SOIL CONSERVATION IN THE TROPICS

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As far as the British Colonial Empire is concerned, it is just sixty-five years ago since attention was directed to the question of soil erosion. It was in 1873 that Sir Joseph Hooker, then Director of the Royal Botanic Gardens, Kew, drew the attention of the Secretary of State for the Colonies to the serious losses of soil which were taking place in Ceylon as the result of the opening for cultivation of the forest-clad highlands of that colony. As the result of this action, legislation was some years later enacted prohibiting the alienation of Crown lands, except in small areas for very special circumstances, at all elevations in excess of 5,000 feet. Similar enactments were passed from the year 1912 onwards in the mountainous islands of the West Indies for heights varying from 1,000 to 1,500 feet according to the particular island concerned.

This system of protecting the forest cover at the higher altitudes of island colonies constituted the first steps which were taken in the British Colonial Empire to deal with erosion. It is satisfactory in the hilly wet tropics only if measures are also taken to prohibit the

opening of steep slopes and to protect the catchments and springs of the principal streams at lower altitudes. All lands opened for cultivation purposes must, however, be specially protected by anti-erosion measures if severe losses of top soil are to be prevented.

I personally began to take an active interest in soil conservation work in the tropics from 1920 when as Director of Agriculture in Ceylon it was apparent that much further protective work remained to be done on the tea and rubber estates in the hilly parts of that island if the enormous losses of soil from erosion were to be checked. The experiences of the Netherlands East Indies were freely drawn upon for control measures adopted and during my service in Ceylon I saw considerable advances made. Clean weeding practices were slowly, but gradually, abandoned, contour drains and silt-pitting increased, low contour stone walls established, the general growing of cover crops begun and the contour platform system in the opening of new lands started. Many were sceptical at first, but progress was made by degrees as the result of experiment, education and propaganda. The results achieved up to 1930 were reviewed by a special Government Committee constituted to examine the position. In the Report issued by this Committee in the following year there was expressed general commendation of the improvements which had been effected during the previous ten years but it was stressed that the position was still regarded as serious. Estate agriculture was considered to be mainly responsible for erosion in Ceylon and it was held that it was essential that the use of ground cover should be universally accepted, as it was only by the adoption of such a policy that erosion could satisfactorily be checked. In recent years, attention has been given also in the village lands and some useful demonstration areas started.

Since 1931 much attention has been focussed throughout the world on the problem of erosion and also on the measures which can be effectively employed to assist soil conservation. The position in the United States which was made clear to the world in the Report of the National Resources Board of 1934, and the action taken as the result of that report, have attracted universal attention. Those who were battling in the Colonies fifteen years ago to secure some recognition of the evils of, and losses occasioned by, erosion, have seen the Governments of colonial dependencies inundated with demands for something to be done and with complaints that anti-erosion work is not proceeding sufficiently rapidly. There is no British tropical possession in which a review of the position has not been made and, where necessary, some measures undertaken to improve matters. Public opinion has been aroused, but not infrequently the staffs available for the work are insufficient and finance inadequate. It

has been recognised, however, that considerable expenditure will have to be incurred and that the most satisfactory results will only be achieved when there is planned co-operation between administrative and technical staffs and the people themselves.

When questions of soil conservation are under consideration it is necessary to contemplate the issues involved in their broadest aspects. They must include not only the consideration of forest protection and anti-erosion measures but also those associated with the maintenance of soil structure and fertility. The reactions of vegetation on soil and possibly climate have their bearing on the general problem, as the whole concept of soil conservation covers the maintenance of its productivity. It is bound up with soil cover, the nature of the soil, the conservation of water supplies, the forestry position, the agricultural occupations of the people concerned and their social and tribal customs.

ACCELERATED EROSION

Accelerated erosion occurs in the form of sheet erosion, water erosion or wind erosion. It is brought about by an interference with the natural vegetal cover, by the omission of suitable anti-erosion measures and the lack of satisfactory methods of agricultural husbandry and of grassland and woodland management. The unthinking stripping of the soil's protective covering of vegetation is primarily responsible, but densities of population and developmental enterprises have required that large areas of hilly lands should be brought under agrarian production.

As far as the tropics are concerned, it is necessary to keep clearly in the forefront of any consideration of the subject the differences between the wet and dry tropics. It is necessary, however, to recognise that the distribution of the rainfall is of greater importance, as far as erosion is concerned, than the actual total falls. Downpours of high intensity over comparatively short periods of duration invariably cause the maximum of "run-off" and erosion is always more serious in areas where long periods of dry weather are experienced than in those where a more even rainfall distribution prevails. In some areas of the wet tropics erosion is not nearly so severe as might be expected because of its more regular spread throughout the whole year. Whereas in the dry tropics the soil during periods of drought is often reduced to dust which may be carried away by the wind or eroded by the heavy tempestuous storms which herald the break of the dry weather season, this dusty soil is but poorly absorbent and in consequence it takes little to remove it from its normal situation.

Again, the configuration of the country must be another factor to receive consideration. The steeper the slope, other things being equal, the less the time for water absorption and in consequence the greater the "run-off." The aspect of the slope is also important, for hilly slopes which face the direction from which prevailing rain storms come, suffer more than those which are favoured by a measure of protection. The size and shape of the watershed also must not be overlooked when the opening of lands from forest or grassland cover is under consideration and a decision being made of the anti-erosion measures to be adopted.

Consideration must also be given to the kinds of vegetation and the extent of the land cover. Forest cover is recognised as affording an ideal protection against erosion. Tree roots bind and hold the soil, leaves and branches break the velocity of the rains which would otherwise compact and erode the soil and the ground cover of forest litter provides that the water is rapidly absorbed, the velocity of surface water from hilly slopes reduced and "run-off" prevented It is the organic litter in the forest which encourages the absorption of water and checks "run-off," but at the same time the more satisfactory soil structure under the forest litter must not be overlooked. Soil under forest cover invariably has a better structure than is the case when a similar soil is subject to cultivation for a number of years.

It should be the aim of all agriculturists in the wet tropics to maintain or to reproduce as far as is practicable the conditions which prevail when the land is under forest cover. Tree crops which produce a good canopy of foliage are more suited for cultivation in these areas than are annual crops which require frequent cultivation. Where the nature of the crop does not permit of forest-like conditions being re-created, the use of contour drains, silt-pits, terraces and ground covers is necessary if "run-off" is to be effectively checked.

In effecting control in the use of land so that erosion may be checked it is important to recognise that it is necessary to protect by means of forest reserves or in grassland cover the major catchments and water sheds, provide for the protection of stream banks and steep hill slopes and prevent the destruction of the natural vegetation on the poorer lands.

In the dry tropics, the position differs from that which obtains in the wetter areas. Here the principal activities which are causing injury to land are shifting cultivation, bush firing, increased agricultural activities and in some places overstocking with cattle and goats. The consequences of the exposure of vegetation to these abuses are a general deterioration of environment, soil degradation, a failure

of water supplies and erosion. In many areas in the dry tropics, forest cover is sparse, and in others savannah or grassland prevails. It is only in recent years that grassland problems have been intensively studied in temperate countries and the work has barely begun in the tropics. Data are available which show that "run-off" from grass covered areas is practically nil and that from an erosion point of view they provide efficient cover. In fact it is now recognised that fibrous rooted crop plants are more effective in providing for water absorption than are tap rooted plants and that a good cover of grass will minimize erosion and increase infiltration of water. If, however, these grasslands are, as is so often the case, overstocked with stock concentrations the soil cover is rapidly eaten down or trampled out. Erosion then becomes serious. Similarly, agricultural cultivations in grassland areas can readily become the cause of extensive gully erosion.

The damage which can occur in grass covered country from overstocking or thoughtless agricultural activity can be seen in many parts of East Africa today.

In dry areas also much damage is occasioned by the annual burnings which occur. These cause a definite retrogression in the growth of vegetation and the absorptive capacity of the surface soil is greatly reduced.

Wind erosion is severe in only the driest areas and occurs only when the vegetation has degraded or has been removed for agricultural occupation. The loss of soil structure is one of the main causes responsible for making a soil liable to wind erosion. In areas liable to wind erosion measurable improvements can be effected by strip cultivations and by rough methods of cultivation which attempt the burial of but a portion of the crop residues. It is only when the pressure of population becomes considerable that lands in dry areas liable to wind erosion should be taken up for arable cultivation.

Protection cannot perforce be carried to the extreme as the populations must produce their food for subsistence and some money crops wherewith to secure the cash for the purchase of clothing and other requirements. It is therefore now necessary to consider the measures of control against erosion which have been shown to be effective.

MEASURES OF CONTROL

These vary in accordance with the particular circumstances of the case. They have been devised by man to counteract the troubles which follow upon his thoughtless action in regard to land. It is unnecessary to go into them in any great detail in a paper prepared

for an audience such as that gathered at this Conference. Neither is it necessary to quote figures from the results of experiments designed to ascertain the amount of soil lost under ranging forms of treatment, nor to list the comparative efficiency of the different methods of control. Year by year additional data are being added and from the results secured our knowledge is steadily increasing. The whole essence of the problem is to remember that the measures which require to be adopted in any particular area depend upon the special circumstances of the case. Generalizations are dangerous and each area and each problem must be examined in detail before any particular line of action is advised.

In Kenya, for instance, where attention has in recent years been centred in erosion problems, it is recognised that the chief causes of erosion have been the following:—

1. The deforestation of the hill tops and slopes and sides of river valleys.
2. The depletion of grassland cover by reason of a general increase in cultivation.
3. The cultivation of steep slopes.
4. Gross overstocking in certain areas leading to a destruction of the vegetal cover, and
5. The concentration of stock at and around water supplies, particularly during the dry season.

In any particular area one of these causes may be of more importance than the others, whilst in another area there may be operative a combination of two or more of them. Each cause of erosion demands specific remedies and it is frequently necessary to combine a number together. Progress is often slow by reason of economic and sociological considerations which have to be given most careful thought and consideration.

It has been demonstrated in the United States of America and elsewhere that erosion cannot be effectively checked in areas where the main cause is overstocking unless and until the number of stock is reduced to the normal carrying capacity of the land and it is clear that in many parts of East Africa similar action will have to be contemplated if the people are to be saved from themselves. In the tropics it is not always easy administratively to secure the adoption of this necessary measure of control because of tribal customs, especially in areas liable to serious outbreaks of epizootic diseases and severe droughts, but it is recognised that it is useless to introduce contour banks or spreading works without controlling

the grazing, and that one of the most important measures to demand attention in dry land grazing country is the provision of adequate and satisfactorily spaced water reservoirs or dams for the stock in order that they may be spread over a wider area and excessive concentrations in particular areas reduced. Gradually, as economic considerations become more recognised by the people, improvements will be effected and more satisfactory systems of range management introduced. Economic advantages inevitably lead to the adoption of measures which at first are difficult to secure by reason of the conservatism of the people concerned.

The conditions in the wet tropics are different from those in the drier areas such as those mentioned above as being applicable to Kenya, and the endeavour must there be made to reproduce as far as is practicable the conditions which prevail in the natural conditions of the forest. Successful agricultural undertakings in the wet tropics, if one excepts the rice cultivations under irrigation, have as I have already mentioned been found to be the tree crops of which rubber, tea, cacao, nutmegs and oil palms may be mentioned. These form a satisfactory leafy canopy and where they do not the introduction of shade trees has been beneficial and the establishment of ground covers adopted. The organic litter which is thereby created plays an all-important part in the control of erosion and this supported by such provisions as platform terraces, box terraces, contour hedges, contour drains and silt-pits normally ensure a reasonably stable condition.

It is unnecessary to give constructional details of different forms of terraces and pitted contour drains nor is it necessary to refer to the systems of broad base or narrow contour banks which have been employed successfully in undulating country of medium or low rainfall.

The use of contour hedges or contour strips of mulch has been shown to be effective in several areas and I have seen in parts of Tanganyika and Kenya marked improvements follow upon the adoption of the former and in Uganda the advantages of the latter. The use of contour strips of mulches of elephant grass (*Pennisetum purpureum*) in Uganda has also shown an inexpensive method of inducing the formation of terraces on gentle slopes of friable soils.

Strip cropping is also being employed with success. It can be used on moderate and ungullied slopes whilst contour buffer strips of close growing grasses or cover crops are also effective in certain places.

Recent investigations have also shown that roads, paths and fire breaks must receive attention in connexion with any anti-erosion

measures and that it is of the greatest importance that most careful consideration be given to the natural drainage channels. The use of vegetation as covers in these water outlets is preferable to the construction of engineering works and the whole tendency of modern thought today in regard to anti-erosion measures is to encourage Nature to do her rightful work and to enlist her aid in every manner possible. The aim should be to get away from engineering structures as far as possible and to make the fullest possible use of vegetation. This is the most economical system and produces the most lasting results.

SOIL STRUCTURE

I will now briefly turn to the question of soil structure. Steadily it is becoming recognised that many of our agricultural difficulties have resulted from a loss of soil structure. Sheet erosion, that most insidious form of soil loss, is often unrecognised at the outset. It may not attract attention until finger or other forms of gullies begin to occur. In Uganda, for example, there has been a progressive increase of sheet erosion since the extension of cotton cultivation became general and it is now recognised that, except in a few areas of that country, the soil losses which are being experienced are due mainly to a loss in soil structure.

Soils under forest cover have as a rule a satisfactory soil structure. The decaying roots and the decomposition of the organic leaf-fall are responsible for this, but general conceptions of soils have changed markedly in recent years. From the geological conception we have been introduced to the biological conception. This in turn has been shown to be but part of the whole story and now our thoughts are being directed to the importance of soil crumb, for without a satisfactory soil crumb water absorption is unsatisfactory, biological activities are affected and fertility reduced. In a soil of good structure the mineral particles are cemented together by the colloids into water-stable crumbs, and where the soil crumb has been lost the soil particles become mere dust which may be blown away by the wind or carried down the slopes by every shower. Optimum crumb size varies with different soils and under differing climatic conditions. It may be defined as that which best secures adequate supplies of air and water for plant existence. In wet climates the limiting factor is the air supply whilst in arid climates water is the controlling influence. It follows therefore that in the wet tropics an open soil structure is preferable whilst in the drier tracts a more compact soil structure is desirable. Martin in Uganda is finding that soil structure can be markedly improved in the cotton-growing belt by the use of rotational growths of elephant grass (*Pennisetum purpureum*) between crops of cotton and food crops.

He has in fact found the improvement of soil structure is better under grass, with its masses of fibrous roots, than when green manures are employed. Similar results, although perhaps not quite so spectacular, are being obtained in the drier areas where permanent star grasses (*Cynodon* spp.) are being employed in the place of elephant grass.

This work appears to be of importance and it may lead to a definite form of alternate husbandry, with say, three-year periods of arable alternated with similar periods when the land is under grass. The system is not very different from that which is now finding favour in England where arable cultivation is being alternated with leys of grasses and clovers for periods of three years upwards.

If the results in Uganda come up to expectations, the change of system is expected to find favour, because it approximates in an organized form to the methods of the shifting cultivations in the grass covered areas.

SOIL FERTILITY

Within certain limitations, a soil owes its character rather to the effects of climate and vegetal cover than to the nature of the parent rocks. Removal of cover and exposure to the sun tends to speed up the chemical processes, while rainfall is responsible especially in the wet tropics for excessive leaching of plant nutrients if the soils are exposed.

In the wet periods, the luxuriance of evergreen vegetation conveys an impression of considerable soil fertility. This has led to the clearing of areas formerly covered with heavy forest for cultivations of both permanent and annual crops. In regard to the latter, many have been the disappointments. Deprived of the products of decay of the forest vegetation the soil has proved to be unproductive and the cleared areas have been abandoned to a useless and often sparse weed growth. Moir, in his article on "Climate and Soil in the Netherlands Indies" has pointed out that heavy rainfall causes leaching and impoverishment of the soil. Under virgin forest conditions, plant nutrients form a kind of closed cycle, whereby the plant food taken from the soil is returned in the form of plant residues; but when that cycle is broken and crops are taken from the land a loss of fertility begins. This loss of fertility may be excessively rapid under the conditions prevailing in the wet tropics and I have seen excellent forest lands opened for pineapple cultivation reduced to infertile white quartz sands within a period of three years.

Hardy has shown in respect of cacao that the chief nutritive feature of organic matter in cacao cultivation is its content of mineral nutrients and that importance should not be placed on nitrogen to the extent to which it was at one time customary. The results which are being obtained from the use of phosphatic manures in rubber cultivations in the East also tend to support this view.

In the drier tropics, attempts have been made to introduce mixed farming, whereby animal husbandry is introduced into the agricultural system of the small-holder for the purpose of producing supplies of organic manures. In Northern Nigeria progress has been made, but here again except for the value of the organic matter in the building up of soil structure it has been determined that the increases of crop yields have resulted from the phosphatic nutrients of the manure added. Attempts are being made to encourage the spread of mixed farming in many parts of the British Colonial Empire and large numbers of experiments are being carried on. It has yet to be ascertained whether the system can be introduced effectively into the wet tropics where, as has been previously stated, it is now recognised that permanent tree crops are more suited to the prevailing conditions than annual arable cultivations.

Trials are also being made with the use of composts. Their value has been demonstrated in nursery work and in garden cultivations but it is doubtful if the preparation of composts is economically sound for large-scale cultures, especially in areas where the rainfall is adequate to ensure a satisfactory break down naturally of organic waste materials within a reasonable measure of time. In the dry areas, the position may possibly be somewhat different if adequate water supplies are available for the making of good composts. From a soil erosion point of view, however, it must not be overlooked that vegetable wastes and stubbles can be usefully employed as part of anti-erosion measures. I would be very loath to see, as I have done recently in Ceylon, the general adoption of a system of clearing undulating land free of waste vegetable matter for conversion into compost to be transported back to the area from whence it came. This is a most wasteful method and one which is liable to encourage an increase of erosion.

With the use of green manures considerable successes have been achieved in the Netherlands Indies but our experiences in the British colonial dependencies have been variable. In Ceylon and Malaya their use has been advantageous and in Nigeria it has been demonstrated that soil fertility can be maintained at a reasonable level by their use. In East Africa, however, their use has not brought about the results which were expected and except where pigeon pea (*Cajanus cajan*) is being employed for the breaking up of lateritic

hard pans there is a tendency now to await the results of the experimental work designed to test whether the improvements of soil structure which result from land being sown or planted with grass as part of rotation are not of greater value than those which follow upon the employment of green manuring. A strong cultivation of grass or a healthy grass sod produces new roots each growing season to replace the older ones which in their turn add to the soils organic matter. When land is under a grass sod the organic matter in the soil is increased and workers with sugar-cane in Hawaii hold that the amount of roots annually produced by a crop of sugar-cane adequately maintain a soil's organic matter content. I am aware of lands in British Guiana which have been under sugar-cane continuously for nearly 100 years, with only those breaks at intervals of 3-4 years when replanting had to be done. Grassland soils are generally richer in organic matter under comparable conditions than are forest soils and we are, I fear, rather inclined to overlook that the grasslands which are associated with the dry tropics often mean poor soils because of low rainfall and stunted growth of the vegetation rather than an intrinsic harmfulness which has so often been ascribed to the grasses themselves.

CONCLUSION

In conclusion, I would like to say that I have endeavoured to treat this subject of soil conservation, which is attracting world-wide attention, in as comprehensive a manner as time permits. Science in recent years has tended to become departmentalized into a series of narrow specialist channels. Co-ordination is often difficult to secure and a clear picture of the whole impossible to obtain. It is the same with matters concerning soil conservation. There are the enthusiasts for certain particular remedial measures and also those who tend to ride their pet hobby horses. But we must approach the subject from a much wider view-point if sound progress is to be attained.

Much time, energy and money have been expended in many countries on the treatment of gullies which are but the indications of troubles further away at the head of the drainage system. Similarly much time and energy have been expended on the development of terraces, contour bundings and other works in areas where the methods of agriculture are faulty.

One knows full well that circumstances in many tropical countries demand immediate and energetic action if increasing losses from erosion are to be checked and ultimate economic ruination prevented. Sound planning of land usage is essential but without

sound methods of agricultural husbandry and range and woodland management attempts to check erosion will be of but temporary value. Soil conservation in its truest sense will not be achieved unless it is tackled in the widest possible way. The building up of deteriorated soils is a relatively slow process for soil building can only be effected if an increase in the organic matter is secured. If this can be accomplished other effects, physical and chemical, will follow.

The present position demands firstly that the rot which is at present occurring in many areas should be stopped and that at the same time strenuous attempts be made to build up sound agricultural practices The marriage of animal husbandry with crop production must be achieved in all areas where the conditions are suitable and where they are not, crop production must proceed along lines which conform with the dictates of Nature.

In the Netherlands Indies, the planned utilization of land has long been the basic policy of the Government and it has long been recognised that agricultural practices should conform to the needs of the land.

It should be our endeavour to foster in every way possible and in the widest circles this thought for the land. Erosion can be controlled if Nature is carefully studied and her secrets ascertained. The land is the chief asset of the tropical peoples and the proper use of that asset by present generations combined with its conservation for those to follow should be the primary aim of all.

Exploitation of soil fertility has gone far enough in many areas, whilst in others it has gone too far. A full stock of the position is now being undertaken and it is to be hoped that all who can will add their quota to the endeavour necessary to improve matters.