STUDIES IN SOIL CONSERVATION AT COWRA RESEARCH STATION, 1941-51

BY

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A LITTLE over ten years ago Cowra Soil Conservation Research Station was a denuded, rapidly eroding area, with numerous active major and minor gullies making it increasingly difficult to carry out normal farming operations. During rain much of the water ran off down these gullies, carrying with it a load of soil and leaving little moisture to feed the crops and other plants growing in the soil.

To-day, after approximately ten years of practical soil conservation management, so effective have been the treatments instituted that the provision of sufficient run-off to fill the available dams with water for the stock is becoming more and more difficult, despite the recent wet seasons.

What has been the reason for this change in the absorptive capacity of the soil? To answer this let us look briefly at the treatment programme. This consisted essentially of two different phases:

1. The construction of numerous mechanical controls, such as graded banks and pasture furrows.
2. The adoption of a land use programme in which emphasis was on the raising of soil fertility, and provision of maximum vegetative cover on the surface at all times.

The first of these phases was aimed solely at controlling the run-off waters in such a manner that they would be unable to carry any large quantity of soil, and of necessity made very little attempt to hold the rain where it fell. This was essentially a short-term treatment, temporarily partly protecting the area while the more far reaching and more effective, but slower acting, complementary land use programme took effect.

The land use programme adopted has been outlined by Smith (1945), and had two essential parts:—(a) the maintenance of a complete vegetative cover on the soil for as long as possible during the year, with a resultant increase in the absorptive capacity; (b) the building of soil fertility so that full advantage could be taken of the increasing quantities of water entering the soil.

After ten years it is felt that the soundness of the basis of approach to the erosion problem has been proved, and the Station stands as a valuable example of the successful practical application of soil conservation in this one phase. However, there still remains room for minor refinements to the general plan of attack, and many problems remain to be solved. This is primarily a research area and has, over the period under review, been devoted to studies in the prevention of erosion and reclamation of eroded areas. This article is essentially a progress report on the various long-term experiments.

The author has had but little contact with this work until recently, results used being extracted from the Station records. Full acknowledgment is made to the various officers of the Service, who, in the course of their duties here, have obtained these results.

Cowra was the first Soil Conservation Station to be established in Australia, and besides the results recorded below, has served many other important functions, such as the development of much of the equipment now standard on N.S.W. Soil Conservation stations, together with the training of numerous technical staff members for the works and extension field of the Service's operations.

RUN-OFF AND SOIL LOSS STUDIES.

One of the first projects on the station was the establishment of a series of layouts designed to measure the reaction of small areas of land to various treatments, measurements being in terms of the water running off the plots and the soil it carries.

The equipment used for this work was described by Wiltshire (1947), being obtained by adapting to Australian conditions

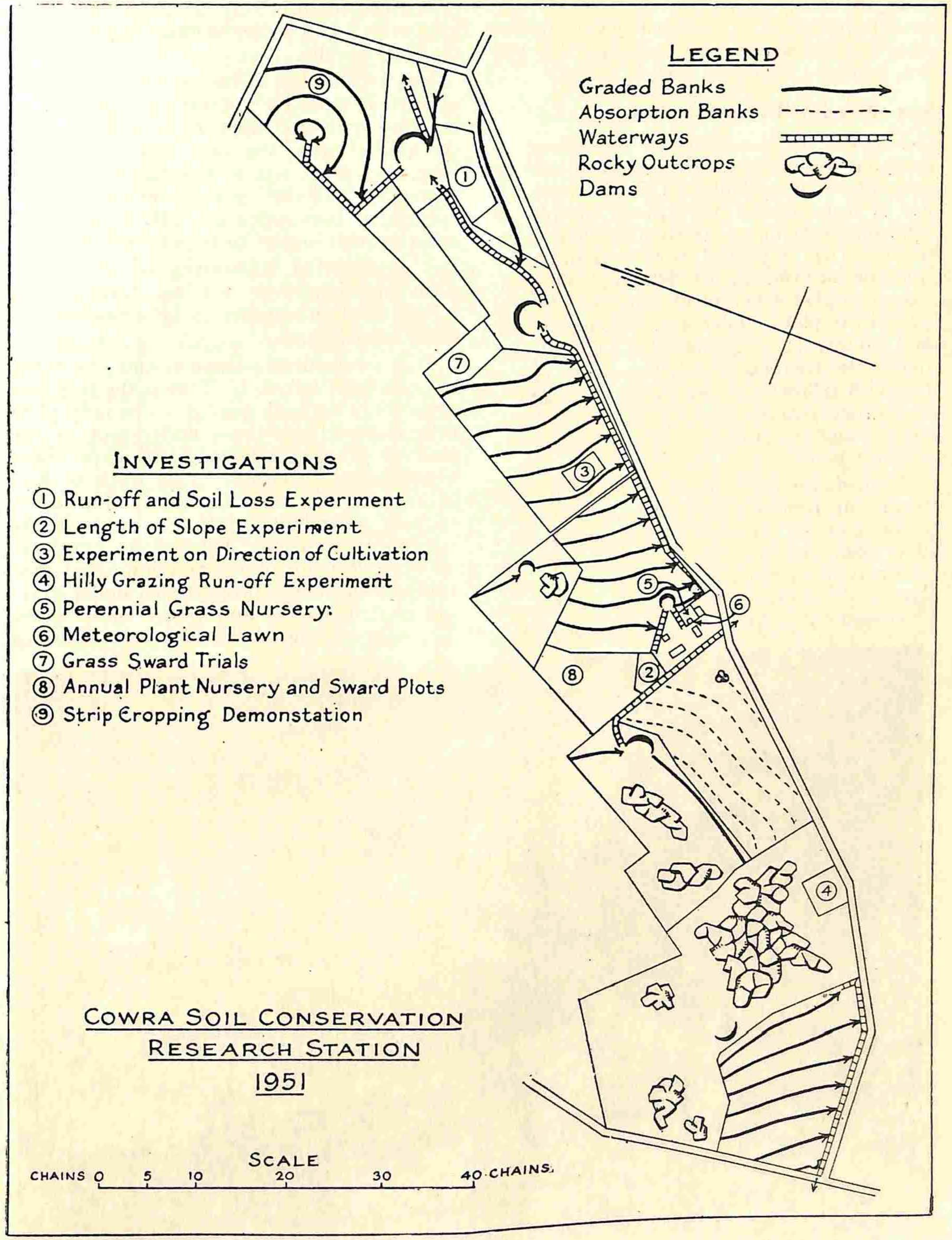

Fig. 1

that previously used in the U.S.A. for similar purposes. Standard plots, unless otherwise stated, are approximately 8 x 136 feet, being 1/40 acre in area.

Run-off and Soil Loss Experiment.

The first of these layouts was aimed at studying the reaction of the land to various agricultural treatments. This involved the use of three sets of eight plots, one plot in each set receiving one of the following treatments: (a) Improved sown pasture, (b) Lucerne for grazing, (c) Retiring from cultivation to give a volunteer pasture, (d) and (e) Two plots under the rotation wheat and fallow, (f), (g) and (h) Three plots under the rotation wheat, two years clover ley with fallowing being carried out late in the second year, *i.e.,* a two-year and a three-year wheat rotation and three permanent pasture plots.

Records for this experiment in its present form date from 1st January, 1943, and full records of all run-off and soil losses since that date are available, together with the characteristics of rains causing these recordings. At present these results are being reviewed by a statistician, and it would be premature to offer any detailed comments. However Fig. 3 shows summarised forms of the total results.

From Table I it will be seen that the most vulnerable time for run-off and soil loss in the Cowra district appears to occur during the period from the new year to sowing time, *i.e.,* from when the effective protection developed during the previous winter-spring has been eaten off, till the new season's growth begins to become effective.

The expected superiority of the three-term rotation over the two-term wheat fallow rotation appears to be supported by these total figures.

When considering these results one thing must be kept in mind. This is the fact that these plots are bulk grazed. The only plots ever enclosed are those under crop at the time of grazing, otherwise the experiment is grazed as an entity. This tends to lead to a bias in the results obtained due to the varying palatability of feed present on the various treatments. This causes considerable overgrazing of ley and improved pasture sections and a proportional under grazing of land retired and wheat fallow plots. The overgrazing of the leys becomes most

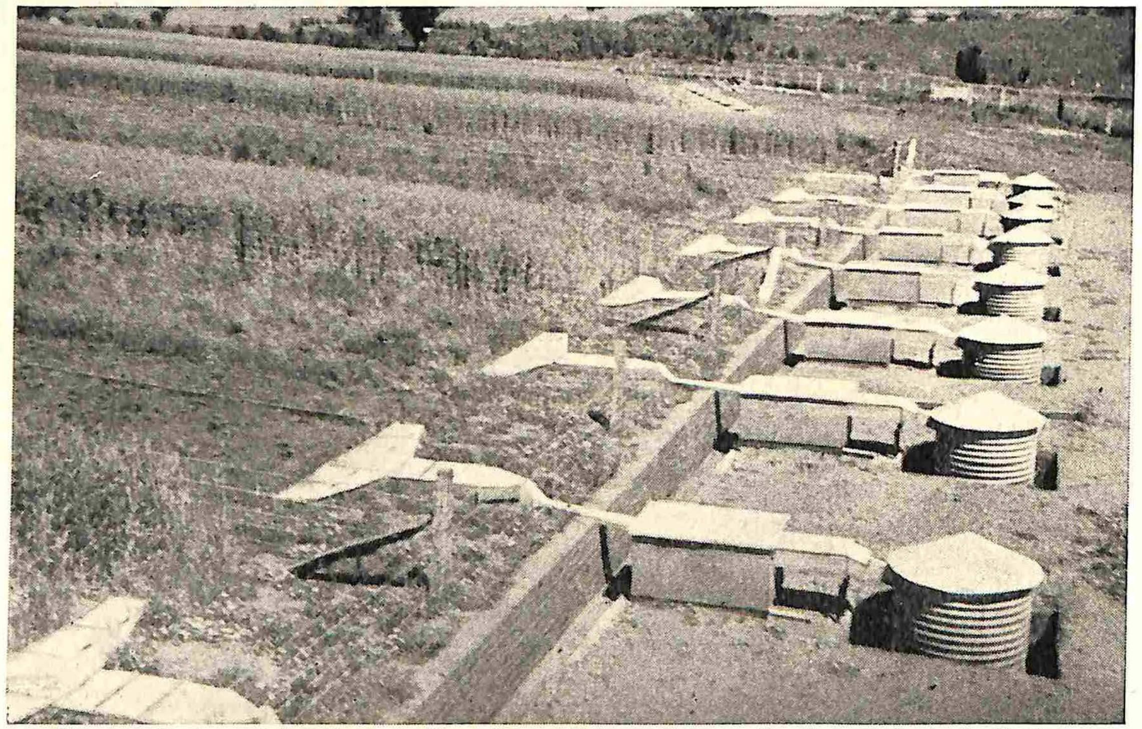

Fig. 2.—Equipment for the collection of run-off from plots on the Cowra Research Station.

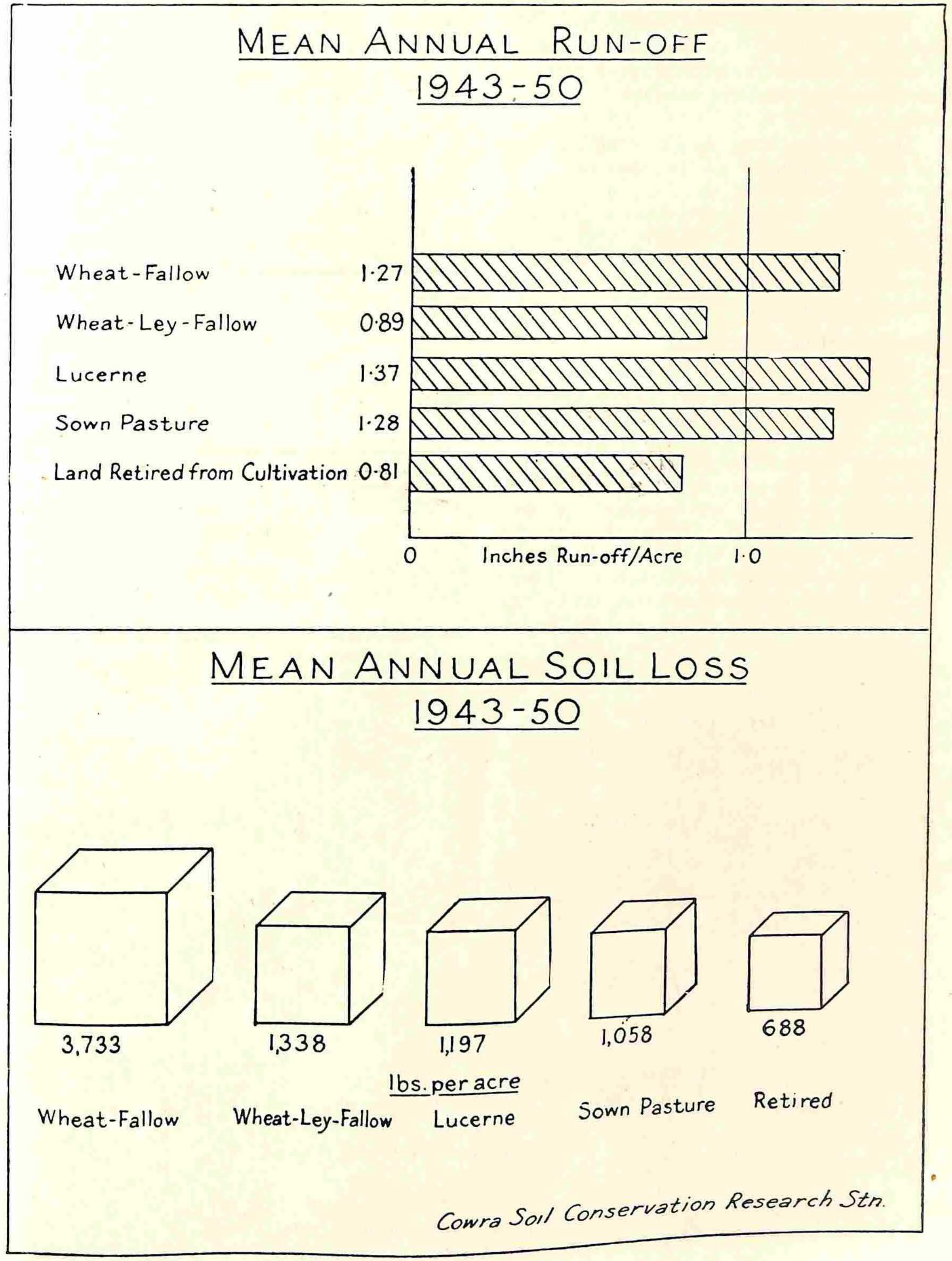

Fig. 3.

noticeable during the late summer months by which time the palatable sub. clover trash has been removed, a thing that can, and should be avoided under field conditions. At the same time the "less palatable" plots still have not approximated field conditions.

The above grazing factor would tend to confirm the validity of the statement that the wheat-ley-fallow is the far superior rotation as regards prevention of erosion. It also indicates that a well developed natural pasture is more effective in preventing erosion than a mis-managed improved pasture as shown by Fig. 3.

Length of Slope Experiment.

The second layout established was aimed at indicating the difference in run-off, etc., likely to be obtained by varying the spacing of, say, graded banks on land under an exploitative wheat-fallow rotation. Here three different sets of plots eight feet wide were compared. One set was standard 136 feet long, one set double this length, *i.e.*, 272 feet (1/20 acre), and one set half normal length, *i.e.*, 68 feet (1/80 acre). There are two plots of each length, one under fallow wheat and the other, stubble fallow each year, making up the wheat-fallow rotation.

These plots are located on a soil of granitic origin, of a light sandy loam texture. This soil has little natural cohesion when wet, particularly under this exploitative cropping programme, and while it absorbs water readily at first it soon becomes saturated and when run-off results soil losses are usually fairly high.

TABLE I.
Length of Slope Experiment.
Cowra Soil Conservation Research Station.
1943–50 (*inc.*).

	Total Run-off Results in Inches.		
	Double Length.	Normal Length.	Half Length.
Fallow–Wheat ...	20.282	25.318	28.893
Stubble–Fallow ...	5.573	8.864	11.773
Total	25.855	34.182	40.666
	Total Soil Loss Results in Pounds/acre.		
	Double Length.	Normal Length.	Half Length.
Fallow–Wheat ...	192,730*	97,205	80,897
Stubble–Fallow ...	30,639	23,663	23,159
Total	223,369	120,867	104,056

* Particularly high, due to a loss in 1950 of 123,432 lb. of soil from Plot A under this treatment.

Fig. 4.—Rilling on double length plot causing heavy loss of soil.

These results have not been analysed but appear to support the conclusions drawn by Miller (unpublished) from the results 1944-48 inclusive. He found the effect of plot length on run-off to be sufficient to over-rule all other factors, such as variations in the condition of the plots and varying rainfall characteristics, to give significantly different results for the various plot lengths. Trends in soil loss, however, were not so pronounced at that stage and are still not significant.

His conclusion was that "as the length of the plot increases, for this particular soil type at least, the run-off decreases proportionally, but the smaller run moves proportionally more soil".

This is the result to be expected. Water flowing from the top of the longer plots has much more chance of soaking into the ground, but the water that does reach the receiver has had all the extra time and a distance in which to obtain a full soil load, so carrying proportionally more soil per unit of run-off.

Hilly Grazing Run-off Experiment.

This is a recently initiated study aimed at testing, under plot conditions, the effect of different grazing intensities on an area of moderately steep, un-topdressed, natural pasture.

Two grazing intensities are being used, heavy, where the ground will be grazed as close and frequently as growth will allow, and light where conservative grazing, maintaining a suitable vegetative cover, commensurate with economic grazing management, will be practised.

Standard receiving equipment is being used and there are three plots under each treatment.

The only results available to date are from a storm of 1.02 in. in $5\frac{1}{2}$ hours on 10th December, 1951. Run-off was very light but indicative of the trends expected. All three heavy-grazed plots shed water, giving average figures of 0.018 in. run-off and 8 lb. soil lost per acre. None of the light-grazed plots gave any run-off.

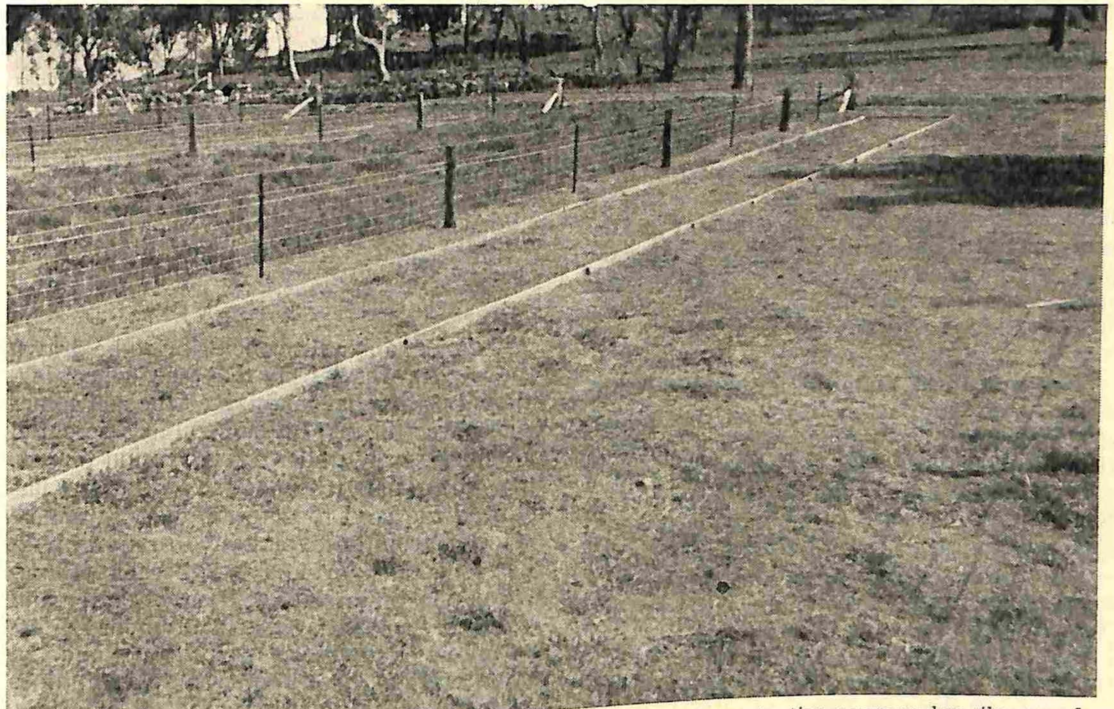

Fig. 5.—Grazing plots on natural pasture showing the difference in protective cover on heavily grazed and lightly grazed areas.

Subsoil Ripping Run-off Experiment.

The above experiments involved the use of rather complex equipment to minimise the sampling errors, particularly for soil loss determinations and to measure any small differences between treatments. In 1946-47 another experiment was laid out using simplified equipment. This consisted of 800-gallon tanks as receivers below appropriate concentrating flumes. It was aimed solely at measuring the effect on run-off of a subsoil treatment, which, if to be an economic method of decreasing run-off, would have to have a considerable effect on the quantity of water entering the soil.

The investigation has been discontinued and results obtained, together with a short discussion of the general layout, are being prepared for separate publication. Briefly, in this instance no significant reduction in run-off was obtained in this rather sandy, semi-podsolized soil of granitic origin. The ripping was done on the contour to a depth of 18 inches.

Return of Land to Cultivation.

Prior to 1940 the area where the run-off and soil loss experiment was established had been cropped fairly intensively on a wheat-oats-fallow rotation. When the experiment was being established in 1941-42 the area around the individual blocks was sown to improved pasture of lucerne, sub. clover, etc., and remained so until recently, when two plots were added to each block of the experiment, and returned to cultivation under a wheat-fallow rotation.

The first three plots were fallowed in the spring 1948, and sown to wheat the following autumn, the remaining three plots were not fallowed until the spring of 1949 and cropped for the first time during 1950. Unfortunately, recordings for these plots could not be commenced until September, 1949, so no records are available for the fallow and crop of the first plots fallowed. During the wet year of 1950, however, some very interesting comparisons were obtained between the various phases of these plots and the plots of the two arable rotations in the main experiment.

Table II shows the mean run-off and soil loss per plot for the various phases of these treatments, together with the significance levels obtained.

TABLE II.

Significance of Results from Phases of Arable Rotations.

Run-off and Soil Loss Experiment.

Cowra Soil Conservation Research Station, 1950.

Mean Run-off Results.

Treatment.	Mean Run-off/ Plot. (Inches per Acre).	Significance.
Fallow-wheat (W-F)	8·979	Sig. higher than all other treatments.
„ „ (RFP)	4·045 } A	There is significant difference between groups A and B, but the differences between means within each group are not significant.
„ „ (WLF)	3·817 } A	
1st. Yr. Ley (WLF)	1·504 } B	
Ley-Fallow (WLF)	1·216 } B	
Stubble-Fallow (W–F)	0·944 } B	
„ „ (RFP)	0·316	

(Minimum difference for significance between means at the 5% standard = 2·190).

Mean Soil Loss Results.

Treatment.	Mean log. of pounds. Soil Lost/ Acre.	Significance.
Fallow-wheat (W–F)	4·363	Sig. higher than all other treatments.
„ „ (WLF)	3·754 } A	There is significant difference between groups A and B, but not within these groups, using the 5% standard.
„ „ (RFP)	3·657 } A	
Stubble-fallow (W–F)	2·138 } B	
Ley-Fallow (WLF)	1·973 } B	
1st. Yr. Ley (WLF)	1·903	
Stubble-Fallow (RFP)	1·208	Sig. lower than all other treatments.

(Minimum difference for significance between means at the 5% standard = 0·580. At the 1% level this minimum would equal 0·793).

Abbrev. (W–F) = Wheat–Fallow Rotation.
(WLF) = Wheat–Ley–Fallow Rotation.
(RFP) = Returned from Pasture.

The most apparent conclusion to be drawn from these results is that the wheat-ley-fallow rotation has maintained the soil somewhere near the run-off and soil loss potential of land recently under a long period of pasture, but the wheat-fallow rotation has allowed the land to deteriorate as might be expected from an exploitative rotation, with the result that during the vulnerable fallow-wheat phase the soil sheds more water and loses more soil than either land under wheat-ley-fallow or the recently cultivated land. In other words, the three-term rotation does seem to be having the desired effect of improving soil texture, making it easier for the water to enter the soil.

METEOROLOGICAL OBSERVATIONS.

The soil conservationist is vitally interested in climate. The reliability with which the growth of vegetation, both crop and pasture, can be expected, together with all other factors affecting plant growth, is intricately associated with the erosion hazards of a particular area. They are particularly important when refinements are contemplated to the basic approach to erosion control or prevention.

Perhaps one of the greatest causes of erosion in Australia is the unreliability of rainfall and season coupled with the failure of the farmer and others associated with the land to make sufficient allowances for this factor.

With these points in mind climatological stations were set up on Cowra and other research stations soon after their establishment. To-day, records are available of maximum and minimum temperatures, frosts, wind mileages per day, evaporation and rainfall, etc. These recordings are all obtained by daily reading of instruments. As well, special automatic recording instruments plot on graphs continuous records of all variations during the day of temperature, barometric pressure and humidity, whilst an automatic rain gauge charts the intensities of fall of all rain. This latter recording is particularly important to the soil conservationist designing mechanical control measures, where emphasis is on the quantities of water that will have to be handled within critical time periods.

TABLE III.

Maximum Rainfalls Recorded for the Durations Indicated.

Cowra Soil Conservation Research Station, Nov., 1941—Jan. 1952.

Duration ...	5 min.	10 min.	15 min.	20 min.	30 min.
Points of rain ...	40	57	78	82	89
Duration ...	1 hr.	2 hr.	4 hr.	8 hr.	12 hr.
Points of rain ...	96	133	145	150	160

PLANT STUDIES.

Vegetation must play a very important part in any erosion control or prevention programme, and as the research programme of the Soil Conservation Service expanded it was necessary for plant nurseries to be established on the various research stations.

This work commenced at Cowra in 1950 and to date approximately 190 samples of seed and plant material have been sown in nursery rows. These represent some 140 different species, the majority of which are imported from overseas. However, attention is also being given to promising native species and strains wherever they are found in the field.

Broadly, the aims of this work are to identify, multiply and distribute any plant likely to be of use to the soil conservationist. These can be divided into three main sections: (a) waterway plants; (b) plants for revegetating specialised areas; (c) general soil-protecting species. Both grasses and legumes are being studied.

(a) The ideal waterway grass must be capable of forming a complete, dense, protective sward at ground level, so binding the soil to withstand heavy flows of water, even when the plant itself be either dormant or completely defoliated. The latter case, it should be remembered, would only be expected under very exceptional circumstances on a well managed waterway. At the same time, the grass should be capable of producing a good bulk of palatable and nutritious feed to provide best economic use of the waterway.

It must be suitable for easy and economical establishment under the adverse conditions encountered on newly formed waterways, which are often formed with a seed-bed of raw subsoil clay. The grass must quickly develop complete protection of the waterway surface so that a minimum of time elapses between forming and availability for use. Ideally the grass should be established by seed, which should set readily, of a type easily harvested, threshed and handled.

The ideal grass is a perennial. This is not so important with the legumes, but they must be capable of persisting in later years. The legume must above all else be an effective nitrogen-fixer, its main job in the waterway being to raise as rapidly as possible the fertility of the initially poor soil, so ensuring maximum vigour of the main protecting species in later years.

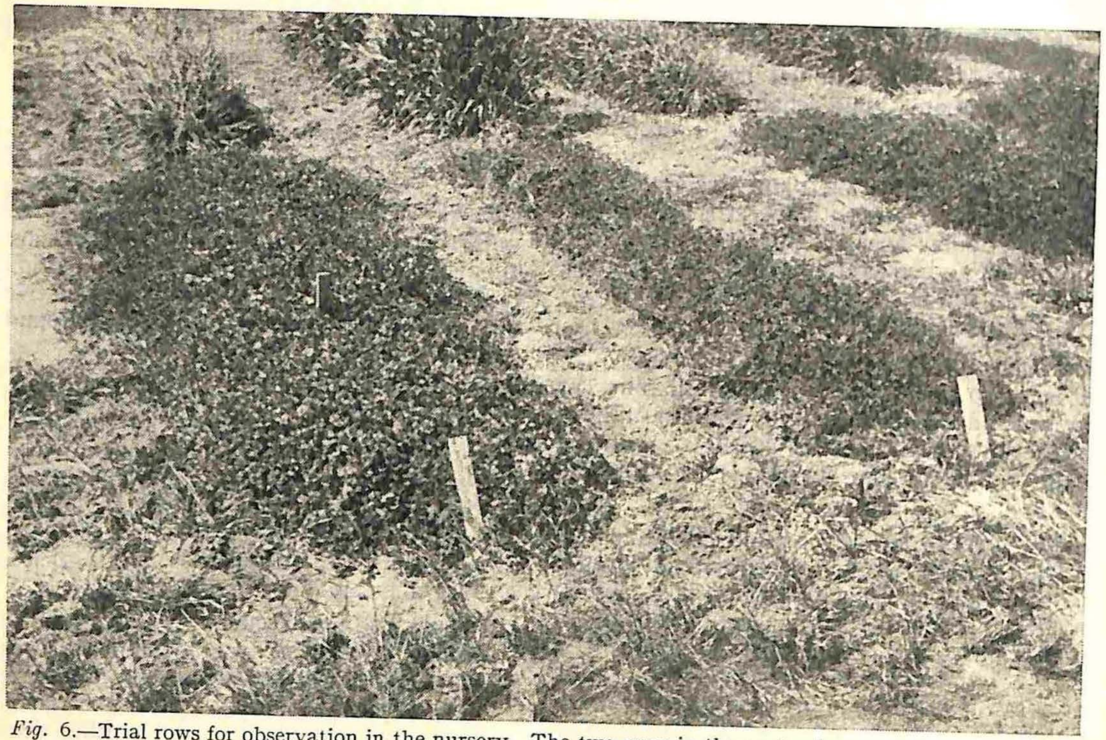

Fig. 6.—Trial rows for observation in the nursery. The two rows in the centre foreground are different strains of subterranean clover.

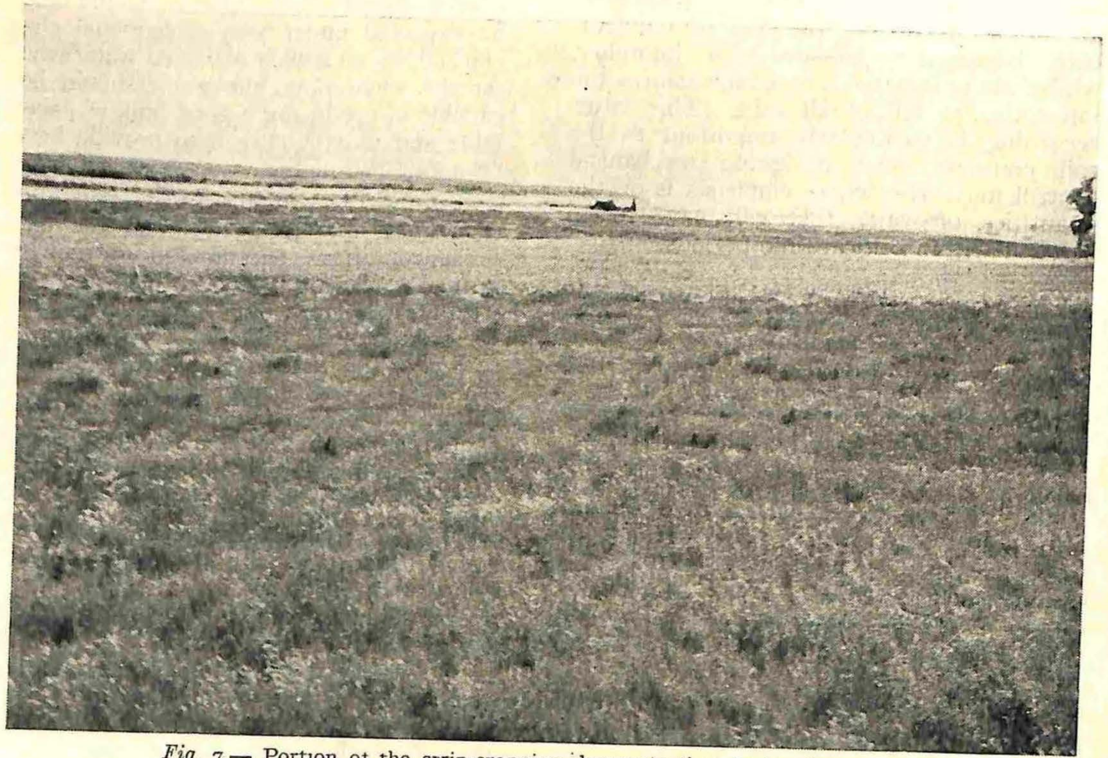

Fig. 7.— Portion of the strip-cropping demonstration during haymaking.

(b) Plants falling into the second section of the work would be used on such areas as the wind scalds of the western districts, coastal sand dunes requiring stabilisation, salted areas on the tablelands, or chronically overstocked areas of considerable erosion hazard, each of which demands different characteristics, the main one being the ability to grow under the individual conditions, so initiating revegetation. At Cowra, of course, such species can only be roughly identified and must be further tested under actual conditions, before final selections for multiplication are made.

(c) The above two form the major objectives of this work, but note is also being taken of the general agronomic characters of the various plants tested, for one vitally important phase of any conservation programme is the protection of arable land during the revitalising pasture stages of the rotation.

At present in southern areas of N.S.W. subterranean clover and Wimmera rye grass are used as temporary pasture, under a wheat-fallow rotation. This has one disadvantage from the conservation angle, because under anything but very careful management the land is left completely unprotected during the most vulnerable stages of the year, the late summer and early autumn.

One way of overcoming this would be the inclusion of a perennial grass with the subterranean clover. This would have to be a species that could be sown with the last wheat crop (when the clover is sown), establishing underneath the wheat without seriously affecting yield or interfering with harvesting. It would also need to be easily eradicated when cropping is recommended. Such a plant would enable a wider rotation than the present three-year phase. This need not result in any decrease in the frequency of cropping, but a change would have to be made in the distribution of crop years in the wider rotation.

Besides providing protection of the soil by the perennial root stocks, there are other arguments in favour of the use of perennial species in the pasture mixture. One of these is the widely recognised superiority of effect of the roots of perennial grasses on the stability of soil aggregates. Not only do they increase the number of aggregates formed over a given period of time, but they also have a more lasting effect.

Plant studies on the research station are directed towards selection of suitable species for all these purposes.

STRIP CROPPING DEMONSTRATION.

In 1941 a demonstration of strip cropping was commenced on an area of rather steep land that had for some years been cultivated on a rotation of wheat-oats-fallow. This demonstration consisted of alternate chain wide strips of wheat and lucerne without any form of mechanical controls. The results obtained under these conditions were so unfavourable that the project was abandoned the following year, the whole paddock being pasture furrowed and sown to an improved pasture of lucerne, sub. clover and rye grass. A good stand was obtained.

The paddock remained under this treatment until 1946 when it was again decided to attempt a demonstration of this form of land utilisation. The first strips were ploughed in April, 1946, and the paddock has been under the various treatments of the demonstration to date. On this occasion the design consisted of small, widely spaced graded banks, with a number of strips between each bank. The two crop rotations, wheat-fallow and wheat-ley-fallow are compared. Much of this land is up to 10-12 per cent. slope, normally considered too steep for cultivation.

Observations on the behaviour of this area have already indicated the value of this treatment. During the period of four years under pasture the stability of the soil had improved so that the excessive rilling that occurred in 1941 was not repeated. However, it is doubtful if this is a practicable method of land use, because the ley strips cannot be grazed during the winter when crops are growing on the other strips. This makes cultivation difficult owing to the bulk of growth on the ley strips, and the subsequent crop is weedy.

In 1951 a cut of pasture hay was taken to utilise this growth and assist cultivation. A good yield of hay was obtained, but this may not be the case every year. If this method of removing excess growth as hay is to be used, the hay must be fed back to stock grazing in the paddock, otherwise part of the value of the rotation in maintaining fertility and stability of the soil will be lost.

CONCLUSIONS.

This is purely a progress report, as the majority of the studies mentioned are of a long-term nature, and will be considered for many years more before final conclusions are drawn. The results to date do indicate the value of the general approach to the erosion problem.

One thing that becomes apparent from these results and general observations on Cowra Research Station is the importance of land management in the prevention of soil depletion. It is of little use carrying out costly mechanical control measures if no attempt is made to reach the core of the trouble and remove the factors that made these measures necessary. Mechanical treatment should always be regarded as a temporary, but essential measure, while the heart of the trouble is being treated, namely, lack of soil fertility and stability due to unwise land usage. The best method of erosion prevention is through the maintenance of a complete, effective vegetative cover during all but the short periods when land is being prepared for sowing. Where erosion has occurred and control is necessary, mechanical works are usually essential prior to the final stabilisation by the application of wise land use measures.

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WIND ACTION IN RELATION TO EROSION

BY

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THE problems related to wind erosion and its control have received considerable study over recent years in many parts of the world. This has become necessary because of the increasing havoc wrought by wind erosion in the low-rainfall agricultural and pastoral areas of U.S.A., South Africa, China and Australia.

Much has been heard of the damage to agricultural land caused by wind erosion in the United States. It has been estimated that wind erosion, resulting largely from cultivation, overgrazing, and depletion of the humus supply, has affected about one-sixth of the total land areas, principally in the semi-arid regions of the Great Plains. The great effort which the United States has made towards solving the problem in marginal cultivation areas has been widely publicised, and should serve as an inspiration to other countries which are in a similar position.

In Australia, wind erosion is active over the greater part of the continent. This is because our continent has only a relatively narrow fringe of land adjacent to the seaboard which receives a plentiful supply of rain. The remainder of the country is arid or semi-arid, sparsely vegetated and composed of light-textured soils which are extremely vulnerable to wind action. With the notable exception of the agricultural lands of the Victorian and South Australian mallee, the country suffering from wind erosion in Australia is used mainly for grazing by sheep and cattle.

In N.S.W. much of the country lying west of the 18-inch isohyet (roughly, west of a line drawn through Walgett, Condobolin and Narrandera), is suffering in at least some degree from wind erosion. The importance of this land to Australia's economy is obvious when it is pointed out that the Western Division of this State alone supports around six million head of sheep. In order to preserve these areas for grazing purposes, it is imperative that the wind erosion and pasture degeneration that have taken place since man introduced his domestic animals must be halted.

THE ERODING ACTION OF WIND.

Before going on to discuss the causes and results of wind erosion, a description of wind flow and a concise account of the forces involved in the initiation of soil movement by an erosive wind are presented.

Wind Flow.

Two types of wind flow are recognised, viz., streamline and turbulent flow.

Under conditions of *streamline* flow, the air consists of a series of layers each moving at different velocities, the layer closest to the soil surface moving the slowest and the layer farthest removed moving the fastest. There is no appreciable exchange of air from any layer to the one above or below it, and the friction exerted by the surface of the air (termed the "drag") is proportional to the average velocity of flow.

This picture of air flow breaks down when the velocity is raised above a certain critical value which is in the vicinity of 2 m.p.h. (or one metre per second). Wind erosion would not occur at such low speeds, so for all practical purposes the consideration of the effects of streamline flow can be neglected.

Above speeds of 2 m.p.h. (for the open atmosphere) the wind flow is described as *turbulent*. Briefly, this means that there is now a great deal of exchange of air from one layer to another; large air "eddies" stray about in haphazard fashion. Thus any measurement of wind velocity under these conditions represents only the average forward motion of the wind as there are large pockets

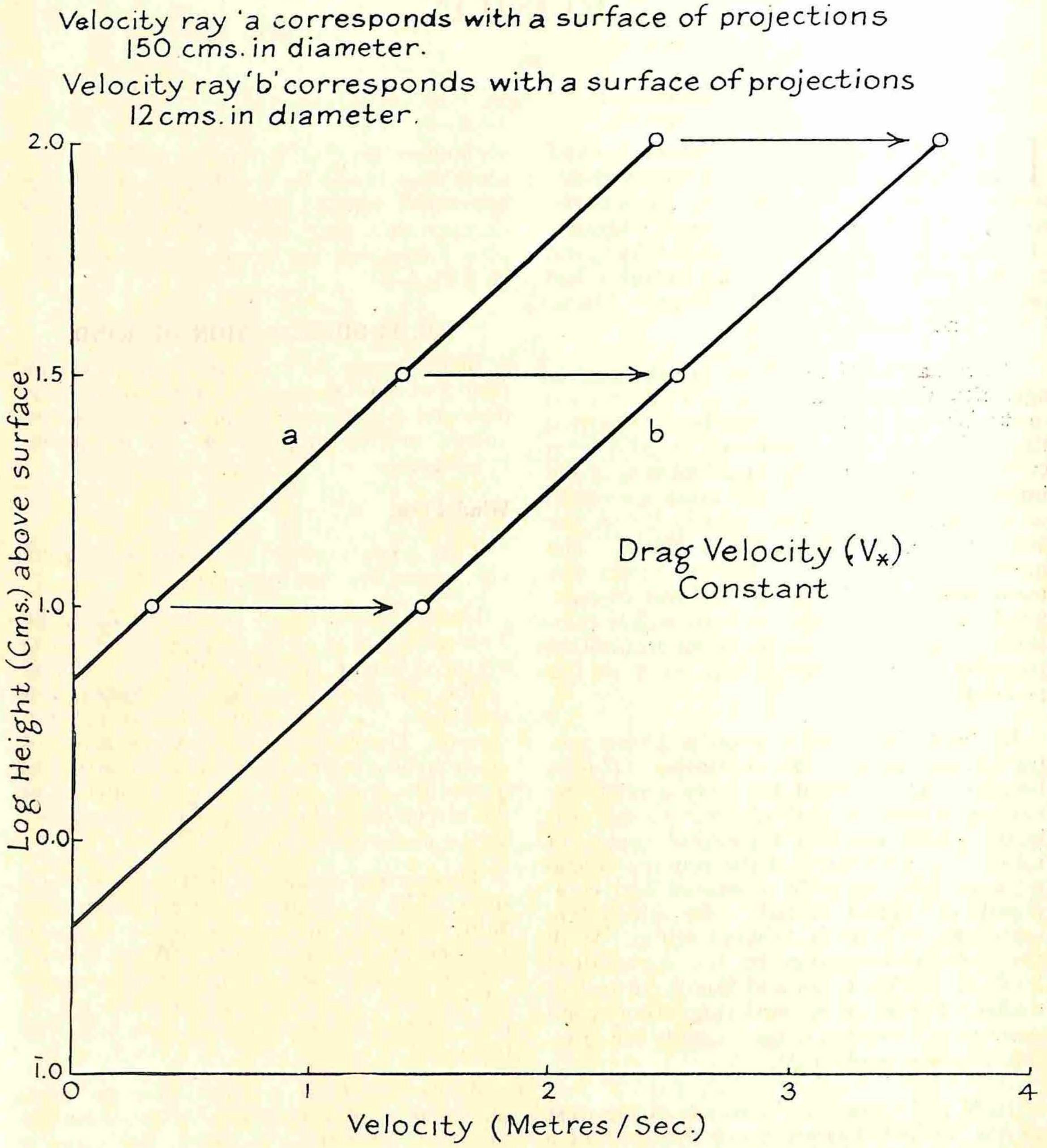

Fig. 1.—*(After Bagnold)* Illustrating velocity-height relationships.

of air that are moving up and down from side to side within the main mass travelling downwind.

The most important feature of a turbulent wind is its velocity-height distribution. If velocity measurements are made at a series of heights above ground level and these recorded velocities are plotted against their corresponding logarithm of the height, a straight line results. Reference to Fig. 1 will make this clear.

Under these conditions, the "drag" (or the pressure exerted by the wind on the surface) of the wind is proportional to the square of the velocity, and the velocity at any height now varies as the logarithm of the height. "Drag" may be considered as similar to the effect of a carpet being dragged over the soil.

If the straight line obtained in Fig. 1 (which we shall call a "velocity ray") is continued till it meets the log-height axis, then we have for any given surface a certain small but definite height above this surface at which the wind velocity is zero. It was found experimentally that provided the size of the grains constituting the surface remained constant for any series of wind strengths, the height above the surface at which zero velocity occurs remains the same. The height of this layer of zero velocity (which we shall call *k*), is approximately equal to one-thirtieth of the diameter of the particles constituting the surface. Fig. 2 shows the velocity rays obtained from measurements of wind velocity over the same surface under two different wind strengths, and shows how *k* is measured:

The value assigned *k*, when determined as above, is given the name *the surface roughness*. Any object which is present on the surface will be reflected in the *k* value. In the case of a bare soil surface, the individual soil grains and aggregates are the only forms of roughness, but the presence of grass, trees, boulders and dead timber are all special forms of roughness and will influence the height of *k*. If the value of *k* for the surface litter is equal to or greater than the diameter of the largest grains of soil on the surface, then these grains are enclosed entirely within the envelope of zero velocity, and so the wind will exert no direct pressure on them.

MOVEMENT OF SOIL PARTICLES BY WIND.

In practically any soil type (with the exception of dune sands) there exists a range of soil particles from finest clay (below 0.002 mm. in diameter) up to large aggregates and clods which may be 50 mm. or more in diameter. It is clear that some of these finer fractions will be extremely susceptible to removal by wind, while others will be virtually non-erodible. There is thus an erodible and non-erodible fraction in our soils.

The erodible fraction may be removed by wind in any of the following ways, depending on the size of the soil particle: "saltation," "surface creep," or "suspension." A description of the terms follows.

(*a*) *Saltation.*

More soil loss occurs through this form of movement than by the other two types. After being rolled along the surface by the wind, the soil particles suddenly leap almost vertically to form the initial stage of the movement in saltation. Some grains may rise only a short distance, while others may jump to heights of over a foot, depending directly on the initial velocity of rise from the ground. Most grains do not exceed an initial jump of more than one foot.

Once the soil particle becomes air-borne, it achieves considerable forward velocity due to the direct pressure of the wind acting on it. From the summit of its initial rise, the grain gradually falls back to ground level, striking the surface at an angle of between 6 and 12 degrees from the horizontal. On striking the surface, the grains either rebound and continue their movement in saltation, or lose most of their energy by striking other grains, causing these to rise upward, and themselves sinking into the surface or forming part of the movement in surface creep.

The forward velocity of a grain moving in saltation increases from the moment it rises into the stream of moving air until it

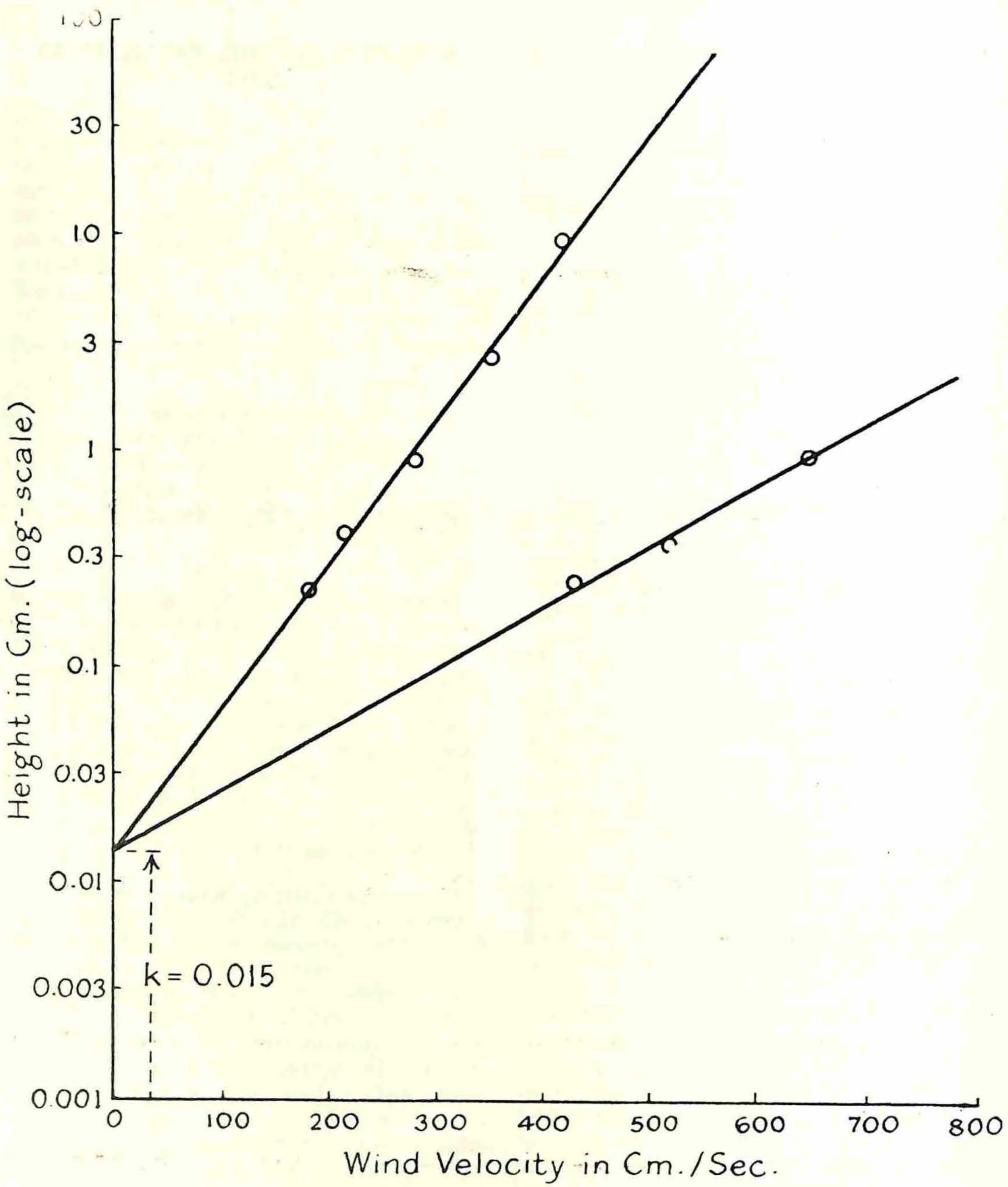

Fig. 2.—(*After Bagnold*) Illustrating effects of "surface roughness" on winds of different strengths. Both rays meet at *k* as will other rays for this one surface.

strikes the surface at the end of its leap. The path described by a grain in saltation is shown in Fig. 3. It will be observed that the length of leap is approximately eight times as great as the height. As most grains do not rise beyond one foot in height, the maximum length of leap would be in the vicinity of eight to ten feet.

(*b*) *Surface Creep.*

It has been pointed out above that the forward velocity of a grain in saltation reaches its maximum on impact with the surface. This velocity has been derived from the wind during the time the grain has been air-borne. On striking the ground, this grain hits other grains and may either project them into the air (in which case they join the saltation flow) or roll them along the surface. Grains as large as 3 mm. may be rolled along the surface due to the impact of descending grains in saltation. To this rolling movement, the name "surface creep" has been applied.

It does not reach the same level of importance as saltation and suspension flow in soil loss.

(*c*) *Suspension.*

Very fine soil particles, that is, those in the silt and clay fractions, are removed from the soil by the direct pressure of the wind only with extreme difficulty. This is because discrete soil particles of this size are too small to project beyond a viscous "envelope" of air of zero velocity existing at the soil surface. Movement of these small particles into the air stream is again brought about by the impact of grains in saltation. These saltating grains blow up little craters of finer particles on impact. Because grains below 0.2 mm. are very light, once they are thrown into the wind they are carried upward due to the wind's internal eddies, and may travel great distances before falling to earth when the wind speed drops or when rain falls.

Of the various fractions transported by an erosive wind, only that portion travelling in suspension will be moved very far from the site of erosion. Particles travelling by saltation have a leap of about only 10 feet and the surface creep flow is very slow and would soon be brought to a halt by obstructions in the field.

Saltation, then, is the main menace, as there would be no surface creep without it and also very little removal of fine dust by suspension.

FACTORS IN THE OCCURRENCE OF WIND EROSION.

Following discussion of the factors concerned in wind flow and the mode of soil loss, we are in a position to apply these theoretical considerations to the problem of wind erosion in the field.

The factors influencing wind erosion are numerous and hence add considerably to the complexity of the problem. The most important of these factors are discussed below; it will be seen that variations of the air, of the surface and of the soil are responsible for the erosiveness of any particular area.

Air.

Velocity.—For any given size of soil particle, there is a critical wind strength at which the pressure of the wind on the exposed particle will set the latter in motion. For particles above 0.05 mm. in diameter, as

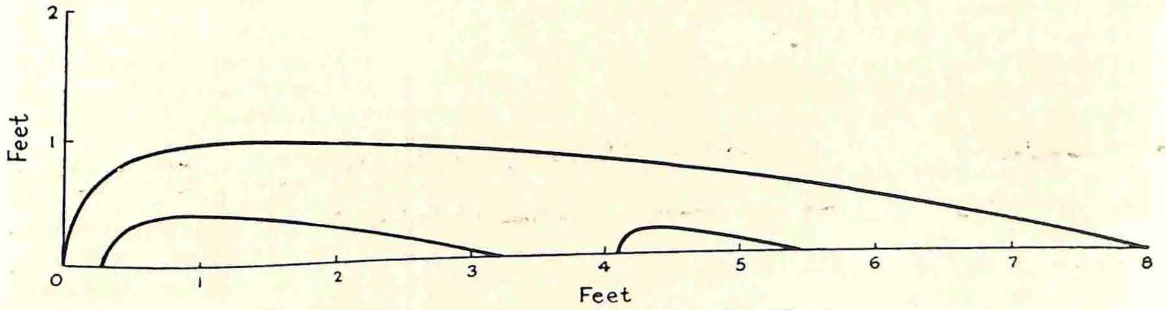

Fig. 3.—(*After Bagnold*) Typical grain paths.

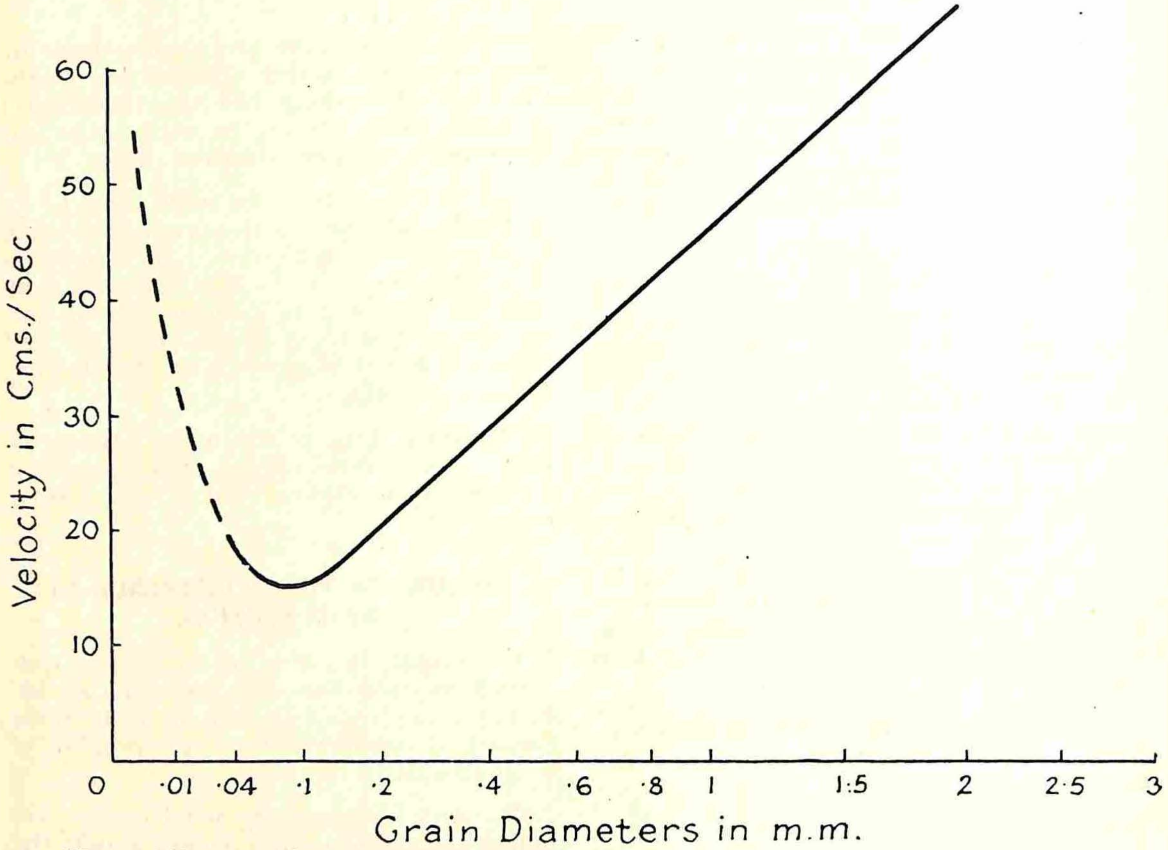

Fig. 4.—(*After Bagnold*) Illustrating relationship between grain diameter and the wind speed necessary to initiate movement.

the diameter of the particle increases, so the wind speed necessary to set the particle in motion increases. Thus, the higher the wind speed, the wider the range of size of individual particles susceptible to movement becomes.

When the grain diameter falls below 0.05 mm., the surface becomes "smooth" and important changes take place in the air flow close to the surface grains. Individual grains now cease to act as isolated obstacles in the path of the wind, and the drag is more evenly distributed over the whole surface. Consequently, a relatively greater wind velocity is required to set the first grains in motion. A "smooth" surface rarely exists in the field, so for all practical purposes this condition may be neglected.

Reference to Fig. 4 will show the relationship of grain diameter (for sand) and the wind speed necessary to initiate movement.

Turbulence.—The greater the degree to which turbulence is exhibited by a wind, the more destructive its effect will be over a field that is eroding. The "drag" of turbulent eddies increases the height that grains reach in their initial rise during saltation, and so they are subjected to the forward pressure of the wind for longer periods. This in turn increases their leap downwind and adds to their kinetic energy which is expended on impact with other grains on the surface.

It is this energy derived from the wind that gives to grains in saltation their great abrasive power. Large non-erodible clods and aggregates are thus abraded into erodible fractions by the impact of saltating grains. The protective value of soil aggregates may thus be lost under an erosive wind if there is sufficient saltation originating from exposed parts of a field.

The erosive power of wind is dependent on the rate of increase of velocity with log-height (see Fig. 1). If the wind velocity rises steeply within the first foot of the surface, then grains in saltation are moved downwind with increased velocities. This increases the amount of soil lost through saltation, and as the other forms of soil movement are dependent on saltation, the over-all loss of soil will be increased.

Surface.

Roughness.—Referring to Fig. 1 it was shown that for any wind strength there remained above the soil surface a layer of air of zero velocity, the height of this layer being approximately equal to 1/30th of the diameter of the particles constituting the surface.

If the soil surface is covered with non-erosive clods (anything greater than 3 mm. diameter will not be moved by the direct pressure of the wind alone under wind strengths met with in the field) then there exists an envelope of still air near the surface in which the finer, more erodible fractions can find refuge from the wind. Loose heavy self-mulching soils, or roughly ploughed ground, are by reason of this, resistant to wind erosion.

Cover.—This is the most important factor in wind erosion control. A complete cover of vegetation, whether it be a surface cover of grass or a tall cover of timber, absorbs all of the "drag" of the wind so that no pressure is transmitted to the underlying soil.

If the ground cover is composed of edible grasses and herbage, the grazier should endeavour to stock his land so that at no time is the cover so thin that the surface soil is exposed to the wind. The importance of perennial species in the ground cover cannot be over-emphasised, as a degree of permanence of cover is thereby assured. Herbage, while providing an excellent ground cover when it is green and succulent, soon dries off after seeding and will disintegrate rapidly thereafter. Its value in protecting soil is thus only of a temporary nature.

Topographic features.—Particularly in treeless country, the intensity of wind erosion is directly related to changes in topography. Elevated areas are frequently seen to be severely wind eroded while the lower surrounding country may be erosion free.

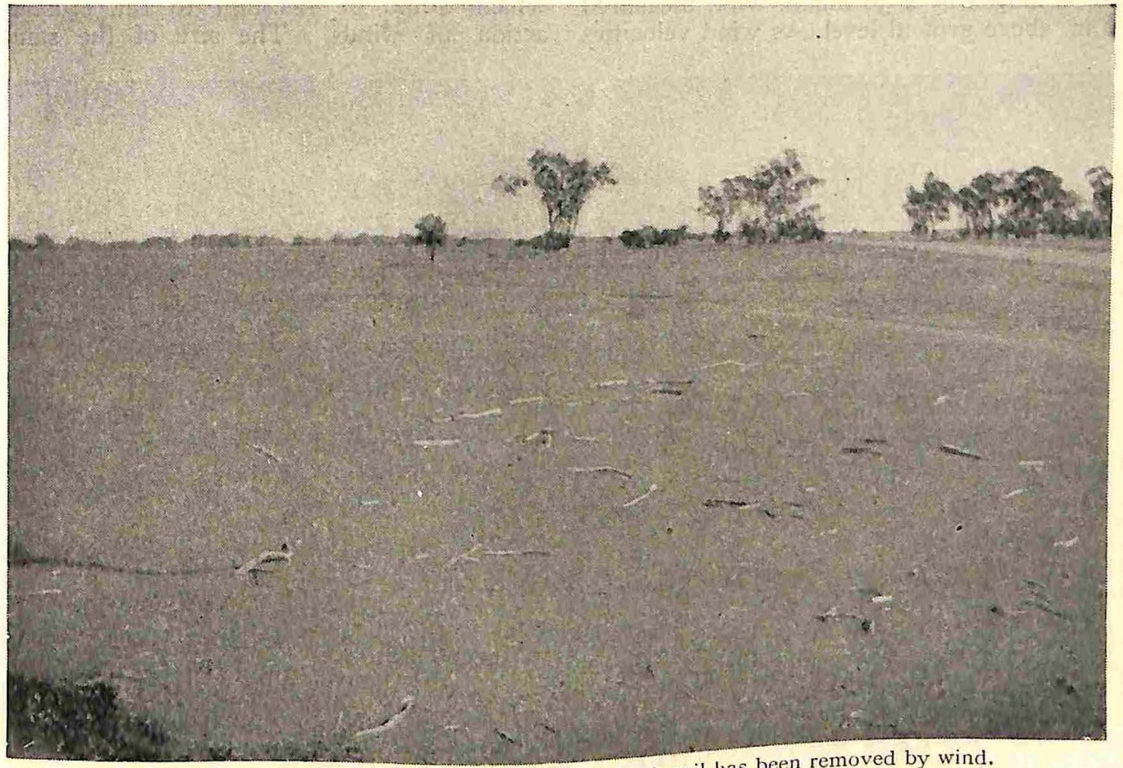

Fig. 5.—Hard scald with smooth surface from which soil has been removed by wind.

The elevated areas are naturally more subject to the drag of the wind as they project into regions of higher velocities. The tendency for stock to camp on elevated low rises is also a factor in their greater susceptibility to erosion.

Soil.

Different soil types vary considerably in their susceptibility to wind erosion. The properties of any particular soil type which will determine its susceptibility to erode are chiefly its structure and moisture content.

Structure.—Soil structure may be defined as the degree of aggregation (or sticking together) of the separate particles which go to make up the soil. The chief agents causing aggregation of individual soil particles are the clay fraction, humus, organic acids and lime. Soils vary from those displaying a complete lack of structure (such as dune sands) to those showing a high degree of aggregation as is found in the soils of our alluvial deposits (self-mulching soils, etc.).

It has been shown that soil particles greater than 3 mm. in diameter are too large to be moved by a 30 m.p.h. wind measured 6 in. above ground level. As wind velocities during dust storms rarely reach this intensity, a soil surface composed of aggregates of this size would be resistant to wind erosion provided saltation from an adjoining area is not subjecting the aggregates to abrasion.

This is well illustrated in our soils of the Western Division. The heavy, black and grey clays of the inland river systems are predominantly "self-mulching" in character, that is, their top soil is composed of aggregates of approximately 4 to 5 mm. in diameter and they are quite resistant to wind erosion. These characteristic aggregates are not destroyed by rain and are a constant feature of these soils. The grey dust that is seen blowing from these soils is due to a temporary loss of structure caused by some mechanical agency, for example, trampling by a mob of sheep or cattle.

On the other side of the ledger, the loose sands and sandy loams of the West Darling region are particularly susceptible to wind erosion primarily because of their lack of structure. Because of low clay content, lack of organic matter and moisture, these soil types are not aggregated into stable particles which would be resistant to the erosive action of winds. The size of the sand grains constituting these soils is such that they are easily moved by erosive winds, and they thus present a serious soil erosion menace in dry seasons when ground cover is scarce.

Fig. 6.—Soft scald with numerous cracks and nutty structure of the soil which is easily broken.

Moisture.—The water-capacity of a soil has a direct bearing on its susceptibility to wind erosion.

Soil aggregates contain a certain amount of "space" which is filled either by air or water. A moist aggregate is heavier and requires a higher wind velocity to initiate its movement than a dry one. Moisture surrounding separate soil particles causes them to stick together and gives to the soil mass a degree of cohesion that is lacking in dry soil. Even loose sands exhibit quite a degree of cohesion when wet, and this will reduce their tendency to erode. Sandy soils, however, are invariably well drained and lose their moisture more rapidly than soils containing a higher percentage of clay and organic matter.

RESULTS OF WIND EROSION.

The occurrence of wind erosion in the field makes itself evident by the formation of either "scalds" or sand drifts. These features are usually complementary, as the soil removed from one area must eventually come to rest somewhere in the immediate vicinity. In cases where a clay soil composed of non-stable aggregates is eroded, then much of the soil is removed as dust in suspension and little will remain in local drifts.

Scalds.

A "scald" may be defined as the bare surface which is formed as the result of removal of top-soil by wind action. The depth of soil removed will depend on the original thickness of the erodible top-soil. Once the subsoil is bared, erosion practically ceases due to the binding action of the clay fraction in the subsoil.

Scalds vary considerably in size and are frequently discontinuous, that is, hummocks of non-eroded soil occur throughout the scalded area interrupting the continuity of the scald. These hummocks are usually caused through obstructions blocking the sand drifting from the eroding area, and it piles up due to the protection thus offered from the wind.

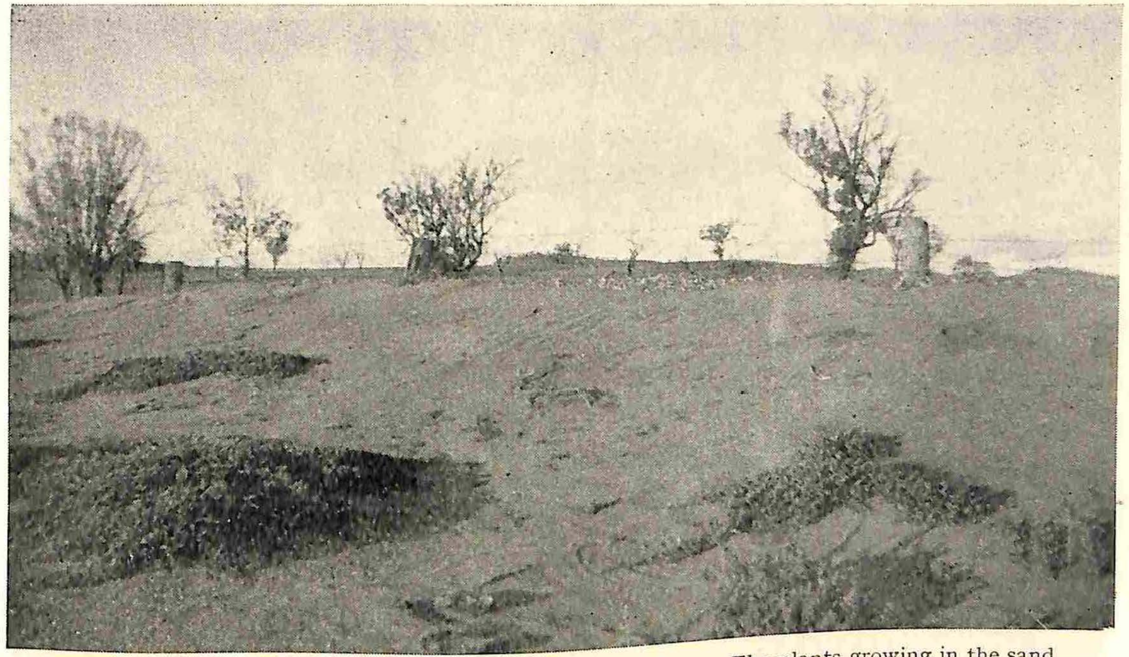

Fig. 7.—Wind-blown sand accumulated against a netting fence. The plants growing in the sand are melon vines.

Once a scalded surface is formed, soil material will not be deposited on it from surrounding eroding areas. This is because the soil particles, moving on to such an area in their saltation, bounce from the hard surface of the scald and bound higher into the moving air stream. They are thus exposed to the pressure of the wind for longer periods and hence will move across the scald with increasing speed until they strike the accumulated soil at its leeward edge. Here they strike with considerable abrasive power and dislodge other particles, the net result, however, being deposition of soil on the leeward edge of the scald.

Thus, once formed, a scald continues to expand in the direction of the erosive winds at the expense of soil from its upwind edge.

Two types of scalded surfaces are commonly met in the field. For convenience, they may be classified as either "hard" or "soft."

Hard Scalds.—These are so termed because the surface of the scald is very hard and compact, and are characterised by the absence of cracks. The surfaces may be either sandy or clayey, the latter type being extremely difficult to disturb. They are formed on soils in which the subsoil contains sufficient clay to cement the sand fraction together into a dense, massive layer. Water penetration on hard scalds is very slow and they present a difficult task of reclamation.

Soft Scalds.—The surface of this type of scald is soft and spongy and can easily be disturbed by a spade or scarifier. These scalds develop on a soil type in which the original surface soil was a sandy loam or loam overlying a clay subsoil which possesses a nutty structure. Erosion of the top-soil bares the heavier textured subsoil which is resistant to wind erosion.

Once the subsoil is exposed, the beating action of raindrops disintegrates some of the structured clay aggregates and results in the deposition over the surface of the scald of a thin layer of clay which greatly retards water absorption. Reclamation of soft scalds has been effectively carried out at our experiment plots at Condobolin. A more detailed account of scald types is given in a previous article in Vol. 4, No. 1, of this journal by Beadle.

Fig. 8.—Leeward side of large sand dune covering grazing land and killing timber.

Sand Dunes.

Scalded surfaces represent areas where soil has been removed; sand dunes and sand deposits represent areas of accumulation.

It has been stated earlier that the soil particles moving in saltation and surface creep do not travel far from the eroding area before being brought to rest by obstructions. Soil particles moving by these modes of travel constitute the sand and fine sand fractions of the eroding soil, the finer constituents being removed in suspension.

The texture of dunes and sand accumulations formed as the result of wind action are thus sandy and contain little silt and clay. They are frequently incoherent and are easily set in motion by erosive winds once the obstruction causing their deposition is removed.

Sand dunes can develop only where there is an abundance of incoherent sand unprotected by vegetation. This condition exists during drought periods in the vast expanse of mulga country situated in the West Darling district. The gradual death of the mulga over the last half-century has rendered much of this country susceptible to sand drift and dune formation. More frequently, however, sand drift results from local scald formation with accumulations of miniature dunes along fences, stock routes, stock watering places and windbreaks.

WIND AS A FACTOR IN SOIL FORMATION.

The results of wind erosion are the removal of the finer constituents of the soil from the site of erosion and the heaping-up of the coarser particles into dunes. Under conditions of extreme aridity, wind action can exert considerable influence on the surface of a continent.

Such conditions of extreme aridity are known to have existed over Australia some 5,000 years ago. During this period the extensive dune systems of our interior were formed, and in the West Darling district it is common to find remnants of sand dune systems as far east as Bourke.

We can safely assume, therefore, that the red sandy soils of N.S.W. lying between Bourke and the South Australian border have been subject to violent wind action. It is not surprising to find that these soils are very sandy in texture as they have had most of their silt and clay fractions removed by the wind.

Following this arid cycle, climatic conditions improved and the gradual vegetation of these wind-swept areas and sand dunes took place. The final stage in the plant succession constitutes the mulga scrub as we know it to-day.

CONCLUSION.

There are three main points for the grazier to bear in mind in his fight to preserve his land from the ravages of wind erosion.

Firstly, he must be able to appreciate the range of susceptibility to wind erosion of the various soil types. The vulnerable soils are those lacking structure and cohesiveness in the dry state, and are represented by the red-brown sands, sandy loams and loams which constitute the major portion of the soils in those areas of the State where wind erosion occurs. It is on such soils as these that the grazier should endeavour to maintain as much permanent protective vegetation as possible under the existing climatic conditions.

Secondly, the grazier should realise that soils are only rendered vulnerable to wind erosion when their natural protective cover of vegetation is removed. Timber is of major importance in this regard. Regeneration of young trees, but mostly of edible shrubs, should be encouraged, but not to the point where they seriously interfere with the growth of the lower herbaceous strata which supports the stock population for the greater part.

Thirdly, it is of paramount importance that the grazier should devote intensive study to the individual plant species that constitute his pastures and be able to recognise the changes that may take place in them under different conditions of grazing.

It is well known that sheep are selective grazers, that is, they show a preference for certain plants and eat them rapidly, whilst they only eat other plants when feed is scarce. These palatable species are gradually removed from the pasture sward, their place being taken by plants less palatable, and frequently of lower feed value. If overgrazing is continued, or the paddocks are not given sufficient opportunity to recover, then the ultimate result will be a pasture composed only of annual species. Annual species are able to persist under overgrazing as they seed heavily and establish themselves quickly each year. Perennials are not nearly as vigorous as annuals in their early growth and so they suffer both from overgrazing and from competition with the annuals.

When a pasture sward is composed only of annual species adequate ground cover is lacking during part of each year, and wind erosion is able to take place on susceptible soil types. Prevention or mitigation of wind erosion depends upon the regeneration and maintenance of perennial ground cover, and grazing management should be directed towards the achievement of this objective throughout our western areas.

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SOILS AND EROSION IN THE MERRIWA DISTRICT

BY

J. W. Roberts, B.Sc., Soil Conservationist.

Since soil is a direct product of the prolonged action of climatic forces on the parent rock, a consideration of the interrelation of the main rock types and resulting soils, and their potentialities for erosion in any district, is within the scope of both the landholder and the soil conservationist.

No extensive knowledge of geology is needed, and recognition of the broad classification of rock types is sufficient to give an indication of the final structure, composition and mineral content of soils formed by rock breakdown.

LOCATION.

The Merriwa district is bounded on the north, west and south by the high sandstone and basalt cliffs of the Great Dividing Range and on the east by a line running roughly through Kerrabee to Willow Tree. It embraces a considerable diversity of soils, derived from rocks of igneous and sedimentary origin. It forms part of the Hunter River drainage system; the main stream in the Merriwa district being the Goulburn River which joins the Hunter near Denman.

SOIL TYPES.

The soil types are varied in the extreme; coarse, infertile, sandy and stony soils being found close to rich heavy loams.

The major soil types are (i) black soil; (ii) red loam; (iii) sandy loam; (iv)a clay soil.

(i) *Black soil* is a heavy friable self-mulching soil, of high fertility, and when well managed capable of carrying a heavy feed cover. It is a direct breakdown product of the Tertiary basalt which has formed extensive flows in this country. As a soil for straight-out grazing, it has no equal in the district, carrying a variety of summer-growing perennial grasses and a heavy cover of trefoils in winter, giving this district the advantage of being a good winter fattening area. This soil type is illustrated in Fig. 1.

(ii) *Red loam* is usually found in close proximity to the black soil and sometimes in wide strips through it. Kurrajongs are numerous on this soil and it is the main wheat-producing part of the district. This soil is also produced from the basalt and owes its red colour to a high iron content.

(iii) *Sandy loam* comes in going south and south-east towards and over the Goulburn River. The parent rock here is mainly a Triassic sandstone interbedded with shales and conglomerates. These give rise to a relatively thin, acid soil which is rather infertile and lacking in organic matter, as shown in Fig. 2.

(iv) *A clay soil* has been formed by the weathering of shales and slates to give a fairly fertile soil mainly in valley bottoms and on top of plateaux. This soil is prevalent in the Goulburn River district further removed from the basalt flows. It has a thin upper horizon fairly rich in organic matter and plant nutrients, as shown in Fig. 3.

CLIMATE.

As soils are formed as a direct result of the action of a set of climatic agents on particular rock types, a brief indication of climatic factors prevailing in the Merriwa district is given here to indicate the conditions under which the soils of the district have developed.

Most of the Merriwa district as described above lies within a natural saucer-shaped depression, of which the climate is largely determined by a salient physiographic feature, the Cassilis Gap. This is a part of the Great Dividing Range of exceptionally low elevation, which causes a low rainfall

Fig. 1.—Black soil, which has been gullied, becoming stabilised by plains grass.

Fig. 2.—Typical shallow acid sandy soil overlying sandstone.

and a distribution of fauna, flora, and general conditions in the Merriwa area similar to those of the Western Slopes.

Precipitation, mainly in the form of rain, is an important factor in soil formation. Its leaching action is the most critical determinent of soil constitution. In this area the comparatively low rainfall has kept leaching to a minimum and, in the black soils especially, the naturally high mineral content is relatively undisturbed. Average annual rainfall is approximately 21 inches, mainly of summer incidence, and heavy storms with consequent accelerated erosion are common. During periods of drought cracks form in the black soil. These cracks are a constant problem in building earth structures such as banks and dams.

TOPOGRAPHY.

The topography has a definite effect on the tendency for erosion to begin, and different rock strata give rise to characteristic degrees of slope. For example, the basalt tends to give rise to long smooth slopes of up to 10 per cent. grade. The length of these slopes may be up to a mile with the result that each watercourse has a large catchment with correspondingly large flows during heavy storms.

In the sandstone and clay soil country however, the rocks are more folded. Due to contortion and faulting in the shales, and to jointing in the sandstones, frequent watercourses are present. These reduce the areas of the catchments and the amount of run-off flowing in each watercourse.

ECOLOGY.

To an observer riding over a property, changes in soil type are registered, perhaps subconsciously, by a glance at the tree-grass association present and their frequent changes.

To most landholders this is second nature and it is quickly seen that on the black soils a heavier cover of plains grass, white top, and trefoils, are found. The tree associated herewith is usually the white box.

The red soil carries mainly corkscrew and wire grasses, with kurrajongs.

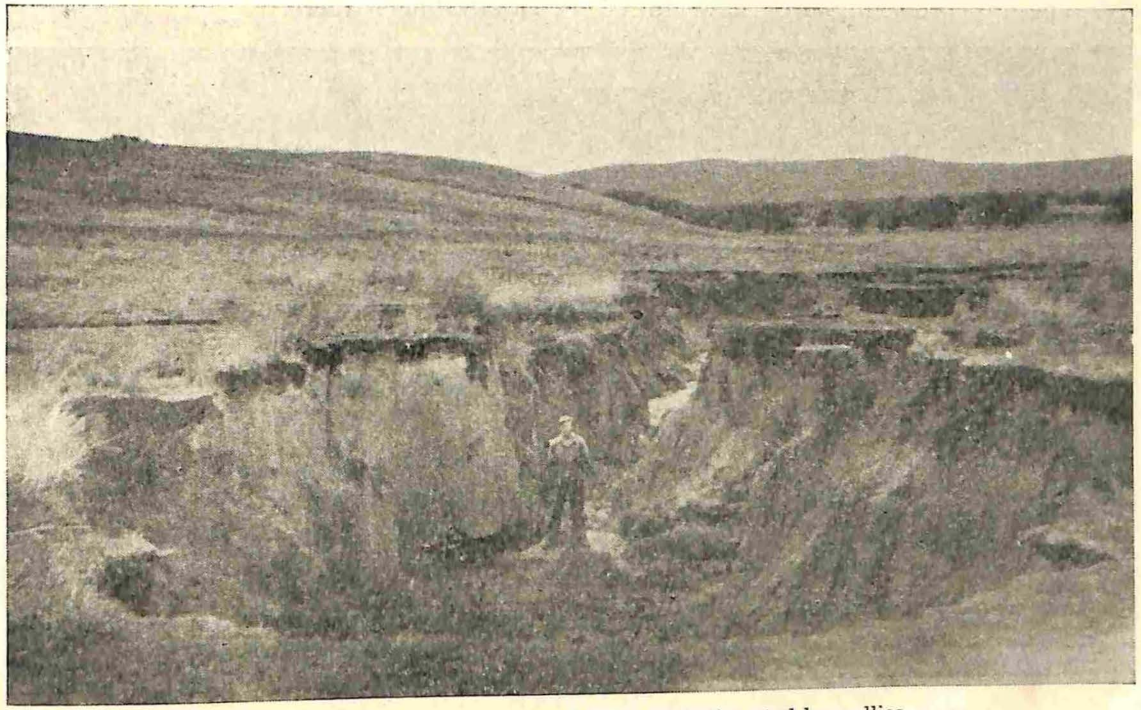

Fig. 3.—Deep clay soil in Merriwa District dissected by gullies.

The sandy soil in its natural state tends more to a scribbly gum and cypress pine association with a scrubby undergrowth, and wire and corkscrew grasses. When these are removed by stock or drought a heavy infestation of stinkwort appears.

The clay soil supports mainly white top, wire grass, some corkscrew grass, and medics, and white box and ironbarks are found on the ridges and yellow box on the flats.

WATER SUPPLIES.

The question of availability of stock water supplies is one that, in this district, has had a significant effect on the incidence of gully erosion, particularly in the black soil.

The presence or absence of water below the ground and the depth at which it will be found is directly related to the underlying rock strata.

The black soil is underlain by a stratum of decomposed basalt or "rotten rock" which is said to be permeable and dams on this soil will not hold water due to seepage. To overcome the problem, bores have to be sunk, sometimes to considerable depths, and to reach water with a minimum of boring they are usually sunk in a gully bottom. Troughs are in the lowest part of the paddock and stock travelling down to water give rise to what appears to be the greatest cause of gully erosion in this particular soil type. The tracks made by stock converge towards the watering place and concentrate run-off so much that gullies begin near the bore and extend out from it by head cutting.

The red soil, although derived from a basalt, differs in composition from the black and forms a suitable dam-sinking medium.

The other soils hold water well where dams are constructed. They are also underlain fairly shallowly by a waterbearing sandstone.

Stock tracks to water in these soil types do not lead to such serious erosion troubles as in the black soil, the cure for which seems to lie in pumping water to elevated ridges, which are usually harder, but if they are not harder, the stock tracks disperse run-off away from the watering place, instead of concentrating it there.

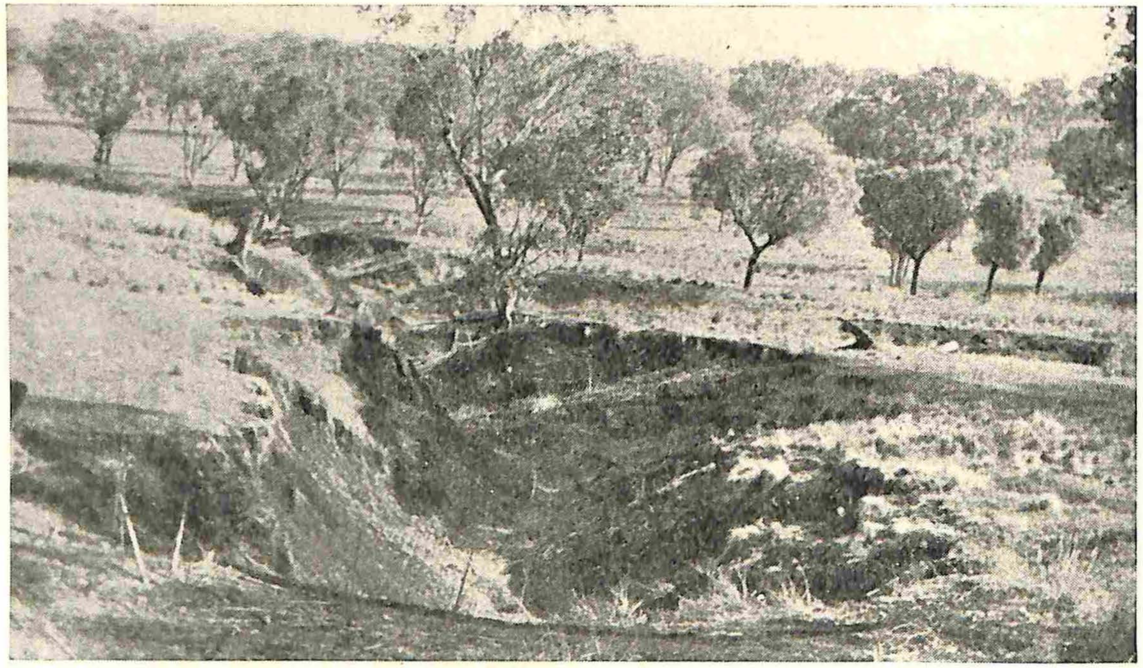

Fig. 4.—Gully in black soil on a long gentle slope.

EROSION.

The above discussion of the relation of factors of climate, topography, ecology and water supplies to the various soil types has been given in an attempt to show how these factors, so dependent fundamentally on the geology of the area, have given rise to different degrees and types of erosion.

The black soil with its high fertility and more palatable grass cover tends by selective grazing to be eaten out in preference to other soil types. It has a high humus content and due to its great depth results of sheet erosion are not serious, but gullying is all too common and obvious.

The red soil is found mainly on flatter areas and is utilised almost solely for wheat growing, and here gullying and sheeting can be controlled by working on the contour, stubble ploughing, and other soil-saving practices.

The clay and sandy soils show considerable evidence of both sheeting and gullying and in some instances severe wind erosion. Once the upper horizon is broken or removed the subsoil is very vulnerable. The usual remedial and preventive measures such as controlled stocking, introduction of new pastures species, and mechanical controls are needed here.

SUMMARY.

The erosion problems in the Merriwa district are many and unusual. Their diversity and their very existence, is dependent on the nature of the underlying rocks, from which over a period of ages, by a process of natural weathering, the soils of the area have been formed.

By an accelerated erosion, over a short time, these soils have been severely damaged and in some cases almost removed.

We cannot accelerate the climatic processes of nature in breaking down raw rock to form fresh fertile soil once the original soil has been removed by erosion, but we may do our part to protect and revitalise existing soils by revegetation, judicious stocking, mechanical controls and the application where needed of fertilisers.

MECHANICAL CALCULATORS FOR USE BY THE SOIL CONSERVATIONIST

BY

H. D. MORT, H.D.A., Soil Conservationist.

IN Vol. 7, No. 1, Dillon described the method of construction and use of a circular slide-rule for computing the discharge of graded banks and waterways, together with a series of graphs for several typical designs. In this article the author describes two other circular slide-rules of very simple construction, one to assist in estimating the discharge from a catchment, the other for estimating the width of a waterway adequate to carry this discharge safely.—Ed.

MANY minor mathematical problems which daily confront the soil conservationist can readily be overcome by the use of mechanical calculators, which, besides being considerably quicker than arithmetical working, overcome the human error otherwise likely to creep into calculations.

With a view to this, an attempt will be made in this article to explain, as simply as possible and without delving into mathematics, the construction and operation of two such calculators, viz:—

(i) A Ramser's Formula Calculator,
(ii) A Waterway Width Calculator.

Both these calculators are in reality circular slide-rules, the former being a normal rule, and the latter one designed for a specific purpose. However, as the name "slide-rule" is likely to strike fear into the souls of the uninitiated, for the purposes of this article the term "calculator" will be used throughout.

THE RAMSER'S FORMULA CALCULATOR.

This calculator consists of two concentric circular scales, the outside one being the base of the calculator, and fixed, whilst the inside one is on a moving disc. For the purposes of facilitating setting and reading a transparent cursor with a hair line is superimposed (Fig. 1).

The two scales are similar with the exception that the outside scale is plotted as a double scale from 1 to 10 through 180° and then repeated through the remaining 180°, whereas the inside scale is only plotted from 1 to 10 through 180°.

The inside or moving scale is marked with an arrow at the 1 graduation.

Construction.

The scales of this calculator are plotted logarithmically. In order to do this Table A was evolved, showing the circular measurement required for each graduation, as follows:—

The logarithms to the base 10 of numbers from 1 to 10 taken every 0.5 were obtained from tables of logarithms. Now, as a complete scale occupies 180°, each logarithm was multiplied by 180 to ascertain the circular measurement representing the logarithm of the various numbers.

TABLE A.

No.	Logarithm.	Plotting.	No.	Logarithm.	Plotting.
1	.0000	Zero	6.0	.7782	140.1°
1.5	.1761	31.7°	6.5	.8129	146.5°
2.0	.3010	54.2°	7.0	.8451	152.1°
2.5	.3979	71.6°	7.5	.8751	158.0°
3.0	.4771	85.8°	8.0	.9031	162.5°
3.5	.5441	97.9°	8.5	.9294	167.0°
4.0	.6021	108.5°	9.0	.9542	172.0°
4.5	.6532	117.5°	9.5	.9777	176.0°
5.0	.6990	125.8°	10.0	1.0000	180.0°
5.5	.7404	133.3°			

Plotting.

Taking any position on the inner scale as zero, mark with an arrow. Now plot graduations around the circumference at 31.7°, 54.20°, 71.6° and so on up to 180° and number them 1, 1.5, 2, 2.5, etc., up to 10.

A

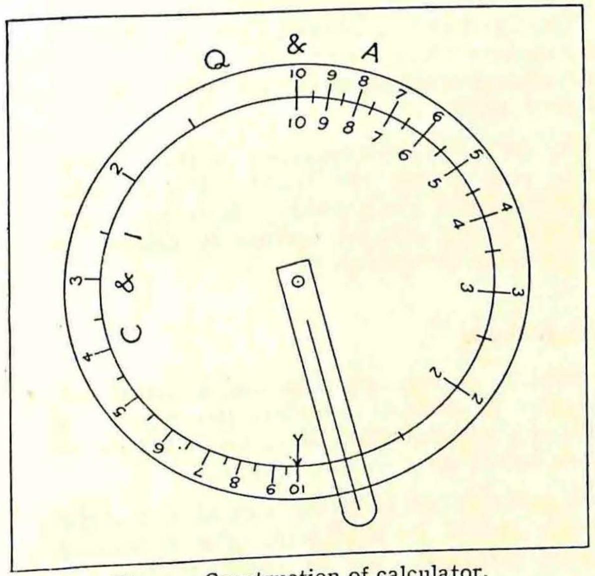

Fig. 1 —Construction of calculator.

B

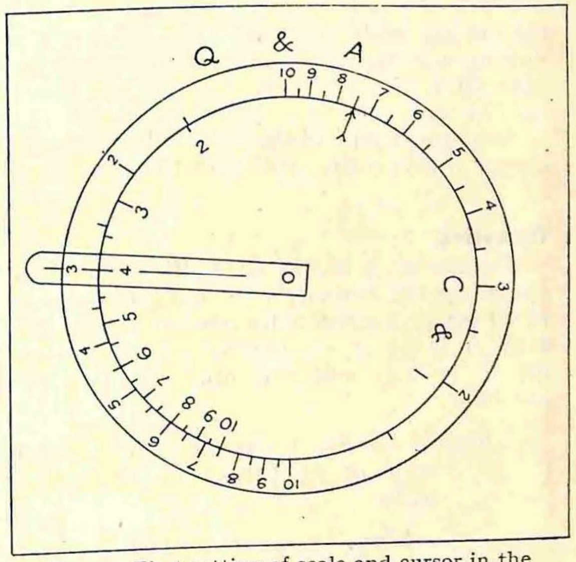

Fig. 2.—First setting of scale and cursor in the example in the text.

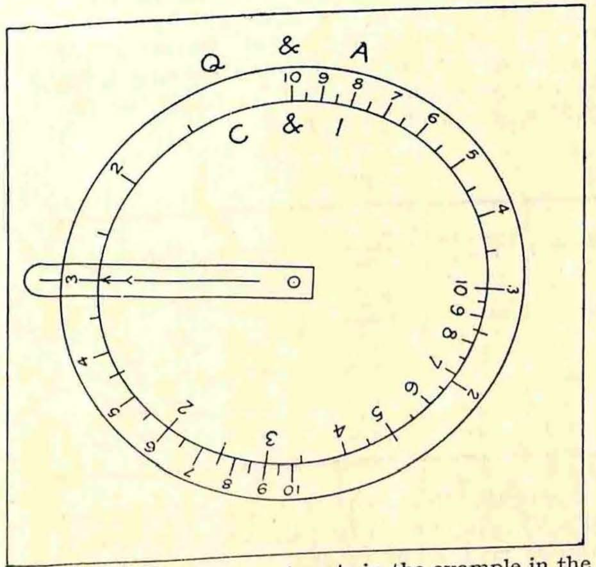

Fig. 3.—Second setting of scale in the example in the text.

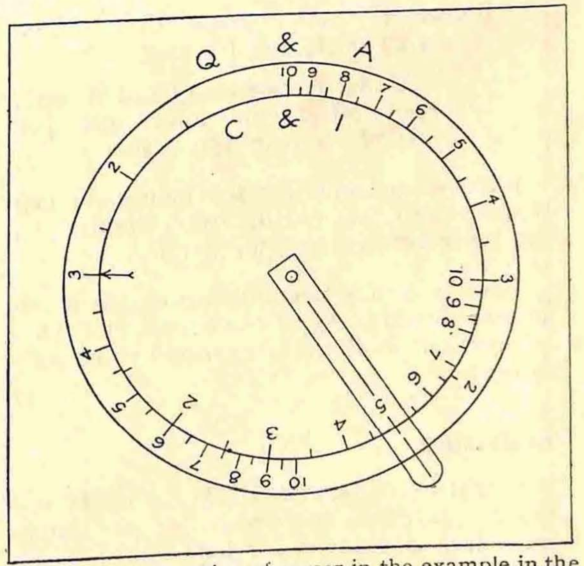

Fig. 4.—Second setting of cursor in the example in the text.

The outside scale is then plotted in a similar manner, but the scale continued a second time. (See Fig. 1.)

Mark the inside scale "C" and "I" and the outside scale "Q" and "A", these representing the terms in the rational equation Q = CIA.

Assemble by pivoting the inside scale and cursor through the centres of the two discs.

Operation.

Figures 2, 3 and 4 show the method of operating the Ramser's Formula Calculator in order to ascertain the run-off when the area A is 75 acres, the coefficient of run-off C is 0.4, and the intensity I is 5" per hour.

Figure 2.—Set 1 (arrow) on C and I scale to 75 (area) on Q and A scale.

Move cursor to 0.4 (value of C) on C and I scale.

Figure 3.—Without moving the cursor set 1 (arrow) on C and I scale under cursor.

Figure 4.—Slide cursor to 5 (value of I) on C and I scale.

Under cursor on Q and A scale read off Q in cubic feet per second—answer 150 cusecs.

It is pointed out that the numeral 1 can represent 0.1, 1.0, 10 or 100. Similarly 3 can represent 0.3, 3.0, 30, 300, etc.

Thus it is only necessary to decide if the answer should be 15 or 150 cusecs, etc. This answer will in all cases be found to be self-evident.

Explanation.

It will be remembered that multiplication using logarithms is effected by the simple procedure of adding the logarithms of the two numbers together and then obtaining the anti-logarithm of the resultant number. This calculator in reality simply adds the logarithms of C, I and A and then gives the anti-logarithm of the resultant, graphically.

THE WATERWAY WIDTH CALCULATOR.

This calculator, like the Ramser's Formula Calculator, consists of a base, a moving disc and a transparent cursor.

The fixed scale is plotted as the logarithms of numbers from 10 to 100 and the inside or moving scale in slope per cent. as explained later.

By the simple manipulation of the moving scale and cursor the width of waterway required for a given volume of water down a given slope can be accurately calculated in a matter of seconds.

Calculations.

Initially it was assumed that a maximum velocity of flow of five feet per second is safe in a grassed waterway, and calculations were based on this assumption.

It was also decided that a maximum slope of 8% would be sufficient as a waterway would rarely, if ever, be constructed down a slope of greater gradient than this.

Calculations, using Manning's Formula, were carried out and the following table (Table B), was evolved showing at what depth water would flow at a velocity of five feet per second in a grassed waterway of level cross-section down slopes varying from 2% to 8%, using the value of 0.045 for the coefficient of roughness *n*.

TABLE B.

Grade.	Depth of Flow.	Capacity in Cusecs per Foot.	Logarithm.	Plotting.
Per cent.	feet.	cusecs.		
2	1·1	5·5	·7404	133·3°
3	·82	4·1	·6128	110·25°
4	·65	3·25	·5119	92·2°
5	·56	2·8	·4472	80·5°
6	·49	2·45	·3892	70·0°
7	·44	2·2	·3424	61·5°
8	·39	1·95	·2900	52·0°

From this table it may be ascertained that on a 2% slope each foot of waterway width may carry 5.5 cusecs at a velocity of 5 feet per second.

Similarly on a 7% slope each foot of width will carry only 2.2 cusecs at the recognised safe velocity of 5 feet per second.

Thus this table alone will greatly simplify the job of designing a suitable waterway. By the simple expedient of dividing the expected run-off by the appropriate figure in column 3 the necessary width of waterway is ascertained.

However, this still entails a simple mathematical problem, so to obviate this and also speed up the process, the Waterway Width Calculator was designed.

Figure 5 shows the waterway calculator set to show the width of waterway required to carry 80 cusecs of run-off down a 5% slope at a velocity of 5 feet per second (viz., 28.6 ft.). For practical purposes this could be called 30 feet.

The outside or fixed scale is plotted as the logarithms of numbers from 10 to 100 through an arc of 180° progressing by 5 each graduation. This scale is used for setting the expected flow in cusecs and reading off the required waterway width.

The inside or moving scale is plotted as logarithms of the flow in cusecs per foot of width experienced at a velocity of 5 feet per second down varying grades (Table

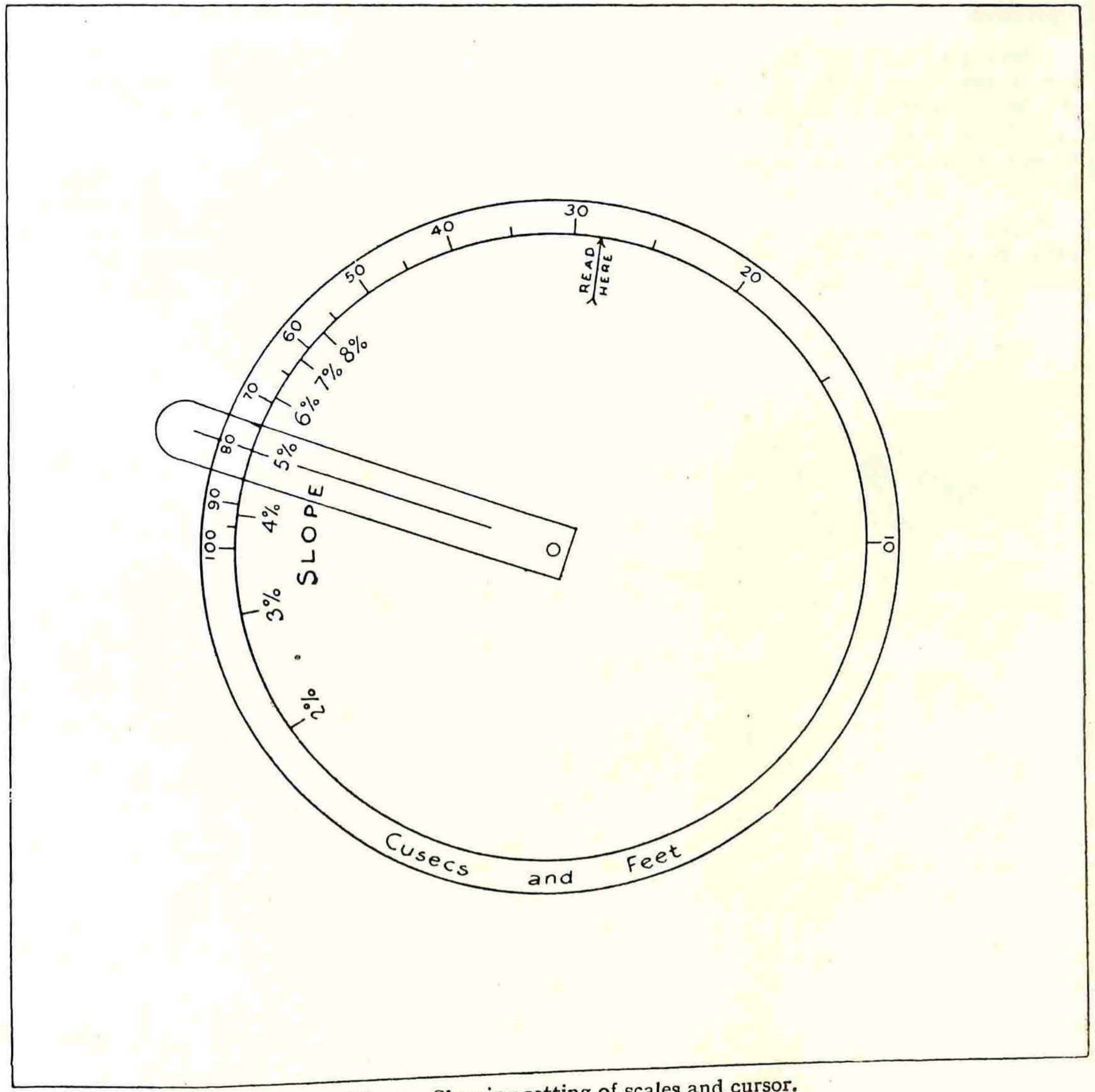

Fig. 5.—Showing setting of scales and cursor.

B, Col. 3). However, to simplify reading, the graduations are marked in slope per cent. An arrow situated at zero (log. 1) is used for reading purposes.

Thus the 8% graduation is located a circumferential distance from the arrow equal to the logarithm of 1.95 = .2900 = 52 degrees. Similarly, the 3% mark is plotted to represent a distance from the arrow of logarithm 4.1 = .6128 = 110.25°. These figures (52°, 110.25°, etc.) are derived from Table B, column 5.

Operation.

The use of the Waterway Width Calculator is simplicity itself. By merely setting the % slope graduation against the estimated run-off in cusecs on the outer scale, the necessary width of waterway required may be read off against the arrow.

This is shown in Figure 5, where the run-off is 80 cusecs and the grade of the waterway is 5%. It will be seen that the width of the waterway necessary to carry this flow at a velocity of 5 feet per second is 28.6 feet.

Should the expected run-off exceed 100 cusecs, the answer may be obtained by taking half the run-off and then doubling the resultant answer.

CONCLUSION.

In this article an attempt has been made to describe as simply as possible the method of construction and use of mechanical calculators which can be constructed and used by the soil conservationist.

By the use of mechanical means the time required to compute any problem is reduced and the risk of mathematical error is obviated.

In a further article the construction and use of a Mannings Formula Calculator will be discussed. This calculator is somewhat more involved, but the general principles are the same, and operation is equally simple.

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