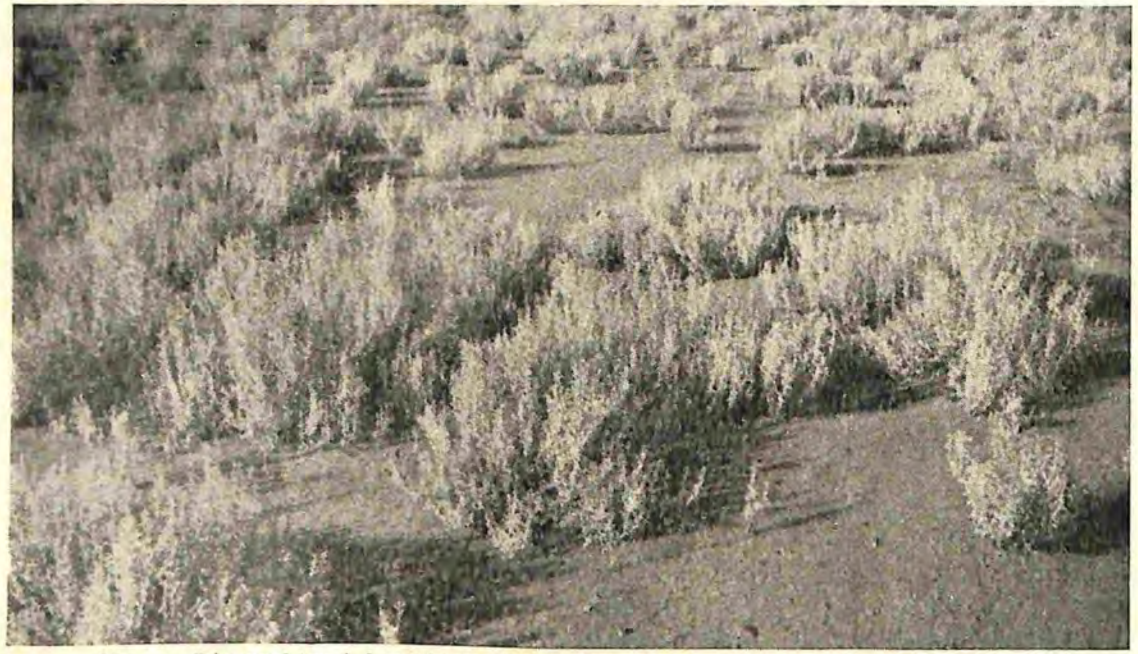

*Fig* 5.— Diamond-berried saltbush (*At. semibaccata*) colonising a scald after flooding.



**Slender-fruited Saltbush** (*Atriplex leptocarpa*).

This is another creeping or prostrate species, similar in habit to *At. semibaccata*, forming a mat over the surface of 1-2 feet diameter. It may be distinguished from the latter species by its almost white, or very pale bluish-grey colouring, and the fruit, which in this case is more or less cylindrical, ¼ inch in length and 1/16 inch diameter. The leaves are long (½-1 inch) and narrow. It is a creeping annual, but in good moisture conditions it may assume a slightly ascending habit. It is found throughout the saltbush plains and prefers the heavier soils, such as the clays and clay loams adjacent to rivers. The species is quite palatable and is regarded as a good fodder plant in the far west, due chiefly to its rapid germination after rain. The plant produces an abundance of seed at any time of the year, which germinates rapidly and freely, and consequently it is of importance as a good coloniser of bare country, particularly on soil which is self-mulching, or on hard clayey soil.

**An Annual Saltbush** (*Atriplex campanulata*).

Another creeping species, similar in habit to *At. semibaccata*, although it may also be erect. It is annual, and quite distinct in appearance from either of the preceding two species. The colour is a pale greenish-grey, with oval to rounded leaves from ¼-¾ inch long. The fruits are small, about ¼ inch, fan-shaped, one fruiting leaf longer and curled slightly over the shorter one, which has two small swollen appendages at its base. It is not a common species, although it is found throughout the saltbush plains, often in the mallee, in the belah and mulga scrub, and occasionally on sand dunes. It is quite palatable and regarded as a good fodder plant.

There are numerous other species of saltbushes which occur throughout western N.S.W., most of which can be recognised by their greyish colour, and fruits composed of two leaf-like bracteoles enveloping a single small seed (round, flattish, and rarely more than ⅛ inch in diameter). These leaf-like bracteoles vary considerably in shape,

*Fig.* 6.—*At. pseudocampanulata* colonising a scalded area that has been treated by concentric furrows.

TABLE I.—Illustrating Characteristics of more important Saltbush Species enabling ready identification (see Figure I for "seed" shapes).

| Species. | Longevity. | Colour. | Habit and Growth. | Leaves. | Fruits. | Seeding. | Male and Female Flowers on— | Special Remarks. |
|---|---|---|---|---|---|---|---|---|
| 1. *At. vesicaria.* "Bladder." | 12–20 years | Pale blue-grey . | Small bush, 1 ft.–2 ft. diameter. | Oval, ½ in.–1 in. long. | Round, spongy, ½ in. diameter. | Moderate — spring and autumn. | Separate plants | Great drought resistance and fodder value. |
| 2 *At. nummularia.* "Old Man." | 20–30 years | Light blue-grey ... | Large bush, 6 ft.–9 ft. diameter. | Rounded, 1 in.–1½ in. long. | Leathery, heart-shape, ¼ in.–½ in. wide. | Heavy — early summer. | Separate plants | Hedges, windbreaks, and drought fodder. |
| 3. *At. stipitata.* "Bitter." | 2–4 years ... | Blue-grey ... ... | Spindly shrub, 2 ft. high. | Oblong, ½ in.–1 in. long. | Kidney-shape, ½ in. wide. | Light — probably spring and autumn. | Same plants or separate plants. | Very bitter and unpalatable. |
| 4A. *At. semibaccata.* "Diamond-berried" (Erect). | 2–4 years ... | Blue-grey ... ... | Small bush with woody stems, 1 ft.–1½ ft. high. | Long, narrow, ½ in.–1 in. long. | Leathery, broad, diamond-shape, ¼ in.–¼ in. wide. | Moderate to heavy —spring and autumn. | Separate plants | Associated with myall country in central west. Useful in scald reclamation in better districts. Very palatable. |
| 4B. *At. semibaccata.* "Creeping." | 1–2 years ... | Greenish, with white under-surface. | Creeping mat form, 2 ft.–4 ft. diameter. | Long, narrow, ½ in.–1 in. long. | Red, fleshy, long-diamond shape, ¼ in. long. | Moderate — any time.* | Same plants ... | Useful for scald reclamation in better districts. Very palatable. |
| 5. *At. inflata.* "Flat-topped." | 6–15 months | Very pale bluish-grey. | Small bush, 6 in.–1 ft. high. | Variable shape, generally oval, toothed, ½ in.–1 in. long. | Angular, spongy, ¼ in.–½ in. diameter. | Very heavy—any time.* | Same plants ... | Moderately unpalatable. Very useful in scald reclamation. |
| 6. *At. pseudocampanulata* "Annual." | 6–15 months | Light bluish-grey... | Small bush, 6 in.–1 ft. high. | Oval, tending to wrap around stem, ½ in. long. | Flat, fanshape, ⅛ in.–¼ in. wide. | Heavy—any time* | Same plants ... | Moderately unpalatable. Very useful in scald reclamation. |
| 7. *At. spongiosa.* "Pop or Spongy." | 6–9 months | Pale greenish-grey | Small bush, 6 in.–1 ft. high. | Rounded, toothed, ½ in.–1 in. diameter. | Spongy, lemon-shape, reddish tinge, ¼ in.–½ in. diameter. | Very heavy—any time.* | Same plants ... | Palatable. Usefulness for scald reclamation being tested. |
| 8. *At. angulata.* "Annual." | 6–15 months | Pale greenish-grey | Small bush, 6 in.–1 ft. diameter. | Rounded, toothed, ½ in.–1 in. diameter. | Flat fanshape, with definite "handle" ¼ in.–½ in. wide. | Moderate — any time.* | Same plants ... | Moderately unpalatable. Usefulness for scald reclamation being tested. |
| 9. *At. leptocarpa.* "Slender Fruited." | 6–12 months | Pale greenish - or bluish-grey. | Creeping mat, 1½ ft.–3 ft. diameter. | Long, narrow, ½ in.–1 in. long. | Slender, cylindrical, ¼ in. long, 1/16 in. wide. | Heavy—any time.* Generally autumn. | Same plants ... | Best development on river soils. Very useful for scald reclamation. |
| 10. *At. campanulata.* "Annual." | 6–12 months | Pale greenish-grey | Creeping mat, 1 ft.–2 ft. diameter. | Oval, ½ in.–¾ in long. | Curled, fanshape, with appendages at base, ⅛ in.–¼ in. wide. | Moderate — any time.* | Same plants ... | Usefulness for scald reclamation being tested. |

* Generally 2–3 months after good rains.



and may also carry unusual appendages. Fig. 1 gives a ready means of comparing or determining any of the species described above.

## CONCLUSION.

The saltbushes not only constitute one of Australia's most important groups of fodder plants, but are also designed to play a leading part in the reclamation of eroded country, particularly scalded areas, and it is principally for this reason that we have paid so much attention to them in these articles. They are particularly suited to the task of scald reclamation by reason of their drought resistance, suitability to heavy soil conditions, copious seed supply and great vigour. Later articles will deal with their use in this respect, together with the development of seed supplies, and their part not only in reclaiming scalded country but in building up degenerate pastures to something of greater value and stability. It therefore behoves every landholder in the western parts of this State, particularly those affected by erosion or degenerating pastures, to cultivate a sound knowledge of this group of plants, so that he may utilise them to the best advantage.