

## THE FACTORS AFFECTING EROSION\*

**T**HE two agents causing erosion are wind and moving water. Although wind erosion can, under certain conditions, cause very severe erosion, it is not intended to discuss wind erosion specifically; the application of some of the principles of soil conservation discussed below will effectively prevent erosion by wind. Erosion by water can be controlled if the causes of its accumulation and the laws governing its flow are appreciated.

Water enters the soil not over the whole surface but by means of the spaces or pores between the particles. The smaller the spaces the slower will be the rate of absorption. Thus, a soil which has been broken down to dust will have very fine pores and absorb water slowly, while a soil in which the ultimate soil particles are cemented together in the form of crumbs, will have large pores and absorb water readily. The run-off, under similar conditions of rainfall, will be less on the latter type of soil than on the former. This is also the explanation of the fact that soil is more liable to erode after long continued cultivation than when first broken from the virgin state. The virgin soil contains an adequate supply of humus to cement the soil particles into crumbs.

The run-off too is greater from a bare soil than from one carrying a vegetal cover. Rain beating on bare soil compacts it, the surface soil is broken up into a thin mud which, passing into the soil pores, clogs them, making them smaller and reducing the rate of absorption. The mitigation of the impact by vegetation helps to prevent the beating of the soil into mud and thus clear water, or water carrying very little in suspension, is absorbed by the soil pores. The litter collecting below a vegetal cover, too, acts as a shock absorber but there are further effects. It has a definite filtering and flocculating effect, clearing any muddy water that may accumulate, permitting clean water only to reach the soil. Lowdermilk has demonstrated the marked effect of a forest litter in maintaining the absorptive capacity of a soil for water. On a fine grained soil covered with forest litter the total run-off, from a rainfall of 200 inches, was only 0.7 per cent. from the same soil, on which the litter had been burned, under otherwise identical conditions the run-off was 38.7 per cent. of the rainfall.

There is yet another effect observed so far on the volcanic red soils only. Under certain types of vegetation, especially under those that produce a heavy litter, there is a marked puffing up of the soil to form a loose tilth of soil crumbs capable of absorbing water rapidly. The same phenomenon is observed under a grass mulch. The importance of this phenomenon lies in the increase in the capacity of soils that have developed such a structure to absorb water.

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\* By V. A. Beckley, M.C., M.A., A.I.C., Senior Agricultural Chemist. Extracted from Bulletin No. 1, of 1935, of the Colony and Protectorate of Kenya Department of Agriculture.

Under a grass cover there is protection of the surface soil but the litter produced is not as efficient as that of forest or mixed bush. The puffed structure does not develop to any marked extent so that there is quite a large run-off under heavy rain.

As soon as there is more water than the soil can absorb it begins to run off and, once moving, it is capable of doing work, the amount depending upon the square of its velocity. Thus a stream of water moving at a speed of two miles an hour can do four times as much work as one moving at one mile an hour. Its carrying capacity, or its erosive capacity, varies as the fifth power of the velocity. In the two streams postulated above, the one has thirty-two times the erosive capacity of the other. The size of particles carried varies with the sixth power of the velocity. Thus, in the two streams, the one will carry particles sixty-four times as large as the other. Not only does velocity affect carrying capacity but so does the amount of silt carried. A heavy silt-charged stream will transport larger masses than its velocity alone would permit. Considering these laws of hydraulics the power of moving water to erode soil is evident.

The factors governing velocity of run-off are slope, nature of surface and volume of water. Other things being equal, an increase in slope of four times doubles the velocity of run-off, that is, if a velocity of one mile an hour is developed on a slope of 1 in 100, a velocity of two miles an hour would be developed on a slope of 1 in 25. The effect of the nature of surface is rather complicated but probably, if it be considered a matter of friction between the water and the surface, a picture of the effect will be gained. On a dead smooth sloping surface there is little friction and water runs off rapidly. If the surface be slightly roughened, analogous to a rolled field, the flow will be retarded by the increased friction; further roughening slows down the flow again, analogous to water flowing off a ploughed field if constant obstacles are interposed as on a grassy slope the flow becomes very slow indeed. But if, at the same time, the volume of water is considerably increased, the water can over-ride the obstacles and maintain a high speed.

In nature the matter is very much more complicated. Water does not flow down a natural surface in a smooth sheet but tends to collect in natural depressions. Perhaps the discussion of an actual case will illustrate the effect better. Visualize a bare sloping field, having the mild slope of one in a hundred under a storm of rain. Water unabsorbed begins to run down the slope. Inequalities in the surface concentrate the water into depressions to form little streams, which become larger as they proceed down the slope. Under quite ordinary conditions the streams at the top of the slope would be half-an-inch deep and three inches wide. As they proceed down the slope they would become deeper and wider (though under certain conditions discussed in the next paragraph, they would remain about the same width). Assume this to be the case here and that midway down the slope the depth has become three inches and at the bottom of the slope it has reached six inches. The velocities of the streams at the three points, according to the laws of hydraulics, would be 0.86, 1.82, and 2.40 feet per second. The erosive powers at the three points

would be in the proportions of 1, 43 and 170. At the top of the slope the run-off can do little damage, at the bottom the increased flow can and does eat into the soil very rapidly. Normally the streams do widen as they become deeper, leading to the development of lesser velocities than those calculated but velocities sufficiently great to do much damage.

The nature of the treatment received by the soil considerably affects the character of the run-off. Very often in cultivating a field the line of least resistance is taken, and implements are run up and down the slope. The traffic of the tools tends to produce small channels to carry off unabsorbed water, while the ridges of compact soil, left below the surface, tend to confine the width of the streams, making them deeper and faster than would otherwise be the case. The condition is that described in the preceding paragraph. If cultivation is across the slope there would be no downward channels to carry off unabsorbed water. With cultivation along contour lines one has a series of parallel channels and, when they fill, a wide stream of low velocity would be produced. It is, however, difficult to plough along contour lines and thus there is always some lowest point towards which water would flow, thus tending to produce one or more large flows. Here the damage would be marked but would immediately call attention to itself and means could be employed to regulate the damage.

The character of the crop, too, affects the nature of the surface over which the unabsorbed moisture must flow. A widely-spaced crop like maize does not interfere much with the flow of water nor does it offer much protection, in its early stages, to the direct beating of rain. Wheat, being closer-spaced, offers more resistance both to run-off and to beating, while a matted crop, like peas grown as a cover crop, offers more resistance still. The distribution of the roots of the crop too affects the intensity of erosion. It is evident that the close packed roots of a crop of wheat will offer more resistance to erosion than the sparse roots of a maize crop.

Soil, lacking in cohesion, if underlain by a more compact layer, is liable to become supersaturated and suspended in the water when the whole mass is likely to slip bodily down the slope. A similar effect happens to the non-coherent soil between the ridges on a slope cultivated up and down the slope.

In this connection the direct abrasive effect of the material in suspension must not be overlooked. The large amount of silt derived from a non-coherent soil gives moving water an enhanced power to tear soil particles away from the main mass.

The structure of the soil, too, affects the rate of erosion. Not only does a well-developed crumb structure mean a good capacity to absorb water but also the crumbs themselves, being compound particles, are heavy, requiring a fair velocity of run-off to move them. When the crumb structure has been broken by bad cultivation the fine particles produced are very readily transported, and such soils erode readily. The property is associated with the nature of the clay in these soils. Unlike the clay

of the black cotton soils, it does not swell much on wetting nor does it become sticky. The crumbs developed do not break down on wetting and continue to provide an absorptive surface. The small tendency to swell also means that the soil pores, down which water percolates to the sub-soil, do not have their effective diameter much reduced. The black cotton soils, although they do develop a good crumb structure under cultivation when dry, lose this on wetting. They are receptive of early rains but soon lose their absorptive surface. The marked swelling reduces the size of the pores, down which water percolates, and very soon these soils cease to absorb rain at all, developing heavy run-off capable of causing severe erosion.

The structure of the sub-soil also affects the rate of erosion. In the red soils the sub-soil is coherent, drying into flat plates of a fair size. Water readily percolates through the cracks which close up slowly on wetting. When the sub-soil has been exposed by erosion the coherent nature of the sub-soil and the heavy blocks prevent any further erosion except at a very slow rate indeed. The black cotton soils dry into a very marked granular structure, very absorptive of water when dry. Once the soil has been exposed and gully erosion starts, the granular structure of the sub-soil permits of very rapid erosion, the individual granular masses break away from the general mass very easily and soon are reduced to fine silt by moving water.

An obstacle in the flow of a stream of water causing a miniature waterfall may, on certain soils, have a very marked effect. The writer once observed a cattle track converted into a donga three feet deep in the course of a single afternoon. The main cause was a stone lying in the track. Water, running away down the track, falling over the stone, had its velocity appreciably increased immediately below the stone. This enabled it to cut away the coherent surface layer, exposing the non-coherent granular soil below. The increased fall further speeded up the flow, augmenting the erosive capacity, and in a very little while a hole developed. The direct abrasive effect of the suspended silt now began to have an effect, cutting away the lower lip of the hole. Accumulating effects soon produced a gully which then proceeded to cut its way backwards into the soil.

Erosion by water is a cumulative process, not only in the manner described above, but in the general effects. The absorptive surface is destroyed by beating, water runs off carrying away the humus-containing surface soil. The soil is now less absorptive of water, run-off increases carrying away more soil; the clogging of the pores further increases run-off. Each increase of run-off means an increase in velocity and an increase in erosion. Therefore, when a case of erosion is being reviewed all the factors and their interaction upon each other must be considered,