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DEVELOPMENT OF LABORATORY INSTRUMENTATION FOR THE STUDY OF SOIL ERODIBILITY

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Abstract

In order to carry out a study of the relative efficiency of various erodibility indices, and of the relative erodibility of soils developed in the Peak District of Derbyshire (England), three instruments were developed. These instruments were: a wet-sieve aggregate analyser of the Yoder pattern, a compact laboratory rainfall simulator using spray nozzles, a radiant drying unit using infra-red lamps. The efficiency of the instruments and the validity of the operating techniques are critically evaluated and suggestions for improvement are advanced.

INTRODUCTION

It has been recognised for many years that the severity of soil erosion at any place is governed by the interaction of four factors: climate, vegetation, topography and soil (Baver, 1933). Although the occurrence of soil erosion depends primarily on the first three factors, even where these factors are alike, the severity of soil erosion often varies, as soils differ in their ability to resist erosion. This variable ability has been described both as "soil erosivity" (Middleton, 1930), and "soil erodibility" (Cook, 1936). The latter term is now generally accepted. At a period when pressure on agricultural land is increasing rapidly, and increasingly marginal land is being brought into cultivation, it is important that a sound basis be established for comparison of erodibility of different soils.

Assessments of soil erodibility may be made on the basis of soil-loss measurements under controlled conditions or on the basis of certain indices of erodibility. While direct measurements of soil-loss are expensive and must be carried out over a lengthy period, indices of erodibility provide immediate information and allow comparison of many soils. Most indices of erodibility used in the past have been measures of the soil's resistance to dispersion, of its water transmission status, or some combination of these parameters. Although a number of indices have been developed, their reliability in use is variable, and in general open to question. Before any index can be employed with confidence, it is necessary that a comparative study be made which embraces all known indices of erodibility.

In order to provide information for such a comparative study, and at the same time, to permit a study of relative soil erodibility in an area of potentially high erosion hazard, a research project was initiated. The sample soils used in this study were obtained from the Peak District of Derbyshire, an elevated moorland area of highly accidented relief. While the soils are derived from a variety of pedogenic environments, they form two well-defined climosequences of development, one developed over calcareous parent material, and the other over non-calcareous parent material (Bryan, 1967).

WET-SIEVE AGGREGATE ANALYSER

Many of the indices of erodibility which have been proposed can be derived directly from standard soil analytical data, or measured using standard equipment. It was necessary, however, to construct a special instrument for determination of aggregate size distribution and aggregate stability. There is a distinction between techniques for these determinations, although some overlap occurs.

Aggregate size distribution may be determined either on a dry sample, in which case the basic technique is sieving, or on a wet sample, when techniques of gravitational sedimentation, elutriation or wet-sieving may be employed. Techniques for both wet and dry aggregate size determinations have been discussed by Russell (1949), and Kemper and Chepil (1965).

Five basic techniques have been developed for analysis of the water-stability of aggregates, with many variations by different workers. Four of these, permeability measurements, suspension density, turbidimetry and wet-sieving, have been discussed by Williams *et al.* (1966). A further technique, the subjection of aggregates to water-drops falling from various heights, was developed by McCalla (1944), and subsequently modified by Smith and Cernuda (1951), and Pereira (1956). No one technique is ideal for all purposes, but the technique of wet-sieving has the advantage that it can be used both for aggregate size and aggregate stability determinations. The original development of the wet-sieving technique was by Yoder (1936), who used it in a study of the relationship between aggregate size and sheet erosion.

Design of Instrument

The instrument developed for use was based on the same principles as that introduced by Yoder (1936). It consists of a nest of 7.6 cm. diameter sieves fitted into an aluminium sieve-holder, which can be raised and lowered mechanically at a controlled rate, while remaining immersed in water. The motive power is an electric motor mounted in a metal casing attached to a tripod stand (Figure 1).

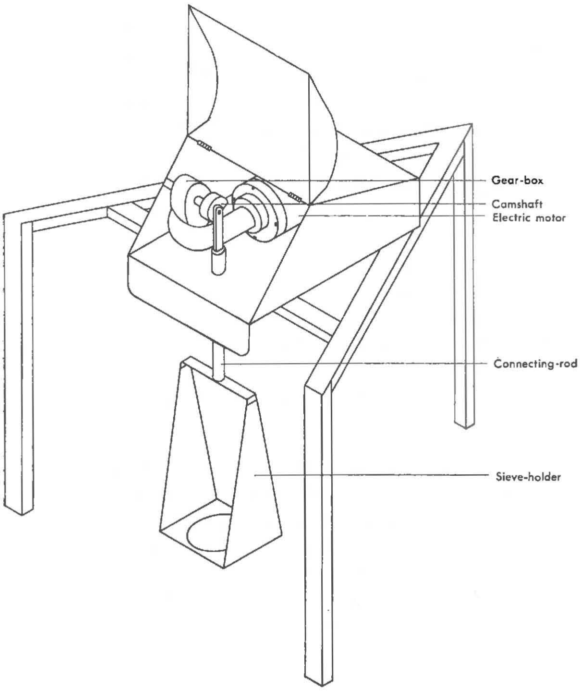


Figure 1. Sketch view of the wet-sieve aggregate analyzer developed for analysis of aggregate size distribution and aggregate water stability.

Figure 2. Detail of the wet-sieve aggregate analyzer, showing the electric motor, gearbox, crankshaft and bayonet junction.

Through a gearbox and crankshaft mechanism, the motor drives a vertical shaft, to which the sieve-holder is attached by a bayonet mount (Figure 2). Beneath the tripod a large plastic bucket is fitted, which is filled with water to a level such that the rim of the uppermost sieve just breaks the surface when the sieve-nest is at the bottom of the stroke. This level prevents floating material being washed out of the sieve-nest, and yet does not allow exposure of aggregates at the top of the stroke. The electric motor was geared to produce a stroke-length of 2.54 cm. at a frequency of 30 cycles per minute. The relatively gentle movement of the sieve nest is designed to reduce mechanical abrasion of aggregates to a minimum, and to prevent aggregates being washed out of the top sieve by violent water movement.

The sieve-holder was designed to allow the use of a nest of up to six sieves, but during this study only four were used, with mesh appertures of 3mm., 2 mm., 1 mm., and 0.5 mm., respectively. The selection was chosen to allow measurement of those aggregate sizes considered to be most significant in soil erosion, and to allow reproduction of erodibility indices used previously by other workers. The number of sieves is a compromise between the requirements of aggregate size and aggregate stability determination. Aggregate size determination would preferably be extended to include more size categories, while aggregate stability determination would preferably be carried out using only one sieve. The use of a larger number of sieves has a damping effect on water movement (Conaway and Strickling, 1962), and the water-stability of the aggregates is therefore not subjected to a very severe test.

Laboratory Procedure

The operational technique involves placing 25 grms. of air-dry soil which has been passed through a 6.19 mm. mesh aperture sieve, into the topmost sieve. The sieve-nest is then gently shaken for one minute, and the weights of aggregates remaining on each of the four sieves are recorded to give the dry aggregate size distribution. The complete sample is then returned to the top sieve, and is flood-wet with a wash-bottle. The initial moisture content of the soil, and the method of wetting are critical. Yoder (1936) showed that aggregate breakdown was at a maximum on dry soils, due to slaking. Panabrokke and Quirk (1957) found a considerably higher resistance to slaking in soils with a relatively high initial moisture content. The method of wetting is important, because rapid wetting will tend to cause maximum breakdown by slaking. Wetting may be by rapid immersion, under tension or in a vacuum. The last two methods involve gradual raising of the moisture content over a period of about 100 hours. Most workers adopt the immersion, or flood-wetting technique, as it bears the closest resemblance to natural conditions (Low, 1954; Clement and Williams, 1959). As it produces the most thorough breakdown of aggregates, it is considered to be the most suitable technique for soil erosion studies (Kemper, 1965).

After immersion-wetting, the sample is allowed to soak for five minutes, then the sieve-nest is attached to the agitating mechanism, and is allowed to agitate immersed in water for 30 minutes. This period of agitation was chosen as the minimum period which would allow adequate breakdown of aggregates. Comparative tests using periods up to 16 hours were carried out, but no significant increase in breakdown was recorded. After agitation, the sieves are dried overnight at 110° C., then the contents of each sieve are weighed. In aggregate size distribution, the simple percentage weight of aggregates in each sieve is reported, but expression of aggregate stability requires the isolation of some index of aggregation. Conaway and Strickling (1962) have made a comparative study of the sensitivity and reliability of 24 aggregation indices. They found that measurement of the percentage weight of aggregates > 0.5 mm. and > 2 mm. diameter were the most sensitive indices of variations in aggregate stability. The first of these measures has also been used quite widely as an index of erodibility.

Discussion

The technique of wet-sieving used is open to criticism on several grounds. One criticism is that it involves a process, mechanical abrasion, which is not always involved in nature. In practice this is greatly reduced by using four sieves, and retaining a gentle agitation. A more serious source of error may be the size difference between wet and dry aggregates. Aggregates which would pass through a given mesh-aperture when dry, might not do so when wet, due to the swelling of clay minerals. The magnitude of error involved will presumably vary with the amount and type of clay minerals present. The most important criticism of the technique is that aggregates which are water-stable in gently agitated water may prove much less stable when subjected to the impact of high velocity rain-drops. It would seem that when the testing of aggregate water-stability as a factor in soil erosion is the chief objective, then a water-drop technique such as proposed by McCalla (1944) would be more suitable.

RAINFALL SIMULATOR

Evaluation of the relative efficiency of indices of erodibility requires direct measurement of the erosional behaviour of soils under specified conditions of slope, vegetation and rainfall, which can be used as a reference standard. Such measurements may be obtained either from field runoff plots under natural rainfall, or from small samples subjected to artificially simulated rainfall in a laboratory. The pioneer work using field runoff plots was by Duley and Miller (1923), the technique being subsequently employed widely by the U.S. Soil Conservation Service.

Field runoff plots have the advantage of using undisturbed soil and natural rainfall, but suffer from a number of disadvantages. They are expensive to construct, and if agricultural land is involved, permission may be difficult to obtain. Although the use of natural rainfall is an advantage, it is necessary to continue observations for a very long time in order to duplicate certain conditions of soil moisture and juxtaposition of rain-storms. Because they cannot be used at a large number of sites, they allow examination only of the surface horizons. While some of the disadvantages may be avoided by using artificially simulated rainfall on field runoff plots, the need for a large water supply renders the arrangement inflexible.

Because of the disadvantages outlined, field runoff plots were not considered suitable for the research project. They were particularly unsuitable as information was required about the erosional behaviour of subsurface soils, which may ultimately be of more importance than that of surface soils. The use of artificially simulated rainfall in a laboratory was the only practicable alternative. The great advantages of the use of simulated rainfall are the replicability of rainfall conditions, the elimination of all variables except soil type, and the possibility of testing samples from any depth in the profile. The chief disadvantage is that any form of simulated rainfall can only partially reproduce the characteristics of natural rainfall. The method of simulation used determines the degree of realism of the reproduction.

Methods of Artificial Rainfall Simulation

Many methods of artificial rainfall simulation have been developed during the past 40 years. Few of these are similar, let alone identical, but two classes may be distinguished by the general method of formation.

A. Rainfall simulation by spray nozzles

Before 1940, all research involving simulated rainfall involved the use of some form of sprinkling or spraying device. The pioneer work in the field was by

Lowdermilk (1930), who used a series of upward-pointing spray nozzles to simulate rainfall, in a study of the effect of forest litter on water infiltration and soil erosion. A more widely used variation was to mount spray nozzles overhead, pointing downwards at the soil surface. The most satisfactory unit of this pattern was developed by Duley and Kelly (1939), which incorporated fan-shaped gardening nozzles in an overhead oscillating sprinkling unit. A number of workers used manually-operated watering cans (Duley and Hays, 1932), which had the merit of cheapness and simplicity, but were of little value as control or replication of rainfall were impossible.

Most of the early rainfall simulators were designed only to reproduce certain rainfall intensities and drop sizes, little attempt being made to reproduce other rainfall characteristics such as impact velocity and drop size distribution. Experiments carried out by Laws (1941), and Laws and Parsons (1943) greatly increased knowledge of these characteristics, and initiated a new concept in soil erosion research. In this soil erosion is regarded as a work process, the energy for which is supplied primarily from the kinetic energy of falling rain. In the light of this concept attempts were made to simulate the terminal velocities of natural raindrops, which Laws (1941) had shown to be achieved at fall-heights of up to 20 m. Attempts to reproduce terminal velocities accurately necessitated use of greater fall-heights and development of different methods of drop formation.

B. Rainfall simulation by drip screens

Accurate reproduction of terminal velocities requires accurately measured drop-sizes, and so more exact methods of drop formation were required than the spray nozzles used previously. Work was concentrated on the production of drops of uniform size, and no attempt was made to reproduce the range of drop sizes found in natural rainfall. The earliest unit, developed by Ellison and Pomerene (1944), supplied water from a tank with holes drilled in the base. Beneath the tank was suspended a screen of chicken wire covered by cheesecloth. Short lengths of yarn threaded through the screen acted as drop-formers, producing drops of diameter 3.5 mm. and 5.1 mm. The unit could be raised or lowered to vary the impact velocity, and the screen was oscillated to randomize drop-fall. A number of workers subsequently used the same basic principle, but the mechanism of drop formation varied. Ekern and Muckenhirn (1947) used hypodermic needles mounted in the base of an aluminium container, while Adams *et al.* (1957) used small capillary tubes fitted with wire inserts.

Design of a Compact Laboratory Rainfall Simulator

Most of the instruments designed to simulate terminal velocities were intended for use outside with potentially unlimited fall-heights. It was essential that this study be carried out in a laboratory, and so the available fall-height was limited. Rainfall simulation by spray nozzles was considered to be more suitable than the drip screen method, provided that a reasonably high impact velocity could be attained in a relatively small fall-height. A series of experiments was carried out, in which water drops of varying diameter were allowed to fall varying distances in still air. The drops were produced by capillary glass tubes, and were illuminated by lamps against a dark screen. The velocity of the drops was measured photographically, using an exposure of 0.01 sec. The largest drop size used was 4.0 mm. diameter, which photographs slowed to attain a velocity of 7.40 m./sec. in a fall-height of 1.66 m. This is 83% of the terminal velocity established by Laws (1941) for a drop of this size. Comparison with Laws' data suggest that the drop-velocity recorded was too high, and that a 4 mm. drop in fact attains only 65 to 70% of its terminal velocity in this fall-height. Two sources of error are involved, the accuracy with which the camera reproduces exposures, and the accuracy of drop-size measurement. Most cameras reproduce low exposures such as 0.01 sec. with

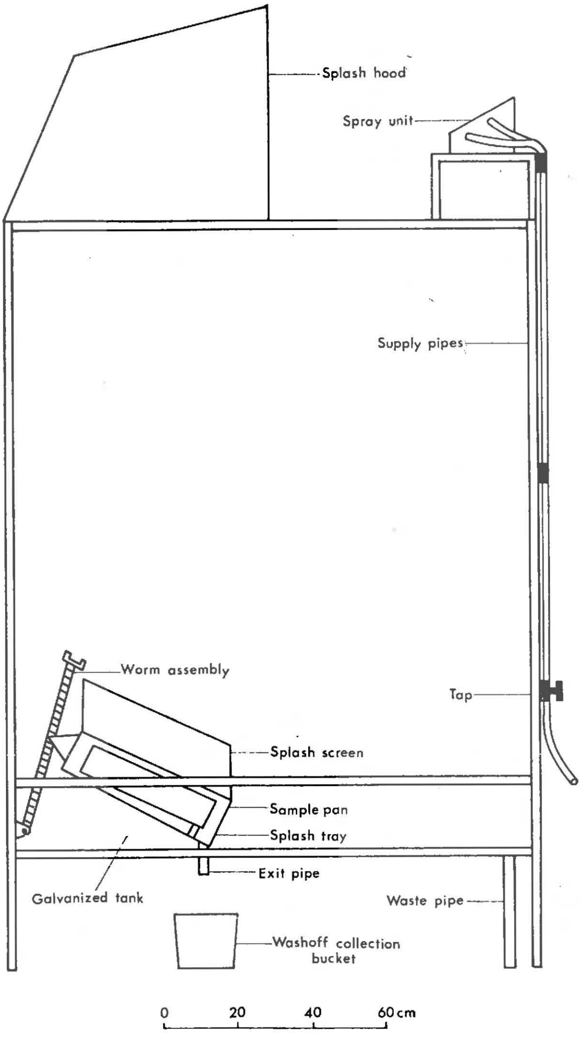


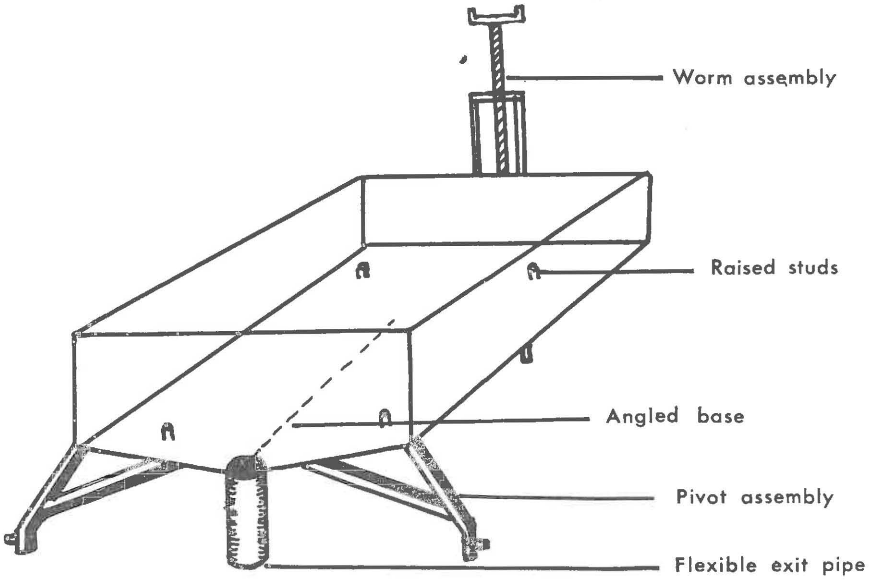
Figure 3. Plan view of laboratory rainfall simulator.

reasonable accuracy, so the second source is more likely. Drops were measured just before parting from the capillary tube, so distortion could have produced too low a reading. Even using Laws' (1941) data, the percentage of terminal velocity attained was sufficiently high to make a compact rainfall simulator feasible.

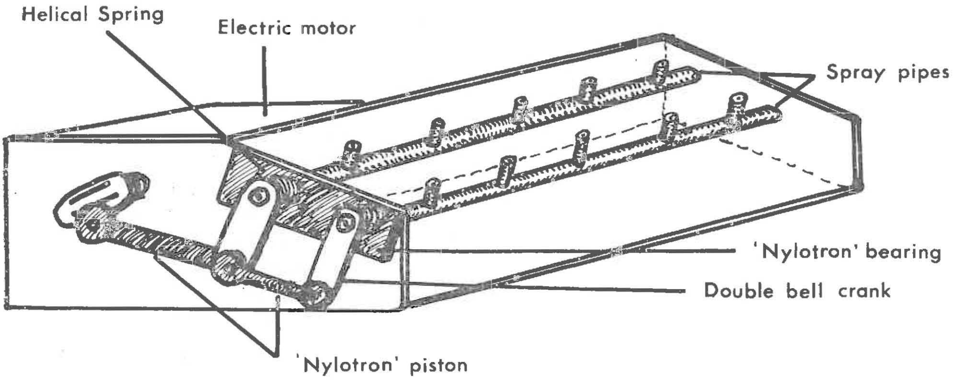
A compact simulator which could be fitted within available accommodation was designed on the basis of 1.66 m. fall-height (Fig. 3). The unit was built up around a framework of angle steel measuring 216 x 121 x 63 cm. At a height of 38 cm. in this framework a 121 x 63 x 15 cm. galvanized tank is supported on a rubber-lined mounting. At one end of this tank a 38 x 38 x 10 cm. tray is mounted, fitted with moveable splash screens. The splash screens collect most of the splashed material; as Ellison (1945) has shown, it would not be practical to collect it all. This tray is mounted on a pivot (Figure 4A) so that by use of a worm assembly its inclination may be varied from —1° to 32° (a small plate brazed on one side serves as a rest for an Abney level. The base of the tray is angled to form a gutter leading to a 2.54 cm. diameter exit pipe at the downslope end. This pipe is connected by a flexible hose to an exit pipe in the base of the galvanized tank.

Inside the pivoted splash tray a removable 30.5 x 30.5 x 10 cm. sample pan rests on four raised studs. The pan is made of sheet aluminium, the base and downslope edge being drilled with 6.4 mm. diameter holes to allow free drainage of the sample. In the pan, samples of 7.5 cm. depth are placed above a layer of 1.2 cm. glass beads, which prevent the sample sliding at high inclinations, and which also assist the sample drainage. Soil splashed and washed off the sample passes with the runoff through the exit pipe to a container beneath the galvanized tank. A separate exit pipe in the galvanized tank carries away water falling outside the splash tray.

A number of commercially obtainable spray units were tested but were found to be unsuitable for use in the simulator. Subsequently a number of different spray units were built out of 9.5 mm. diameter copper piping. The unit finally adopted



A. Detail of splash tray, without splash screens



B. Detail of spray unit

Figure 4A. Sketch view showing detail of the pivoted splash tray.

Figure 4B. Sketch view showing detail of the piston and bell-crank linkage in the spray unit.

consists of two pipes set horizontally in staggered formation (Figure 4B), from each of which project six 1.25 cm. lengths of 4.7 mm. diameter piping. The ends of these pipes were brazed, then drilled with 0.39 mm. and 0.79 mm. diameter drills to give jet sizes which produce two ranges of drop-size. The 0.79 mm. jets give a range of 0.84 mm. to 3.98 mm. diameter, while the 0.39 mm. jets give a range from 0.67 mm. to 2.87 mm. diameter. Measurement of drop-size was by the flour-tray method of Bentley (1904), modified by Laws and Parsons (1943). The jets project water upwards in an arc, the apex of which is 1.66 mm. above the sample pan. At this fall-height the larger drops attain 70 to 75% of their terminal velocity, using Laws' (1941) data as a basis for calculation. Laws' measurements did not extend to drops below 1.15 mm. diameter, but as these drops attain 89% of their terminal velocity in a fall-height of 1.66 mm., smaller drops should closely approach their terminal velocities. The kinetic energy produced by the largest drops (3.98 mm. diameter) was calculated to be 0.5 kg./m. giving a total of 200 kg./m. for the complete sample area. Jets were arranged so that a uniform distribution without overlap was obtained. Minor adjustments could be made after assembly, by bending the jets.

The 9.5 mm. diameter copper spray pipes were brazed at one end, water from the mains being supplied at the other end through polyethylene piping. Supply of water from one end caused some deflection of the water arcs, making jet adjustments necessary. The spray pipes were set in greased "Nylotron" bearings, leaving them free to rotate. The actuating mechanism for the rotation (Figure 4B) is a piston and bell-crank linkage driven by an electric motor geared to 6 r.p.m. (Figure 5A). The mechanism rotates the pipes through an arc of 5°, allowing rainfall to cycle on and off the sample six times per minute. The rainfall intensity was measured at 12.70 cm./hour using a standard British Meteorological Office rain gauge. This intensity was chosen as the highest ever recorded in the area, so that the results of tests should give an indication of the maximum vulnerability to erosion.

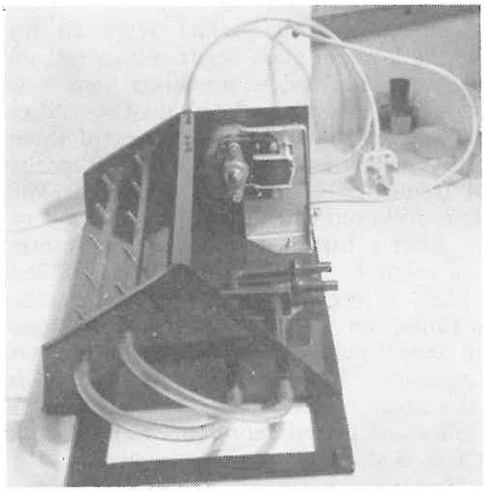


Figure 5A. Spray unit developed for use with the rainfall simulator, showing two banks of spray pipes, the electric motor, and supply pipes.

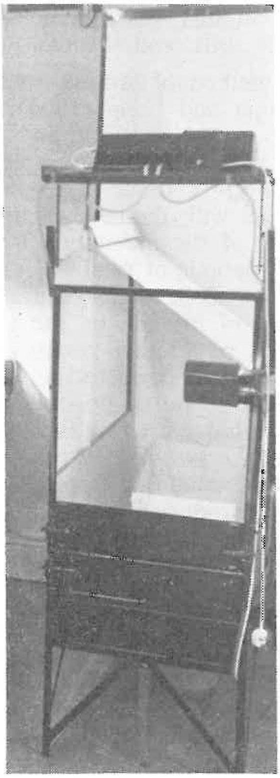


Figure 5B. Laboratory rainfall simulator.

The steel framework is sheathed on three sides by sheet aluminium, while a perspex screen on the fourth side allows observation of the sample (Figure 5B). A 71 x 71 cm. door in one side provides access to the sample, and also serves as a rainfall shut-off mechanism. A splash hood built above the main framework to a height of 46 cm. also serves as a datum for adjustment of the apical height of the water arc. This eliminates the need for a pressure-gauge in the supply line from the mains. A combination of supply pipes and taps allow either bank of jets to be used separately, or together in combination. The rainfall intensity of 12.70 cm./hour was produced by the bank of 0.79 mm. jets used alone.

Laboratory Procedure

There is no standardised method of preparing samples for testing. Most previous studies under simulated rainfall used soil disturbed in some way, but the degree of disturbance varied. In some cases blocks of soil carefully cut out have been used, while in others (Neal, 1938; Moldenhauer and Long, 1964), air-dry soil was passed through sieves of different mesh apertures. Woodburn (1948) went to the extreme of pulverising the soil with a heavy roller before using it in an oven-dry condition. It was originally hoped that cut samples with structure intact could be used, but this was impossible due to the stoney and heavily rooted nature of the sample soils, and the relative inaccessibility of the sample sites.

The method of sample preparation adopted was essentially similar to that of Moldenhauer and Long (1964), samples being passed gently through a 6.19 mm. aperture square-hole sieve, and used in an air-dry condition. The sieved air-dry sample is poured into the sample pan above the layer of glass beads, which rest on a single layer of tissue in the base of the pan. The soil is smoothed until it is exactly level with the edge of the pan, and is then placed in the simulator. After adjustment of the inclination to 20° the sample is subjected to a series of three 30-minute periods of rainfall. Choice of a 20° inclination for testing was primarily because this slope-angle occurs with high frequency in the Peak District. The first period of rainfall, on the air-dry soil, is followed after a drainage period of 60 minutes, by another period of rainfall. After a further interval of 15 minutes the sample is subjected to the final period of rainfall. This sequence was designed to reproduce as far as possible conditions likely to occur in the Peak District. So the first period corresponds to heavy rain falling on a soil which has been dried out during the summer. At the start of the second period the soil is moist, but has drained to a condition approaching field capacity. This is the situation which is probably reproduced most frequently in the area. It corresponds to a Class A storm in Horton's (1933) classification. The third period represents rainfall on a saturated soil, corresponding to Horton's Class B storm.

At the end of each period of rainfall material splashed and washed off the sample is collected in a bucket beneath the galvanized tank. Material caught in the splash tray or on the sides of the sample pan is washed down the exit pipe by a wash-bottle. The average quantity of soil suspension after each period is about eight litres, which precludes evaporation of the complete sample to dryness. The sample is thoroughly agitated, then a 500 cc. sample is poured off into a graduated cylinder. The remaining suspension is immediately poured off, and sediment from the base is collected and dried overnight at 110° C. The 500 cc. sample is filtered through a Buchner funnel attached to a vacuum pump, and filter paper plus residue is dried overnight. From the weights of these two fractions the weight of the solid material in the total sample may be calculated.

Discussion

The most serious criticism of the instrument and technique developed is the use of the soil samples in a sieved, disturbed condition. Theoretically it would appear that such treatment will destroy the natural structure of the soil. In practice, if the mesh aperture is not too small and the treament is not too violent, the ultimate structural elements will be preserved in most soils. Exceptions are soils which have large prismatic or columnar peds, particularly soils with a high clay content. Amongst the samples examined, only one taken from the B/Cg horizon of a ground-water gley was considered to have been significantly affected. Although theoretically preferable, use of undisturbed samples would reduce the value of this form of testing. When the samples are sieved and prepared, any differences which appear during the course of testing may be attributed to differences in soil properties. When the samples are undisturbed, differences observed may be due to other influences, such as root development, which are essentially relict features of other factors, and which obscure the effect of the soil factor.

Another important criticism of the technique is that samples from horizons are tested in isolation, so that the effect on a given horizon of a lower horizon with different water transmission characteristics cannot be assessed. This is a valid criticism, but in practice, as samples from all horizons are tested, a composite picture of the erodibility of the whole profile can be built up, using Lutz's (1934) "limiting layer" principle.

Although the instrument was not designed for prediction of actual soil-loss in the field, it is necesary to assess the possibility of applying results to field conditions. The use of the sieved soil should raise splash erosion above the natural level, as Woodburn (1948) found in tests on pulverized soil. On the other hand, permeability will tend to be higher than in the undisturbed soil (Rose, 1962) leading to a decrease in washoff erosion. The higher splash erosion and the lower washoff erosion counterbalance one another to a large extent, so that soil-losses recorded are a close approximation to those which would occur under similar conditions in the field.

The rainfall simulator was designed so that it would be suitable for use in a number of different research projects. It was not possible in this project to test the full potential of the instrument, but as a result of the tests carried out, some improvements can be suggested. Incorporation of an automatic pressure control in the water-supply pipe would ease operation, and allow the instrument to be left unattended. Redesign of the splash pan so that wash and splash erosion losses could be separated would also be a useful modification. Such separation is important as the relative erodibilities of different soils for splash and wash erosion are not necessarily the same (Adams *et al.* 1958). These two modifications would increase the accuracy of the instrument in the measurements for which it was primarily designed. A number of further modifications could be made to extend the range of research for which it can be used. The most obvious of these is the incorporation of a wind tunnel to allow study of the effect of wind-driven rain on soil-loss.

RADIANT DRYING UNIT

Preliminary testing of soil samples under artificially simulated rainfall showed a very marked variation in the effect of rainfall on the soil surface. While some soils showed very little breakdown of aggregates, others showed almost complete de-structuring of the surface, accompanied by development of miniature soil pillars under stones, and development of a thin impermeable surface crust (Figure 6A). Predictably there was a strong positive correlation between extensive breakdown of structure and high soil-loss. Development of surface crusting has been studied by a number of workers including Carnes (1934), Duley (1939), McIntyre (1958), and Tacket and Pearson (1964). While it is undoubtedly related closely to aggregate stability, there is not complete agreement on the mechanism of formation or the relationship of crusting to other soil properties such as texture. Because of its close relationship to erodibility, it was desirable to obtain some measurement of crusting, on the different samples. A small radiant drying unit was developed to assist in such measurement and to allow examination of desiccation cracking (Figure 6B).

Figure 6A. Sample from A1 horizon of an iron-podzol after subjection to three periods of simulated rainfall, showing destruction of surface aggregation and puddling.

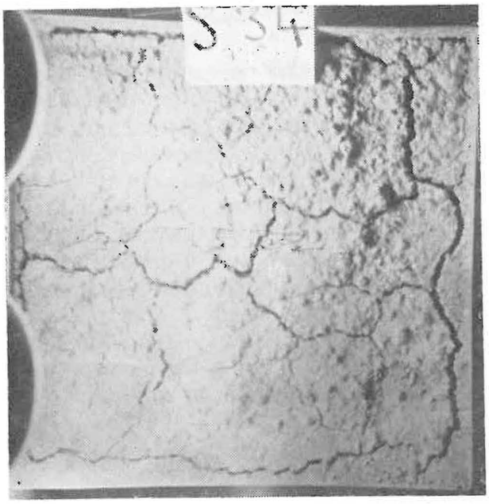


Figure 6C. Sample from the B/Cg horizon of a surface gley after subjection to simulated rainfall and radiant drying. Surface structure is completely destroyed apart from residual soil pillars, and a hard, impacted surface crust has formed, penetrated by desiccation cracking.

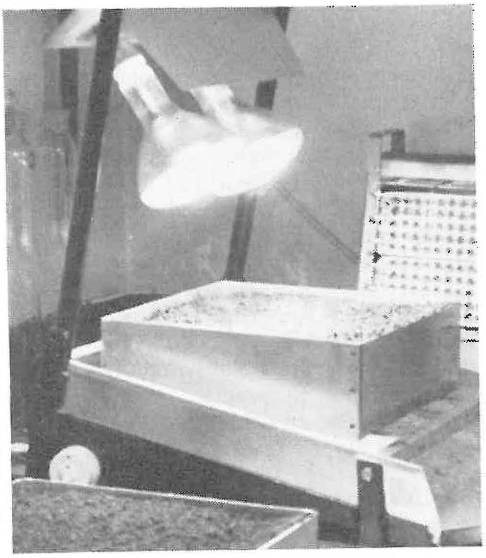


Figure 6B. Radiant drying unit.

Design of Instrument

Radiant drying of soil samples has been carried out by a number of workers, including Rose (1962) and Schmidt *et al.* (1964). Most work appears to have centred around the use of infra-red lamps, but little detailed information is available. The instrument designed for use in this project consists of a framework of angle steel, measuring 37.5 x 35 x 40 cm. The basal portion of the framework slopes at 10° from horizontal, while the uprights are perpendicular to the portion to give an L-shaped frame. Inside the basal portion is mounted an aluminium tray which is angled to form a gutter. Inside the tray is a grid of angle aluminium on which the sample pan rests horizontally, clear of the tray. The sample is thus able to drain freely, drainage water passing through the gutter to a plastic bucket. The uprights bear a strong steel plate on which two 250-watt infra-red lamps are mounted in porcelain bases. The lamps are mounted so that they project at an angle towards the sample, clearing the surface by 15 cm.

Laboratory Procedure

Immediately after subjection to the third period of simulated rainfall, samples are placed on the drying unit. The period required for complete drying varied greatly between soils. In most cases a period of more than eight hours was necessary, but a very few samples were found to dry completely in less than three hours. After drying, measurements of the shearing resistance of the surface were made using a small dropping-weight penetrometer. Depth of crusting and extent and pattern of desiccation cracking (Figure 6C) were also recorded.

Discussion

Because of the lengthy drying period required for most samples time did not allow the complete investigation of crusting originally intended. The preliminary investigation carried out was sufficient, however, to support the view that crusting is usually the product of a complex interaction of a number of mechanisms. The dominant mechanisms are physical compaction, destruction of aggregates, redistribution and filtering out of disaggregated separates, but there is a possibility that some chemical process is also involved.

Although the work carried out was only a preliminary investigation of surface crusting, it did give some indication of the efficiency of the drying unit. The chief criticism is the lengthy drying period required for most samples. This could certainly be improved by enclosing the unit completely in polished aluminium. The assymmetric position of the infra-red lamps caused local hot-spots, with possible effects on cracking patterns. A more even spread of heat could be achieved by mounting the lamps vertically above the sample. The lamps used proved entirely satisfactory, each being used for more than 300 hours without replacement. Although the instrument as designed is not entirely satisfactory, the modifications necessary are very minor.

CONCLUSION

All the instruments and techniques described were developed for use in a closely defined research project. Despite this narrow approach in design, it is felt that they are inexpensive research tools which might well be suitable for use in a wide range of research projects. While improvements have been suggested, none of the modifications would involve major re-design or greatly increased cost.

ACKNOWLEDGEMENTS

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