SOIL CONSERVATION*

FOREWORD BY
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I WISH to take this opportunity, on behalf of the Government of Southern Rhodesia, to thank and congratulate the Soil Conservation Councils, the Propaganda and Local Sub-Committees, and the Local Technical Assistants, on the good work they have done in connection with the Soil Conservation campaign, not only in getting the landowner and the general public to realize more fully the grave danger of soil erosion, but also—and this is very important—in making known by means of lectures and demonstrations practical and cheap methods of preventing erosion. The result of their labours is now beginning to be seen throughout the Colony, but we still have a very long way to go. I trust this Bulletin will be studied by all owners of land, and that it will be translated and explained to all natives in our Reserves.

The question of soil conservation is truly a national one, and must play a great part in the development of our Colony.

CHAPTER I.—GENERAL.

Introduction.

It has been said that " the skin of an animal is not more necessary to its well-being than is the vegetative cover of the earth essential to the proper condition of the soil ". This statement epitomises the problem of soil erosion, and points the moral that it is the hand of man that has turned formerly fertile and populous lands into deserts of desolation by the removal of that protection.

Historical Evidence.—History and archæology offer overwhelming evidence to support this view. There is ground for belief that all the great deserts and waste lands of the earth once supported enormous populations. The Sahara, the Central Asia deserts, arid parts of Palestine, Mesopotamia, the Gobi and North China deserts, all show remains of cities, temples, reservoirs, aqueducts and other evidence of vast cultures and civilizations, long since vanished and buried beneath the sands of the deserts that man's destructive handiwork had created out of the once fertile lands on which he depended for sustenance. These catastrophes have often been attributed to adverse climatic changes, but there is evidence to show that man-made erosion is sufficient to account for the wasting process without prior climatic change.

American Experience.—We have a modern example in North America. Three hundred years ago the colonists began the exploitation of a continent of enormous natural resources. In extending the bounds of civilization they

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cleared the forests and exposed the soil to cultivation, on a scale which ran eventually to millions of acres. Their pioneer work was magnificent, but the results have been disastrous, because it was not realized that pioneer methods must be drastically altered once a country has become permanently settled. America has witnessed a process of erosion and desiccation that has probably been more rapid than any hitherto known to history. In that brief period, through suicidal misuse of land, 51 million acres are estimated to have been utterly destroyed and abandoned (not including vast areas under semi-desert conditions), and 200 million more to be in the clutches of erosion. All good land in that vast continent has been taken up, and it is no longer possible to move on to new lands in the west. The time has come for the conservation of the remaining soil.

Position in Southern Rhodesia.—We in Rhodesia have a similar problem to face, smaller in scale and as yet not so far advanced, but equally rapid in its progress, if not checked in time. The process has begun. Parts of Matabeleland were well grassed and watered by permanent streams forty years ago. To-day those areas are denuded, and the river-beds are filled with dry sand. In Mashonaland the areas of rich virgin soil which have been opened up since the days of the early settlers have in many cases been " mined ", and the soil impoverished by continuous cropping and erosion until many of those lands have been abandoned as useless. The best land is often the worst sufferer, owing to the owner's blind faith in its supposedly inexhaustible fertility, and conversely the best farmers are often found among those who have had to struggle with poor shallow soil and have realized its limitations and the danger of erosion. In other cases, farmers continue to flog the dead horse by trying to extract a living from an impoverished soil. Owing to the reduced yield the acreage is extended in order to obtain a larger crop, and this process continues whether prices are high or low. When prices are low every effort is made to increase the volume of production in order to meet working costs. When prices are high the farmer is anxious to take advantage of the opportunity for a bigger return.

Conservation vs. Exploitation.—The policy of exploitation is a short-lived one, and can only have one end—abandonment of the land. Good land is not plentiful, and every acre sacrificed to a temporary cash return means a loss of capital which the country cannot afford. Exploitation should be and is obsolete, and what is required is a new attitude of mind, an attitude which is convinced that exploitation is the more expensive process in the long run, and that it must be replaced by conservation.

General Process of Erosion.—Rainfall is disposed of in four ways :—

1. Run-off.
2. Evaporation.
3. Absorption.
4. Transpiration by plants.

The first two are essentially wasteful, and only the last two are beneficial.

Upsetting the Balance of Nature.—Under its natural covering of vegetation, the earth's surface maintains a natural balance between the processes mentioned above, the rainfall is checked when it reaches the earth, and a maximum amount is absorbed and made available for plant growth and for the replenishment of the underground reservoirs which feed the springs that maintain stream flow. When the vegetative cover is removed by any agency (such as overstocking or the cultivation of the land) the amount of rainfall lost by direct run-off and evaporation is increased at the expense of absorption. An accelerated process of erosion begins at once. The exposed surface of the earth, unable to restrain the amount and velocity of the run-off water, is torn away by the rush of water, the lightest and most fertile top-soil being the first to go, and before long the intractable and unproductive sub-soil is exposed. Floods increase in violence, and the rivers are swollen beyond their bounds and in many cases cause untold damage. The clear waters of the rivers are turned into torrents of liquid mud, and dams and weirs are silted up at a disastrous rate, reducing the useful life of the reservoirs and leading to unnecessary expenditure on replacing or enlarging water storage schemes. Grazing deteriorates, due to the lack of fertile top-soil, and the deterioration of grass cover leads to accelerated erosion, so that grazing areas become progressively less able to support animal life.

Evaporation.—The losses of water through run-off, particularly flood run-off, are so strikingly obvious that it comes as a surprise to most people to learn that evaporation losses are actually very much greater, although invisible and difficult to measure. The Union Drought Commission found that only 6½ per cent. of the total South African rainfall reached the sea, and that of the remaining 93½ per cent. a large proportion, possibly the majority, must be lost in evaporation.

Evaporation from an open sheet of water is sufficiently serious under arid conditions (up to 100 inches per annum), but it takes place even faster from damp soil, owing to capillary action which draws water to the surface, and within reach of the sun and wind, even after it has sunk into the soil. Evaporation is aggravated by the same process which increases run-off, namely, the destruction of the vegetal cover and the erosion of the absorptive surface soil. Evaporation depends principally on two factors : temperature and wind. When the natural protection of the earth is removed, the soil is exposed to the fierce heat of the sun and the drying action of the wind. Moreover, the destruction of grass and bushes eliminates the channels by which the water was able to penetrate the sub-soil. Furthermore, the top-soil is the more porous, owing to the humus it contains but when swept away by erosion the sub-soil, which is often relatively impervious, is exposed and the water, unable to penetrate deeply, is lost by run-off and evaporation.

This brief explanation shows why the destructive processes described under the heading " Veld Erosion " have such a disastrous effect on the water resources of the country. The same ill-effects take place on cultivated lands, if they are not properly protected.

Effect on Cultivated Lands.—Lands cleared for cultivation are the natural prey of erosion. The unprotected surface soil is rapidly carried away by "sheet" or gully erosion, or both. What is left is coarse material or poor sub-soil, the lighter and more productive elements, such as the humus and the soluble salts, being the first to go. Crop yields deteriorate, and crops are more liable to disease and parasites, such as witchweed, that are washed into the land from the veld. The soil's power of absorbing water is decreased, which in itself accelerates the rate of run-off and erosion, and the crop is liable to suffer quickly from drought in dry spells of weather. Gullies grow, and cut into the land, draining away the moisture and the soil, and making it impossible to work the land as a whole. Every farmer will admit the difficulty of growing good crops, except under favourable conditions; with an unchecked process of erosion, every hand of Nature is turned against him.

Effect on Water Supplies.—The reduction of the amount of water absorbed into underground supplies leads to a falling-off of the flow of springs and streams and the disappearance of wet vleis, which dry up more quickly. Underground supplies to wells and boreholes are diminished, and it is found that the "water table" has fallen seriously. To this extent there is foundation for the oft-heard statement that "the country is drying up". It is not that the climate has changed, but that the *effective* amount of rainfall tends to become less and less.

The Drought Commission.—In this connection it is instructive to quote the Drought Investigation Commission, appointed in the Union of South Africa in 1920. Their report states :—

"As a result of the conditions created by the white civilization in South Africa, the power of the surface of the land to hold up and absorb water has been diminished, and the canals by which the water reaches the sea have been multiplied and enlarged, with the result that the rain falling has a lower economic value. The diminished capacity of the country to hold up and utilize the rain which falls has been caused by the deterioration of its protecting vegetal cover and by soil erosion."

Water and Soil Conservation Related.—A whole volume could be written on this subject alone. The preceding paragraphs must serve as an introduction and should have indicated that soil erosion and wastage of water are essentially complementary, and are both caused by the removal of the earth's natural vegetal cover. This fact cannot be too deeply impressed.

Several lessons are to be learnt from this bald statement of fact :—

(*a*) that soil conservation works and methods will have a beneficial effect on water supplies, and conversely, the building of dams and weirs, particularly small ones on the head-waters, will act as a check to soil erosion;

(*b*) that where nothing is done to prevent soil erosion, the construction of water storage schemes will be a sheer necessity, and these schemes will be expensive and short-lived owing to the violence of floods and the deposition of silt.

The two subjects are seen to march side by side, and in practice their relationship is illustrated in a great variety of ways.

Examples.—As an example of (*a*) above, a case may be quoted of a farm, originally waterless, where the " contour-ridging " of the arable land and the prevention of burning on the adjoining veld has resulted, in four years, in a permanent flow of water in the hitherto dry stream below the land. On the other side of the picture is the position which sometimes arises from the necessity of constructing a large system of storm-drains round cultivated lands in hilly country. For the sake of economy, these drains are often made of small dimensions and steep gradient, with the result that large volumes of storm-water, no longer able to soak away into the long grass which originally covered the now cultivated area, are discharged in miniature floods. It must not be forgotten that the volume of storm water has all too often been increased by burning and over-grazing the hillsides. A prevention of these evils will improve the position, but something more is required ; the provision of small dams in the vleis and stream channels in order to retain the water on the farm and put it to beneficial use. This is a subject which is beginning to have greater attention paid to it, and as time goes on it will become of more and more importance.

Small Dams.—Passing to the second part of (*a*) above, it is, not yet sufficiently realized what benefits can be secured from the construction of small dams in minor valleys and vleis, or at what small cost. With a dam scraper and a few oxen at odd times when they can be spared, the actual cost is very small, and the benefits out of all proportion. Soil erosion is decreased, grazing is improved, temporary water supplies are obtained, the general water level is raised, the intensity of floods is reduced, with a corresponding check on the growth of gullies, and an otherwise inferior stretch of grazing land turned into permanent asset.

In the same way, small dams of earth or stone built across small gullies in arid areas, even though they may not hold water for more than a few days or weeks, will impound a portion of every storm and so add greatly to the underground storage in the immediate locality. A well sunk on the bank of the gully near such a dam or system of dams might otherwise be dry, but will usually be found to give a good supply, as it will have an underground reserve to draw upon.

One might multiply examples, but the moral is clear.

Storage Schemes.—With regard to the construction of large storage schemes, it is sufficient for the purposes of this article that their construction is essential to the development of arid or semi-arid areas, particularly when the country becomes desiccated and surface water disappears. The Union of South Africa has spent vast sums on such schemes, and this Colony is forced to follow a similar policy in the more arid areas, though on a much smaller scale. The point with which we are at present concerned is how far the construction of storage works is affected by soil conservation or the lack of it. In the first place, the actual necessity for many of these dams, particularly of that large class of dams of moderate size intended for watering stock, is caused by the very denudation of the country, such as the filling of the rivers with sand and the disappearance of surface water supplies. In this way large sums of money are forced to be spent in order to remedy the destruction of natural resources.

Secondly, there is the increased cost of these structures, due to the evils of silting and the violence of floods resulting in the necessity of building dams of excess storage capacity and greater strength, and of replacing them by further dams as they silt up. Expenditure on these lines has reached vast proportions in America.

The short cut to avoiding such unnecessary expenditure of public and private funds is to alleviate the trouble at its source and prevent and repair the ravages of erosion in its early stages.

Chapter II.—Veld and Gully Erosion.

Veld Erosion.—The general causes of veld erosion have already been indicated. The specific causes with which we are mainly concerned in this country are :—

1. Over-stocking.
2. Wood cutting and burning.
3. Cattle tracks.
4. Roads.

These factors, of course, are often inter-connected. Thus overstocking leads to formation of cattle tracks, cattle tracks often become roads, and wood cutting leads to an excessive number of tracks and roads.

Over-stocking.—It is necessary to realize that the " carrying capacity " of a grazing area varies enormously according to the climate, character of soil and type of grass. What is moderate in a humid well-grassed country will be excessive in an arid land. Over-stocking is therefore at its worst, from the erosion point of view, in an arid or semi-arid area. It is hardly necessary to elaborate the destructive effects of stocking at a rate of five acres to a beast on country which is barely capable of supporting a beast on 20 to 30 acres. In a few years the grass is totally trampled out, the soil is swept into the gullies and " rivers ", which are filled with sand, water supplies both surface and underground disappear, cattle deteriorate in physique until all virtue except precarious survival is gone from them, and in time of drought, which is naturally more severe and prolonged under such conditions, they die by thousands. In the 1936 drought, losses of 50 and 60 per cent. of the herds were common in parts of Matabeleland, both in native and European areas. Such a state of affairs causes terrific loss to the country, in two ways : (*a*) the actual loss of the stock, to say nothing of the impoverished condition of thousands of others that survive, and (*b*) more serious still, the eventual loss beyond recovery of vast areas of country that will infallibly revert to desert.

Remedial Measures.—There are only two remedial measures, and both are dependent on adequate fencing :—

(*a*) reduction or re-distribution of stock to a degree comparable with the " carrying capacity " of the land, combined with a rotation of grazing controlled by fencing into paddocks, and

(*b*) provision of a sufficient number of dip tanks and water supplies to prevent excessive trekking and concentration of stock.

The effect of giving a grazing area a rest can be little short of miraculous. An example occurred during the outbreak of foot-and-mouth disease, when a five-mile strip adjoining the Bechuanaland border was kept clear of stock for a couple of years. At the end of that time the country, which had been as bad as any, had recovered to a remarkable extent.

The value of a rotation of grazing lies in the fact that it is the *trampling* of animals in search of food and water, and not the actual grazing down, that causes erosion. In other words, the hoof is worse than the mouth.

Over-stocking is probably the largest single erosion problem that faces the country. It is a more difficult problem than that of erosion on cultivated land, for the reason that it applies to a vastly greater extent of the land surface, and is complicated by all manner of factors such as the native ownership of stock (cattle *and* goats, the latter being the more destructive), the adverse climatic conditions in those areas where the problem is most serious, and above all the expense of applying the remedial measures on a large scale in the present state of the cattle market.

Nevertheless, the problem must be solved, or the "cattle country" of Rhodesia can have little hope of escaping an eventual, and not distant, fate of abandonment.

Government assistance is already available in connection with fencing, dip tanks and water supplies. Special Irrigation Loans on easy terms are available for the sinking of boreholes and the construction of dams and weirs. Fencing and dip tanks are among the permanent improvements covered by the short-term loans obtainable from the Land Bank, and it is hoped that more extensive assistance in the matter of fencing may be provided.

Paddocking.—The ideal to be aimed at is a ranch or farm divided up into paddocks of a size suitable to the type of country, each paddock having direct access to water (such as a borehole sunk at the junction of four paddocks). It is to be noted that the provision of a few large water supplies, without paddocking, is not likely to improve the position, nor, conversely, will a system of paddocking be effective without an adequate provision of water supplies. No rule can be laid down as to the number of dip tanks, but it should be according to the distances involved and the total number of cattle. The number and size of paddocks will depend largely on topographical conditions and the possibility of providing water supplies where required, but they should be planned with a view to regular rotation of grazing, bearing in mind the diminished feeding value in the dry season. In this connection a great deal more might be done in the matter of growing summer crops to provide feed during the dry season.

The relation between water and soil conservation has been dealt with already, but it should be noted here that for *permanent* results a system of dams is better than boreholes, since without the conservation of surface water the underground supplies will be weakened.

Wood Cutting and Veld Burning.—Much damage has been done in the past, and is still being done, by these abuses. One has only to mention mining and

tobacco farming to call to mind the many denuded areas in this country. The evil of wood cutting lies not so much in the destruction of the actual timber, as in the countless wagon roads that are made for the transport of the wood and are, in so many cases, left to wash out and become courses for torrents of destructive storm-water. It is to be hoped that the position will be improved by the more general modern use of crude oil engines and the activities of the Electricity Supply Commission, in the case of mines, and by the adoption of the more efficient furnaces now available, by the tobacco farmers.

The work of re-afforestation deserves every encouragement, and it is to be hoped that farmers in suitable areas will push on with a regular programme of tree-planting. Judicious felling of trees on hillsides is often found to improve the grazing and provide a better cover of grass, and this is true, provided that over-grazing and burning are avoided. It should be made a rule to prevent grazing on recently felled land, until the grass has become well established.

Veld burning is still all too common a practice in this country. There may be some excuse and foundation for burning in very humid areas, but there is no question that under any other conditions regular burning is a powerful cause of soil erosion. The fallen vegetable matter which should be allowed to decay and replenish the humus in the soil, is destroyed, and the surface of the soil, instead of being in an absorptive condition when the rains come, is baked hard and dry.

The usual excuse for burning is that the new spring grass is made more easily available to stock, but it is not sufficiently realized that better results, from both the grazing and erosion points of view, can be obtained by properly controlled rotations of grazing and by cutting the long grass for hay. It is pleasing to note that the latter practice is becoming more and more usual with progressive farmers than it was in the past. Advocates of spring burning should realize that a diet of pure young grass, unaccompanied by coarse roughage, causes scouring in cattle and is therefore very lowering. For this reason, working oxen are often at their poorest a month after the rains begin. Another excuse often given for burning is the destruction of ticks. This is a fallacy, since ticks are dormant during the dry season, at the time that the veld is commonly burnt.

Uncontrolled Burning.—The most dangerous and harmful type of burning is the uncontrolled veld fire which sweeps across miles of country every dry season. In some cases they are due to lack of supervision or experience in burning grazing areas or fire-guards, but in others the origin is malicious or wilful and the culprits more difficult to trace and farmers should in their own interests make every effort to prevent uncontrolled burning, and report offenders to the police at the first opportunity. Under the new provisions of the Herbage Preservation Act, a farmer wishing to make fire-guards is entitled to call on his neighbour to do likewise, and farmers are urged to make use of this measure to prevent the spread of uncontrolled fires.

Cattle Tracks.—These are due to the concentration of stock, and are commonest near kraals, gates, watering places and dip tanks. Much can be done to reduce the danger of erosion if these places can be arranged to be

situated on level, and preferably stony, ground, and in the same way the routes along which cattle are driven out to graze should be as much as possible along the contour. That animals are wiser than men is shown by the fact that on steep hills sheep will invariably walk on the contour. Concentration can also be reduced by providing a larger number of water supplies and, if necessary, dip tanks. The formation of gullies can be reduced by preventing cattle being driven up the centres of hillside valleys and insisting of them being kept on higher ground.

Roads.—The roads, and particularly the old ones, of this country have much to answer for in the way of erosion. Chief among the offenders must be placed the wood cutting roads, which so often run up to the hills and follow the lines of natural hollows. They therefore concentrate the flow of storm-water and soon wash out into ugly dongas, which in many parts of the country are a source of great trouble and damage. Miners and farmers should co-operate to block a road at frequent intervals once it has been abandoned.

Road authorities to-day are alive to their responsibilities and dues in the matter of drainage, and the position is briefly covered by the relative provisions of the Roads and Traffic Act, from the points of view of the road authority and the landowner. The principle involved is that each party is responsible for leading his storm-water to the nearest natural channel (within the same watershed) without trespass or damage to the other party's property, and if this principle is liberally interpreted by both landowners and road authorities many potential disputes will be avoided. What is needed is a generous attitude of give-and-take on both sides.

The subject is referred to later under the heading of " Legal Considerations ".

Gully Erosion and Control.—Gullies are formed by the concentrated flow of water at a velocity sufficient to overcome the resistance of the vegetation and the cohesion of the soil.

Causes of Gullies.—They have their root cause in the interference with Nature through the removal of the vegetal cover. In the case of veld erosion, they may be due to any or all of the agencies discussed in the preceding paragraphs. On cultivated lands they may be due to the ploughing of a natural channel, to farm roads, to ploughing down the slope, cultivating slopes that are too steep, broken contour ridges, the ubiquitous " closing furrow " down a slope, boundary drains or other artificial channels on too steep a slope, or a dozen other causes.

Whatever their origin, they constitute a rapidly-growing and extending menace, and the longer their treatment is postponed the more expensive and difficult they are to control. The problem is complicated by the fact that a gully is often the only outlet for the storm water, and must perforce be used for that purpose.

Treatment.—A study of the definition printed in italics above will indicate the means of control to be adopted. Gullies are formed by water moving at too high a velocity. High velocities are partly due to excessive volumes of

water, since on a given slope a large volume will travel with greater velocity than a smaller volume. Hence gully erosion may be reduced by any means tending to prevent excessive run-off from the catchment above the gully. These means include such measures as contour ridging on cultivated land, and improving the vegetal cover, *i.e.*, prevention of veld fires and over-stocking, &c. Secondly, the gully, if not too large, can be made to resist erosion if the bed and sides are covered with resistant vegetation. This can be done by sloping the banks of a gully and planting, or encouraging the growth of suitable grasses or shrubs. These will not only resist erosion, but reduce velocity.

Thirdly, and most important, the velocity of flow is caused by the steep gradient of the gully bed. This must be flattened by the construction of check dams. Of these more anon.

The treatment of any particular gully will depend on local conditions. As a general measure, the reduction of run-off water feeding a gully should be aimed at, by the construction of contour ridges or the improvement of the natural vegetation.

The worst type of gully is usually characterized by its sheer or overhanging banks, due to the cracking and breaking away of the clayey sub-soil. This type of gully grows laterally by the falling-in of the banks through undermining and the formation of tributary gullies, and it grows up the slope for the same reason by the cutting back of its head, which may be very rapid. When the gully is very big, its control is difficult and expensive, which is all the more reason for tackling gullies at the outset.

Control by Vegetation.—When a gully is small and the gradient not too steep, vegetative control may be sufficient, and the same treatment may be combined with other measures in bigger and steeper gullies. Two conditions are necessary for the success of this treatment : (1) suitable soil and climatic conditions, and (2) the sloping of the banks. The reason for this is that grass will not grow on sheer banks. The banks should be cut back to a slope which should not usually be steeper than 1 vertical to 1½ horizontal, so that for a gully 6 feet deep the horizontal distance from top to toe of the bank should be 9 feet. In some cases the natural grass will take possession of this slope, but in others it will be necessary to plant the slopes. Among resistant grasses may be mentioned the various types of couch grass, paspalum, Napier fodder, Kudzu vines, and in general any local type of close-growing grass that does well, and in some cases poplar or willow may be effective. In any case the gully should be regularly inspected until it is evident that permanent results have been obtained. In small shallow gullies, strips of Napier fodder, &c., may be planted in rows across the gully at intervals, and are very effective in holding up coarse silt.

Check-dams.—The " stepping " of the bed of a gully is carried out by means of what are known as " check dams ". These may be of all sizes and types, ranging from small temporary constructions of stakes and brushwood to large permanent earth dams and concrete weirs. In this country, owing to the ravages of white ants, wooden structures are too short-lived to make them usually worth the labour of making them, and more permanent materials are to be preferred. Checks of stakes, brushwood and grass are often effective

in the sand veld, in areas free from white ants, and are also useful as temporary measures pending the building of more permanent checks, or while vegetative control is being established.

The following points should be carefully observed in installing check dams :—

(1) The height should not be so great as to cause the gully to overflow and create new channels.
(2) The ends of the dam must be carried well into and up the gully banks, to prevent outflanking.
(3) The foundation of the dam must be deep enough to prevent undermining.
(4) The centre of the dam must be low, and the ends high so as to concentrate flow in the middle of the stream.
(5) In nearly all cases it is necessary to provide an " apron " to prevent the formation of a pothole below the drop caused by the dam.

In addition to these points it should be remembered that a high-check-dam is more likely to fail or cause trouble than a low one, and it will usually be better policy to build a series of low-check-dams and add to them in successive gully silts up.