

## SOIL STRUCTURE IN RELATION TO SOIL EROSION

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### SUMMARY

**T**HE part played by soil structure in relation to soil-erosion is discussed.

The primary aim in anti-erosion measures is the reduction and if possible the prevention of surface run off of rain water, which carries with it the valuable surface soil.

The physico-chemical processes, which govern the loss of soil and the principles underlying aggregation or crumb—formation in soils are discussed.

The ameliorative measures that should be carried out on (a) light and (b) heavy soils with a view to decreasing their erodibility are dealt with from the practical standpoint.

The soil of a country is one of its most precious possessions. Accordingly, the first condition which must be fulfilled by any system of agriculture is that every effort should be made to conserve it.

In any discussion on the methods of controlling or checking soil erosion, it is usual for one to lay very great emphasis on the importance of a good ground cover, &c., and the control of the movement of free surface water but to neglect or to a greater or less extent overlook the essential factor of the amelioration of the soil so that it attains its maximum absorptive capacity and its minimum erodibility.

The primary aim in anti-erosion measures must be the prevention of surface run off of water during periods of normal rainfall and the reduction of such run off to the barest minimum during periods of high to exceptionally high intensity, which is by no means infrequent in a tropical country like Ceylon. This object can only be effectively carried out by obtaining the greatest absorption of the rain water by the soil, and the more the water absorbed, the less there is to run down the slope carrying surface soil with it. Surface soil contains the greatest part of the mineral nutrients and practically all the organic matter. Moreover, it is also the centre of activity of micro-organisms that bring certain nutrient materials into a condition assimilable by plants. Of the soil constituents, it is the most important clay particles, which are readily lost, as they are held in suspension in water for long periods, owing to their very minute size. It has to be mentioned that clay soils erode more than sandy soils at low gradients, but less at gradients above 15 per cent. H. H. Bennett holds the view that soils having  $\text{Si}/\text{O}_2$   $\text{R}_2/\text{O}_3$  (molecular) ratios greater than 2 are generally plastic and erodible, while those

with lower ratios are friable and non-erodible. Although this simple generalization does not hold widely, it is one of the single value soil properties which has been found to be related to the rate of erosion in Ceylon soils. Whatever be the nature of the soil, it is clear that any loss of surface soil, and particularly of the clay fraction from it, if allowed to continue unchecked will so reduce the fertility of a soil (through internal erosion) that its cultivation will ultimately become unprofitable.

From the physico-chemical standpoint the problem of erosion has to be tackled in two ways, which are, however, not entirely distinct. The first is by suitable treatment of the soil with a view to increasing not only its absorptive capacity for water but also its rate of imbibition of water, since the latter has an important bearing on the amount of run off. The second method of reducing losses by erosion is by promoting the clay particles to form aggregates, called crumbs, and thereby improving the structure of the soil. The two favourable conditions desired in the first instance can be secured by the same means, viz., by a combination of lime and organic manure treatments. It is well known that turning under the vegetation of leguminous and other green manure crops not only improves the fertility of the land but also is one of the principal means of soil conservation. Apart from these, the soil building crops include most of the grasses. Both these classes of soil conserving crops are benefited by the application of lime, because they grow best and produce most vegetation when the soil is kept nearly neutral in reaction. Organic matter—even in an unhumified condition—has a high absorptive capacity for water (and as we shall see later also promotes crumb formation when humified), whilst the lime improves the physical condition of the soil by flocculating the clay and thereby bringing about better aeration and drainage in the soil.

The second and perhaps the more important measure in combating soil erosion is the production of a good structure in the soil by the promotion of soil aggregates or crumbs which have a far less tendency than individual particles to be carried in suspension in free surface water.

Before proceeding to deal with the means available for promoting crumb formation it is deemed necessary to deal at some length with the principles underlying aggregation.

When a wet soil gradually dries up the clay particles approach one another closely and form aggregates called crumbs. This phenomenon is said to be due to the negative clay micelles as well their cations (positively charged exchangeable ions) causing the bipolar water molecules to undergo orientation, the extent of which depends on the intensity of the charge of the cations and also of that of the clay micelles. With further drying the cations attract water molecules already orientated by two or more different clay particles and a system is built up which becomes more and more rigid and finally yields "dry" crumbs. If such a system is well shaken with water there is a break down, but once again it is reformed on drying. A crumb formed by quick drying is usually small. The mechanical strength of the crumb, however, depends largely on the base exchange capacity of the clay. Where this is high the soil produces crumbs, the stability of which is unaffected on rewetting and this is specially so in the presence of calcium ions. Although electrolytes help in crumb formation, the crumbs formed remain more stable

in their absence. It is noteworthy that good crumbs have a dense arrangement and are rather rigid. When the crumbs contain small amounts of silt and sand the resulting structure is favourable for cultivation purposes.

In the presence of organic matter the crumbs formed are very stable owing to soluble alkaline earth salts of some of the complex humic acids precipitating on the soil particles and causing them to adhere. Thus, in the formation of crumbs, silt and sand particles are caught up with the clay and humus, and, if sufficient of the latter two are present, the whole soil can take on a crumb structure. These crumbs in their turn can unite to form aggregates of various sizes. On light soils owing to the insufficiency of colloids, the crumbs remain loose and separate, while on heavy soils they unite into hard steely lumps or clods, which are broken down only with difficulty. It is the intermediate state, described as "granular", which is regarded as the most perfect development of structure and which is least liable to erosion. The optimum size of these soil granules should be about 2 mm. and not less than .25 mm. in diameter. Smaller crumbs merely block the coarser pores and restrict drainage without appreciably increasing the water-holding capacity of the soil. Moreover, a good soil structure should be stable against the pulverising effect of wind and the shattering action of rain. From the soil standpoint a stable crumb structure is undoubtedly a valuable physical property. It is one of the most important factors in preventing erosion.

No special attention has been paid in Ceylon to the effect of artificial fertilizers on soil erosion. Mention, however, must be made that repeated applications of nitrate of soda will result in deterioration in the physical structure of soils. This will be markedly so in the dry zone soils as this fertilizer has the tendency to deflocculate the clay causing its dispersion and movement into the sub-soil. On the other hand, the long continued use of sulphate of ammonia, whilst making soils more acid, has practically no effect on their physical structure. The immediate action of applying potassic fertilizers is the same as that of other neutral salts, namely, to intensify soil acidity, but the ultimate effect, especially in the case of sulphate of potash applied over a period of years, is to conserve the exchangeable calcium in the surface soil and thereby to promote soil aggregation. Phosphatic fertilizers either reduce the acidity of soils or have practically no effect on soil reaction, and this is true even of superphosphate, which is an acid phosphate. Thus, in many instances the use of artificial fertilizers may result in the building up of soils to withstand erosion.

It now remains to detail the principal methods by which soil aggregation and consequently soil erosion can be controlled. For the purpose of this discussion it is convenient to take the two extreme categories of the physical classification of soils, viz., (a) light soils and (b) heavy soils.

(a) *Light Soils*.—Firstly, the basic calcium ion associated preferably with phosphate should be applied, e.g., basic slag. Secondly, on account of the low clay content, the insufficiency of colloids has to be made good by liberal and frequent dressings of bulky organic matter. The ploughing in of green leguminous crops is recommended as, in general, it is more efficient than the incorporation of cattle manure, because plant residues are rich in "binding material". Thirdly, it is known that aggregation can be controlled in some measure by suitable cultivation. This process depends both on the

moisture content of the soil and the degree of compression to which the soil is subjected. It is therefore necessary that all light soils should be cultivated in a wet condition (near the sticky point moisture level as aggregation is then greatest) by means of an implement such as a mould board plough.

(b) *Heavy Soils*.—Firstly, excess acidity in these soils must be neutralized by means of lime, disked in. In those cases where the soil is not unduly acid, a small amount of lime should nevertheless be applied to increase the carrying capacity of any pasture on it. Secondly, although heavy soils need less organic matter than the previous class, bulky organics should, nevertheless, be given. As an alternative it is a good plan to put the land down to grass, especially of the perennial type for a period of at least two years. Thirdly, the cultivation operations should be *commenced* with an implement that causes least compaction. Tillage is best carried out after the soil has been allowed to dry completely and is remoistened slightly. In other words the soil should be worked far below its sticky point. Saline soils must first be reclaimed and drained free of salts before any attempt at building up structure is attempted.

Finally, it has to be emphasized that profitable money crops and nutritious food crops can only be produced economically by the production of a good structure in the soil, which by itself can considerably help towards minimizing the loss of the most valuable soil constituents brought about by erosion.