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SOIL EROSION

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Introduction. Soil erosion is the depletion of soil from cultivated and cultivable land by various natural agencies. Unchecked erosion leads to the deterioration of the soil and the consequent impoverishment of the cultivator. This important subject is now engaging the earnest attention of all agricultural countries throughout the world. The chief object of this article is to bring to the notice of the Indian public the havoc played by soil erosion, and the seriousness of the problem in India so that by concerted action this evil may be successfully combated.

Erosin—Nature and Losses. There are three major kinds of erosion (1) Sheet erosion, (2) Gully erosion, and (3) Wind erosion. The first and second are caused by water. Sheet erosion occurs owing to flooding by heavy rains and water running off the land in sheets. This is responsible for the largest soil losses. Gully erosion is concentrated or localised erosion. It makes trenches in the soil which deepen every year and gradually become *Dongas* when neglected. At this stage plots of flat land become subdivided and profitable agriculture by the use of implements becomes practically impossible. Wind erosion occurs in arid and semi-arid regions. Fine particles of soil and sand are blown away by wind from bare patches of land and this removal gradually impoverishes the soil.

Research on soil erosion was carried out at the Missouri Experiment Station, U. S. A. by Miller and Duley(1) for a number of years. They subjected a number of plots to different treatments of cropping and cultivation. They found, in terms of rain-water, the run off from the uncultivated plot was nearly 50 per cent of the total rainfall, while from a cultivated plot it was only 25 per cent and from a grass plot only 12 per cent. The plots under corn and small grains have amounts of run off intermediate between the two extremes.

As regards loss of soil(2) by washing, land ploughed 8 inches deep, lost nearly 2½ times as much soil as land having no cultivation. Land ploughed 4 inches deep lost nearly as much as that ploughed 8 inches deep. Sod land (land under pasture grass) was most efficient in preventing erosion and absorbed a greater percentage of rain-water than any other soil. Land under a suitable and well balanced rotation, for example corn, wheat and clover, lost only during the growing season of the corn, while wheat and clover protected the soil.

Briquettes were made of different types of soil and their slaking value was noted by Middleton,(3). Technical methods were evolved and made use of to determine the silica sesquioxide ratio, the erosion ratio, and the ratio of colloid to moisture equivalent. These proportions have been found to have the greatest influence on soil erosion. Soil material which is easily brought into suspension is naturally more readily carried away by run-off water. Non-erosive soils are considerably heavier in texture than erosive soils. As for the quantity of soil material eroded, these experiments show that with a slope of 3·68 per cent over a length of 90 feet and with an annual rainfall of 37 inches, in an average of 12 years' measurements, bare, uncropped and cultivated land has suffered an annual loss of 43 tons of soil per acre. Under the same conditions, land cropped with corn lost 20 tons per acre annually, with wheat 9 tons, and in a good rotation 3 tons, while land left in continuous sod lost only at the rate of ⅓ of a ton annually. Under these conditions 7 inches of soil could be lost in 23 years from uncropped cultivated land, in 50 years from corn land, from the wheat land in approximately 100 years, from the land in good crop rotation in 350 years, while under sod it requires almost 3000 years. These figures show the very great influence, the system of agriculture, particularly the cropping system, exercises on erosion losses.

The slope of the land has a direct influence on soil erosion. With a slope of 3·68 per cent, land in continuous corn lost 26 tons per acre annually. With a slope of 6 per cent the annual loss was approximately 85 tons and with a slope of 8·5 per cent the loss was nearly 150 tons. In the last case the surface soil was removed at the rate of 1 inch per year, and exposed the sub-soil in less than 10 years. Owing to the fact that several other factors also intervene, it has not been found possible to establish mathematical relationship between the slope of land and the amount of erosion.

The erosion measurements at the Missouri Station include some data as to the quantity of elements lost in the eroded material. These data show an annual acre-loss from 3·68 per cent slope under continuous corn, of about 65 pounds of nitrogen, 18 pounds of phosphorous and 610 pounds of potassium. In a balanced rotation the loss is reduced to 18 pounds of nitrogen, 4 pounds of phosphorous and 140 pounds of potassium, while under continuous sod they reach extremely small quantities of less than a pound of nitrogen and phosphorous and only 4 pounds of potassium.

An analysis(4) of the eroded material revealed that the amounts of nitrogen, phosphorous, calcium and sulphur lost may equal or exceed the amounts taken off in the crops. Mechanical analysis showed that the material eroded from the bare plots contained a higher percentage of sand and a lower percentage of fine material than the soil lost from the other plots.

It has also been found that the chemical composition of soil has no influence on its erosion, and that only the physical properties are involved in the problem.

The relation of soil character to erosion losses is not well understood. It has been shown that the so-called " dispersion ratio " is the most important single factor governing erosion. This ratio refers to the proportion of the silt and clay easily dispersed in water. Generally soils having a medium texture of surface soil like silt loams, loams and sandy loams suffer most, particularly from sheet erosion and that such losses decrease as the texture reaches the extremes. If such soils are under-laid with a tight clay sub-soil the loss from erosion is generally intensified. Small gullies form readily in soils of medium texture with tight sub-soils, while deep gullies are developed when such soils are under-laid with loose silt loam, or sandy loam.

On hill sides clean culture and indiscriminate removal of forest growth tend to increase floods and increase soil erosion. The erosion becomes chronic where a large percentage of rains is of a torrential nature.

The laterite soils of the tropics do not erode seriously even under very excessive amounts of precipitation. It has been suggested that this is associated with the high silica and low sesquioxide content of these soils.

The Effect of Erosion. The evil effects of soil erosion are so patent that they do not require to be dialated upon. Agarwala[5] says that it is the greatest single menace to the well being of the people for it removes not only the plant food from the soil but also the whole soil itself. It is a loss of capital. Miller from Missouri[6] has called attention to the fact that erosion may be the principal contributing factor responsible for the deterioration of agricultural land. Ten or more inches of soil from the surface have been sometimes found to have been removed within 30 years. The damage is undoubtedly cumulative increasing somewhat as the absorptive power of the soil and its content of organic matter decrease.

Under a slope of 8·5 per cent on loamy soil at Missouri planted continuously to corn, the surface soil was removed at the rate of one inch per year. The normal depth of the soil there is about 9 inches, so that under such conditions sub-soil was exposed in less than one decade. It is under these circumstances that sheet erosion becomes very destructive in removing the fertility which nature has taken thousands of years to accumulate in this humus-bearing layer of surface soil. Land has consequently been abandoned without cultivation and such useless and unreclaimed land increases the poverty of the nation.

General Control Measures. The several modes of treatment for the prevention of soil erosion are alike in principle, all operate through

the regulation of the movements of the surplus water which freely runs off the land.

Green manuring and the increase of humus content of soil diminishes erosion. The presence of plenty of organic matter in the soil improves its water holding capacity and the run off consequently becomes less.

The planting of spineless cactus and American aloes or agave along contour lines retains soil on the upper side. The aloes should be planted in a number of rows or ranks close to each other to avoid gaps. Other suitable hedge plants can be selected according to local experience. Aloes are recommended as they are hardy and drought-resistant.

In England (North Somerset) Roper(7) describes experimental work with *Spartina Townsendi* in an effort to establish the grass on the extensive mud flats of the river Severn as a means of protection against erosion from the high spring tides and winter storms. The plant is said to give considerable promise for the future. A study of the indigenous grasses for purposes of preventing erosion will reveal many promising types suited to each locality.

Terracing helps and is obtained by levelling lands which are sloping. As far as possible, broad level terraces should be made. By terracing, the main field is divided into smaller fields one below the other in level, but fairly level within itself. This prevents water running off from the land rapidly as it has to go down terrace by terrace and erosion is thus checked.

For gully erosion of the medium and large size, a carefully constructed earth dam with surface inlet known as the Christopher or Dicky Dam is said to be the least expensive method of control in America.

Dam embankments(8) across *dongas* consisting of stones, boulders or brush wood held by fences, may be erected. Rough masonry work and wire netting may also be erected across small streams at intervals along the course of the stream. Even big *dongas* can be blocked by means of suitable masonry structures and when the up-stream silts up, vegetation takes root.

Contour ridges, made up 80 yards apart by means of a ditch hauled by a tractor and trimmed by hand labour have been found to be useful in checking erosion in Rhodesia.(9) The cost has worked out to 1 penny per yard length or 4 sh. per acre of land. The ridges can be put to sunnhemp or maize which will prevent weeds colonising.

In grazing areas and arid regions, wind blows off dry soil from bare patches. To minimise erosion caused by wind, contour trenches may be dug to trap the fine soil and wind-breaks erected at intervals,

consisting of hedges to check erosion of this type. Crop rotation may be planned in such a way that land will be covered for as long a time as possible with a growing crop which will protect the soil. Soil is lost only when it is unprotected and freely exposed to the action of heavy rains for a long period in the year. Thick-growing crops which cover the ground and which are effective in checking erosion must be included in the rotation.

The control of soil erosion is a continuous fight and one must always be ready to patch up, and repair and carry the work further. Soil erosion works will generally not be of a permanent character and hence they are liable to be damaged. This should not discourage the cultivators and they should be alert in mending, always remembering that a stitch in time saves nine.

A direct incentive to farmers to come to grips with the problems in S. Africa, is that expenditure incurred in stopping soil erosion is deducted with assessment of land tax. This shows the interest the Government takes in the soil conservation and encourages the cultivators to proceed with the work effectively and put a stop to it. This is an example which could profitably be followed in all countries.

To sum up, the following are the ways by which soil erosion is generally prevented. (1) Providing suitable storm-water drains, at proper places with effective vents at required levels. (2) Ploughing fields across slopes and planting crops similarly. (3) To grow more fodder crops and encourage permanent pastures. (4) In special cases growing more trees. (5) General good farming with particular attention to prevent erosion by terrace sloping etc., (6) Filling up gullies by brush wood dams, mounds, stones and rough embankments etc. More than half the battle lies in the prevention of erosion. Prevention is easier than cure.

The Problem in Foreign Countries. In the United States of America the problem of soil erosion is of major importance. It has been estimated that 10 million acres have been abandoned and 4 million acres devastated due to soil erosion. There are several soil erosion experimental farms where fundamental research on erosion is conducted. Practical and useful knowledge gained at these stations is given wide publicity.

In South Africa, that the Departments of Agriculture are determined effectively to tackle the problem of soil erosion, was evidenced by the Soil Erosion Conference which was held in Pretoria on 14th November 1929(10). One of the most important recommendations of the conference was that the Minister of Agriculture should be responsible for the policy governing soil erosion and that he be assisted by an advisory council consisting of representatives of State Departments, Provincial Administrations, Municipal Associations and Agricultural Unions. Several important recommendations of the council have been

put into practical effect. Some of the chief recommendations are—(1) that a special competent Soil Erosion officer be appointed for the purpose of co-ordinating and carrying out work pertaining to soil erosion, (2) that there was an urgent necessity for investigational work to be done and the carrying out of initial experiments in the schools of agriculture, (3) that small areas be first handled, (4) that detailed contour surveys be made by the irrigation department, (5) that when results are obtained greatest publicity be given to them, (6) that loans be granted for conservational works, and (7) that efficient propoganda work be done to educate the masses. There is thus no doubt that South Africa is forging ahead with her schemes for the prevention and control of soil erosion.

In Ceylon the Government have fully recognised the seriousness of the situation. They have appointed a committee consisting of Planters' representatives and Officers of the Revenue, Forest and Agricultural Departments to consider this question and make recommendations for averting erosion after making a thorough study of the causes, rate and trend of soil erosion.

In Java where this subject has received attention, they employ the *Kotak* system, by which small rectangular terraces are made instead of long ones with ditches. An open drain is located at the foot of the terrace.

In China(11) prevention of soil erosion has been attempted at great expense and the results have justified the outlay. The fields were so constructed as not only to avoid erosion but to catch the maximum amount of soluble and suspended matter in the run off. Hillside fields have been terraced and carefully graded and bounded by raised rims which retain the run off until the suspended matter has settled. Heavy mulching(12) with straw has been found to check erosion effectively.

In Japan the problem of control of soil erosion in valleys which contain paddy fields is so serious, that the Government have felt themselves justified in spending on control measures as much as ten times the value of the land under erosion, a state of affairs which shows that the problem is recognised as one for the state rather than the private owner.

The foregoing facts reveal that soil erosion has become a world problem and in every country adequate steps are being attempted to control this evil.

The Problem in India. The problem of soil erosion and its control in India, should form an integral part of any comprehensive plan for the development of the natural resources of the country. India is essentially an agricultural country and the loss of soil by erosion is a national loss.

When compared with the work done in foreign countries for the prevention and control of soil erosion practically very little has been done in India either in realising the seriousness of the question or attempting to control it on an All-India basis. A few Provinces like Bombay have been trying to do something but the other Provinces are sadly lagging behind, letting the finest soil of our country go to waste.

The Board of Agriculture in India[13] met at Pusa in 1916 and took up the question of soil erosion for discussion. Dr. Mann recommended that an engineer be placed at the disposal of the Agricultural Department, Bombay, to take up the work of the prevention of soil erosion. Mr. Taylor suggested that the problem should be tackled by the Agricultural Chemist, while Mr. Bent was of opinion that famine labour should be diverted to this. The Director of Agriculture, Bombay, said that the Collector of Ahmednagar was given a grant for the construction of small bunds as famine relief work, but that the bunds had breached in various places and that no sustained care had been bestowed on this. Small bunds strengthend with stones have been useful. Wiers must be constructed at proper levels to let clear water run off. Mr. Evans suggested that grass lines across slopes reduced erosion. Mr. G. D. Hope suggested, for tea lands, contour planting, contour drains, terracing and the use of leguminous plants like Tephrosia for hedging, to prevent erosion.

Control Measures so far attempted in India. At Pusa large fields have been divided into small field by Howard[14] so as to break up the run off into units and so dissipate its destructive energy. Each small field is surrounded by trenches and small grass borders which conduct away the run off and also hold up the fine soil. Each field deals with its own rainfall only.

In Bombay this work has been taken up with earnestness. The Department of Agriculture in Bombay has realised that soil can be retained by effective field embankments. Two officers have been doing experimental work. In 1914-15 an enquiry was started into the problem of bunding and levelling. In 1915-16 it is reported that soil erosion work was in full progress. Many embankments and waste wiers were being built. This became so popular that applications were being received to put up embankments and the staff at the disposal of the department was unable to cope with it. In 1921-22 the Government announced that they would appoint a Land Development Officer for collective schemes of irrigation. In 1922-23 a systematic study of soil erosion was made and suitable recommendations were being put into practice. In 1926-27 a Superintending Engineer was appointed to provide technical skill in preventive works of large size while smaller schemes were in the hands of the Department of Agriculture. Three men have been employed as " Bunding Officers " and extensive work is being undertaken and pushed through.

The collectors were issuing *takavi* loans to suitable applicants and the Registrar of Co-operative Societies advanced loans to individuals for embanking. The District Agricultural Officers were also being trained in the work of the prevention of soil erosion. It was being fought on almost all fronts.

Let us now turn our attention to the problem in Madras. No adequate attention has been paid either to assess the loss to our province by soil erosion or take steps to combat it. The natural agricultural capital of the country is slowly running into waste. The loss of soil fertility reacts on production and the consequent well-being of the people. It will mean debt, increased liability to disease and finally rural depopulation. The gradual denudation of the soil of the country is the real economic drain.

The monsoon rains are not an unmixed blessing. Soil erosion is an attendant evil. Fine soil particles get washed and create minor depressions in the soil which are accentuated every year so much so ravines and gullies are gradually formed in badly neglected cases and soil in very appreciable quantities gets washed away every year through streams across the fields. This is a very common sight in the dry lands of the Ceded Districts. This evil is not chronic in wet lands and is not absent in garden lands.

It does not require high technical skill to combat soil erosion of minor types. Leaving aside *Porombokes* all minor erosions in cultivated lands must be bunded up at the outset so that they may not become bigger streams. There will be always enough stones and pebbles in the field itself that could be picked and laid across so that regular streams may be made into many little cascades.

Regular carting of silt from tank beds and giving it back to the soil will generally make up much of the loss from erosion. To lessen the cost of this work it should be taken on hand when cattle have no other work. In the first instance silt can be made into a bedding for cattle. After it has absorbed the urine it should be put into the manure pit where it makes an excellent starter for cholam stubble and other straw and when fit may be spread on the land.

By suitable publicity of their evil effects, an end must be put to the reckless destruction of forests to over grazing and careless farming. Measures should be taken to conserve forests in valleys and water sources, and to see that such places are not brought under tea, coffee or other planters' crops.

It is suggested that this soil erosion problem should be taken up seriously by the Madras Agricultural Department. Agricultural Demonstrators should be given training in methods of erosion control and be asked to put them into effect in their centres of activity. Fundamental research on the erosion of South Indian soils should be

made and any useful results obtained may be vigorously advocated. A systematic survey of the Presidency has to be made for assessing the seriousness of the problem in Madras, so that adequate measures for the prevention of soil erosion may be put into operation. The disappearance of the prickly pear through the cochineal insect has resulted in the loss of a valuable plant, which until man found it necessary to remove it and cultivate the cleared land, has been one of the best agencies in the protection and retention of the soil.

Soil erosion is a national menace and calls for joint action and sustained effort on the part of the cultivators on the one hand and the Government on the other. If this colossal waste of basic capital accumulated patiently through centuries is prevented, the foundations of a new agriculture will have been well and truly laid.

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MECHANICAL ANALYSIS OF SOILS

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Though a detailed mechanical analysis is done as a regular routine in the course of a soil study, a rapid separation into two fractions one of which is the coarse fraction including coarse and fine sand and the