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THE PRACTICE OF SOIL CONSERVATION IN THE BRITISH COLONIAL EMPIRE

by

SIR HAROLD A. TEMPANY, C.M.G., C.B.E., D.Sc., F.R.I.C.

Formerly Agricultural Advisor, Colonial Office



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PREFACE

Soil erosion is a major problem in the Colonial Empire and of late years the practice of soil conservation has extended greatly.

Progress has varied; in some dependencies it has been spectacular, and conservation work has become one of the main activities of the Departments of Agriculture; in others developments have not advanced beyond the initial stages.

The position has been reviewed from time to time, the last occasion being in 1944^[28]. It then appeared that the dangers of erosion and the need for measures to combat it were widely appreciated. There was also growing realization that conservation measures should not be regarded as separate ends in themselves, but must be integrated into systems of husbandry capable of maintaining and enhancing fertility.

In many dependencies there is now considerable accumulated experience of the practical application of conservation measures; some of it has been published in departmental journals, bulletins and reports, but much more exists in unpublished records; published accounts are scattered and not always easy of access, while publication has been restricted owing to war and post-war paper shortages.

It appeared that it would be useful if the experience of workers in different territories could be collected and summarized; accordingly, in 1946, with the approval of the Secretary of State for the Colonies, a questionnaire was prepared and sent to the Directors of Agriculture in dependencies where soil conservation had obtained considerable development, seeking information on a number of points.

In the account which follows, the information contained in the replies has been supplemented by data taken from published papers and reports and material supplied from other sources. It is believed that it gives an accurate and reasonably up-to-date account of the position.

The territories which furnished replies to the questionnaire were Kenya, Tanganyika, Uganda, Nyasaland, Northern Rhodesia, Southern Rhodesia, Basutoland, Swaziland, Ceylon, Cyprus, Jamaica, the Windward Islands and the Leeward Islands. To the Directors and other officers of the Departments of Agriculture concerned, acknowledgment is made of the voluminous and detailed information supplied.

The section of Chapter VIII dealing with legislation in the Colonial Dependencies is based upon copies of the original ordinances supplied by the Legal Library of the Colonial Office ; of this, acknowledgment is also made.

It is also desired to acknowledge the assistance of Mr. G. N. Sale, late Conservator of Forests, Palestine, in supplying information concerning the fixation of sand dunes in that territory.

Finally, special thanks are due to Messrs. G. V. Jacks, Director of the Commonwealth Bureau of Soil Science, G. W. Nye, late Director of Agriculture, Nyasaland, and now Deputy Agricultural Adviser at the Colonial Office, and D. Thornton, Agricultural Officer of Tanganyika Territory, who have read the manuscript and have made a number of valuable suggestions and criticisms which have been incorporated in the text.

LONDON

H. A. TEMPANY

THE PRACTICE OF SOIL CONSERVATION IN THE BRITISH COLONIAL EMPIRE

CHAPTER 1

PRELIMINARY CONSIDERATIONS

INTRODUCTION

In the British Colonial Empire, soil erosion is in many territories a serious menace. The rapidity with which development has occurred has often led to the employment of agricultural methods conducive to erosion and, in consequence, large tracts of land have already been rendered unproductive, while much larger tracts are threatened. If measures are not taken to avert the danger, ruin and desolation on an ever-increasing scale are inevitable, while any hopes that may be entertained of raising the standard of living of colonial peoples are foredoomed to failure.

Fortunately the dangers are now widely appreciated and the general character of the measures needed to counteract them are well-known. In many territories there is extensive provision for soil conservation and large sums of money have been provided from Colonial Development and Welfare Funds and from Colonial revenues to meet their cost.

Conditions in the different Colonial Dependencies vary considerably, and, in consequence, methods of soil conservation which are well suited to some localities may not succeed so well elsewhere. Considerable experience is now available of the results of the application of a wide range of methods under a variety of colonial conditions; in what follows the attempt has been made to summarize this information in the belief that it should be of service to those engaged in soil-conservation work in the different territories.

With a few minor exceptions the whole of the Colonial Dependencies lie within the tropics or subtropics, which may be taken as bounded by the 35th parallels of latitude north and south of the equator; the majority are in the tropics proper, i.e., between the Tropics of Cancer and Capricorn, 23½° north and south. They fall into seven main regional groups, viz.—the East African group comprising Kenya, Tanganyika, Uganda, Zanzibar and British Somaliland; the Central African group comprising Nyasaland

and Northern Rhodesia, with which is also associated Southern Rhodesia geographically and to a certain extent politically; the West African group comprising Nigeria, the Gold Coast, Sierra Leone and the Gambia; the West Indian group which includes Jamaica, Trinidad, British Honduras, Barbados, the Leeward Islands, the Windward Islands, the Bahamas and Bermuda; the Eastern group comprising Malaya, Mauritius, Borneo, Aden, Hong Kong, the Seychelles and Ceylon (geographically and until recently politically); the Western Pacific group comprising Fiji and the other island groups of the region; the Mediterranean group which includes Cyprus, Malta and, until recently, Palestine; in addition, the South African High Commission territories are usually included, comprising Swaziland, Basutoland and Bechuanaland. Soil-conservation measures have made the greatest progress in the East, Central and South African groups and in the Eastern, Mediterranean and West Indian groups.

All these territories possess the common feature that during a considerable part of the year temperatures are high, although this varies with elevation and proximity to the equator. They show, however, marked differences in rainfall and atmospheric humidity, conditions varying from superhumid and humid to subhumid, semi-arid and arid. This profoundly affects the natural vegetation and the crops that can be grown as well as the incidence of and liability to erosion, and may decisively influence the type of soil-conservation measures employed.

FACTORS AFFECTING THE INCIDENCE OF EROSION

Erosion is the result of the impact of climatic forces such as rainfall, wind and frost on the land under varying conditions of slope and natural vegetational cover. It is one of the most fundamental of natural processes and the result of its action is seen in the configuration of the land. Under natural conditions, the normal rate of erosion is balanced by the rate of soil formation, protection being afforded by the natural vegetational cover; erosion is retarded and topsoil develops faster than erosion can carry it away. When the balance is upset by the removal of the vegetational cover, accelerated erosion sets in, and, unless it is checked by adequate treatment, becomes steadily worse and leads to the eventual ruin of the land. Accelerated erosion or, as it is usually termed, soil erosion, is therefore an abnormal process and soil conservation consists of measures to redress the balance and mitigate the evil effects.

The extent to which erosion is liable to occur will vary with the conditions, but at any point its incidence is determined by the following factors:—

- (a) The amount, distribution and intensity of the rainfall.
- (b) The force of the prevailing winds.
- (c) The configuration, and particularly the slope, of the land.
- (d) The erodibility of the soil.
- (e) The vegetative cover.
- (f) The system of husbandry and soil management practised.

As regards rainfall, it is not so much the amount of rain that falls during the year that is important, but rather how it comes and when it comes. A single heavy fall of rain in a few hours may occasion very severe soil losses and damage, while the same precipitation distributed over an interval of several days or weeks can occasion little harm. Such heavy falls are characteristic of the tropics, and soil-conservation practices there must be designed to take account of this and be capable of dealing with the heaviest falls likely to be encountered, with some margin for safety. The rate of movement of water depends on the slope of the land. Other things being equal, the steeper the slope the more rapidly does water run down it, and rapidly moving water has great erosive power. Theoretically, if the rate of flow is doubled, the scouring capacity is increased four times, the carrying capacity thirty-two times and the size of the particles carried, sixty-four times.

Some soils erode easily while others, under the same or comparable rainfall with similar slope and vegetational cover, erode very little. The texture of the soil (by which is meant the size distribution of ultimate particles) is an important factor. Coarse-textured soils permit rainfall to penetrate easily and thus reduce the amount of run-off and thereby resist erosion, but where such soils have impervious sub-soils and impeded drainage serious erosion may nevertheless occur; in such conditions special provision may be needed to carry off the storm water.*

The structure of a soil, by which is meant the state of aggregation of the ultimate soil particles into larger water-stable compound particles known as crumbs, has also an important influence on erodibility; soils in which a crumb structure is well developed are more resistant to erosion and allow easy ingress of rainwater and deep root penetration. Crumb structure is intimately connected with the treatment the land receives; continuous cultivation tends to break down the soil aggregates, while resting land under a suitable fallow cover tends to promote crumb formation. Consequently one of the aims of soil conservation should be to encourage the formation and maintenance of a crumb structure to as great an extent as possible.

Grasses have been shown to be particularly effective in promoting crumb structure, and the use of grass covers consequently assumes great importance in as much as not only do they provide mechanical protection of the soil surface against eroding influence, but also tend to promote crumb formation; there is, however, considerable variation between individual genera and species in their power in this regard.

The capacity of a soil to form crumbs is basically dependent on the amount of colloidal material it contains, and a soil which has a low colloidal

* W. D. Ellison in the United States has directed attention to the splash effect of falling raindrops as a factor influencing erosion. Splash erosion occurs at the soil surface and is due to the impact of the raindrop; the magnitude of its effect increases with the size and velocity of the falling drops. The effect of the impact is to break up soil aggregates. Soils vary in their susceptibility to this effect, in some the aggregates are much more readily broken down than in others. For this property he has devised the term "detachability." Light soils are, as a rule, the most "detachable." The effect is considerably influenced by the nature and effectiveness of the soil cover and is most pronounced on bare soils.

content cannot be expected to show a high potential in this regard. An indication of the potentialities of a soil for crumb formation can be obtained by the determination of the "sticky point" which may be defined as "the point at which a kneaded moist soil just ceases to adhere to external objects" [13, 14].

Soils with a low value for the sticky point have a low crumb-forming potential.

Soil texture and soil structure together with the content of organic matter are intimately related factors, and their combined effect largely determines the erodibility of a particular soil on a given slope.

This is not to say, however, that erodibility may not be influenced by the type of the parent material from which a soil is derived and the type of weathering it has undergone. Certain rocks and minerals give rise to soils that are more easily eroded than others. Thus, for example, soils derived from limestone are usually moderately resistant to erosion. Several indices of erodibility have been suggested, but none of them sufficiently reflects field behaviour to warrant the belief that it has anything more than qualitative significance. For tropical soils perhaps the most significant criterion is the silica-sesquioxide ratio, soils with low ratios being relatively slightly erodible. It is fortunate that the type of weathering that normally occurs under the conditions of high temperature and high rainfall characteristic of large parts of the tropics, tends to produce soils of this type. Were it otherwise, erosion losses would be far more disastrous than they actually are.

EROSION IN ARABLE CULTIVATION, PERMANENT CULTIVATION AND GRAZING LAND

In arable agriculture crops vary widely in their effect on erosion losses. Inter-tilled crops such as maize, cotton and tobacco can be classed as erosion-inducing; grass, forage crops, many leguminous crops and sugar cane are erosion-resisting; other crops, such as the small grains, stand between these two extremes as an intermediate group. In these conditions the advantages of crop rotation are obvious since erosion-conducting crops can be alternated with erosion-preventing crops, and the losses minimized; probably the most important single step in erosion control on arable land is the introduction of a suitable system of rotation.

Rotation, however, is inadequate to ensure complete control unless it is combined with measures for the maintenance of fertility, and, where necessary, the correction of acidity, and for protecting the soil in other ways. Further, the success of any one measure of defence may depend upon another; a satisfactory cropping system may fail unless it is supported by suitable mechanical measures for the prevention of erosion, while the latter are equally prone to fail without the support of a proper cropping system, suitable soil treatment and suitable cultural practices.

In the cultivation of permanent tree or bush crops similar considerations hold true; unsuitable methods of cultivation and the absence of precautions to ensure the conservation of soil may lead to severe losses from erosion. In former days grave damage occurred in tea, rubber and coffee plantations in the Far East through over-insistence on the practice of clean weeding and the neglect of soil conservation. Methods suited to arable farming are frequently not applicable to permanent crops although the principles involved are the same. Practices suited to particular crops and the conditions under which they are grown require to be evolved, but, just as in arable cultivation, methods are often interdependent.

On grazing lands erosion as a result of excessive concentrations of livestock, or unsuitable management of the grazing area, or both, may lead to extremely serious losses. Indeed it is probable that in many parts of Africa erosion induced by these causes is responsible for losses which in the aggregate considerably exceed those which occur in arable and permanent cultivation. In such cases soil conservation is bound up with the effective management of the livestock and the control of the grazing areas.

It can, in fact, be said that soil-conservation is bound up with the proper utilization of the land, and for success the requirement is an overall plan for the management of the whole agricultural area in which all concerned bear their part and in which the interrelation of the various sections and measures is maintained.

The matter may be summed up in a quotation from a publication of the United States Department of Agriculture^[30]:—" Really to be complete a soil and water conservation programme must bring into use all of the known good practical means of soil and water saving adapted to an area, and it must bring them into use on all of the land, not only on a segment of it. This must be done in such a way that the farmer is able to maintain or increase his income after the conservation methods have been applied to his land.

" A co-operative control programme is the proper method of attack on the problem and this pre-supposes that each piece of land will be put to the use to which it is best adapted. Thus, erodible slopes should be clothed with trees or grass, and cultivated crops restricted to gentle slopes and less erodible land. Sloping fields should be protected by such safeguards as strip crops, terraces and other measures; soil improving rotations should displace soil depleting and erosion permitting cropping systems . . . such a programme can succeed only by co-operative effort, neighbour with neighbour, and community with community, working when necessary with State or Federal Government agencies."

It is clear that soil-conservation programmes must take into account all the factors operating under particular local conditions. Practices fully suited to any one set of conditions can only be evolved as a result of local experience, but information derived from experience at other points can provide a very useful guide although they cannot always be expected to provide complete ready-made solutions. It is the task of the soil-conserva-

tion officer to ascertain how far experience at other points is applicable to the conditions under which he is working and to modify his own operations to suit them.

In the words of Mr. Colin Maher, Soil Conservation Officer, Kenya, "Soil conservation can only be successful if it is related to improved husbandry, including a rotational system with grass leys and the maintenance of soil fertility and soil structure by all the methods known to the good husbandman. Soil-conservation methods which are not based on this (and this in Native Reserves may involve sweeping social and economic changes) are waste of time and money and will not have lasting results in preventing the deterioration and ultimate ruin of the land."

CLASSIFICATION OF SOIL-CONSERVATION METHODS

The methods available for use in soil conservation fall under a number of heads and may be roughly classified as shown below :—

- A. Protective measures depending on the use of earth structures and including terraces, ridges and bunds, trenches and drains, stormwater channels and the reclamation of gullies.
- B. Cultural methods including methods of ploughing and cultivating, strip cropping, cover cropping, mulching etc.
- C. Protective measures depending on the employment of living plant material and including contoured grass strips and hedges, live wash-stops and windbreaks and the proper use of forestry in its relation to agriculture.
- D. Agricultural systems including pasture management, de-stocking, the control of bush and grass burning, provision of water supplies for livestock, as well as rotational systems of cropping and mixed farming.
- E. Administrative provision designed to secure the application of conservation measures.

In the following pages the various methods will be examined and discussed in the light of experience in the Colonial Dependencies.

CHAPTER 2

METHODS OF SOIL CONSERVATION DEPENDENT ON THE USE OF EARTH STRUCTURES

TERRACING, RIDGING AND TRENCHING

Of all methods of mechanically conserving the soil, terracing is probably the oldest and most widely tested. The word is derived from the Latin *terra* (earth) and is applied to operations which tend to reduce the slope of the land and to check the downward flow of water. The remains of bench terraces dating back to very ancient times can be seen in many countries, e.g., China, Mediterranean countries, Asia Minor, Peru, Bolivia. Where they have been maintained it has been possible to continue to produce good crops over indefinitely long periods, but where they have fallen into disrepair the soil has been washed or blown away, and the land rendered unproductive.

Latterly the term has become extended to include the construction of banks or earthworks along, or approximately along, the contours of moderately sloping lands, with the object of breaking the long slopes into numerous short slopes, and, by checking the flow, promoting the absorption of the maximum amount of water by the soil; the surplus is led slowly and safely into drainage channels and thence disposed of. Such banks may be constructed at one level throughout, in which case they are said to be level or on the contour, or they may be sloped so as to induce and regulate the flow of water, in which case they are said to be graded. The slopes may be uniform throughout, in which case they are termed uniformly graded, or they may vary at different points, when they are said to be variably graded. They are very often termed broad- and narrow-based terraces, the distinction depending on the width of the base.

They have obtained widely extended use in the United States of America and also in South and East Africa. In other parts of the Colonial Empire their employment is still largely in the experimental and demonstrational stage. On slopes of more than 15 per cent bench terraces may be employed. These are level or slightly graded platforms separated from one another by a more or less vertical drop, their forward edges being protected

by a bund and usually a vegetational cover as well. They are the only form of protection that can strictly speaking be described as terraces, and are frequently used in the cultivation of permanent crops on steeply sloping land. They are also used for annual crops, particularly in areas where land is scarce and populations dense.

Modifications of these forms of construction include contoured stone bunds, which consist of stones or boulders piled in rows along the contours; contoured trenches are another form of protection which may be associated with bunds or terraces.

In addition there must be provision to enable surplus run-off to be removed from the land without doing damage; this includes storm drains which follow the contour and protect the heads of fields, and storm-water channels down the slopes. The effective disposal of storm water is very important and must be adequately provided for in any protective system.

In the ensuing pages the various types of construction are considered in detail.

BROAD-BASED TERRACES OR RIDGES

Broad-based terraces or ridges (sometimes known as "Mangum Terraces," after Priestly Mangum, a North Carolina farmer, or "Nichols Terraces" after M. L. Nichols of the U.S. Soil Conservation Service, who developed their use*), are essentially wide banks of earth thrown up, approximately along the contour, on gently sloping land most usually with a gradient of not more than 5 per cent. In East Africa, however, ridging of this type may at times be practised on lands with a considerably greater slope. The authorities of the United States Department of Agriculture give the maximum slope on which terracing of this description can be satisfactorily used as between 8 and 12 per cent^[19] but in East Africa it is apparently employed on slopes up to as much as 15 per cent. The maximum depends on certain conditions, particularly rainfall and the erodibility of the soil: the less erodible the soil, the greater the maximum slope.

Generally speaking, the greater the slope the narrower is the base of the terrace. In Basutoland, Tanganyika and Nyasaland the base width varies between 10 and 40 feet, in Kenya the maximum base width is 30 feet, while in Southern Rhodesia it varies between 8 and 16 feet. (In Southern and Northern Rhodesia the term terrace is not used for this type of structure, the word ridge being preferred).

The height of the ridges varies between 18 and 30 inches as a general rule, but in Tanganyika ridges up to 48 inches in height are employed at times. They are evenly rounded in form, though the cross section may

* Mangum terraces are constructed by taking soil from both sides with a broad shallow channel on the upper side. Nichols terraces are constructed by taking soil from the upper side only and developing a deeper channel on the upper side, the bottom of which is well below the level of the surrounding land.

vary to some extent. Usually they have a channel on the upper side to carry off surplus water, though this is sometimes omitted where rainfall is low and soils are of high absorptive capacity. The form of the channel varies: in Basutoland wide shallow channels 20 to 30 feet in width are used; in Kenya, on slopes up to 8 per cent, narrow channels with a trapezoidal cross section of 12 square feet and a width of 4 feet are employed; on slopes greater than this, channels with a triangular cross section are used.

In Southern Rhodesia standard types of bank and channel are used for different types of cultivation. Cross sections and dimensions of two of these are shown in Fig. 1[1].

In Northern Rhodesia the standard dimensions of ridge and trench are:—base of ridge 8 feet 6 inches, height of ridge 18 inches, depth of trench 9 inches, width of trench 7 feet.

The gradient may vary from a practically level grade throughout to a maximum of 1 in 200 or even more on occasion. Where the rainfall is low and the absorptive character of the soil good, level banks and channels can be used facilitating the maximum conservation of water, but on heavy soils or on soils with a clay subsoil there is no advantage in using level ridges as the soil soon becomes saturated, and no more water is absorbed. Most usually channels are graded towards the outlets; the grading is generally not uniform, but increases as the outlet is approached, ranging from 1 in 1200, or sometimes even less at the commencement of the grade, up to 1 in 200 at the outlet. Care is necessary to ensure that the grading is correctly done, and in the case of heavy soils or soils with a clay subsoil it is most important that the bed of the water channel should be very accurately pegged and constructed. Uniformly graded ridges are, however, sometimes used, e.g., in parts of Tanganyika. The length of ridges from outlet to outlet varies with the rainfall, the slope of the land, the character of the soil, the type of ridge employed and the crop grown. In general they do not exceed 300 to 350 yards, but in some circumstances this may be considerably exceeded and ridges up to 1000 yards in length and even more are used.

The vertical drop and the horizontal interval between ridges also vary with the slope of the land and with the character of the soil and the rainfall. The following table gives details concerning the practice in this regard in Kenya, Tanganyika and Nyasaland.

Slope	Vertical drop between ridges (feet)			Horizontal interval between ridges (feet)	
	Kenya	Tanganyika	Nyasaland	Kenya and Tanganyika	Nyasaland
%					
1—3	2—2½	2—2½	2½—3	200—100	150—100
4—7	3—3½	3—4	3—4	100—50	100—57
8—11	4—4½	—	4—5	—	57—46
12—15	—	—	5—6	—	46—42

Similar figures for Southern Rhodesia are as follows :—

Slope	Vertical drop between ridges (feet)	Horizontal interval between ridges (feet)	Max. length of variable-grade ridges in yards, with gradients		
			For maize	For tobacco	
%					
1—3	3 — 4½	225—180	} 500 — 350	650 — 500	
4—7	5½—6½	150— 90		1/600	1/1000
				to 1/400	to 1/400

Spacings between ridges should be reduced when conditions are unfavourable, while areas can be increased by lengthening the ridges or increasing the spaces between them when conditions are favourable. In Northern Rhodesia the maximum vertical and horizontal intervals between ridges are respectively 7 feet and 195 feet.

In Basutoland it is usual to make ridges up to 1000 yards long, with the following succession of grades : level at one end of the field for the first 100 to 200 yards, increased to 1 in 1000 for the next 200 yards, and thereafter successively to 1 in 500, 1 in 333, 1 in 250 for each succeeding interval of 200 yards ; the last one hundred feet may be given a grade of 1 in 100 if it disposes into a meadow strip (see below), or even 1 in 50 if it discharges over solid rock. If the terrace is 500 yards in length the grade changes every 100 yards. Grading may be in one direction only, or the flow may be divided in the middle and thus be in two directions, in which case the length of the banks can be doubled.

The construction of ridges of this type is expensive on account of their size ; where labour is cheap and plentiful they can be constructed by hand, but more usually implements are employed. In either event the line of the ridge is laid out and marked by pegs and thereafter construction carried out by striking out a marking furrow, and following this in mechanically constructed ridges with suitable implements, usually some form of terracer, dam scraper or leveller drawn either by tractors or oxen. Construction should always be from the top side down. Particulars of the implements used in different territories are given in a later section. The rates of construction will of course vary according to conditions, but the following figures give some indication.

For ridges 15 to 30 ft. wide and 1 ft. 6in. to 2 ft. in height

	Kenya	Nyasaland
By crawler tractor plough and grader	1 to 1½ miles per day	—
By ox teamplough and grader	400 to 600 yards per day	—
By hand	8 yards per man day	8 to 9 yards per man day

	<i>For ridges 10 to 15 ft. wide</i>	<i>For ridges 8 ft. 6 in. wide and trenches 7 ft. wide</i>
	<i>Southern Rhodesia</i>	<i>Northern Rhodesia</i>
By crawler tractor and terracer or grader	1½ miles per day	—
By ox team of 4 to 6 oxen with dam scraper	100 yards per day	—
By hand	15 yards per man day	8 to 17 yards per man day

Terraces or ridges of this type and the associated channels are cultivated and thus facilitate the use of large mechanical units or combines. They are accordingly favoured on large properties as they ensure that no land is withdrawn from cultivation. Generally terraces of 30 to 40 feet base width are preferred, but in Southern Rhodesia it has been found that terraces with a narrower base width of 10 to 15 feet can safely be incorporated in the cultivated area provided that, especially in the earlier years, care is taken to ensure the maintenance of the bank and channel. Ploughing should during the first few years be conducted so that the soil is thrown uphill, thereby ensuring the widening of the bank and trough and resulting in the gradual strengthening of the structure. It would seem that the minimum width of terrace which can be safely cultivated depends on the amount and distribution of the rainfall, as well as on the character, texture and structure of the soil and subsoil. (Fig. 9).

NARROW-BASED TERRACES OR RIDGES

Under this head are comprised banks of varying dimensions constructed approximately on the contour in the same way as broad-based ridges. The standard narrow-based terrace is usually 10 to 15 feet wide at the base and 1 to 2 feet high with a channel on the upper and lower sides. The upper channel may be either wide and shallow as with the broad-based terraces, or narrow and deep. They can be constructed either by hand or with medium-sized mechanical units, or with animal-drawn ploughs, graders and ditchers. The cost of constructing them is less than that of broad-based terraces. It is usually accepted that they cannot be cultivated and have to be protected by a vegetational cover; on this account they are not popular on large properties. As pointed out above, however, terraces of these dimensions are successfully cultivated in Southern Rhodesia.

They can be made on the contour, i.e., dead level from one end to the other or on a uniform or variable grade falling one or both ways. It is not considered practicable to employ them in cultivated land having a slope of more than 15 per cent, but in grazing areas they have been used on lands with slope up to 25 per cent. The vertical distance between them will vary with the slope, but in general they should follow the same standards as those for broad-based terraces. In Basutoland, in native-cultivated areas, most of the terraces are of this type since with native systems of ploughing and cultivation the objections raised in the case of large properties do not apply. (Figs. 8 and 10).

CONTOUR BUNDS OR NARROW CONTOUR RIDGES

These are essentially narrow-based ridges constructed along the contour or slightly graded, but considerably smaller than the narrow-based terraces or ridges described in the previous sections; they are extensively employed in native areas in Kenya, Tanganyika, Uganda, Northern Rhodesia and Nyasaland. They vary in base width from 3 to 8 feet and in height from 12 to 24 inches; after construction they are grassed over either by actual planting or by allowing natural revegetation to occur; they are not planted under crop, and have also been used to advantage in grazing areas. (See Fig. 11).

The vertical interval between them varies in different territories. In Kenya 3-foot intervals are used and in Tanganyika they are stated to have been employed on lands with a slope up to as much as 30 in 100 with vertical intervals of 5 to 8 feet; in Nyasaland the intervals are from 2 ft. 1 inch to 5 ft., in Uganda 2 to 8 ft. and in Northern Rhodesia approximately 2 ft. 6 inches.

In Nyasaland, Uganda, Tanganyika and Northern Rhodesia construction is by hand with the hoe, in Kenya they are made either by hand or with a plough. The labour requirements for making ridges of this type are stated to be in Nyasaland 50 to 70 man hours per acre, in Uganda 40 yards of bund per man day is stated to be a normal task, in Kenya the figure given is 35 to 50 yards per man day, in Tanganyika 10 yards of bund and trench and in Northern Rhodesia 8 to 17 yards per man day. Ridges of this type were at one time employed in the United States of America, but of late years they have been superseded by broad-based terraces. In East Africa, however, they continue to be very useful. They may be constructed either at one level throughout or graded: in the latter event they have to be provided with outlets, and provision made for dealing with the discharged water. In many localities in East Africa, however, even after heavy storms very little water will lie above them.

In Uganda it is considered^[11] that under local conditions and for small cultivators they have only one serious competitor, namely contoured stop-wash hedges or grass strips. As compared with these, contoured bunds have the advantage that they accomplish more effective prevention of erosion with less maintenance and are preferable wherever, owing to pressure of population, cultivation has to be permitted on slopes up to 30 per cent.

The main disadvantages of bunds as compared with stop-wash hedges under Uganda conditions are considered to be that:—

- (a) bunds are more expensive to make;
- (b) in areas where the livestock population is heavy gaps are quickly knocked in bunds, although this may be countered to some extent by planting thorny hedges along them;
- (c) bunds are more liable to break than hedges if low places occur;

- (d) much more accurate surveying is necessary in constructing bunds than in laying down hedges. The latter can at a pinch be done by eye, but accurate levelling is needed for bunds.

In Tanganyika they are much favoured in areas of low rainfall, i.e., about 20 to 25 inches per annum. The method used has been described by Staples^[23]. Briefly, it consists of making a bank of 6 to 8 feet base by excavating soil from a shallow trench on its upper side. The banks are made dead level; to minimize the flow of water in the trench it is usual to leave a section about 1 foot wide unexcavated every 10 yards or so. Fuller details of construction are given in a paper by Savile^[21].

In Tanganyika the following advantages are claimed for this system.

- (1) In areas of low rainfall it can retain almost all the rain which falls.
- (2) In areas where planting in the dry season is essential on account of low rainfall and short rainy season, it gives protection to the land without interfering with normal agricultural practices.
- (3) Bunds are relatively permanent structures which do not require a great deal of maintenance and remain effective when the land goes out of cultivation.
- (4) Bunds that have been grassed over are less liable to damage by livestock than are contoured grass strips or hedges.

On the balance of these views from Tanganyika and Uganda, it would appear that the relative values of contoured bunds and contoured grass strips are about equal in areas of moderate and well distributed rainfall, but where rainfall is low contoured bunds may have advantages.

In the Eastern Provinces of Northern Rhodesia the method adopted in making contour ridges is as follows. Near-contour lines are demarcated using a road tracer and are marked by pegs at close intervals. The cultivators follow the work of the tracer gang by hoeing marker ridges along each line of pegs; these are very small and are intended to define the contours; in the first season after the contours have been demarcated each ridge is built up by the cultivator to a base width of six feet and a height of at least six inches. In succeeding years the base and height are increased until a ridge eight feet wide at the base and eighteen inches in height has been completed. Usually the ridge is completed by the end of the second or third year. The ridges are made discontinuous at intervals to allow of water disposal wherever natural waterways occur. The waterways may not be cultivated.

In the Western Province of Northern Rhodesia where soils are cultivated for short periods and cultivation is normally on the flat, a modified system is used. Contour lines are demarcated as in the previous example, but the vertical interval is less, only two feet. As each peg is placed, the operator paces five yards downhill at right angles to the line of pegs and places a second mark. The cultivator converts this five-yard strip into two or three small cultivation ridges each 9-12 inches high with a base of 4-5 feet.

The ridges may be planted to any crop other than cereals or root crops. The method is really a form of strip cropping with subsidiary ridge cultivation, and its chief advantage is that it is more acceptable to the natives of this province than other methods.

BENCH TERRACES

As has already been stated bench terraces consist of a series of strips cut into and running across the general land slope, giving the effect of steps. Their use is confined to steeply sloping land. They may be level or they may be slightly graded across the slope. The vertical interval between bench terraces varies considerably, depending on the slope and also on the type of soil and subsoil. The actual width of the terrace bed will also vary with the slope, and the steeper the slope the narrower the terrace or bench. Bench terraces are usually given a slight slope from front to back, and at the back a shallow drain is provided along which surplus water flows to storm drains, while the front of the terrace is protected by a narrow bank or bund usually about 4 to 6 inches in height. The intervals between the terraces are nearly vertical and are never cultivated; they and the bund along the front edges of the terrace should be protected by a vegetational cover, and for the top of the bund some thick tufted grass is often chosen. On very steep slopes and in areas in which stone is plentiful the terraces are often built up with stones packed to form a dry wall. (Figs. 12 and 13.)

In constructing bench terraces two alternative methods can be employed. In the first which we can call type (a) the fall between succeeding terraces is kept constant, which means that the breadth of the terraces will vary with the slope of the land; in the second, type (b), the fall between the terraces is not kept constant, but is adjusted so that the width of the final terraces is approximately the same. Bench terraces are costly to construct and are only used where population is very dense or where the crop grown is a valuable one. They are extensively used in permanent cultivation, especially for tea and rubber in hilly areas in Ceylon and Malaya, for tea in Nyasaland and Tanganyika, and for fruit-tree cultivation in the Mediterranean area. They are occasionally used for annual crops, e.g., for vegetable growing in hilly areas of high rainfall in Ceylon and Malaya. A special form of bench terrace is seen in the terraced rice fields which are a striking feature in Ceylon, Java and the Philippines; in these the terraces are bordered by a relatively high bund which is puddled to make it impervious to water, the irrigation water stands in the basins so formed on each terrace and its flow from one section of terrace to that immediately below is regulated by suitably placed outlets—very often bamboo pipes.

A variant on bench terraces, often seen in cultivation of rubber and tea in hilly country of the Far East, is what are known as contour platforms; these are used where the gradient does not permit of the construction of a continuous terrace or where construction is very costly. They consist of individual platforms, one for each picket planted, following the contour,

the intervening spaces between the platforms being kept under a vegetative cover.

The construction of bench terraces may be by hand or, when the slopes are not too steep, the operations may in part be performed by implements. On very steeply sloping land construction must be entirely by hand. In hand construction the contours are first marked off and the terraces made by cutting out to half the depth and filling up the other half with the spoil so removed ; this type of construction is open to objection on the score that it involves exposing the subsoil and this may give rise to difficulties when the subsoil is infertile ; the alternative is to start the construction from the bottom of the slope making the terraces up with subsoil, but taking the top soil from the terrace immediately above to cover the surface of the one below.

In Kenya on slopes up to 25 per cent D6 tractors are being used for making bench terraces ; they can be also formed by gradual development between contour lines of a vegetative wash-stop, such as Elephant grass, using the hillside plough for the purpose. In Kenya it is estimated that 300 man days are required to make bench terraces on 1 acre on a 25 per cent slope. In Uganda at Serere Experiment Station to construct bench terraces on one acre took 350 man days and 257 ox days. In Cyprus bench terraces are usually constructed by erecting dry stone walls and filling in behind them ; it is estimated that by this method effective bench terracing may cost as much as £500 per acre.

STONE TERRACES OR STONE CONTOUR BUNDS

On very rocky land use can be made of available rocks and stones to build contour stone bunds or terraces. They are constructed in the form of low, strong, contoured stone walls. In making them a line of pegs is laid out on the contour, the intervals between the lines being governed by the slope and the type of soil. A shallow trench about 12 in. wide and 6 in. deep is dug on the lower side of the pegs and stones are collected and packed into this to form the wall. The lower sides of the wall should be given a slight slope backward towards the hillside, and they should not in the first instance be built higher than 18 in. above the ground level on the upper side. The soil from the trench is spread out on the upper side of the wall to reduce water penetration.

In time contour stone terraces may become converted into bench terraces as a result of gradual filling up, while on steeply sloping lands the construction of contour stone bunds may pass into the construction of bench terraces without any very definite boundary line between the two types.

In Ceylon^[5] emphasis is laid on the necessity of constructing contour drains above stone terraces if heavy annual expense in the maintenance and repair of stone bunds is to be avoided. They recommend the establishment of permanent contour hedges along the upper sides. Stone bunds

are employed extensively in Ceylon, Cyprus, Jamaica and also to some extent in other West Indian Islands. In Africa they are much less used although they are employed to some extent on small holdings in Nyasaland. Figures for the cost of construction of stone bunds are not available in most areas ; it will of course vary with the slope of the land, the availability of materials and labour rates. In Ceylon, on a pre-war basis, the cost of constructing stone terraces on land of gentle to moderate slope, i.e., from 5 to 10 per cent was placed at Rs. 35 per acre which may perhaps be translated to mean 30 to 40 man days per acre. (Figs. 7, 24 and 26.) -

CONTOUR TRENCHES

There are many variants of these. They may be a complementary part of the construction of contoured bunds and broad- and narrow-base ridges, designed for the removal of water, in which case they are graded, open throughout their length and act as drains, or they may be level and provided with stops at intervals so as to prevent the lateral movement of water in them when they are termed "blocked contour drains." Modern practice, however, does not favour this type of construction. They may be continuous or they may be echeloned across the slopes. The size may vary considerably. In Ceylon, where they are widely used, they are frequently 18 in. deep and 3 ft. wide at the top with a cross section similar to the lower half of a hexagon. Whether the excavated earth is thrown on the upper or lower side of the drain depends on the slope and character of the soil. On steep slopes and with a friable soil the excavated earth should be used to form a bund on the lower side of the drain until a satisfactory contour hedge has been formed on the upper side ; whenever practicable, under Ceylon conditions it is considered that a low bund should always be constructed along the upper side of a contour drain.

SILT PITS

These are modifications of contour trenches and consist of lines of pits dug along the contours, each pit being separated from the next by a table of undisturbed soil. The size varies, a common size being 3 ft. long, 6 in. wide and 9 in. deep with a 3-ft. table between each two pits. The soil from making them is usually thrown up in a continuous bank above or below the line of the pits, and protected by some form of vegetational cover. This type of protection has been used extensively in rubber cultivation in Malaya and also in coffee cultivation in Tanganyika. Silt pits and blocked contour trenches gradually fill up with soil and require to be cleaned out once a year usually before the onset of the rains.

PROTECTIVE STORM DRAINS OR TRAINING BANKS

When cultivated lands are liable to receive uncontrolled flood water from uncultivated or unprotected lands above them it is usually necessary to construct protective diversion ditches or storm drains along the upper boundaries to carry off the surplus water. These ditches are sometimes

referred to as training banks, and on long slopes it may be necessary to construct one for every 50-ft. vertical interval, or whenever a suitable point occurs, for disposal of surplus water.

Essentially they are wide shallow channels, and the soil excavated from them is heaped up on the lower side to form a stable embankment ; this serves to increase the carrying capacity of the drain and acts as a safeguard against the flooding of the land below during heavy storms. The completed drain consists of an open trench, an embankment along the lower side of it, a discharge channel on a steeper gradient than the rest of the drain (and therefore requiring protection against scouring), a properly protected outfall and a recipient for the outflow from the drain.

The size of the drain is determined by the amount of storm water requiring to be dealt with and the character of the soil ; these determine also the gradient which is safe against scouring, and the latter determines the rate at which the water in the drain runs away.

An additional drain is sometimes dug below the embankment to supply earth to increase the size of the embankment and to act as an additional outlet for water in case the storm flood should overtop the bank.

Drains are usually dug to a depth of 12 to 18 inches ; their size should be increased by widening rather than by deepening the channel. They may have a bed width of from 2 to 18 ft. and the grade may vary from 1 in 400 to 1 in 100. It is inadvisable, when excavating drains, to dig deep into the subsoil since this may be detrimental to the establishment of a grass cover in the drain. The height of the training bank varies according to the conditions and the size of the drain, but it may have to be raised as much as 3 feet above the level of the surrounding land, thus giving a maximum difference of 4 ft. 6 in. between the top of the bank and the bottom of the channel. The bank should be wide at the base and the slope of the sides should not be less than 1 in 1½. Thus an embankment 2 feet high should be not less than 6 feet wide at the base. The sides of the embankment should be protected by a grass cover. (Figs. 21, 22 and 23.)

In constructing the drain the site is chosen to conform with the area to be protected and the location of a suitable point for discharging the flow. The line of the drain is set out with some form of level, and it is always advisable to start with the discharge end. The depth of excavation is demarked by depth pegs, and to ensure that the drain between depth pegs is cut to the required level "boning rods" can be used to check the construction at intervals. On this system a trench with vertical sides is first dug to give the correct bed width, and the sides subsequently dug away to give the required slope. When digging a drain it is important that the bed of the drain should be slightly canted towards the slope and away from the bank, as this keeps the main force of the stream away from the bank and localizes any scouring which may occur to the parts of the drain best able to withstand it. Fig. 2^[1] shows two types of storm drain in use in Rhodesia. Drains should not be more than 400 yards long if the discharge

is all in one direction, but if the drain is so graded as to discharge at both ends the length may be doubled.

The cost of making channels and heavy banks varies considerably with conditions and depends particularly on the slope and the type of soil to be dealt with.

Construction may be either by hand or by implement or a combination of the two. In Basutoland construction of training banks and drains is stated to cost approximately £1 per 100 yards for banks up to 3 ft. high and channels 10 ft. wide and to require $3\frac{1}{2}$ man days, $1\frac{1}{2}$ ox days and $\frac{3}{4}$ of a D6-tractor hour.

In Southern Rhodesia, using entirely manual labour, in channels up to 12 ft. in width, the rate of excavation is stated to be in the region of 3 cubic yards per man day, while in Nyasaland it is said that a man can excavate from 5 to 25 cubic yards of drain with a bed width of 2-3 feet on an overall width of 6 ft. 6 in. and a depth of 15 in. per day depending on the type of soil and the obstacles encountered.

DISCHARGES FROM STORM DRAINS AND RIDGE CHANNELS

No system of protection by storm drains and ridges can be fully effective unless satisfactory provision is made for conducting water off the land into stabilized drainage channels, and for its ultimate disposal. In disposing of surplus water full advantage should be taken of natural drainage channels which so far as possible should be the backbone of any drainage system, but it may be necessary to strengthen, deepen and protect these, and on occasion it may also be necessary to construct lengths of storm drain down the slope. A diagrammatic representation of a system of this description is given in Fig. 3[1].

Outfalls from level or graded storm drains and from terrace channels should be on a gradient slightly steeper than the rest of the drain and should discharge not at right angles to the line made, but along it. Inadequate or badly constructed storm-drain and ridge outfalls are a fertile source of trouble. Fig. 4 shows the correct method of discharge[1].

Outfalls should always be protected against scouring; if the gradient of the outfall is gentle, planted grass may provide sufficient protection, but on steeper gradients stone packing with grass planted between the stones, paving, cementing or concrete may be necessary. If the soil is very soft it may be necessary to install "bolsters" or other check drops at intervals in the drains. Where concrete or masonry installations have to be made they should have adequate openings for water flow as well as ample cut-offs and extension head walls to prevent overtopping and undermining.

Drains running down the slope and taking the water from the ridge channels are often referred to as ridge outlets, they are usually at right angles to the ridges and may run the whole length of the slope. They are planted or sown to a carpet of thick growing or well matted grass, and on this account are sometimes termed meadow strips. They are usually established before the area is actually ridged. They vary in width from

10 to 50 ft. depending on the volume of water they may be expected to have to deal with, and are usually graded up in the form of a very wide V with a fall of 0.1 foot for every 5 ft. from each side towards the centre. It is stated that in Basutoland meadow strips grassed with a strong running grass like Kikuyu have worked well on grades up to 25 per cent and have stood up to flood velocities of as much as 12 ft. per second over short periods. (Figs. 16, 17, 18 and 19.)

Broader natural depressions are often smoothed out and planted with grass in the same way to receive flood water. These are termed water meadows; in Basutoland, they may be as much as 100 yards wide and up to 3 miles long. They can be very valuable sources of fodder and can be cut for hay and grazed during the winter months. (Fig. 20.)

Inlets into dongas and natural waterways may be of well sodded grass. In Basutoland, for example, where nearly every valley has a donga running through its whole length and where there are very few rock outcrops in the valley bottoms, the final disposal of surplus flood water is often a difficult matter. The method there adopted for making outlets is to cut down the steep sides of the donga to a slope of 1 in 4 to 1 in 10, depending on the volume of water to be handled and the type of soil. The sides of the donga are sloped back roughly by hand, sufficiently to allow oxen with plough to climb up and down, and the ground is then ploughed and scraped away till the desired slope is attained. The slope is then finished off by hand so as to give an even gradient down into the donga, the channel, however, having a V-shaped dip towards the centre. The whole channel is then solid-sodded from bottom to top, the first row of sod being started level with the bottom of the donga. Grass inlets of this type are stated to have proved extremely satisfactory in Basutoland.

In steeply sloping country, and particularly if the face of the slope consists of long rolling spurs, special care may be needed to protect outlets from scouring back into the hillside and incipient gullying, and in such circumstances herbage protection may not suffice to provide all the necessary safeguards. If stone is plentiful and there are outcrops of rock that can be used, the bottom and sides of the drain can be built of stone, while it may be necessary to construct outlets of masonry or concrete to water courses. A simple form of outlet is a masonry or concrete weir built across the stream bed where the drainage line joins the major drainage channel, and raised above the level of the bed. Such weirs should be built on a rock foundation and the ends well keyed back into the sides of the donga. They are useful as silt traps and in the reclamation of gullies. A more complex form consists of a culvert or box flume built under the wall of a gully dam and then bent up in the form of an L to the level of the top of the donga.

LOCK-AND-STEP DRAINS

The principle underlying the construction of drains of this type is the same as that involved in blocked contour drains or boxed or listed furrows (Chapter III), and implies throwing across the course of a drain barriers

which will arrest the course of the flowing water and slow the movement down, thereby causing deposition of silt and lessening erosive action. The blocks may take various forms. One form which is used in Ceylon and elsewhere in graded drains across the slope consists of interposing blocks of earth across the width of the drain every 15 ft. ; the blocks themselves being 5 ft. in length at the base narrowing to 3 ft. at the top and with a height of 9 inches. The overflow from each block is protected by a stone splash cushion. (Figs. 5 and 6.)

In other cases the term lock-and-step drain is applied to barriers of wood across the course of large drains carrying flood water down a slope. To prevent scouring the barriers have to be keyed back into the bank. This type of drain is regarded in many quarters as expensive to construct and to keep up, and not particularly effective. An alternative system is to cut the drain in steps in the first instance and to protect the edges of the steps with stone or wood.

GULLY CONTROL

Gullies are the most spectacular result of erosion, but they are really the culmination of processes that have been at work on unprotected lands ; if erosion control is effectively carried out the causes leading to their formation will be eliminated and the gullies themselves will tend to disappear since the natural forces at work will be given a chance to repair the damage.

The ultimate object of all operations for gully control is the establishment of a thick cover of erosion-resistant vegetation on the site of the gully, and methods should aim at accomplishing this with the minimum expenditure.

The first objects will be to seek out the cause of the gully and eliminate it, and to stabilize the soil in the floor of the gully by means of checks at sufficiently close intervals, so as to permit of the establishment of living plant barriers, and to smooth down the sides of the gully to a stable slope in order to prevent any further crumbling of the bank. The size and nature of the checks will depend on the size of the gully, the flow of water and the material available. Work should always proceed from the head of the gully downwards.

In the smallest gullies the checks need consist only of sods of some suitable grass laid in position ; with somewhat larger gullies it may be necessary to hammer pegs in the sods to hold them to the gully floor, or mesh wire held down by pegs may be used to keep the sods in position. Another method is to employ sod bags, which are old fertilizer or feed bags, for example, filled with sods and imbedded in the bottoms of gullies. The sods are cut into small pieces, leaving as much soil as possible clinging to the roots. Small gullies may often be effectively and cheaply treated by constructing dams of brushwood, loose rock and other materials that may be available ; they serve two purposes (a) to collect soil in which vegetation may be started and (b) to prevent washing until vegetation by itself is

adequate to effect control. Numerous small check dams of this description are far more effective than larger checks at greater intervals.

When large gullies with steep sides have become established and threaten to eat their way further into the adjoining lands, considerable preparation is usually necessary before the area can be secured by vegetation. Often the banks are too steep for vegetation to be able to gain or maintain a foothold, while sometimes the soil on the gully bottom is so poor that plants will not grow in it. In such cases it is necessary to slope the sides of the gullies in the manner already described under grass outlets, using hand labour and ploughs, and to throw soil into the gully bottom. For operations of this sort bulldozers pushed by tractors have been successfully used in many cases, while dynamite has also been employed.

One of the most difficult problems is to keep water out of a gully while these operations are in progress, and it may be necessary to construct a temporary diversion ditch round the gully head until adequate vegetation is established.

Occasionally the value of land or the proximity of dwellings and roadways may make it feasible to construct substantial concrete or masonry works as part of a programme of gully control, but such structures are expensive and require skilled engineering assistance so need not be further discussed here.

The control of gullies may sometimes afford an opportunity for constructing dams for the conservation of water for watering stock and so combine two features in a programme of soil conservation; this aspect is dealt with in Chapter 4. Selection of suitable vegetational types for use in the control of gullies is dealt with in the next Chapter.

CHAPTER 3

METHODS OF SOIL CONSERVATION DEPENDENT ON CULTURAL PRACTICES AND THE USE OF LIVING PLANT MATERIAL

Cultivation on the contour should be an essential feature of soil-conservation practice and is one of the most effective measures of soil defence. It has been shown by experimental work in the U.S.A. that, if ploughing and all other cultural operations are conducted on the contour, on the average 70 per cent of the run-off is checked and soil loss reduced by 50 per cent. Accordingly cultivation on the contour should be combined with other measures of defence such as terracing, bunding and construction of contour drains.

CONTOUR PLOUGHING

Contour ploughing has attained a fair degree of application in East Africa and Southern Rhodesia. On lands which have been protected by broad-based terracing not only must ploughing be done on the contour, but the operation must be conducted in such a way that the terrace channels are maintained and kept open on the up-stream side. In other words the soil is "gathered" (turning to the right) about 3 to 4 yards above the terrace, and this has the effect of widening the channel with every ploughing. If normal ploughing is practised (turning to the left and throwing the first cut on the edge of the channel) and continued for a few years, it will have the effect of forming a bump above the channel; this will prevent water draining into the graded channel and will tend to make it lodge in the middle of the field, which may cause damage to crops.

On the lower side of the terrace bank the earth is thrown up against the bank which is thus widened and strengthened in each subsequent ploughing.

It is a comparatively simple matter to plough terraced land where terraces are equal distances apart, but few fields are of sufficiently even grade to permit the uniform spacing of terraces and this constitutes the chief problem of ploughing terraced land.

The terrace should always be ploughed by throwing the furrow slice towards the centre of the ridge, this broadens and heightens the terrace ridge. The first time a terrace is ploughed the most usual practice is to plough the terraces as described and then to plough the intervening strip,

leaving a dead furrow midway between the terrace ridges. The second time the field is ploughed the area between the terraces may be ploughed first, ploughing being started in the dead furrow left when the field was first ploughed. On the third ploughing the procedure is the same as when the land was first ploughed.

In ploughing terraced land two-way ploughs eliminate some of the difficulties.

CONTOURED PLANTING RIDGES

In many parts of East Africa contoured planting ridges are taking the place of planting mounds or planting up and down the slope which was formerly the current practice.

The traditional mound-planting system of, for example, the native areas of Northern Rhodesia or Nyasaland leads to rapid erosion since on many of the soils the soft newly constructed mounds wash away with astonishing rapidity in heavy rainstorms. The provision of graded contour ridges of the bank-and-drain type is unsatisfactory when used in conjunction with mounds for planting since the drains quickly become blocked with material eroded from the mounds, leading to overflows and breaks in the ridges. To give satisfactory results planting on mounds requires to be replaced by ridged planting on the contour, which can usually with advantage be accompanied by protective contour or graded ridges and trenches.

In native areas contour ridges are most frequently made by hand with the hoe, but they are sometimes made with the plough and the use of the plough for the purpose is extending in some areas. In the Mwanza district of Tanganyika the practice is to make the ridges at 5-foot intervals from the crest of one ridge to that of another with a distance of one to two feet from furrow bottom to crest top, the crests of the ridges being rounded. In Mwanza with an annual rainfall of about 35 inches it is considered that sufficient protection can be provided by the use of contoured ridges of these dimensions and that the provision of protective contoured bunds in addition thereto is unnecessary. To ridge one acre in this way by hand is stated to take 15 man days.

In Mwanza a refinement of this process is sometimes carried out by native cultivators, and consists in burying bundles of cut grass in the contour ridges at the time of construction. When these have rotted the ridges are divided at the centre and the halves of two adjoining ridges brought together to form a new ridge. This assists materially in maintaining the humus content of the soil.

In other parts of Tanganyika and in Kenya and Uganda smaller ridges are used, a usual size being about 3 feet from crest to crest. Such ridges by themselves are, however, insufficient to provide full protection against erosion and require to be combined with a system of graded or contoured bunds or graded strips or hedges.

Contour bunds serve to mark the contours permanently and the contour-planting ridges can be remade annually parallel to them. Sometimes a somewhat larger planting ridge is made at intervals to serve as a marking ridge, but this should not be confused with a contour bund as it is planted under the crop.

In Northern Rhodesia the practice is to remake the contoured planting ridges every year. In the process soil is gradually moved downhill and a gradual bench-terracing effect is produced behind the main contour bunds or ridges. The main ridges are not cultivated and are allowed to grass over.

TIE RIDGES, BOX RIDGES, LISTED FURROWS AND BASIN LISTING

Tie ridges or box ridges are a development and improvement on contoured ridges and consist essentially of ridges raised at intervals across the furrow between two contour ridges, the object being to prevent water gathering force and so averting damage. They are normally made later in the season than the planting ridges and are usually weaker than them. In consequence they breach more readily, but the flow of water that occurs tends to be horizontal rather than vertical. Two forms are used, in the first the ties are about half the height of the planting ridges and are spaced at intervals of about 3 to 4 yards. In moderate rains this prevents the flow of water along imperfectly aligned furrows; if a very heavy fall occurs the ties are overtopped, but surplus water can find its way to the furrow outlet without breaching the main ridges. It takes about four man days to construct ties of this type on one acre.

In the second form the ties are of equal breadth and height to the contour furrows and are spaced about five yards apart, thus sealing off every furrow in five-yard lengths. The system is stated to give excellent results when the banks are large, but is unsatisfactory and dangerous when the banks are low, owing to the possibility of overtopping and breaching.

The ties or bars are in Africa usually made by hand, they should be staggered and should not run in a straight line up and down the slope.

Furrows constructed in this way are often spoken of as listed furrows or listed basins in the United States of America. Listing is done very extensively in the mid-Western States of the U.S.A. to conserve winter snows, while a form of basin listing is also practised on steep slopes in Utah and California. Here the basins are made with tractors operating bulldozers and the barriers finished off by hand.

MULCHING

In permanent crops, mulching the soil by means of a covering of vegetable trash is extremely successful in combating erosion in addition to its primary function of conserving soil moisture and adding organic matter to the soil. Complete mulching affords 100 per cent protection against erosion, particularly in permanent crops such as coffee. In estate cultivation it is comparatively little used mainly on account of the labour

involved and the difficulty in obtaining suitable material. Experimental work in Tanganyika has shown that banana-leaf mulch is the most suitable of all mulches tried on coffee, the next best being Guinea grass (*Panicum maximum*) and Elephant grass. Experiment has shown that mulches are most effective under East African conditions when applied once yearly at the end of the main rains, the amount recommended being 80 lb. per coffee tree. Applications at this rate effectively stop soil wash and in addition there is the further advantage that weeding costs are much reduced. Mulching in coffee has already obtained considerable application in peasant holdings both in Tanganyika and Uganda. In Uganda mulching alternate rows has given satisfactory results in coffee cultivation; it possesses the advantage that it is much more economical both in labour and material.

Surface mulching is standard practice in some of the drier parts of Jamaica, predominantly in the Southern St. Elizabeth area where a more intensified form of agriculture than occurs in other parts of the island is practised. Vegetable material usually in the form of Guinea grass and leafy shrubs and bushes is cut from adjacent uncultivated land and applied as a mulch 4 to 6 inches thick on cultivated lands during the dry season subsequent to cultivation and prior to planting. It is a common practice to establish lands in Guinea grass and other fodder grasses which are used for surface mulching.

STRIP CROPPING AND ROTATIONS

Probably one of the most important single steps that can be employed in erosion control is the establishment and maintenance of a satisfactory system of crop rotation. By alternating intertilled crops with non-tilled crops the time during which land is exposed to serious erosion can be reduced to a minimum. It cannot be said, however, that the problem of working out satisfactory rotations has as yet been completely solved for most areas in the Colonial Dependencies. Some annual crops such as maize, cotton and the like are conducive to erosion since by the manner of their growth they afford in themselves little protection against soil wash, while other crops such as sweet potatoes and groundnuts give some protection on account of their creeping habit. By alternating crops with these two characters a degree of protection can be achieved.

But the most significant advance has been the development of a system in which grass is rotated with arable cultivation and it is now widely appreciated, especially in East Africa, that an effective system of rotation which will afford protection against erosion must include a period of several seasons under grass.

It has been shown by W. S. Martin and his co-workers in Uganda that a grass cover promotes crumb structure in soils. Experimental work at Serere in Uganda has shown that under the conditions there prevailing any system of rotation involving continuous cultivation, even when combined with applications of pen manure, is unsatisfactory if a period under grass is

not included. In Uganda, it has been shown that a system in which arable cultivation is alternated with two to three years fallow under Elephant grass enables fertility to be maintained and provides protection against erosion.

Grasses differ considerably in their power to promote crumb structure, some being much more effective than others. Grasses which have been shown to be particularly effective include Elephant grass (*Pennisetum purpureum*), Guinea grass (*Panicum maximum*), a species of *Paspalum* and various species of *Cynodon* [^{8, 13, 15}].

Strip cropping is now widely practised in the U.S.A. It may be employed either alone or in conjunction with terracing. It has the advantage that it compels the farmer to put rotation into practice. The rotations are carried out on strips in each field each year instead of on individual fields as a whole. The strips follow the contour across the slope and may, for example, comprise a root crop followed by a strip of legume, followed by a strip of grass or lucerne, followed by a strip of small grain or cereal. The effect is to break up the slope, prevent accumulation of water and provide protection. In general the width of the strips ranges from 75 to 200 feet on more erodible soils, and on steep slopes the strips should be narrower.

It cannot be said that strip cropping has yet attained any wide degree of extension in East Africa, though it is practised to some extent on European estates in Kenya. The effectiveness of a system of strip cropping based upon alternate grass leys and arable cultivation has been proved in Uganda, and its adoption by cultivators is the aim of agricultural policy in Buganda. In Nyasaland attempts to initiate trial areas under strip cropping are being made, but little evidence of results is yet available. The principal difficulty arises from the necessity of reallocating land in densely populated areas, where every piece of land has a claimant to usufruct. The change from random to strip cropping means that many cultivators must relinquish their claims to particular pieces of land in order that all may conform to the strip lay-out. Another difficulty is the objection in native eyes to fallow strips on the ground that they may harbour vermin.

In Northern Rhodesia the method of erosion control introduced among the Lamba of the Western Province is in effect a form of strip cropping. In the Southern Province the objective is to achieve the adoption of a system of agriculture based upon the use of cattle manure and rotations of cereals with beans and groundnuts. The legumes form at least one quarter of the total acreage under crop and, as the farms are divided by contour ridges and worked on the contour, in effect this is a simple form of strip cropping. So far precept and example only have been used to introduce this system, and progress has been slow.

GRASSES SUITABLE FOR COVERING DRAINS, SPILLWAYS AND CONTOUR BANKS

For covering drains, contour banks and spillways, the natural velt grasses are used in the East African area. They include such grasses as *Themeda triandra*, various species of *Hyparrhenia*, *Eragrostis* and *Cynodon*.

Probably the most useful is Kikuyu grass (*Pennisetum clandestinum*) which, provided the rainfall is sufficient, is very effective over a wide range of conditions. It can only be propagated by root cuttings or runners, but if conditions are suitable it rapidly establishes itself and gives very effective cover. In Basutoland the annual Blue grass (*Panicum laevifolium*) and *Setaria* spp. make very quick early covers on bunds running through cultivated land and may persist for two or three years until perennials come in. Experience in regard to seeding down grass areas is limited, and on the whole reliance has been placed more particularly on the perennial species.

CONTOURED GRASS STRIPS

Strips of vegetation to control erosion may be either a supplement or an alternative to contoured terraces, ridges or bunds. In the simplest form uncultivated strips may be left between strips of contoured cultivated land and either allowed to grass themselves naturally or planted with indigenous grasses. This is now established practice in the Teso district of Uganda. In Kenya such strips are generally regarded as a palliative until terracing can be started; their efficiency depends largely on the type of sward established. Their width depends on the slope. On estates in Kenya strips of 50-foot grass between 150-foot strips of cultivated land are sometimes used and rotated with cultivation.

In Basutoland permanent grass strips across the slope are usually referred to as "buffer strips". They vary between 3 feet and 9 feet in width, and follow the contour. In laying them out the upper and lower edges are marked out, and a plough furrow is run along the line throwing the ground either up or down the slope; this leaves a defined strip 5-6 feet wide which can be left to grow grass or planted with any fibrous rooted soil-binding grass. In certain areas in Basutoland the strips are sown to *Hyparrhenia* sp. or *Themeda triandra*; the success of buffer strips depends on how quickly the grass cover comes in, and this in turn depends on weather and soil conditions and the amount of water entering the field from the grassland above it.

In Northern Rhodesia natural grass strips on or near the contour are used to a considerable extent. Their chief advantages are considered to be that they are rapidly and cheaply demarcated, require little upkeep and are practically fool-proof. In the Eastern Province when new land is occupied the gardens are laid out in alternate contoured strips 50 yards and 10 yards wide. The 50-yard strips are cultivated and the 10-yard strips left under natural grass. For this reason any contoured grass strip is known throughout the province as a "ten-yardi."

The main objection to such grass strips is that unless they are so closely spaced as to raise insuperable objections on the part of the cultivator their efficiency is low, except on relatively level lands and on soils which are only cultivated for brief periods.

Grass strips are also used as a subsidiary measure in the native maize-growing areas in the Southern Province on land with slope not exceeding 1 in 80 which has not been severely eroded. The strips are generally 5 yards wide and spaced at a horizontal distance of approximately 50 yards. They are laid out in conformity with the general plan for the area and are demarcated by rough wooden posts 10 yards apart at the upper and lower edges of each strip.

The only after care given to grass strips is to protect them from cultivation and late fires. In the Eastern Province they are usually early burned, but in the Southern Province where the fire hazard is less, complete protection is the rule.

There are indications that in some areas in the Southern Province continuation of the policy of fire exclusion may lead to the replacement of the grass cover by bush and tree growth; in this event it will probably become necessary to introduce cutting or occasional burns in order to preserve the grass.

CONTOURED PLANTED GRASS WASH-STOPS AND CONTOURED HEDGES

Contoured planted wash-stops of grass or other material give fairly efficient protection and are gaining increasing popularity in many parts of the world. In East Africa, particularly in Uganda, they are regarded as an efficient substitute for the more expensive contoured bunds. The plants employed must be erect and stiff stemmed and must tiller freely since success depends on the mass of vegetation being able to arrest the downward flow of water and cause deposition of silt; grasses are most usually employed, but other plants may be used including various species of *Coleus*, *Agave* and other plants.

The grass that has attained the greatest popularity is Elephant or Napier grass (*Pennisetum purpureum*), but its employment is confined to areas which have a moderately well distributed rainfall, and it is unable to stand up to conditions which include an annual long dry spell. (Fig. 15.) In Uganda wash-stops of Elephant grass are regarded as the cheapest and most efficient system of protection in the long grass country of Buganda and the Eastern and Western Provinces, but they cannot be used in the drier areas in the North. In establishing wash-stops of Elephant grass mature stems are laid in pairs across the slope in shallow trenches, covered with soil and compacted. The rows are set out at intervals of 20 to 25 yards. Sprouting takes place at each node and, if planting is done in wet weather, a continuous and dense wash-stop is rapidly obtained. About 130 yards of Elephant grass can be planted per man day. After care consists in cutting the grass to near ground level once every 3 months to restrict excessive top growth, and digging back the edges of the hedge with a hoe to discourage excessive lateral root growth and spread. The trash which is obtained can in the early stages be disposed of by laying it along the line on the upper side to increase the wash-stop effect, but after a time more trash is obtained than can be disposed of in this way, and the surplus can be used for com-

posting, mulching or as building material. In Uganda it is stated that contoured hedges of Elephant grass will hold up any normal flow of water or earth and there is little danger of gullyng.

In Kenya, however, it is stated that contoured hedges cannot deal with the surplus run-off which runs through the grass and down the slope and may cause gullyng. It seems possible that this difference may be due to difference in growth under different conditions, or it may be the result of varying habit in the strain of grass planted, of which several are known to exist.

Contoured wash-stops of Elephant grass are the only means of sheet-erosion control which have so far been attempted in Swaziland on any scale. They have been carried out with varying degrees of success in both native and European areas. The width between contours varies with the slope, but on land with from 10° to 15° slope the vertical intervals are about 4 to 5 feet.

Experience on the Aird Government farm in Swaziland shows that on a sandy loam soil with a rainfall of 35 inches per annum live wash-stops of Elephant grass combined with the use of a hillside plough result in the almost complete cessation of erosion. In native areas in Swaziland this method of control has been effected over a wide area ; where the system has failed it has been on account of lack of interest on the part of native farmers who have not maintained the continuity of the banks.

In Northern Rhodesia on the other hand Elephant grass (or, as it is there termed, Napier fodder) has not so far proved very satisfactory as a wash-stop. Its use has been confined to native gardens in the Southern Province and to slopes not exceeding 1 in 80. Where such wash-stops have been employed they are generally 1 to 2 yards wide and are spaced 50 yards apart.

The objections to the use of Elephant grass under Northern Rhodesian conditions are as follows :—

(a) The grass cannot be seeded, and cuttings or roots must be planted ; bulking up to provide sufficient material takes too much time, and cultivators are unwilling to undertake the labour involved in planting.

(b) The grass does not spread to give a good cover when it is removed from its natural habitat in moist situations and along the sides of streams.

(c) Water tends to flow between the stools of grass and to form dongas.

(d) The strips suffer a good deal of damage from cattle grazing and trampling.

(e) After four or five years the grass tends to become ousted by naturally occurring species.

One objection to the use of Elephant-grass wash-stops, wherever they have been used, is the marked edge effect which they exert on crops growing

on lands alongside them, and becomes particularly marked in seasons of low rainfall. For example, it has been stated that in Swaziland, in dry years it affects unfavourably the growth of crops up to 10 feet on either side of a wash-stop. Another disadvantage is that when conditions are favourable the grass has a marked tendency to spread, and in consequence it requires to be kept in check.

From what has been said it is clear that, having due regard to the drawbacks mentioned in the last paragraph, Elephant grass has great value as a wash-stop provided conditions are suited to its requirements. It needs a moderately humid climate and a fairly evenly distributed rainfall and does not do well under drier conditions. A number of strains of the plant exist, and for success strains which tiller freely should be chosen.

Another grass which has given good results under a wide range of conditions is vetivert (*Vetiveria zizanoides*). It is favourably reported upon from Kenya and Uganda, and in Tanganyika is considered to be the most effective of all the grasses so far tried as a wash-stop. It has given good results in Jamaica and in the Windward and Leeward Islands in the West Indies as a wash-stop on hillside lands, and has been successfully employed in Ceylon and Malaya as a wash-stop on the edges of bench terraces in the cultivation of permanent crops such as rubber. It is also extensively planted round the edges of sugar-cane fields in Mauritius (mainly to provide thatching materials). It has thus a wide range of tolerance. It is readily propagated by root division and establishes itself easily; it has little or no edge effect and is resistant to termite attack. Moreover, it supplies large quantities of excellent thatching material, while the roots yield vetivert oil by distillation with steam. It appears to be worthy of extended trial as a stop-wash.

The oil-bearing species of *Cymbopogon*, including *Cymbopogon citratus* (Lemon grass) and *Cymbopogon nardus* (Citronella), have also been tried as wash-stops. In Uganda Lemon grass is considered to be less valuable as a wash-stop than Elephant grass owing to its tendency to become gappy after one or two years, and also on account of its liability to attack by termites. It has, however, given excellent results in Porto Rico where these disadvantages do not seem to have been encountered.

Among other grasses which have been used as wash-stops, Guinea grass (*Panicum maximum*) has given excellent results in the West Indies and parts of Africa in regions where the rainfall is well distributed and exceeds 40 inches per annum; it possesses the advantage that it yields supplies of excellent fodder for livestock. In Nyasaland *Paspalum nodosum* has been well reported upon in the same connexion and appears to be promising. *Saccharum ciliare* has also been tried and found useful under certain conditions. Certain species of bamboo have also been used, though their chief application seems to be in gully stopping.

There is thus a wide range of choice already available, and it is sure to be extended as experience accumulates.

CONTOURED PLANTED WASH-STOPS AND HEDGES USING PLANTS OTHER THAN GRASSES

In Kenya various species of *Coleus* are fairly extensively employed as contour hedges; they are stated to be very fairly effective in holding up the soil; their main drawback is that they are brittle, and on this account are liable to breakage. In native areas they have not given satisfaction mainly on account of the difficulty of maintenance.

In Tanganyika in drier areas *Agave sisalana*, *A. angustifolia* and *A. variegata* as well as *Euphorbia tirucella* have been tried with some success as contour hedges; *A. angustifolia* and *A. variegata* are considered the best plants as they form a tighter hedge and occupy less land than *A. sisalana*. *Euphorbia* hedges are easier to establish, but soon become gappy. Agaves should be planted upon well prepared land and spaced about 18 inches apart; either bulbils or suckers can be used.

For use as contour hedges in coffee plantations only deep rooting plants can be recommended. Experience in Tanganyika which is supported by evidence from Uganda indicates that the most successful so far tried has been *Leucaena glauca*; it can be cut back from time to time and the loppings laid on the ground above the contour hedge. Various species of *Crotalaria* and *Tephrosia* have also been experimented with, but experience showed that, while all were successful in controlling wash, all had harmful effects on the coffee as shown by stem and growth measurements.

Other plants which have been used in native cultivation for contour hedges in the Usambara and Kilimanjaro mountain regions in Tanganyika are *Vernonia subiliquina*, *Adhatoda engleriana*, *Iboza multiflorum*, *Coleus kilimancheri* and *Pyenostochip umbrosus*. They all grow readily from cuttings, but unless they are planted very closely do not form a very dense hedge.

In Ceylon the establishment of contour hedges of a permanent nature as soon as possible is considered an essential feature of soil-conservation practices. They should be established along the edges of contour drains and bench terraces.

Plants recommended are *Tephrosia candida*, *Tephrosia maxima*, *Clitoria cajanifolia*, *Desmodium gyroides* and in drier localities *Leucaena glauca*. The following are also stated to be useful as contour-hedge plants: *Sansevieria thyrsoiflora*, *Tithonia diversifolia*, Pigeon Peas (*Cajanus cajan*) and Pineapple (*Ananas* spp.)

LIVE WASH-STOPS FOR GULLY STOPPING

Many of the plants previously mentioned can be successfully employed for gully stopping under suitable conditions. A limitation to their use is, of course, that the floor of the gully must not have been so much eroded as to prevent growth.

Conditions are not usually favourable for establishing plants in gullies even after the gully has been check-dammed and the dams partly filled

with soil. The plants employed are usually shrubs, xerophytes and hardy grasses which can stand up to the dry conditions, have strong binding roots and are vegetatively propagated.

In Nyasaland a number of plants have been tried successfully. The ordinary reeds of different species as well as bananas do well in dampish areas and soon completely stabilize a gully. Bamboo and sisal have also shown their value in this regard, and Elephant grass has also proved useful. Certain indigenous trees such as *Pterocarpus angolensis* and *Terminalia sericea* which grow readily from cuttings have given useful results and seem to be worthy of extensive use in suitable situations.

In Basutoland, *Agave americana*, planted in close double rows across a gully, has been used with success.

Usually, before planting, temporary check dams of stakes and brush-wood or rough stone checks are used to stabilize the soil at intervals depending on the slope of the land, while the sides of the gully may also be cut back and the soil spread at the bottom to facilitate the establishment of permanent soil binders. Once the checks are well established colonization by natural vegetation soon takes place.

PROTECTIVE COVERS

In permanent and semi-permanent cultivation the use of protective covers is a measure of great value. They can, to an extent, also be employed in some annual crops and on lands left fallow. In general, leguminous plants are the most favoured as not only do they protect the soil, but also increase the nitrogen content. In certain localities the use of protective covers is limited by climatic reasons; thus in Basutoland the winters are too cold and dry for most cover crops and Kikuyu grass is one of the few exotic grasses that has done really well. On most denuded slopes indigenous grasses like *Hyparrhenia eragrostis* and *Cymbopogon* come in quickly on fallow areas that require to be protected for only two or three years. In cultivated land the only cover crops that can be grown are cowpeas in the lowlands and green peas in mountain areas. In Southern Rhodesia very little has been done on the use of protective covers mainly because the long eight-months dry season precludes the use of anything but natural grass or weeds at the beginning of the rainy season. In Nyasaland the following types have been used as cover crops: *Indigoplica* sp., *Desmodium* sp., *Calopogonium* sp., *Tephrosia* sp., *Cajanus* sp., *Crotolaria* sp., *Stizolobium* sp., *Dolichos* sp., *Phaseolus* sp.

Various crops themselves are a very effective cover when they are planted within the rotation in native reserves. Sweet potatoes and pumpkin are included within this class, as also groundnuts and various species of beans and peas. In Malaya and Ceylon much attention has been devoted to the establishment of protective cover crops in rubber and tea and a considerable number of creeping covers, some leguminous and others non-leguminous, have been developed for this purpose. (Fig. 25). The

most important are: *Calopogonium mucunoides*, *Centrosema pubescens*, *Dolichos Hosei*, *Indigofera endecaphylla*, *Pueraria phaseoloides*, *Mikania scandens*. All of these have been extensively employed in rubber cultivation in Malaya. It has been found that sometimes a combination of two or more cover plants is more successful than one alone; thus mixtures of *Calopogonium* and *Centrosema* and also mixtures of *Pueraria* with *Dolichos* have under certain circumstances given excellent results. In Ceylon certain indigenous covers have also been developed including the following: *Alternanthera* sp., *Desmodium* spp., and *Eupatorium*.

In Malaya, and to some extent Ceylon, the encouragement of natural covers in rubber with selective weeding has been advocated and obtained some extension. It is difficult to compile lists of species which should be encouraged, particularly as the flora varies from point to point, but as a general principle it is considered that in selective weeding plants retained should be soft stemmed with large succulent leaves, while those with hard woody tissues which are resistant to decay or with tufted roots, thorns and so forth, should be removed or at least kept in subjection.

WINDBREAKS

Windbreaks are used to prevent erosion of the soil by wind and also by water; they can exercise these functions in addition to reducing evaporation and providing shelter for livestock and crops, but they should not entirely restrict wind penetration or the advantage may be greatly reduced. On this account, it is important that the correct density should be obtained. The sheltering effects of a windbreak are felt at 2-5 times its height on the windward side and from 10-20 times on the leeward side. If the correct density of planting is obtained, a certain amount of wind percolates through the belt which acts as a cushion for diverting wind which comes from above the windbreak.

Windbreaks and shelter belts may in their simplest form be strips or groups of indigenous trees left when stumping new land, or they may be formed of single or multiple rows or groups of planted trees. They may be planted in single, double or treble rows. Single-row planting has the advantage of occupying little space, but should be used only when economy of space is an important consideration and is not recommended for main belts in as much as if one or two trees are in poor condition or have died, the windbreak loses its efficiency. Moreover, if the belt is planted with fast-growing trees, the lower part is apt to open up with advancing age. When multiple rows are employed, one row should be of tall fast-growing trees and the other of slower or more bushy ones. A suitable combination is eucalyptus on the windward side and on the leeward side a row of conifers or other slow-growing trees. A windbreak of three or more rows, in addition to providing shelter, can, by regulating cuttings, be used for the production of timber and fuel.

In Tanganyika, in areas of low rainfall (20 in.), *Cassia siamea* planted fairly closely has given useful results in breaking the force of the wind and

keeping wind erosion to a minimum. A drawback to its use is the effects which it has on adjacent arable land. In the *Brachystegia* area in Tanganyika with 35 inches of rain, various species of eucalyptus have been useful, notably *E. maculata*, *E. corynocalyx* and *E. maideni*, particularly in alternating rows with *Cupressus lusitanica*. Planting distances are from 8 ft. by 8 ft. to 15 ft. by 10 ft.

In Nyasaland many species of cassia and eucalyptus are used in addition to *Greville robusta*, *Cedrela* sp., and certain indigenous types, e.g. *Albizzia* sp., *Khaya* sp., and *Terminilia sericea*.

In Kenya and Uganda a similar range of genera has been successfully employed, in Uganda *Ficus* spp. are also used, but are not very satisfactory as they are shallow rooted and frequently blow down in heavy winds.

CONTROL OF SHIFTING SANDS BY VEGETATIONAL MEANS

In areas of very low rainfall, particularly in regions bordering desert country, much damage is liable to occur owing to the drifting of wind-blown sand and the formation of shifting sand dunes. Areas of productive land may be increasingly encroached upon as a result of this and rendered unproductive and infertile; the process is sometimes referred to as "the advance of the desert." In such areas the anchoring and stabilizing of the sand dunes by the establishment of a protective cover of vegetation is an important step since this tends to prevent movement of the sand and so affords protection to the adjacent areas.

The matter is one for the forester rather than for the agriculturist; it involves the colonization of the dunes first of all by whatever forms of vegetation can be induced to obtain a foothold thereon. The choice is usually limited because the areas are of very low rainfall; if creeping grasses and creeping vines can be found which will establish themselves under the prevailing conditions they can be used to afford initial protection and permit of more erect forms being introduced later. The question is really one of finding a suitable vegetational succession.

In the Sudan an introduction originally intended to reduce the dust problem around the towns of Khartoum and Omdurman may be capable of wider use in this connection; this is the South American "Mesquite" (*Prosopis* sp.) which forms dense thickets 8 to 10 feet high in 5 years and grows under an annual rainfall of 4 inches. The procedure is to erect stockades until some 2 feet of sand have accumulated and then to dry-plant the seedlings.

The beans and the pods can be used for human and animal food, and it is stated that the pods from 8 acres will keep one beast for a year.

Near Khartoum there has been a big natural spread, while many isolated plants have arisen from one planted some years ago. The possibility of using this rapidly growing crop for erosion control in dry localities seems well worthy of full exploration, particularly having regard to its potentialities as a producer of human and livestock food. [?]

In Palestine a technique for the fixation of sand dunes has been successfully evolved.*

Most of the coastal strip of Palestine south of Acre is more or less sandy and over considerable stretches the sand has blown up into dunes and invaded the plain, forming in places high, bare and moving dunes. Rainfall varies from 14 inches at Gaza in the south to 26 inches at Acre in the North ; strong winds are often prevalent and soil temperatures are very high in summer.

After trial it was found that the best results were yielded by *Acacia cyanophylla*, and since 1936 upwards of 2000 acres have been treated successfully ; the fixation of the whole coastal stretch of sand dunes is now regarded as a practicable proposition.

In practice seeds are sown in boxes or nursery beds and are transplanted into pots filled with a mixture of soil, sand and manure as soon as practicable. Plenty of water is given, and the pots are sunk in sand to reduce evaporation. At the end of a year the plants are 4 to 6 feet in height while the pots are filled with a mass of fibrous roots. In February the plants in the pots are transported to the site selected and planted in pits 3 feet deep which are afterwards filled in with sand so that only the top twigs of the plants are visible. The original roots of the plants are thus in a sand layer which is always moist and cool while roots also develop on the older branches below ground level. Where the sand surface is specially loose, branches from older plantations are strewn over the area, and where high winds are very prevalent the butts of these are sometimes buried. Cuttings of *Tamarix* are planted as windbreaks along the shore.

The essence of the method is the employment of big plants and deep planting pits, the initial high cost being offset by low costs of maintenance and subsequent recruitment.

Success varies with conditions. When these are favourable soil movements are checked 3 years after planting and an auxiliary cover of grasses, *Artemisia* and other low shrubs will have established itself. Such compartments form thickets at 6 to 7 years, and thereafter the sand remains hidden under a deep litter of leaves, twigs, etc.

When conditions are more difficult the process takes longer and repeated recruitment may be necessary. Such plantations may remain 5 years behind the best.

For success complete exclusion of grazing and human interference is necessary and it is preferable if possible to protect the area for a few years in advance of planting, in which event volunteer growth of grasses, *Artemisia* and other plants may come in and facilitate subsequent plantation.

Once plantations have been established they can be worked systematically for the production of firewood. It seems likely that the first crop can be cut 10 to 15 years after planting, and thereafter subsequent coppice rotations of 10 years can be envisaged.

* Privately communicated by G. N. Sale.

The establishment of a dense scrub cover on practically pure sand can be considered a most satisfactory achievement. It leads to the formation of a forest soil and it seems possible that subsequent succession to a more valuable form of forest crop may be practicable, or even the use of small parcels of the land for cultivation under suitable crops, though here great care would be necessary to avoid further soil movement.

AFFORESTATION AND TREE PLANTING

It is not proposed to discuss forestry relationships in any detail but the importance of forests and their correct treatment in any regional scheme of conservation can hardly be exaggerated. In many European countries the maintenance of at least 20 per cent of the land area under forest is regarded as essential for the provision of timber and fuel, the protection of the land surface, the maintenance of favourable hydrological conditions and the preservation of wild life. It is probable that under the conditions of the humid tropics a higher proportion may be necessary, since the need for protection and conservation is higher than in Europe and the standard of cultivation from the point of view of protection from erosion is lower.

As a general rule (although there may be exceptions), when new lands are being opened up and there is a choice between forest and grassland, forest should be left until experience has shown how the land can best be managed. Grassland soils, other things being equal, have greater inherent resistance to erosion than forest soils, though neither are erodible when carrying their natural cover. There is, of course, no objection to utilizing forests, preserved primarily for protection, for timber production, provided an adequate protective canopy is maintained, which in effect means managing the forests on a sustained-yield basis.

One of the first steps in undertaking a comprehensive soil-conservation policy is to demarcate protection forests on watersheds and around the headwaters of rivers, since erosion in such areas is liable to be particularly harmful and give rise to damage from flooding and silting further downstream. Fortunately such regions, on account of their location in hilly and mountainous country, are usually not well suited for cultivation, although they are liable to be cultivated when, as a result of pressure of population or for other reasons, more suitable land is not available.

If the upper slopes are adequately protected by forest a good grass cover usually suffices to hold the soil on moderate slopes below, even though they may have been originally clothed in forest, provided that the sward is not deteriorated or destroyed by excessive grazing. It should, however, be noted that pasture will not always hold very steep slopes in natural forest regions even though it may be well managed.

In soil conservation the work of the agriculturist and the forester is very closely linked ; in the preceding sections we have seen the close association which exists between them in the establishment of windbreaks and the control of shifting sands, and in other directions also their work must be closely associated and co-ordinated.

To the forester belongs the duty of protecting watersheds and mountain regions ; it may be that as a part of this function contoured bunds, contoured drains and other protective works have to be constructed within forest reserves ; in such a case they should obviously be linked to, and be continuous with, the system of protection adopted in the agricultural lands below. There must also be close collaboration between the forester and the agriculturist when questions arise of withdrawing lands from cultivation for the establishment of protective forest reserves thereon.

Another aspect is the establishment and maintenance of reserves for the supply of fuel and timber to village and agricultural communities. In many areas which are densely populated timber resources have become almost completely depleted and the consequent dearth of wood supplies for fuel and constructional purposes is a source of great difficulty. Examples of such areas are the Mwanza district of Tanganyika and large parts of Basutoland. In both places the burning of cowdung is extensively practised owing to the lack of other sources of fuel. This entails loss of fertility since it precludes the use of the material as manure.

To deal with this the establishment of village forest reserves and the planting of village lots on a communal basis have been undertaken. It necessitates a measure of land planning, and in Basutoland the setting aside of definite areas for planting in trees forms a part of the accepted policy for development and conservation. For this type of planting quick-growing trees are used, particularly various species of eucalyptus. Work of this type constitutes another example of the need for close collaboration between the forester and the agriculturist in conservation measures.

CHAPTER 4

THE CONTROL OF GRAZING AND LIVESTOCK MANAGEMENT IN RELATION TO SOIL CONSERVATION

It is at least probable that in Africa defective methods of livestock management, including overstocking, overgrazing, uncontrolled burning of pastures and bush, over-concentration of cattle at water sources, particularly during dry periods, and the like, are in the aggregate responsible for greater damage by erosion than defective methods of cultivation, great though the effect of the latter may be.

DE-STOCKING

Overstocking is much more liable to occur in native areas than on European-owned properties where, generally speaking, sheet erosion due to overgrazing is not a serious problem. European farmers are primarily concerned with their livestock as the means of producing commercially meat, milk and other products of animal husbandry for sale. Consequently, uneconomic concentrations of livestock in poor condition on European properties are the exception rather than the rule; there is growing appreciation of the principles of economic grazing management, and where poor conditions exist they are mainly due to lack of capital for the provision of fencing material or equipment.

In native areas, however, the position is far otherwise; the traditional attitude of the African to his livestock, whereby the emphasis is laid on numbers, irrespective of the condition and quality of the beasts, as an index of social standing, and the "loblolo" social system which dictates that the price of a wife is reckoned in terms of heads of cattle, are powerful factors tending to keep up numbers. Formerly widespread epidemics of cattle disease periodically took heavy toll of livestock and served as a natural check, but with the development of veterinary services and of remedial and prophylactic measures for the treatment or elimination of disease the increase in numbers has been accelerated.

Thus between the years 1931 and 1944 the native cattle population of Swaziland increased from 311,000 to 383,000 head,^[27] while between 1931 and 1936 that of Uganda increased from 337,000 to 385,000 head.^[28]

The effect of over-concentration of livestock and consequent overgrazing is seen in the destruction of the vegetational cover and exposure

of the soil to the action of wind during dry periods and to erosion, both of the sheet and gully type, on the onset of rains. In areas where the dry season is prolonged and water becomes scarce, there is always bound to be concentration of livestock around the available sources of water, and this aggravates the evil; linked with the problem is the practice of the native of firing the country during the dry season in order to obtain the young succulent grass which develops after a burn. The light covering of ash is largely dispersed by the wind, while much of what remains is washed off the land by the first heavy showers of rain, the result being that even the ash of the former vegetational cover is lost to the land on which it grew. Thus overgrazing and annual burning combine to retard the regenerative process and to intensify the erosion which is bound to occur on overgrazed land. The most pressing problem is therefore to limit the number of stock to the carrying capacity of each native reserve. The task is not an easy one, and involves educating the African to modified ideas as to the place of livestock in his economic and social system. From the point of view of de-stocking, "loblolo" certainly complicates the problem, but it must be acknowledged that it does exercise a stabilizing and beneficial moral effect on the character of the people, and its retention in some modified form seems desirable. The acceptance of cash instead of cattle should be encouraged by all possible means, despite the fact that at present money has not the same social significance that attaches to cattle in native eyes.

The inauguration of cattle sales has had useful results in various territories, notably in Tanganyika and Swaziland. Another outlet for surplus stock is local native butcheries. The diet of Africans in the East and South African territories is deficient in animal protein, so that the increased consumption of meat is, from a nutritional point of view, very desirable. Considerable success has followed the establishment of native butcheries in Uganda, and to some extent also Swaziland. A point of some importance is that they should be accompanied by adequate provision for the inspection of meat in order to minimize the risk of increase of, e.g., tapeworm infection in humans through the consumption of infected meat.

In Kenya and Tanganyika factories have been opened for the preparation of canned and preserved meat, as an aid to providing a market for surplus cattle.

These measures appear to be having considerable effect in some areas, notably in parts of Uganda, but in other places they have proved insufficient to bring about the reduction in numbers that is essential to safety, and recourse to compulsory measures to ensure the necessary measure of de-stocking are in contemplation.

In Tanganyika de-stocking on a considerable scale has already been achieved in one district. This was done by the establishment of special culling markets. The stock of particular areas were examined at collecting points by officers of the Veterinary department who pointed out to the owners the aged and otherwise unproductive beasts and urged their sale, supported in their exhortations by Administrative Officers. There is as yet

in Tanganyika no law under which unwilling owners can be forced to sell, but many natives were willing to do so and large numbers of culls were sold in the auction rings which were provided for the purpose.

The practice of culling has now become firmly established among this particular tribe and it has become possible to discontinue the holding of culling markets ; culls are now brought voluntarily to the ordinary cattle markets.

A large measure of de-stocking is to be attempted in the near future, in the Irangi plateau of the Central Province of Tanganyika, but it will not be de-stocking pure and simple since it is intended to move a large proportion of the people off the plateau and it is assumed that they will take their cattle with them. In this case the people can be compelled to move under rules made by the local Native Authority with the consent of the Governor.

In Nyasaland de-stocking is essential in certain areas. Attempts to effect this by means of propaganda to induce owners to avail themselves of facilities for the sale of cattle at reasonable prices proved ineffective. The people expressed willingness to sell, but insisted on prices that were uneconomic. Plans were formulated for the removal of cattle to alternative grazing areas, but these were strongly resisted. As a result it has become plain that resort to compulsion backed by explanatory propaganda is inevitable. The stock-carrying capacity of all registered grazing areas has been determined, and the number of excess cattle in each village using each area notified to the Native Authority. The Native Authority has expressed willingness to compel the disposal of excess stock by this method, but if it should prove that it is unable to do so recourse will be had to legal powers under the Natural Resources legislation.

In Swaziland the position is rather similar, and by 1944 a proclamation and regulations thereunder had been proposed to enable the compulsory culling of large and small stock on over-stocked areas. The regulations provide that in regions in which overstocking exists areas may be declared land units in which the reduction of stock is authorized. Once an area has been declared a land unit, counts of livestock will be instituted, and if the counts show that the number of stock exceeds the maximum that has been prescribed for the area, the number of heads of stock of all kinds which may be kept by each native will be determined and the excess culled by a culling officer. Culled animals will be branded, and the owner instructed to slaughter them or cause their removal from the unit within six months. If at the end of that time a culled animal is still in the unit it will be seized and sold at the highest price obtainable and the money handed to the owner after deduction of expenses. The introduction of any stock into a unit except under permit is prohibited, and any livestock which is found to have been introduced into a unit except under permit can be seized and destroyed or removed.

No information is yet available as to how this legislation is likely to work, but it is appreciated that, except in districts where the situation is

so bad that immediate action must be taken, the bringing of it into force should be deferred until sufficient time has elapsed to enable its provision and its objects to be fully explained to the people through a propaganda campaign. In assessing the individual quota for owners due recognition will have to be given to the status of chiefs and headmen. The reduction to the fixed quota will be effected gradually, while culling would be on a selective basis, large herds receiving more drastic treatment than small ones.

In Basutoland control of overstocking has been achieved on communal grazing areas in the following manner. The livestock-carrying capacity of each communal grazing area is assessed and the number of stock which can be grazed thereon is laid down. Should it be found that the actual number being grazed exceeds the carrying capacity, fair allocation of stock is made to each family using the area, and the surplus is then compulsorily sold for slaughter or removal. A basic allowance of six head of large stock is made to each family, and stock in excess of this amount is reduced in proportion to the holding of each family.

In Southern Rhodesia the need for de-stocking has become urgent in native reserves, and a policy of compulsory limitation of livestock has been adopted in critical areas, by means of the organized culling and sale of scrub animals.

CONTROL OF GRAZING

While the reduction of the numbers of livestock in native reserves to the carrying capacity of the grazing areas must exert a beneficial effect on the pasturage and reduce the intensity of erosion, the full benefit cannot be derived nor can the carrying capacity of the grazing areas be very greatly enhanced unless they are accompanied by systems of controlled grazing and pasture management.

The first requirement, especially in densely settled and overstocked areas, is the demarcation of land for arable and grazing purposes, combined with powers to enable livestock to be excluded either temporarily or permanently from areas from which it is necessary to institute systems of deferred or rotational grazing or to retire from grazing altogether.

For this, provision of fencing is highly desirable, but large-scale fencing in native reserves is at present excluded by the high cost and relative scarcity of fencing material and, although sometimes the use of fencing on a limited scale has to be resorted to, recourse is mainly made to beacons or hedges.

In Basutoland the practice is to prepare a register of all families who by native custom are entitled to land, and to demarcate by means of beacons, areas set aside for arable cultivation, vegetable gardens and tree planting. The remainder of the land is allocated for communal grazing and divided by stone beacons into three sections, so as to enable deferred grazing to be practised. The operation of the scheme is supervised by land-management committees, and it is understood to be working satisfactorily.

In Nyasaland a somewhat similar procedure is followed; with the consent of village headmen land is subdivided into arable, grazing and forest areas. No set formula has been found to work, but a common desire to safeguard crops from damage by livestock acts as an incentive, although, even where agreement has been achieved, permanent segregation is difficult unless some form of fencing is resorted to. A considerable obstacle has been the general belief that forest land is suitable for grazing. The method of fencing adopted has been to establish sisal hedges under a "nurse" of two strands of barbed wire, nurseries of sisal plants being established a year in advance. A stockproof hedge can be expected in from 3 to 4 years, when the barbed wire can be removed for use elsewhere.

In Tanganyika the permanent closure of hilltops to grazing is being attempted in many localities, with the object of protecting them with a permanent cover. In such cases where natural features such as rocks and trees do not provide permanent landmarks, xerophytic plants such as sisal or candelabra cactus planted at 20-yard intervals have been found to answer requirements as beacons.

In open grazing lands which are to be closed temporarily similar plants may be used, or holes 2 feet square and 3 inches deep are used as markers, or convenient stones or trees may be designated as beacons by splashing them with a mixture of gum and whitewash. The most important matter appears to be effective policing rather than actual demarcation, and the sketchiest demarcation is found to be effective provided a grazing guard is on the land. Where the effects of reserving grazing areas have been seen and appreciated by the natives the system works well and co-operation with authorities is excellent; there is already a tendency for successful reserve systems to be absorbed into traditional tribal practices. The general practice is to close the grazing reserves as soon as the grass has begun to flower, i.e., from mid-February, and they are normally re-opened for grazing in June.

In Northern Rhodesia large areas have been reserved for grazing in the Southern Province. They are demarcated by *Afrormosia* posts set along the boundary at 25-yard intervals. The posts are durable, but in some cases cuttings of *Euphorbia truticelli* are planted alongside the post so that when it perishes the plant will remain as a mark. In the Eastern Province where posts are not available areas are demarcated by open boundary lines, consisting of ridges 1 foot high, 3 feet long and 3 feet apart along the boundary. Village grazing areas are demarcated so far as possible by natural features, but where no suitable features exist lines are cut with pole beacons at each corner. The villagers slash the lines annually, and each time this is done each villager places a stone at the base of the post so that a permanent beacon is formed before the post rots. Villagers usually require little encouragement to observe the demarcations, but if need be the prohibition of cultivation within demarcated areas is enforced by Native Authority Rules.

FACTORS AFFECTING THE CARRYING CAPACITY OF GRAZING LAND

Under the low rainfall conditions characteristic of large parts of Africa, the prevalence of trees and shrubs is the factor most affecting the carrying capacity of grazing land and the even distribution of feed throughout the year. The matter has been discussed by R. R. Staples^[24] who points out that the above desirable qualities depend in large measure on the presence of a fair proportion of perennial grasses, and that a rainfall in the region of 20 to 30 inches a year is insufficient to maintain them if they have to compete with woody vegetation. Over large areas both in East Africa and Rhodesia and also in many parts of the Union of South Africa the encroachment of various species of thorn bush (varying from low shrub to substantial trees) has resulted in serious reduction of carrying capacity over extensive tracts of good country accompanied by increased erosion.

It appears clear that where a delicate balance exists between grasses and woody vegetation, full use cannot be made of grazing land unless measures are taken to keep it free of excessive numbers of trees and shrubs. Under suitable conditions controlled early burning may assist (see following section), and Staples and the Hornbys have shown that goats can assist in keeping down woody growth and so materially reduce the cost of weeding^[25].

Experimental data by Staples show that it takes about 75 man days to clear, burn and stump an acre of dense brushwood and plant it with Star grass, and two man days per acre subsequently to clear out invading woody species before grazing commences. Once grazing has begun it takes about four man days per acre per annum to maintain it reasonably free from bush.

In densely populated areas, *e.g.*, the Lake, Central and Western Provinces of Tanganyika, the Kavirondo, Kikuyu and Machakos reserves of Kenya and in Basutoland there are to be found open lands maintaining, for the time being at any rate, dense human and stock populations. In such areas the destruction of woody vegetation is frequently so thorough that the inhabitants have difficulty in obtaining even their fuel requirements. Stock densities are sometimes as high as one beast to the acre, while three acres to one beast is common. Often such areas are not only overstocked but overpopulated, and it is impossible to expect that they can remain in permanent occupation indefinitely with the primitive methods of crop and animal husbandry usually employed; the effects of continuation of such conditions are to be seen in the Machakos reserves in Kenya. If stable conditions are to be maintained populations, both human and livestock, have to be reduced to values consonant with the carrying capacity of the land, and systems of husbandry and grazing control adopted that will ensure the land being put to the most efficient use. Even where there are optimum concentrations of population and livestock a certain amount of weeding of pastures will be necessary. Where the grazing is on a communal basis the work of weeding can best be carried out on the same basis.

In regard to controlled grazing, results of experimental work carried out at Mpapwa in Tanganyika show that owing to lack of perennial grasses the response to deferred grazing is less in bushland than it is in open grassland. In conditions where rainfall is higher and perennial grasses normally occur in woodland and open bushland, the benefits of deferred grazing on bushland would be greater, but even under Mpapwa conditions resting bushlands during a part or whole of the growing season did give an increased measure of protection and a greater reserve of feed for the dry months.

On open grassland the response to deferred grazing is spectacular. Resting during the second half of the growing season gave rather better results than either resting for the whole of the growing season or for the first half. The improvement is shown not only by increased carrying capacity but also by a denser cover to the soil and better distribution of feed throughout the year.

Two alternative methods of implementing deferred grazing have been proposed. (a) A seasonal system in which the pastures are rested from February to June every year, use being made during this time of grazings reasonably near by which are relatively unused owing to the absence of permanent water supplies. It is only applicable when conditions permit, but has given excellent results in the Central Province of Tanganyika. (b) A chess-board system in which the land is divided into squares demarcated by euphorbia and sisal plants at 100-yard intervals, one set of squares being rested one year, and one the next year. The system can be used where conditions are not suitable for the seasonal deferred method owing to population density, although it is appreciated that with resting one year in two the response cannot be so great. Attempts have been made to introduce it in the densely populated areas in the Central and Lake Provinces of Tanganyika with promising results.

GRASS AND BUSH BURNING

There has been considerable controversy in the past regarding the practice of bush and grass burning, and there is still much that requires clarification by observation and experiment; certain points are, however, universally conceded; it is for example recognized that uncontrolled burning is an unmitigated evil. It is further clear that the total prevention of fires, especially in dense long-grass country, is impracticable if indeed it is not impossible. Moreover under certain conditions the controlled burning of grass and bush at appropriate season may be a desirable practice, and its omission may be almost as great an evil as uncontrolled burning. One obvious advantage of burning which has caused the practice to become widespread is that it removes the old dried vegetation of little nutritive value that remains on grazing lands at the end of the dry season, and allows the springing up of young new grass at the onset of the first rains; it is also claimed that it tends to keep bush encroachment in check, although this is not universally conceded, and in some territories continued early burning has actually been found to encourage it. In its natural state grass-

land is normally in a delicately balanced condition ; in much of Africa fire has undoubtedly played an important part in grassland development, any change therefore in the incidence of this factor either in frequency or fierceness may be expected to bring about considerable changes in the condition of grassland.

The effects of burning may vary widely with different types of pasturage. Staples^[25] classifies pasturage in Southern Rhodesia under three heads, viz., sweet veldt, mixed veldt and sour veldt, which have been defined as follows :—

Sweet veldt— Occurs mainly at low elevations, the herbage comprises almost exclusively annual species which remain palatable when mature and make good winter grazing. The grass cover is readily damaged by fire or overgrazing.

Mixed veldt— Occurs mainly at medium elevations, herbage comprises both perennial and annual species, grass cover denser than sweet veldt.

Sour veldt— Occurs mainly at higher altitudes, herbage mainly perennial and comprised of sour grasses palatable only in the young leaf stage. Cover much more resistant to fire and overgrazing.

Staples^[25] provisionally suggest the following principles for the different types of veldt on ranching properties where burning can be controlled.

Burning of sweet veldt is in principle undesirable except where scrub and thorn encroachment is a serious problem. This, however, is unfortunately often the case ; when burning has to be undertaken it should not be more frequently than once in four or five years, the land should be protected during the previous growing season and fired at the end of the dry season. Care must of course be taken to confine the fire to the area which it is desired to burn.

Burning of mixed veldt is also normally undesirable if the land is fully stocked and bush encroachment can be controlled economically in other ways. If, however, burning has to be undertaken to get rid of surplus growth or keep bush encroachment in check, the land should be rested during the last part of the previous season and burnt at the end of the dry season or after the first rains. Burning should not be more frequent than once in three or four years.

On sour veldt the need for burning is greatest, especially if mowing for hay or compost is not possible. It improves the grazing and assists the development of a denser sward with diminution in the number of coarser grasses. It would seem advisable to burn understocked veldt once every two years at least, fully stocked veldt may be burnt every two or three years.

It is obvious, however, that no programme of controlled burning can be successfully carried out on ranching properties without adequate provision of paddocking and firebreaks.

In native areas the total suppression of grass fires in areas where grass burning is an established practice is impracticable, and from what has already been said is probably on balance undesirable. The essential point is to ensure that firing shall take place at a time when the vegetation is in a condition which will not give rise to fierce conflagrations which may occasion extensive damage to vegetation, prevent regeneration if the burnt surface is left long exposed and encourage erosion by wind and rain. On this account it is usually considered that early burning is desirable, while late burning at the end of the dry season should be discouraged.

This may, however, be subject to modification in areas where tsetse fly is prevalent since it has been found that early burning may be followed by invasions of the fly in burned areas, consequent on the increase of scrub ; this is stated to have actually occurred in the Buruli district of Buganda. In such conditions it is considered that late burning is preferable.

It would appear accordingly that while the balance of opinion favours early burning under the majority of conditions, in some localities, where special circumstances prevail, late burning may be preferred.

Legislation for the control of grass and bush burning exists in most of the African dependencies and elsewhere, but its successful operation is dependent on securing the collaboration of native authorities. Thus in Basutoland legislation prohibits the burning of grass or bush in any grazing areas or in any arable area, but there is a proviso that a chief may, after consultation with the District Agricultural Officer, permit the controlled burning of grass where this is considered necessary for the maintenance or improvement of the grass cover.

In Nyasaland the policy followed is to endeavour to ensure that burning is completed as soon as a reasonably complete burn can be expected, thereby avoiding the fierce fires which do so much damage if burning is deferred to late in the dry season. Protectorate legislation provides for fixing dates by which burning in the different districts must be completed, and this is supplemented by Native Authority regulation in a similar sense. By native custom it is the responsibility of each village headman to authorize burning, thus making village headmen personally responsible for the occurrence of late fires. With adequate supervision this system is stated to have given satisfactory results.

In Tanganyika it has been found that wherever there is a tradition of deliberately firing grass and bush, complete suppression of bush fires is impracticable, and, more often than not, deliberate burning at the end of the rains is advisable. At that time a slow burn is obtained while grass and bush are still sappy and they have a chance to grow again after the fire. An area which is successfully protected from fire till near the end of the dry season and is then fired, burns so rapidly and so fiercely that more damage is done than if no protection had been exercised.

In Northern Rhodesia early burning has been put into force over a large area in native occupation over which some measure of control can be exercised. In each locality a date by which the burning of grass and bush must cease is fixed each year by a committee composed of European officials and native representatives (generally in June or July). After that date anybody who causes a fire commits an offence and is liable to a fine if he is caught. The African staff of the Department of Agriculture tour the district some time before the final date for completion of burning and do as much of the burning as possible themselves, at the same time encouraging the people in the area to follow their example.

Considerable efforts are also made to instruct the native peoples concerning the need for early burning and the advantages which follow the practice. At the Ndola Experiment Station late burned, early burned and completely protected plots have been maintained during the past twelve years; for some years past the differences resulting from the various treatments have shown up in spectacular fashion.

A visit to these plots is included in the annual courses of general instruction for Chiefs; similar demonstrations have now been started at a number of other agricultural stations in various parts of the country. As part of the propaganda campaign to popularize early burning a large poster has been prepared showing photographs of the Ndola plots with descriptive letterpress in the six major languages. The poster has been widely distributed throughout the territory.

PROVISION OF WATER SUPPLIES

In countries with low and variable rainfall that have a long dry season the provision of water supplies for livestock and for human beings during periods of drought is an important factor in the control of erosion. As the dry season progresses ponds, springs and streams dry up, and as this occurs concentrations of livestock around those which still yield water become more and more intense, with consequent gross overtrampling of land in their vicinity, leading to destruction of vegetation, exposure of soil and loss by erosion.

Consequently under such conditions provision of additional water supplies often is a matter of vital urgency.

Ways in which this may be done include the provision of wells and bore holes, diversion ditches from permanent rivers, and the erection of dams to conserve run-off.

In many parts of Africa, notably in Kenya, Tanganyika and Uganda there is Government provision of boring equipment, and the work of making boreholes is proceeding, the rate of development is limited by the availability of equipment and the difficulty of obtaining it under present conditions.

The erection of dams at suitable points constitutes the principal alternative method of solving the problem. The relative value of the two depends on conditions. There are localities in which boring cannot be successful owing to geological conditions, and there are areas in which it may be inadvisable to install dams.

The advantages of reservoirs are that they are relatively cheap and easy to construct. Little is required in the way of maintenance and there is usually little difficulty in drawing water from them. On the other hand they are liable to pollution, may dry up or fill up or may be destroyed by sudden exceptional floods.

Boreholes are relatively expensive and require skilled staff and special machinery for their construction. They are not effective everywhere and are liable to wear and tear. On the other hand when they are properly maintained they give perennial supplies of relatively pure water. A judicious combination of boreholes and dams appear to be the most appropriate solution.

It would be out of place here to enter into any discussion of the technique of sinking boreholes; the construction of small dams on the other hand requires no great amount of special technical knowledge and can be and frequently is undertaken as part of operations for soil conservation. The reclamation of gullies often affords an opportunity of providing water supplies by the erection of dams across them, and in Basutoland the majority of the 160 dams have been constructed across dongas.

The Governments of Kenya and Tanganyika have published excellent bulletins describing methods of constructing earth dams and the following notes have been abstracted from these and from information supplied from other territories^[10, 2].

In constructing small earth dams the following are among the points which require to be taken into consideration:—location, character of the soil, character of the rainfall, size and condition of the drainage area which supplies water, spillway requirements, construction cost and maintenance cost.

The size of the dam must be related to the size of the catchment area supplying the run-off, which must be sufficient to fill the dam, having regard to the nature of the vegetative cover, the topography and the intensity of the rainfall. Large catchments are likely to entail difficulty and expense in the provision of an adequate spillway. If possible natural spillways of soil or rock should be used.

Dams must have a suitable foundation with an impervious layer near the surface. Fine-sand or clay foundations are suitable, gravel is also suitable but requires specially effective water cut-offs or seals; solid-rock foundations with high bearing power and resistance to erosion and percolation are the best, but seams and cracks in the rocks frequently need sealing by grouting with cement.

When the site has been fixed the height of the dam must be decided, and this should be as high as practicable to secure the greatest possible depth of water, thereby lessening evaporation losses. On the other hand the inherent lack of strength of earth dams limits their height to a maximum of 20 ft., except where skilled engineering advice is available. The length of the dam and the width of the valley are a first consideration; as a rough

guide it is accepted in Uganda that for a length of 400 ft. dams should not exceed 10 ft. in height, for 300 ft. they may be 15 ft. high, and for anything shorter 20 ft.

This does not of course necessarily represent the depth of water since allowance must be made for the spillway which is placed below the level of the dam summit. 4 ft. is considered a safe margin although for wide shallow dams this may be reduced to 3 ft. The slope of the bank may vary somewhat according to conditions, the most generally accepted figure being 3 : 1 in parts of the dam to be submerged and 2 : 1 in parts away from the water. The crest width of the dams is usually 4-6 ft.

Before commencing construction the site of the dam must be prepared and all vegetational matter including grass, trees and roots removed, since matter liable to decay causes settlement and leaks. Similarly all anthills must be cleared away and their underground galleries dug out. The clay from which anthills are formed is often very useful for making puddled cores for dams.

The material from which dams are made must be sufficiently impervious and coherent when wet, but must not be liable to crack and shrink excessively when dry. Every effort must be made to build the bank with the same material throughout.

Before actual building is commenced provision must be made for a puddled core wall to the dam ; this is essentially a narrow wall of material as waterproof as possible, built in the heart of the bank and carried down as deep as may be necessary into the floor of the valley below the bank. Usually this is best done by digging a trench of, say, 3 ft. width to a depth sufficient to ensure that no water can seep under the dam ; usually 2 ft. suffices at the centre of the dam, but the depth will have to be increased as the sides of the valley, with their usually sandier soils, are approached. The trench is then filled up with puddled clay which is carried up, say, 2 ft. above ground level ; each day's work requires to be well bonded into the sections done on the previous day. Failure to provide a puddled core may result in the failure of the dam, and in Basutoland recorded dam failures are mainly ascribed to this cause.

Spillways are, after the bank, the most important feature of the structure. They should not be cut into the built up bank nor should water carried by them run in contact with the ends of the bank. They should be straight and if possible should be lined with stone, but if this cannot be done they can be grassed.

The banks themselves also require to be protected as soon as possible after construction ; if this is not done the earth surfaces rapidly become scored and eroded by rain and, if the contained water surfaces are extensive, by wave action. Pitching or covering with stone is probably the best protection but normally grassing them over is a satisfactory procedure, preferably with creeping varieties.

Where dams are constructed in valleys which carry a permanent stream flowing along the bottom, or are liable to sudden rushes of water, it is neces-

sary to leave a safety gap through which water can pass until the final stage is reached. The filling of the gap is an operation which requires to be undertaken with considerable expedition and care. The material must be bonded into the bank and should be exactly similar to the material employed for the rest of the structure.

It has to be borne in mind that banks inevitably tend to subside under their own weight, and consequently it is necessary to build them up in the first instance to a height greater than that which it is intended they should reach in final form. Uganda experience indicates that one additional foot of height is wanted for this purpose for each 7 ft. of final height. Thus a bank of 10 ft. would have to be built in the first instance to 11½ ft., and a 15-foot bank to 17 ft.

In Southern Rhodesia, in addition to dams of the type described, another type of construction is also used termed "vlei dams". They are small dams instituted in groups of three or more at intervals of 200 to 300 yds. along a general depression. The uppermost is located that distance from the head of the watershed, the total catchment from watershed crest to the lowest dam being about 200 acres. The dams are 7 to 8 ft. in height, and with a freeboard of about 2 ft. they contain some 500 to 600 cubic yards of earth. With this method of siting it is claimed there is no need to install erosion-resisting spillways. It must be remembered that grass-covered spillways are only suitable for small catchments. Dams for large catchment areas over about a square mile in area will need masonry spillways.

Dam construction may be by hand when labour is cheap and plentiful, but more usually dam scoops are used holding about 5 to 10 cubic yards of earth and drawn by 4 or 6 oxen. The method is cheap, but somewhat tedious unless a large number of scoops are put to work. A tractor bulldozer rotary scraper is quicker. In Rhodesia it is stated that seven 5-cubic-foot scoops will construct an 8000 cubic-yard dam in 2½ months.

In Tanganyika a simple form of damming dry river beds, which have long deeply cut approaches in the form of gullies, is practised and has been used to impound fairly large quantities of water. The damming is done at the narrowest point with the assistance of stockades of poles driven vertically and deeply into the river bed. The poles are bound with rope and the bank is built over them with earth and stone. A large overflow discharge is provided to obviate the breaking down of the dam during heavy rains.

In the same territory the digging of furrows from permanent rivers to supply water to fill natural cavities is also practised. These furrows often cross small natural rivulets, and at each crossing a small dam is made with the furrow as its discharge. The result is the formation along the length of the furrow of a series of small ponds each of which contributes to the flow into the reservoir at the end. In selecting natural cavities for this form of treatment it is essential that they should have a clay bottom which does not allow water to seep away.

EROSION FROM THE USE OF DIPPING TANKS

In areas in which cattle dipping is practised erosion may arise from the trampling of paths by large herds of cattle on the way to be dipped. This is particularly liable to occur if the provision of dipping tanks is insufficient. In Swaziland it is probably one of the most serious causes of erosion ; in that territory it is not unknown for cattle to have to walk as much as 10 miles once a week to a dipping tank, and it is common to find up to 3000 to 4000 head of cattle being dipped in one tank area. The erosion caused in this way may be particularly serious in the middle- and high-veldt areas where often cattle tracks lead over unprotected water sheds and down very steep slopes.

The remedy is of course the provision of dipping tanks in sufficient numbers to obviate these dangers and to render unnecessary such high concentrations of cattle at dipping points.

CHAPTER 5

SYSTEMS OF AGRICULTURE IN RELATION TO SOIL CONSERVATION

Soil conservation must be integrated into systems of husbandry and not regarded as a separate end. Changing conditions may involve great changes in agricultural methods, and a system capable of indefinite continuation if conditions remain unchanged may break down under the stress of altered circumstances. This in fact is what is occurring in many parts of the Colonial Empire where soil erosion and declining fertility are spectacular symptoms of the changes resulting from the conversion of a stable agricultural system into one possessing marked instability.

THE REQUIREMENTS OF A STABLE AGRICULTURAL SYSTEM

In their original form the traditional systems of shifting cultivation are stable, since the resting period during which the land reverts to bush and grass is sufficiently long to allow the soil to regenerate its structure and its humic and nitrogen contents, and to make available reserves of plant food, while the cropping period is sufficiently short to obviate severe losses from erosion.

When, however, the resting period becomes too short, or the land is continuously cultivated without manuring and provision for the prevention of erosion, decline in productivity and ultimate exhaustion is inevitable. The remedy is the substitution of intensive systems which ensure the conservation of the soil and the maintenance of fertility ; but where lands have been reduced to the point of exhaustion, soil conservation, particularly by methods which depend on mechanical protection, is of little avail unless it is accompanied by measures to restore the lost fertility.

There are abundant examples of intensive systems of agriculture in the tropics. In the West Indies, Mauritius and other places lands have been cultivated continuously under sugar cane for 100 years and upwards without diminution in their yielding capacity, while in the densely peopled countries of South Eastern Asia, notably in Java and South China, lands have been continuously cultivated for indefinitely long periods and continue to yield good crops.

In these places manuring is a part of agricultural tradition and in some cases methods have been improved and modified as the result of

scientific investigation. Indeed under almost any circumstances increasing pressure of population leads to the evolution of intensive methods by the cultivators themselves. Thus in the densely populated area around Kano in Northern Nigeria the collection and application to the land of animal droppings and refuse from the town is regularly followed, while cultivation on the contour is practised to some extent. Among the pagan tribes of the Bauchi plateau and in Adamawa Province in Nigeria terracing is widely practised in hilly districts, while at Bauchi and in the densely populated areas around Zuanguru in the Northern Territories of the Gold Coast the people make use of animal manure mixed with household ashes to manure their crops.

In other places however, and particularly in East, West and Central Africa the use of manure is largely unknown and there is no tradition of soil conservation. Formerly shifting cultivation provided a stable system, but rapid increase in the population, coupled with the demand for products for export, has caused development to outstrip the power of cultivators to evolve new methods of their own initiative ; consequently active intervention is needed if the situation is to be retrieved.

BASIC CONSIDERATIONS UNDERLYING THE MAINTENANCE AND RESTORATION OF FERTILITY

(a) PHYSICAL FACTORS.

The possibility of regenerating deteriorated and eroded soils depends largely on the soil type and particularly on the mineralogical, chemical and physical characters of the parent material from which it is derived. Thus material rich in unaltered nutrient-containing minerals (such as a fresh volcanic ash) will readily regenerate a fertile soil when it is intensively cropped with leguminous plants that can assimilate atmospheric nitrogen, or is treated in some other way so as to provide the chief missing nutrient, nitrogen. On the other hand, a parent material consisting of heavily leached mineral residues may take a long time to regenerate and require expensive intensive treatment [7].

Similar considerations affect the agricultural system including the crops grown and the character of the rotation, and, if this includes a fallow period, its duration and frequency ; they will also influence the choice of soil-conservation measures, e.g., the number, dimensions and spacing of protective drains and terraces.

The latter are further influenced by the physical relief of the country, the climatic conditions, the character of the vegetation, and by other factors including the incidence of disease of human beings, livestock and crops. These physical factors determine the size of the population which an agricultural area can carry ; they therefore require to be known with exactitude to provide a basis for development.

(b) SOCIAL AND ECONOMIC FACTORS

Where the carrying capacity of an area has been exceeded or, what amounts to the same thing, where it has been greatly reduced owing to unsatisfactory practices, the only possible remedy is the reduction of population pressure by transfers of population or the absorption of the excess into other occupations. Where the situation has not reached this length the introduction of modified agricultural systems may yet be urgently required to avert threatened dangers.

In either case new methods must be capable of assimilation to existing practices, while account must also be taken of tribal relationships, existing social customs and religious and superstitious traditions ; here also exact knowledge is a necessary preliminary.

SURVEYS AS A MEANS OF PROVIDING ESSENTIAL INFORMATION.

The necessary data can only be obtained through surveys.

Soil surveys based on geological surveys and accompanied by similar data for vegetational and climatic conditions are an invaluable adjunct for working out husbandry systems.

The aims of a soil survey are as follows^[31] :

(a) To determine the kind, yield and quality of crop plants that may be grown under different systems of soil management on various soil types. This implies the definition and mapping of soils in the field in accordance with an accepted system of examination, classification, description and nomenclature.

(b) To determine the chief physical, chemical and biological features of soil types by means of field and laboratory studies of representative soil samples collected from profiles and deep sections.

(c) To determine the responsiveness of soil types to management (tillage, drainage, irrigation, manuring, crop rotation, and anti-erosion measures).

(d) To determine the capabilities of soil types under agricultural and silvicultural usage on the basis of field and laboratory data and of actual experience on the land.

Soil maps based on the results of surveys, by delineating areas possessing similar levels of inherent fertility and physical features can indicate cultural practices and methods of soil conservation suited to particular areas and crops. An additional application is the formulation of productivity ratings for different crops on different soil types and, from them the preparation of crop-productivity maps^[31].

In the Colonial Dependencies a good deal of preliminary work has been done in this direction, but its scope has been limited hitherto by lack of resources and lack of staff. A full survey has been carried out on the agricultural lands in Trinidad and some other West Indian islands, notably Antigua ; partial outline surveys have been carried out in other West Indian Dependencies, in Nigeria and the Gold Coast, in some of the East African

Territories and in Malaya and Ceylon. With the assistance of resources provided under the Colonial Development and Welfare Act the intention is to undertake full-scale surveys in the East African and West Indian regions, and similar developments in other parts of the Colonial Dependencies may be anticipated in due course.

On the social and economic side, surveys of agricultural conditions are equally necessary. They should cover as many aspects of rural life as possible and are best organized on a team basis. They should take full account of all the circumstances of agriculture including the area cultivated, the size of holdings, the crops grown, the yields obtained, the details of cultivation, the numbers, kinds and methods of management of livestock, the income of cultivators, the disposal of produce, etc. [17].

Surveys on these lines have been carried out in a number of dependencies including Uganda, Kenya, the Northern Territories of the Gold Coast, the cocoa zone of the Gold Coast, the Windward and Leeward Islands and British Guiana.

THE DEVISING AND TESTING OF NEW FARMING SYSTEMS

The evolution of new and modified systems of husbandry is primarily the concern of the experiment stations and the technical and scientific officers attached to them. It involves research and investigation to elucidate the various factors operating. The provision must cover the whole range of conditions. The work may proceed concurrently with the surveys. Such investigations are in progress in Nigeria, Uganda, Tanganyika and in various West Indian colonies.

Means are also required to test new systems in practice in the area for which they are intended, and to ascertain the economic results of their operation. The only practicable way of doing this is by what has been termed the "unit-farm technique" or some modification of it. The method was first devised and applied in Nigeria; it consists essentially in operating the system under trial on farms conforming to the conditions of the country by means of a selected peasant cultivator and his family, who work under close supervision of the Department of Agriculture. He is paid a wage, but is also allowed to convert to his own use the produce of the farm; he is required to follow implicitly instructions given in regard to the various farming operations under trial. The farm is equipped with the necessary buildings, farm equipment, livestock and materials for the operation of the system. A full account is kept of expenditure on capital account and on labour and materials, including the work of the cultivator himself and his family. The yields and values of produce are also recorded, including materials consumed by the cultivator and his family. Working in this way it is possible after several years' trials to assess the value of a system.

The method has been applied extensively in Nigeria and also in the Northern Territories of the Gold Coast; a modified form has been used at Bukalasa and Serere in Uganda and is now being employed at various points

in the West Indies and in Nyasaland. Once a system has been tried and its value and suitability proved, the way is clear for demonstration and propaganda directed to securing its adoption by cultivators.

The sequence is a logical method of approach and has given satisfactory results wherever it has been applied. It, however, involves a considerable length of time, and the need for new methods to save a rapidly deteriorating situation may be so urgent that it is not always practicable to await the results of full investigations. In such circumstances it may be necessary to proceed by a system of trial and error, making use of experience at other points.

Nevertheless the sequence of operations outlined is the only fully satisfactory procedure so far devised.

METHODS OF MAINTAINING FERTILITY

Methods of maintaining and raising fertility may be classified broadly as under :—

(a) Natural recuperation, including shifting cultivation and bush fallows ; an extension of it also includes temporary leys and rotations.

(b) The use of manures of local origin including animal excreta, vegetable material, ashes, town and household waste, composts, crop residues, etc. ; mixed farming implies the use of this method and green manuring is an extension of it.

(c) The use of fertilizing material brought in from outside, either as artificial fertilizers or feeding stuffs fed to livestock, and applied to the soil in their excreta as manure.

When the parent material of the soil is deficient in mineral plant food the general fertility can only be raised when fertilizing material is brought in from outside ; method (a) can bring about vertical transference of plant food from deeper levels to the surface layer of the soil, while method (b) may cause horizontal translocation from adjoining areas used as pasturage or to supply fodder for livestock, and so lead to local enrichment of the surface layers of the soil and consequent secular rise in fertility.

There is considerable divergence of opinion concerning the effects of organic material in tropical soils. In arable cultivation green manures have given conflicting results under different conditions ; with permanent crops on the other hand better and more consistent results have been obtained. In a review by the Commonwealth Bureau of Soil Science included as an Appendix to [?] it is concluded that “. . . the general indication is that the value of green manuring in hot countries depends on the nitrogen, phosphorus and potash contents of the material and not on the organic matter” and that “although authentic cases have been reported of tropical crops failing entirely when dressed with artificials but growing well when treated with dung, most of the evidence indicates that the value of dung on tropical soils is confined to its nutrient content ; any physical effect is transitory ”.

The question seems to be closely tied up with the nitrogen status of the soil, and Eden[4] has pointed out that the efficiency of green manures and composted materials under tropical conditions depends on their carbon/nitrogen ratios; materials with high ratios may have an adverse effect when incorporated in the soil, while materials with a low ratio have a favourable influence; the difference being due to the stimulation of soil bacterial activity by large amounts of carbonaceous material leading to the temporary immobilization of available nitrogen. This being so, much depends on the age and nature of the material and on weather conditions when it is turned in.

It has been suggested that compost and green manures may encourage mycorrhizal growth and may also affect the activity of free-living nitrogen fixing bacteria in the soil, while it has been recently claimed by Dhar in India that additions of carbonaceous material to tropical soils are accompanied by direct nitrogen fixation under the influence of sunlight.

There has been much discussion of recent years as to whether the animal contributes something to the soil that the plant cannot synthesise and that for this reason composts are not really effective unless they contain animal wastes, but the evidence is not sufficiently strong to warrant an expression of opinion.

Sampson and Crowther[20] have pointed out that the interplanting of leguminous crops, notably cowpeas and Lima beans, between other crops is widely practised throughout Africa. This provides presumptive evidence that the practice is of some direct benefit although its nature is not known. They suggest that the study of mixed cropping on these lines might open the way for modified systems of husbandry.

Keen, commenting on the subject with reference to agriculture in the Middle East[7] remarks "It will be clear that the role of organic matter is an urgent subject for fundamental research and technological investigation. The relative importance of its . . . effects needs examination for each of the modes of application; farmyard manure, green manure, ploughed-in temporary leys and composts". With this view unhesitating agreement can be expressed. Apart from nitrogen the fertilizing constituent in which tropical soils are most general deficient is phosphoric acid, and the problem of meeting this is often difficult.

NEW AND MODIFIED SYSTEMS IN PRACTICE

Using the unit-farm method a system of mixed farming suited to conditions in Northern Nigeria has been worked out and successfully applied. The essential feature is the employment of animals for ploughing and cultivation and the collection and composting of their excreta for manuring. The fattening of animals for slaughter and, to a limited extent, dairying have also been incorporated into the system at some points. The animals are penned at night and are fed on crop residues with some crop produce and grass from adjoining lands. The system has been shown to give an

economically profitable return to the cultivator under average conditions in Northern Nigeria. A similar system has been worked out and is being applied in the Northern Territories of the Gold Coast. In both places the development has been rendered possible as a result of the successful work of the Veterinary Department in controlling rinderpest which formerly took heavy toll of the cattle population.

Efforts are being made to evolve systems applicable to the Middle Belt of the Western and Eastern Provinces of Nigeria, and to the southern parts of the Gold Coast. Here the limiting factor is bovine trypanosomiasis which to a large extent precludes the utilization of cattle. Attempts are being made to develop a modified form of mixed farming using the dwarf breeds of cattle indigenous to West Africa that show some degree of resistance to trypanosomiasis ; other measures under trial are the development of dairying in fly-proof byres and the use of small stock, sheep and goats ; some success has attended attempts at sheep raising in cocoa cultivation, the animals being pastured on a cover of *Centrosema pubescens* planted through the orchards ; the main difficulty has been the incidence of intestinal worms among the sheep. Pig raising has also been made the subject of extensive and fairly successful trials in Nigeria and the Gold Coast though at one point there has been trouble owing to trypanosomiasis, and keeping pigs in fly-proof piggeries has been tried. Recently there has also been some trouble in the Gold Coast with swine fever.

The control of animal disease is one of the keys to the maintenance of fertility through mixed farming and the work of the veterinary officer in this aspect of soil conservation is therefore essential.

The methods described are essentially variants on the soiling system depending on keeping the animals in pens or stables, feeding them on transported fodder and using the manure for application to the land. The system has also been advocated for the coastal lands of British Guiana and trials of it on a considerable scale are there in progress with promising results so far.

In the southerly parts of the West African Dependencies the climate is very humid and the soils are deficient in lime and phosphate, while trypanosomiasis is rife ; Sampson and Crowther^[20] have expressed the view that under these conditions mixed-farming systems on these lines may be less applicable than in areas where the rainfall is lower.

In Uganda work at the experimental stations at Bukalasa, Serere and Ngetta has shown that fertility and soil structure can be maintained by a rotation of planted grass and that in this way the intervals between cropping can be appreciably shortened as compared with the traditional method of bush fallowing. In the long-grass areas in Buganda where Elephant grass can be grown, the indications are that fertility can be maintained by a rotation of three years' continuous cropping followed by three years under planted Elephant grass, as compared with three years cropping followed by eight years bush fallow under the traditional practice

of the country. In the short-grass areas of the eastern province, similar results can be obtained by two years' cropping followed by three years under planted grass using species indigenous to the area.

In this connexion Martin^[19] states "The optimum period of rest and the best type of resting cover must depend on local conditions . . . but there is some evidence that once land is in good heart, the resting period may be shortened and the period of cultivation correspondingly lengthened".

In East Africa as a whole there is growing acceptance of the view that a system based on grass fallowing provides the most satisfactory basis for the maintenance of fertility^[16]. This however does not imply that full use should not be made of whatever materials may be available as manures. The combination of grass fallowing with the production of cut fodder from the resting areas for use in a soiling system is one possible development; permanent grass wash-stops of Elephant grass or Guinea grass can also provide useful additional supplies of cut fodder for the same purpose.

In Uganda a recent development in the country surrounding Kampala has been the keeping of cattle on the soiling system, for the production of milk and manure; formerly there was little or no animal husbandry practised in this area.

Resting areas can also be used for grazing, and Martin^[19] has remarked "In cattle country grazing of resting land can do nothing but good, provided that it is grazed lightly at first and progressively more heavily, always under strict control".

In Nyasaland experience strongly favours a combination of Elephant grass and pigeon peas (*Cajanus indicus*) as a cover during resting periods. A resting period of three years has given favourable results in station trials^[16].

Green manuring has given conflicting results in arable farming in Africa under conditions of moderate rainfall. In Nigeria it has been moderately satisfactory in the Western Province, but not in the Northern and Eastern Provinces. In Uganda^[29], trials at the experiment stations at Bukalasa and Serere indicate that the inclusion of a green manure in rotations has not been productive of benefit. The Nigerian experience is therefore of interest, especially in the light of Crowther and Sampson's remarks previously quoted.

The collection of cattle droppings for use as manure is extending in certain densely populated areas in Africa such as the Lake Province of Tanganyika and Basutoland where it was formerly not collected or burnt as fuel; the manurial value of cattle dung without the urine is probably not high, while in any event under conditions in the Lake Province the amounts that could be collected by a native cultivator are small and inadequate to maintain fertility owing to the shortage of bedding material^[16].

Composting has received considerable attention of recent years, an impetus having been given thereto by recent work in India. Mention has

been made of practices in this regard in West Africa. A recent development has been the composting of town refuse by the municipality of Kampala in Uganda, the product meeting with a ready demand from cultivators. Information concerning its efficacy is not, however, available. During the war the composting of town refuse was also carried out on some scale in Cyprus, the product having about half the efficacy of farmyard manure. The value of composts naturally depends on the materials used and often urban refuse contains much matter of low fertilizing value. There has been growing interest recently in the possibility of incorporating human excreta in composts. This material has been used as manure in the Far East from time immemorial, but the practice has hitherto been regarded with disfavour by sanitary authorities on account of the risk to human health. The work of Scharff and others in Malaya prior to the war indicates that provided precautions are observed in composting such material, including the use of earth as an absorbent material, the danger to health can be minimized and the waste of valuable fertilizing material entailed by other methods of disposal avoided. Simpson and Lau Sing Nam^[22] have described the manner in which Chinese market gardeners in Malaya have succeeded in bringing exhausted mining land to a relatively high state of fertility by the use of organic material, including pig manure and composted human excreta.

In regard to crop residues, in Uganda and Tanganyika little use was formerly made of cotton seed, but experimental work at Serere in Uganda has shown that applications of cotton seed increased the yield of cotton by 100 per cent while dressings of cotton-seed ash gave increases amounting to 40 per cent. Equally good results have followed applications of cotton-seed ash in Tanganyika^[16].

Artificial manures are extensively used in a number of tropical plantation industries, notably in the sugar industry in the West Indies, Mauritius and Fiji where as a result of extensive experimental work the requirements of the crop are known with a high degree of precision, as well as in the tea, coffee and rubber industries. Among peasant agriculturists their use is usually very restricted although they are employed in some sugar-producing countries; in Malaya local deposits of guano are used in rice cultivation and the Malayan Government has recently made provision to enable the deposits to be worked more extensively for the benefit of cultivators. In Swaziland the use of superphosphates has lately attained some extension among peasant farmers.

Where their use is economically practicable fertilizers could be a valuable aid in restoring exhausted and eroded land, and there is a strong case for investigating the reactions of various peasant crops to them; apart from other considerations such trials would provide information as to the nutritional factors influencing yield. The transport of bulky organic manures to remote smallholdings is often difficult and costly, and is a deterrent to their use; fertilizers are much less bulky and if their value was proved they might enable manuring to be practised where none was

formerly possible. Moreover, recent work indicates that economies are possible by applying fertilizers at points where they will be immediately available to the roots of the growing crop.

There is a possibility that undiscovered deposits of mineral fertilizers may exist in Colonial territories. Recently the Colonial Advisory Council on Agriculture recommended that geological surveys in Colonial territories should in adequate measure direct attention to ascertaining whether such deposits exist. When they are found the first step should be to ensure that the needs of the country in which they occur are met before export is commenced. A necessary concurrent step is to ascertain whether the material can give satisfactory results under local conditions. The recent discovery of phosphatic deposits at Tororo in Uganda is an example of this, and steps are being taken to test the value of the product in cultivation in East Africa.

GENERAL CONCLUSIONS

Under tropical conditions rotational grass fallows appear to provide a satisfactory basis for farming systems for arable crops in medium rainfall areas. They facilitate the restoration of fertility during the resting period and they improve soil structures and thereby resistance to erosion. Moreover, they readily admit incorporation in the farming system of animal husbandry and mixed farming, the use of manures and fertilizers, and soil-conservation measures.

The detailed application of the system must necessarily vary greatly with conditions. Thus the choice of the cover and the length of the fallow period will depend on the character of the soil and the rainfall. In densely populated areas difficulties are bound to occur owing to the need for retiring from cultivation each year a considerable fraction of the cultivable area and these will have to be surmounted, but in the last resort the determining factor is the carrying capacity of the land under the most efficient method of farming. If this is exceeded, diminution of the pressure by population transfers is the only remedy.

At first sight also it would seem that the fact that in the West Indies and elsewhere sugar cane has been continuously cultivated for very long periods on the same land without lowering fertility invalidates the assumption that grass leys are necessary, but sugar cane may itself influence soil texture in the same way as other grasses. Moreover its free-tillering habit and the thick covering of cane straw which it gives to the land makes it one of the most erosion-resistant crops.

Experience in the Sudan Gezira indicates that under the specialized conditions existing there, on irrigated heavy sodium-clay soils, satisfactory results are given by a rotation comprising cotton, "dura" (Guinea corn), "lubia" (*Dolichos lab-lab*) and bare fallow. The full course occupies eight years, and the land is under fallow for four years in all. For the maintenance of fertility recourse is had to dressings of artificial fertilizers, mainly sulphate of ammonia and nitrate of ammonia supplemented, to some extent, by

droppings of cattle which are allowed to graze on the crop residues after cultivation of dura and lubia. The annual rainfall is from 6 to 12 inches, and it all falls within a period of about six weeks ; this gives rise to some weed growth but experiment indicates that better results are obtained when the fallow areas are weeded than when the weeds are allowed to persist and are turned prior to planting.

The proved effectiveness of bare fallows under these conditions is a matter of considerable interest, it is not however clear to what extent they may be affected by the incidence of wind erosion.

To sum the matter up, it is clear that the maintenance and restoration of soil fertility is intimately bound up with the conservation of the soil. A considerable amount of information has become available concerning methods by which this can be accomplished, but no prescription is, or can be, universally applicable under all conditions. Measures suited to particular areas have to be worked out on the spot by trial and error and the results applied in practice. Moreover many points are still obscure and require to be elucidated by research ; this applies particularly to the role played by organic matter in tropical soils in its chemical, physical and biological aspects. Other matters which need elucidation are the effectiveness of artificial fertilizers, particularly for native-grown food crops, the economics of their application in practice, and the part played by minor fertilizing elements.

CHAPTER 6

OTHER FACTORS AFFECTING CONSERVATION

SOIL EROSION AROUND BUILDINGS^[12]

Soil erosion caused by run-off from house compounds and from roofs is often a major problem especially in densely populated native areas. Another aspect is the damage caused by large buildings built by Europeans or developed under European influence.

EROSION FROM NATIVE HOMESTEADS

The most obvious preventive measure is a satisfactory selection of site. Level land should be chosen for hut building wherever possible, but it often happens that little land is available and houses have to be built on slopes. In this event it is very important that the area levelled around the hut should be as large as possible. Usually the tendency is for the area levelled to be just sufficiently large to take the base of the hut, but this is unsatisfactory since the larger the level area around the house the more water can be absorbed before it spills over the edge and plays havoc with the cultivated land below. Ideally the whole area round a house should be bench-terraced for some distance.

The next safeguard is to plant the whole of the compound with grass, since a surface of trampled bare earth will only absorb a small portion of the rain that falls on it, while an area covered with grass will absorb the greater part of it even on slopes and during heavy storms.

In the past the tradition has been to maintain a clean bare earth surface in native compounds, and this has been insisted upon by sanitary authorities in order to keep down vermin and mosquitoes. Probably the original intention was that long grass and accumulations of rubbish should not be permitted near houses, but too literal insistence on the observance of this provision has often led to serious erosion. Grass plots established for protection generally require to be cut regularly.

In cases where the top soil has become eroded away it may be necessary to undertake deep cultivation and levelling, combined with bringing in top soil from outside, in order to establish a grass cover. Where labour is not available it is sometimes practicable to peg down lines of logs, sticks or banana stems at frequent intervals across the slope of the compounds, that will catch transported soil on their upper sides and make possible

the establishment of lines of grass which will later spread over the intervening spaces.

In large compounds the planting of contour hedges at the upper and lower sides is a useful measure. On steep slopes such hedges can hold up considerable amounts of soil which would otherwise have been washed away. To be fully effective hedges require to be regularly trimmed and pruned to induce thickening at the bottom, with strong low branches.

Run-off from roofs is a cause of considerable erosion. It is liable to be a greater source of difficulty from corrugated iron roofs than from grass roofs, because the impact is greater from the iron roofs, owing to the flow becoming canalized in the corrugations and to the usually greater height of the edge of the iron roof above the ground.

With grass roofs and small iron roofs grassing usually affords sufficient protection, but where, owing to lack of light or other cause, it is impossible to establish a satisfactory grass cover up to the walls of a house, the best procedure is to place a broad line of stone under the eaves; this allows a certain amount of absorption and prevents surface erosion from the impact of drip.

Where such measures are insufficient to provide adequate protection, it may be necessary to provide ditches under the eaves to lead the water from the roof to the lowest point where it can be discharged either into a natural drainage channel or onto grass or into a suitable soak-away pit.

EROSION FROM LARGE BUILDINGS

The basic problems and the principles involved in their solution are the same as for small homesteads. A first point is to ensure that platforms of adequate size are provided for the building and that they are grassed. Roofs should be provided with guttering wherever possible and provision made for the proper disposal of the roof run-off. The use of concrete drainage channels is so obvious a provision that it needs no discussion, but, as in the field, the point where concrete drainage channels end and the water discharges onto soil needs special attention. There should be a protective apron, and channels onto which drainage is spilled should be grassed.

A point at which erosion frequently arises in the compounds of private houses and public buildings is the entrance drive. Protection here is essentially the same as in roads which are dealt with in the following section.

ROADS AND SOIL CONSERVATION

In making roads the main point is to ensure that the alignment is satisfactory and the drainage good. The sides of roads should be sloped back, drains should be broad with gently curving sections, and roadside slopes, road edges and drains should be planted with grass. When roads are made in cultivated areas where soil-conservation methods have been carried out, it is usually advisable to link road drains with the storm-water drainage from the area.

There is no doubt that lack of attention to the laying-out of roads and the provision of adequate drainage has been a fruitful source of erosion, and advance attention to the matters can do much to avert unnecessary damage and expense.

The slope of road drains is also important ; it is sometimes stated that they should not be steeper than 1 in 200, but experience in Kenya and Uganda indicates that considerably steeper gradients than this can be safely used; in Kenya it has been found that roadside drains may be as steep as 12 or 15 per cent if they are covered with Kikuyu grass, Star grass or other suitable grass.

When roads must run almost straight up and down hill and where there is open land on either side, the water in the side drains may be intercepted at intervals of 30 yards by herring-bone drains on a gradient of 1/100 provided with wide outlets so as to spread the water far enough away to prevent its return to the proximity of the road.

When a side drain has already commenced to erode it must either be treated as a gully or a grass strip prepared just outside the gully, and as soon as a new drain or strip has become established with grass the gully can be knocked in and small dams made across it so as to intercept the water and discharge it into the grass strip.

In making farm roads, it should be borne in mind that even an un-surfaced earth road will last a long time if it is well crowned and the drains constructed so that water can at once run away from the edge of the road.

If a road is crowned and well drained only the surface will become wetted during a storm and it will soon dry out while the road material underneath will remain hard and dry. Whenever possible earth roads should not be used during and immediately after rain, as once ruts are formed and water collects in them, it leads to waterlogging the foundation. It is impossible to prevent slight depressions being worn in wheel tracks and rain water will tend to run down them and erode roads which have a fall. The only remedy is bolsters which can be put in every thirty yards or so and need not be more than a few inches high.

A frequent source of damage to roadside drains is grazing livestock, and wherever it is practicable the prohibition or reservation of grazing on lands bordering on roadsides for a fixed distance from the road boundary is a highly desirable provision^[9].

In some African dependencies courses of instruction on anti-erosion measures in road construction and maintenance are regularly given to native administration road overseers.

EROSION IN MINING AREAS

Erosion of a special type is liable to arise as a result of mining alluvial mineral deposits. This is particularly evident in tin-mining areas, and in a number of countries large tracts, usually on steep slopes, have suffered losses of top soil followed by deep gullying as a result of uncontrolled

surface mining for tin ore. A further effect is the pollution of streams and rivers by transported silt.

Where alluvial deposits are mined by dredging, destruction of soil may also occur unless special precautions are taken to avoid it. In dredging operations a separation is effected of the coarser and finer particles of the soil and subsoil, the coarse particles are left behind the dredge as a thick layer of dredge tailings of no agricultural value, and the fine particles flow away in the water used to wash the soil from the ore. Moreover, if the wash waters are discharged with their full load of silt into natural drainage channels, heavy pollution of rivers occurs, river channels become choked with deposited silt and destructive floods result in periods of heavy rain.

It constitutes a special case of erosion and, where the deposits mined are extensive, may lead to the complete destruction of large areas of agricultural land. In Malaya the evil has been much in evidence, and measures to counteract it have received the attention of the Government.

Under the Federated Malay States Mining Enactment the working of hillsides for the extraction of tin ore by washing away the soil is now prohibited. The same legislation also prohibits the discharge of effluents from mines and dredges into rivers and streams, if they contain more than 800 grains of suspended matter per gallon. Compliance with this requirement necessitates the settling-out of a proportion of the suspended matter, usually referred to as slimes, before the effluents are discharged. It ensures that a fair proportion of the slimes are retained, but as the settling-out was in the earlier days performed on very small areas no benefit to agriculture resulted.

A later improvement was to require that slimes should be settled out more or less evenly over lands that had been worked, but, even when this was done, the conversion of dredged or open-cast tailings to agricultural land still remained an unsolved problem, since the slimes contained no organic matter and would not support crops.

The Malayan Rice Cultivation Committee urged that further investigation was needed into the reclamation of mined lands for subsequent use in agriculture^[18]. They suggested that the possibility of removing the top soil before mining commenced and replacing it after mining was finished should be examined. This is feasible, but is only economic if the price for tin is high and the deposits mined are fairly rich.

Investigations were started in 1926 by the Malayan Department of Agriculture to ascertain whether reslimed lands could be reconverted to cultivable soil by simple forms of treatment^[9]. They took the form of attempts to establish leguminous plants thereon. It was found that provided the lands were deeply and thoroughly drained some success could be achieved. After preliminary trials with a large number of plants the following four were selected for further investigation on a larger scale: *Mimosa invisa*, *Tephrosia candida*, *Crotalaria usaramoensis* and *Crotalaria striata*.

Plots of 2½ acres each were established on slimed lands under each of these leguminous plants. After some initial difficulty they made moderately

good growth ; at the end of three and a half years the land was ploughed and the plant material ploughed in. After a further interval the land was flooded and a crop of rice planted. It made fairly satisfactory growth, and a crop was reaped.

It would appear that working in this way it is possible to restore the fertility of mining lands, after dredging has been completed.

CHAPTER 7

INSTRUMENTS, IMPLEMENTS AND MACHINERY USED IN SOIL CONSERVATION

INSTRUMENTS FOR SURVEYING AND LEVELLING

For really accurate work the use of the standard types of surveyor's levels and associated equipment is necessary. The Abney level is a very satisfactory form for use by Agricultural Officers, and in Tanganyika an instrument called the Farmers' Irrigation Level is stated to be simple to use and very accurate.

For less accurate work various forms of road tracer are useful. The Ceylon type is very popular and before the war cost about 50/- in Ceylon including a staff having a fixed slit target.

In the absence of proper surveyor's equipment and for the type of rough work that is wanted much can be done with home-made instruments.

In Tanganyika a locally made road tracer is used, consisting of a pendulum telescope made of $\frac{3}{4}$ -inch galvanized-iron piping 18 inches long with a sighting hole made at one end of the tube and a cross wire placed at the other. The tube is welded to a piece of flat mild steel bar $\frac{3}{8}$ -inch thick and about $1\frac{1}{2}$ inches wide so that an inverted T is formed with the bar joined to the middle of the piping. A hole is drilled in the free end of the iron bar about $\frac{1}{2}$ -inch from the end, and through this the contrivance is bolted loosely to a wooden staff so that it can hang and swing freely at the height of the eye of the operator. At one end of the pipe a screw pipe socket facilitates adjusting the tube so that it hangs with the eye-hole on the cross wire dead level. A pole with the target cut exactly at the height of the cross wire enables the operator to sight level contours from eyepiece to staff.

A useful implement that has been devised by the soil-conservation engineer in Kenya is known as the "quick-set" staff. It has two targets

superimposed on the usual survey staff ; one is long and marked into divisions to give the appropriate grade for every 50-ft. traverse, and over this is a second target which, for each measurement, is moved opposite the appropriate mark on the first target.

The striding level is a simple device used for contour work in open country : it consists of a 10-ft. plank supported on edge at each end by legs, one of which is provided with a slotted lengthening device while the other is fixed. Both legs are provided with flat feet to prevent them sinking into the ground. In the centre of the upper edge of the plank a glass spirit level is fitted. In operation the surveyor moves forward ten feet at a time, always keeping the bubble in the level at the central position, and placing a peg at each position of the front leg.

The string level is a somewhat similar simple device used for setting out drains and for checking gradients over short distances. It consists essentially of a spirit level provided at each end with a hook from which it can be hung at the centre of a line stretched between two uprights. In operation one plank is held vertically at the lower point of the gradient to be tested and the other at some convenient distance higher up, usually from 25 to 50 ft. The line is then slowly lowered down the upper plank until the bubble of the level is central. The distance which the line has been lowered represents the difference in level between the upper and lower points.

Boning rods are a simple but effective means of maintaining uniformity of gradients when constructing channels and banks of contour ridges and storm drains. A boning rod consists of an upright plank about 5 ft. long, to the end of which is nailed or screwed a cross piece about 2 ft. long so as to form a T. A set of three is required and they must all be of exactly the same length. In use one rod is held vertically, with the cross piece uppermost, at a point which is known to be at the correct level; and a second rod is held by an assistant at a second point, also known to be at the correct level, a convenient distance away (on straight runs this will be 300 ft. or more).

A third rod is placed at any intermediate point and a line is sighted over the first and second rods; this will enable any error in level to be detected at the point at which the third rod is situated.

TRACTORS AND OTHER EQUIPMENT FOR CONSERVATION WORK

The D6 crawler tractor has given satisfactory results in Kenya, Tanganyika, Basutoland and Cyprus. It is of the Diesel-engine type and runs on crude oil. The cost is of the order of £1500 c.i.f., and the working cost is estimated to be in Kenya 10/- per hour, in Basutoland 4.6/- per hour and in Cyprus 6/- per hour. The Cyprus and Basutoland figures include depreciation, but not repairs. The D4 tractor, also of the Diesel type and costing about £1000, has given satisfactory results in Kenya and Basutoland. The cost per hour of running is 8/- per hour in Basutoland. In Kenya and Cyprus the D2 caterpillar tractor and in Basutoland the RD4 tractor,

both of the Diesel track-laying type, have given good results for lighter work. The cost of running the latter in Basutoland works out at 3.4/- per hour. In Basutoland the Little Cat 22 which runs on petrol has been very useful.

In Tanganyika the Farmall wheeled tractor has been used, but the general experience is that track-laying tractors are greatly preferable to wheeled tractors for conservation constructional work.

TERRACERS AND GRADERS

To operate the large plants satisfactorily it is necessary to have the correct size of grader. In Kenya and Tanganyika the following have been employed for terracing.

The No. 2 caterpillar terracer	(2 tons)
„ No. 22	„ (1 ton)
„ No. 1	„ ($\frac{1}{2}$ ton)

In Basutoland the No. 16 Sawyer Massey grader drawn by the RD6 tractor has given good results for broad-based terracing and making training banks; for lighter work the No. 33 caterpillar grader has given good service behind the RD4 tractor.

In Tanganyika and Kenya the combination of a D6 tractor drawing a No. 2 terracer is considered the most effective combination for broad-based terracing. In Kenya the cost of making broad terraces with this combination works out at 120/- to 200/- per mile according to conditions and whether a flat channel or a V-shaped channel is made. The number of acres to a mile vary from 5 to 24, the average being 7 to 8 acres per mile. In Tanganyika the cost for similar work is 38/- per acre. For narrow-based terracing in Kenya the No. 1 with the D2 grader is used, the approximate cost per mile being 80/- to 100/-.

In Tanganyika the No. 1 terracer is used successfully for making terraces and for digging drainage channels. It is light and the subsoil has to be ploughed ahead of it after a few cuts have been made. It is most suitable for making smaller earthworks.

In Tanganyika adequate terraces have also been made with a 6-inch or an 8-inch harrow plough drawn by oxen or a small farm tractor.

In Southern Rhodesia the work of constructing bunds and ridges has hitherto been mainly carried out either by hand or by oxen-drawn implements, the land first being ploughed and the banks constructed by the use of dam scrapers, levellers or ditchers. During the last 5 years, however, tractor units and caterpillar terracers of the types already described have been successfully introduced.

In Basutoland the 22 petrol-driven tractor has been employed for making light banks with solotrac plough and an improved Eaton ditcher. It is usual to plough two furrows on each side and to follow this up with the ditcher. Under certain conditions the ditcher may be hitched up behind the plough.

For making dams in Basutoland it is possible to hitch 7 dam scrapers of 5 cubic-foot capacity behind a D6 tractor, while the D4 tractor will haul 5 scrapers of similar capacity.

AERIAL PHOTOGRAPHIC SURVEYS

As a preliminary to planning the lay-out of large-scale soil-conservation measures, aerial-photographic surveys can be of very great assistance.

They have been employed with considerable success in Northern Rhodesia; using vertical overlapping photographs on a scale approximately 1 to 10,000. In practice the general lay-out of the scheme is planned with the aid of the photographs, including the location of water-disposal channels, meadow strips, etc., and on the basis so provided subsequent work in the field is carried on.

So far the method has not been employed in other Colonial territories but its extension appears to be desirable wherever it is practicable.

CHAPTER 8

LEGISLATION AND ADMINISTRATION IN RELATION TO SOIL CONSERVATION

GENERAL CONSIDERATIONS

To be fully effective, soil-conservation measures must be applied to the countryside as a whole and not piecemeal to individual properties; there must be complete co-operation throughout the farming community and not isolated efforts. Communal action in fact is called for which may involve drastic modification in land utilization and great changes in agricultural practices. In the Colonial dependencies the difficulty of securing this is probably the greatest obstacle.

In many territories, particularly in Africa, the difficulties are increased by the fact that most of the cultivated area is made up of scattered small holdings worked by peasant farmers whose educational attainments are low.

On the other hand, the native African tradition, which regards the land as the possession of the tribe or community as a whole, favours communal action directed to the preservation of fertility once the need for it is understood; it is in fact in many ways less of a barrier to the introduction of conservation measures on a communal basis than the concept of individual ownership which in Europe and America, until comparatively recently, insisted that the manner in which the land was handled was a matter which concerned only the owner and the occupier.

In the United States of America, for example, the idea that society as a whole has an interest in the privately owned farm, forest and grazing lands at least equal to that of the individual owner, and that the soil represents a basic national asset, was a startling new idea with far-reaching political implications ; in Africa it is a part of the accepted tradition.

Obviously the preservation of this outlook is essential to the introduction and development of the new methods of land use and land management inherent in an overall policy of soil conservation. This, of course, does not imply that substantial changes in, for example, traditional systems of land tenure may not be necessary to meet conditions arising from the introduction of new crops and new agricultural systems, but any such changes must be in harmony with the traditional collective interest of the community as a whole in the land, and the need for their introduction must be understood and accepted.

Clearly the first approach must be through propaganda and demonstration designed to bring about appreciation of the dangers and of the effectiveness of the remedies which it is possible to employ. Success cannot be achieved until the majority of the community comprehend the position and are willing to accept the necessary degree of control. Great importance therefore attaches to the method of propaganda employed. There are many methods of approach, but experience shows that they must be based on practical demonstrations of the efficacy of the methods themselves. As adjuncts to these lectures, talks, meetings and literature are of great value, but they must all be based upon visual examples on a sufficient scale of the methods in practical application. The use of the cinema has been advocated in this connexion, and in Kenya considerable use has been made of a touring cinema unit exhibiting films showing the effect of erosion and the methods of combating it. Experience, however, seems to indicate that this method, while it has the merit of attracting people, can only be useful if it is closely followed up by, and associated with, an intensive drive based upon field demonstrations.

Methods employed in field demonstrations must be of proved efficacy and, particularly where their appeal is to primitive communities, they must be capable of ready adoption by the people themselves.

The introduction of legislation to ensure that conservation measures are applied wherever the need arises, and to compel their adoption by owners and occupiers of land in eroded areas who are unwilling to undertake them of their own volition, is an obvious development, but it is not free from difficulty. In places where the majority of the community has accepted the necessity for conservation, powers to compel a recalcitrant minority to conform to measures which are for the public good should clearly exist, but legislation on these lines is bound to be extremely difficult of application unless there is general appreciation of the need for it.

In the United States of America the decision was reached in 1936 that while demonstrations of soil conservation could show the way in which

the problems could be solved, legislation must be provided to enable tested practices to be applied to all land suffering from erosion, and since 1937 a large number of States have passed Soil Conservation District Laws. As this legislation is the outstanding example of an attempt to overcome the difficulties indicated above and as moreover it is the prototype of legislation which has since been adopted in certain Colonial dependencies its essential features are summarized below.

SOIL CONSERVATION LEGISLATION IN THE UNITED STATES OF AMERICA

The legislation is permissive in character and takes the form of enabling acts by State Legislatures that permit farmers to organize to form soil-conservation districts which have the status of governmental subdivisions of the State. There is nothing in the laws that makes it mandatory for the State to form such districts, the initiative in the matter lying with the farmers themselves. Once a district has been formed and granted a certificate of organisation by the State it becomes possible for farmers to engage in co-operative action to combat erosion and to vote land-use regulations on themselves. Supervisors are appointed who have powers to carry out soil-conservation operations, enter into contracts with farmers, make loans and grants to farmers both financially and also of equipment and machinery, buy lands for retirement from cultivation, take over and operate projects and formulate plans for soil-conservation projects.

The supervisors can also formulate land-use regulations which, after they have been submitted to farmers and approved by a referendum, are given the force of law.

Supervisors are appointed from among local residents, there are usually from three to five of them for each district, and together they constitute a board. The usual term of office is for three years. Each district is an independent unit and is not subject to control by the State Soil Conservation Committee, which is also created under the law. The functions of the latter are to encourage the formation of districts, to define their boundaries, to carry out the legal work incidental to their formation, to encourage the exchange of information and experience between the districts and to co-ordinate district programmes with one another so far as this can be done by consultation and advice. Usually the membership of the Board is made up *ex officio* of people holding official positions in the agricultural services of the State. The operations of the district organizations are financed by grants from the State and Federal Governments and by contributions from the farmers themselves^[30].

LEGISLATION IN THE COLONIAL DEPENDENCIES

Legislation has been enacted in a number of dependencies to enable conservation measures to be instituted and enforced where necessary. In certain dependencies, however, where erosion is a serious problem and operations on a considerable scale for its control have been undertaken,

there is as yet no overall legislation for the application and control of conservation measures, recourse being had where necessary to local rules made by tribal or native authorities—for example, in Tanganyika, Uganda and Basutoland.

Where legislation exists it may either take the form of the inclusion of powers to control erosion or enforce the conservation of soil and water, of laws relating to land use and land tenure, or of special ordinances intended to secure the same result. Examples of the first type occur in Ceylon and certain West Indian Colonies. Elsewhere the legislation is of the second type. The latter exhibits considerable divergences. It may take the form of an ordinance empowering the Governor to make regulations for the purpose of enforcing conservation measures; an example of this is the Palestine legislation. Or it may empower district officers or other local authorities to make specific orders for the carrying-out of conservation measures in particular cases or prescribed areas; an example of this is the Malayan legislation. Or it may follow approximately the American model and provide for the setting up of conservation authorities for the whole territory, the establishment of analogues of the American Soil Conservation Districts and the appointment of local authorities therein, combined with the definition of the powers of such authorities and the manner in which they shall be exercised. Examples of this are the legislation in Nyasaland and Southern Rhodesia.

Legislation is in existence in eleven territories* altogether, viz:—Ceylon and Malaya in the Far East, Kenya and Nyasaland, and also in Southern Rhodesia in Africa, Palestine and Malta in the Mediterranean, certain of the Windward and Leeward Islands, in the West Indies and in St. Helena.

The provisions of the legislation in each of these are summarized below.

CEYLON

Provisions for soil conservation is included in the Land Development Ordinance of 1938, Chapter 320 of the 1938 consolidation and revision of the Laws of Ceylon. The ordinance is a general one which covers all matters relating to the alienation, leasing and development of Crown lands in the territory. Chapter II of the ordinance provides for the mapping-out and reservation of Crown land for specified purposes, which include village and town expansion, cultivation, colonization, the protection of the sources and courses of streams, the prevention of erosion and the making of forest reserves and plantations. Under it the Government Agent for each Province is required to prepare schemes and diagrams specifying the mapped-out areas and the purposes for which the lands thereon have been reserved. Local Land Advisory Committees may be appointed for any revenue district, the duties of which include the examination of all schemes and diagrams and the making of recommendations thereon to the Government Agent. When agreement has been reached on a scheme, it is sent to the

* Since the above was written Ceylon has attained Dominion status, and the British mandate over Palestine has terminated. So far as is known, however, the legislative position remains unaltered.

Land Commissioner who may either confirm it or again refer it to the Government Agent for further examination. When a scheme has been finally confirmed it is published in the Government Gazette and thereafter cannot be altered without the approval and consent of the Executive Committee of Agriculture and Lands. The ordinance thus provides for a considerable measure of land planning. In addition powers are provided to enable the Executive Committee for Agriculture and Lands to make regulations, *inter alia*, for the maintenance of reserves, for the preservation of sources and courses of streams and for the prevention of erosion of the soil.

Soil Conservation Regulations have been made in relation to new plantings of rubber (Ceylon Gazette Notice No. 8600 of December 15, 1939), which require that every holder of a permit for the planting of rubber must comply with the soil-conservation measures prescribed in the schedules to the regulations, of which there are three, viz.:—

Schedule A. Relating to natural drainage lines and storm-water drains for the prevention of soil erosion.

Schedule B. Relating to earth or stone work for the prevention of soil erosion.

Schedule C. Relating to soil-conserving vegetative covers.

MALAYA

In Malaya powers are provided under the Control of Silt Enactment, Chapter 143 of the Consolidated and Revised Edition of the Laws of the Federated Malay States issued in 1935. The original enactment was passed in 1922 and was amended and revised in 1933. It is thus by far the oldest provision of this description in the Colonial Empire and probably in the world, and is accordingly of some historic interest. It was supplemented by legislation applying to the hill lands of the Straits Settlements (which prior to the Japanese occupation were a separate administration) in 1937 (Straits Settlements Ordinance No. 44 of 1937 amended by Ordinance No. 44 of 1939).

The Silt Control Enactment of the Federated Malay States provides that whenever it appears to a district officer that damage is being caused or is likely to be caused to any land or to any other land or watercourse adjoining it, by the removal by erosion of earth, silt or stone, he may call on the proprietor to show cause why an order should not be made prohibiting him from doing or causing him to do things specified in the order. If no sufficient cause is shown, the district officer, with the sanction of the Resident of the State, may make an order (a) prohibiting or restricting the removal of vegetation on the land, (b) requiring the construction of drains, water-courses, dams and retaining walls of specified character and dimensions, (c) requiring any other things to be done which appear likely to prevent the occurrence of erosion. Orders may prescribe a time limit within which the work required must be completed. If the work has not been completed within the prescribed limit the Government may enter upon the land and do the work, recovering the cost from the proprietor.

The Hill Lands Ordinance of the Straits Settlements provides for the declaration by the Governor, by order in Council, of any land to be hill land. On land so declared removal of vegetation and the plantation of short-term crops are prohibited except under permit issued by the Collector of Land Revenue for a district that shall specify the conditions under which they may be done. Powers are also provided for the acquisition of land for the purpose of preventing soil erosion and for the making of rules for giving effect to the purposes of the ordinance.

KENYA

In Kenya powers are provided under the Land and Water Preservation Ordinance No. XI of 1943. The law consolidates and repeals previously existing legislation on the same subject. Under it the Governor in Council is empowered to make rules (a) prohibiting or controlling the breaking-up of land for cultivation, the grazing of livestock and the firing or clearing of vegetation; (b) requiring and regulating afforestation, the protection of slopes, the construction of contour banks and terraces and the repairing of gullies; (c) requiring the uprooting of vegetation planted in contravention of the rules; (d) requiring the performance of any acts or abstention from other acts with the object of protecting land against erosion; (e) to provide for the appointment of officers to assist in carrying out the provisions of the ordinance.

The rules are applied to such areas as the Governor in Council shall appoint by notice published in the Gazette.

Before a rule is applied to any area the Director of Agriculture is required to forward a copy of it to the local authority in the area with a notice stating the period within which objections to it may be entered (the period to be not less than one month). Objections are considered by the Governor in Council.

When a rule is in force in any area the Director of Agriculture may be empowered to issue orders to persons in it requiring the performance of, or abstention from, specified practices and imposing conditions and time limits thereon. An appeal against any order may be made in the first instance to the Director himself and in the second instance to an Appeal Board for the area in question appointed by the Governor. In the case of Native Land Units and Crown Lands no order may be made by the Director without prior consultation with the District Commissioner who, if he does not agree with the order, may appeal to the Governor through the Provincial Commissioner.

When an owner declines or fails to comply with an order or if the owner cannot be found, the Director of Agriculture is empowered to enter the land and carry out the work specified at the expense of the owner and, if the cost is not paid within 30 days, to apply to the Agricultural Bank of Kenya for payment of the expenses by an advance as if he was the owner of the land.

Any person required to carry out any act involving expenditure may apply to the Agricultural Bank for an advance to defray the cost. Advances

so made are from funds provided by the Government to the Bank for the purpose; they bear interest at an approved rate and are repayable in equal yearly instalments. The Governor in Council is empowered to make regulations governing the making of advances. Penalties for breach or nonobservance of any rule or order are fixed by the Governor in Council by rule, with the over-riding proviso that no penalty shall exceed a fine of £100 or imprisonment for six months or both.

NYASALAND

In Nyasaland legislative powers to enforce conservation are provided under the Natural Resources Ordinance No. 9 of 1946. This provides for the establishment of a Natural Resources Board composed of the Director of Agriculture who is also the Board's executive officer, two other official and three unofficial members appointed by the Governor.

The functions of the Board are partly advisory and partly executive; they include the exercise of general supervision over natural resources, propaganda to stimulate interest in conservation, the examination of conservation projects, the recommendation of legislation in this connexion, the making of orders, approving of works and apportionment of costs for conservation projects, making recommendations in relation to Forest Reserves, stock limitation, the provision of advances to owners of land for carrying out conservation works, and for the setting up of local Conservation Councils, as well as carrying out any other functions which the Governor may require.

The Board has power to call for information and to receive representations, it may subpoena witnesses and receive evidence on oath, and it may call for the production of documents.

Conservation Councils may be set up by the Governor on the advice of the Board for particular areas; their functions are generally to co-operate with and assist the Board, to formulate schemes for the area to which they relate, and, on the recommendation of the Board and with the approval of the Governor, to undertake the construction of works and other measures for the conservation of natural resources.

Orders to undertake conservation measures may be issued by the Board to owners and occupiers of land, relating to the use to which land may be put, the protection of streams, the prohibition or restriction of cultivation, methods of cultivation, manners of depasturing, watering and moving livestock, the control of water including storm water, and the construction and maintenance of conservation works.

Orders relating to unalienated Native Trust land must, however, be addressed to the Provincial Commissioner for the area in which the land is situated.

An owner or occupier who fails to carry out orders within a time limit fixed by the Board is guilty of an offence, and a court order may be made requiring him to comply with the original order in addition to any penalty

inflicted. In the case of constructional works the Director of Agriculture may enter the land and carry out the works at the expense of the owner. In the case of Native Trust land, the Native Authority is informed by the Provincial Commissioner of orders issued by the Board and is then responsible for their being put into force by the users of the land.

If the Board decides that any work recommended by the Director is in the public interest, but should not be made the subject of an order, the work may be done by the Director at the cost of the general revenue.

Advances may be made to owners to enable them to carry out works specified in an order, carrying interest at rates not exceeding $3\frac{1}{2}$ per cent. The Board may also decide what part of any works shall be carried out at the public expense and what part shall be borne by the owner or occupier.

Powers are also provided under the ordinance to enable the Governor to authorize the reduction of the numbers of livestock in any area, to prescribe the maximum number and class of animal which may be depastured there, and to make rules in this connexion. The Governor can also make rules prescribing the manner in which Conservation Councils exercise their functions, the conditions under which loans and advances may be made to Conservation Councils for carrying out conservation schemes and the manner of apportioning costs between owners. There is also provision for the appointment of Conservation Officers.

SOUTHERN RHODESIA

Southern Rhodesia is not a Crown Colony, but natural conditions resemble those in other territories in Colonial Africa, while conservation measures have attained considerable extension there, including the provision of comprehensive legislation, which has apparently served as a basis for the legislation in Nyasaland. An account of it is included accordingly by reason of its special interest for Colonial workers.

The legislation is contained in the Natural Resources Act of 1941. It provides for the establishment of a Natural Resources Board consisting of a Chairman and not less than three other members to be appointed by the Governor. In making appointments regard is had to the representation of the sectional interests, and representatives of such interests may submit a panel of names of persons considered suitable for appointment. The functions of the Board include—

- (a) Supervision of natural resources.
- (b) Stimulating public interest in conservation.
- (c) Recommending to Government legislation for conserving natural resources.

At the request of the Minister of Agriculture the Board reports to Government on projects for soil and water conservation ; it has power to consult technical experts, summon witnesses, take evidence on oath and call for the production of documents. The right of appeal to the Minister against any determination of the Board is provided for.

In areas other than native reserves the Governor on the recommendation of the Board may set aside Crown land or acquire by purchase or expropriation privately owned land for the conservation of natural resources.

The Minister of Agriculture, also on the recommendation of the Board, may construct upon any land works for—

- (a) the protection of streams,
- (b) the disposal and control of storm water,
- (c) the control of erosion,
- (d) the conservation of water,

the cost in the first instance being met from public revenue, but if it appears that the owner of the land should contribute to the costs of the works, the Board assesses the amount and the Minister collects from the owner by the processes described under the Act.

The Board is further empowered to give written orders to owners of land to undertake measures for the conservation of soil, water and vegetation, and these may relate to :—

- (a) the construction and maintenance of soil-conservation works,
- (b) the preservation of streams,
- (c) the depasturing of stock,
- (d) methods of cultivating the land,
- (e) the prohibition or restriction of cultivation of any part of the land,
- (f) the control of water including storm water.

If the owner fails to comply with an order within a period fixed by the Board he is guilty of an offence. The Minister can on the recommendation of the Board make advances to owners to enable them to carry out works prescribed in an order at interest rates not exceeding 5 per cent. The Minister has powers to enter on land and carry out orders if the owner fails to do so, and to recover the cost from the owner. If the works carried out on any land benefits adjoining land its owner may be called upon to bear a part of the cost as determined by the Board.

If owners of land in any area wish on their own initiative to undertake conservation measures in it they can petition the Minister to declare the area to be an intensive-conservation area. If the petition is granted the declaration is made by notice in the Government Gazette, and thereafter the owners are required to appoint from among their number a Conservation Committee for the area. A Conservation Committee is a body corporate with all the usual powers, and its functions are to undertake the construction of works in the intensive-conservation area in which it operates and to co-operate with the Board in carrying out the purposes of the Act. The cost and maintenance of works carried out by a committee are defrayed by members in mutually agreed proportions, in case of dispute the matter

being adjudicated by the Board. The Minister on the recommendation of the Board can make loans and grants to Committees for the construction of works, loans to be repayable over a term of years not exceeding fifty years and bearing interest at a rate not exceeding 5 per cent.

In Native reserves where land is deteriorating from overgrazing or other misuse, the Board with the approval of the Board of Trustees for Native Lands may direct that the whole or part of it shall be reserved from human occupation or use. No reservation can, however, be made until the Board of Trustees is satisfied that suitable provision has been made elsewhere for persons affected by the reservation. Land so reserved is demarcated by boundary marks and fenced, and any one contravening the reservation or interfering with the demarcation is guilty of an offence.

If the Governor is satisfied on the report of the Board or the Minister for Native Affairs that land in a native reserve is deteriorating as a result of overstocking, he may authorize the reduction of the number of animals, and prescribe the maximum number and class of animals which may be depastured on a fixed unit area of land. Destocking and stock limitation is made in accordance with regulations made under the Act.

The Governor, on the recommendation of the Board and with the approval of the Board of Native Trustees, may set aside areas in native reserves for the conservation of natural resources, and the protection of water supplies for native areas.

A Native Commissioner may give orders to users of land in a reserve to undertake conservation measures and to prevent injury to natural resources under the following heads :—

- (a) the depasturing of stock,
- (b) methods of cultivating the land,
- (c) prohibiting or restricting the cultivation of any part of the land,
- (d) the control of water including storm water.

Any user of land who fails to carry out an order is guilty of an offence, while any native who fails to maintain any part of works carried out in an area which affords protection to his land is also guilty of an offence. Provision exists for an appeal to the Board against any orders made in these connexions in a manner prescribed by regulations.

In addition to the bodies already described, the Act also provides for the appointment by the Governor of Conservation Councils for prescribed areas, the duties of which are to confer with and advise the Board on conservation matters in the area for which it is appointed.

It also provides for the appointment of conservation officers and for the right of entry of authorities under the Act to land or premises, for the exercise of powers or the discharge of duties under the Act, as well as for the making of regulations in regard to matters already mentioned.

PALESTINE

In Palestine powers are provided under the Flooding and Soil Erosion Prevention Ordinance No. 12 of 1941. The ordinance is an enabling one and under it the Governor is empowered to make rules for all or any of the following purposes :—

- (a) providing for the examination of land and, if he thinks fit, declaring it to be a special area,
- (b) prohibiting or regulating the pasturing in or passage through a special area of all domestic animals,
- (c) prohibiting or regulating the cultivation of land in a special area,
- (d) prohibiting the cutting, breaking, burning or removal of any vegetation in a special area,
- (e) providing for the carrying out of any work in a special area and the maintenance of any work so carried out.

So far eight special areas have been declared and rules relating to them made. The effect of the rules is simple, and gives power to certain officers, most usually the Conservator of Forests, to prohibit or to allow to be done under permit the various things mentioned in the ordinance itself.

In Palestine there is also provision to deal with the control of drifting sand and the reclamation of lands which have become covered with sand drift, in the Sand Drift Ordinance Chapter 131 of the Laws of Palestine 1933. The ordinance provides that when it appears that sand has drifted or is likely to drift over cultivated land, the Chief Forest Officer shall by Gazette Notice define the boundaries of the land affected and declare intention to take steps to stop the drift of sand and reclaim lands covered with sand. It also provides for the recognition of rights of ownership in land covered with drifted sand and for co-operation of land owners and villagers in control and reclamation work, either by provision of finance or labour or both.

MALTA

The legislation in Malta is of a highly specialized type and arises out of the need which occurs in a small and densely populated island community for conserving all available soil. It is contained in the Fertile Soil (Preservation) Ordinance of 1935, Chapter 130, of the revised edition of the Laws of Malta. The ordinance provides that no new building may be erected in Malta without first removing the fertile soil existing on the site and depositing it on other lands in accordance with directions issued by the Director of Agriculture, so as to ensure that it remains available for purposes of agriculture.

LEEWARD ISLANDS

ANTIGUA

The Land Settlement and Development Ordinance No. 7 of 1946 contains provision for dealing with conservation. It provides for the estab-

lishment of a Land Settlement and Development Board charged with the duty of promoting the interests of agriculture, the development of land-settlement schemes and the encouragement of agricultural enterprise. The Board is empowered to acquire, lay out and develop land so as to conserve its natural resources, lease lands for agriculture and to attach conditions to leases which will ensure the maintenance of good husbandry. The Board consists of five members, two official and three unofficial. Its executive officer is the Agricultural Superintendent, and the Chairman and Deputy Chairman are appointed by the Governor from among the members. The Director of Agriculture for the Leeward Islands is *ex officio* an honorary member of the Board but may not vote at meetings. It appears probable that similar legislation may be enacted in other presidencies of the Colony.

WINDWARD ISLANDS

ST. LUCIA,

DOMINICA

Some provision for dealing with certain aspects of soil conservation exists in St. Lucia Ordinance No. 6 of 1945 and Dominica Ordinance No. 14 of 1946. The short title of both ordinances is the Forest, Soil and Water Conservation Ordinance. The ordinances are identical in all essential respects and are concerned mainly with the protection and management of Crown-land forests. Both, however, contain clauses enabling the Governor to proclaim lands other than Crown lands to be protected forests whenever it appears to be necessary for any of the following purposes :—

- (a) protection against storms, winds, floods and landslides,
- (b) the prevention of soil erosion and the formation of ravines and the deposit of mud, sands and stones on agricultural land,
- (c) the prevention of wastage of timber resources,
- (d) the maintenance of water supplies,
- (e) the protection of roads, bridges and communications,
- (f) the preservation of health.

The Governor is empowered to make rules relating to protected forests, prohibiting or regulating the felling of trees, the clearing and breaking up of land for cultivation, the pasturing or trespass of livestock, the setting of fire and other acts likely to be prejudicial. The Chief Forest Officer is the authority responsible under the ordinance, but the Agricultural Superintendent and agricultural assistants as well as forest rangers and guards are deemed to be forest officers for the purposes of putting into effect the provisions of the legislation.

ST. HELENA

In St. Helena powers to enforce conservation measures are provided under the Agricultural and Livestock Improvement Ordinance No. 5 of 1940.

The ordinance is an omnibus one, and empowers the Governor in Council to make rules for, *inter alia*, prescribing measures for the protection and preservation of the soil and the prevention of erosion by wind and water. Other matters affected include the improvement of cultural conditions for specified crops, the quality and marketing of produce, the control of diseases, pest and weeds, improving the quality and regulating the numbers of livestock, etc.

HIGH COMMISSION TERRITORIES OF SOUTH AFRICA

No actual legislation has yet been enacted in the High Commission Territories, but in Basutoland certain measures have been taken in concert with the tribal authorities, and in Swaziland legislation is under consideration.

In Basutoland the following measures have been drawn up ; the majority have been accepted by the National Council and are in operation. They constitute an example of the way in which control may be exercised through tribal authorities and are included on this account.

(1) The Paramount Chief on the Advice of the Department of Agriculture and after consultation with the Chiefs, Sub-Chiefs, Headmen and people may declare any area to be an Agricultural Improvement Area. Areas should be of sufficient size to embrace a minimum of 500 families.

(2) In any Agricultural Improvement Area the Ward Chief, with the advice of the Department of Agriculture, prepares a scheme for the rehabilitation of the area for consideration and approval by the Paramount Chief. The scheme comprises the following points.

- (a) The preparation of a register of all families in the area entitled to land by Basuto custom, showing the name of the head of the family, the number of persons in it, the amount of land worked and the number of stock owned by them.
- (b) A rough survey is made of the arable land and the acreage for each registered family is determined. The arable section is then demarcated by stone beacons.
- (c) Subsequently, suitable sites for vegetable gardens and tree planting are demarcated, sufficient land being set aside to provide $\frac{1}{4}$ acre for vegetable growing and one acre for tree planting for each family. The tree-planting area is in the nature of a village wood lot, trees are planted by each family at the rate of 100 trees per family per year.
- (d) The remainder of the land is set aside for communal grazing and divided into three sections for deferred rotational grazing.
- (e) A Land Management Committee is appointed for each Agricultural Improvement Area.

(3) The Land Management Committee lays down the methods to be followed for the management of the arable land, including contour ploughing, rotations and manuring.

Under these arrangements each registered land holder is issued with a registration card, and is required to appear on his holding on a fixed day in each quarter bringing his registration card with him, when the Government Agricultural Officer or his deputy instructs him concerning the operations he should carry out during the succeeding quarter and enters them on his registration card.

If a registered land holder consistently refuses to follow the instructions entered on his card, action is taken against him in the Chief's court.

The arrangements for the management of the communal grazing areas have already been described in Chapter 4.

In Swaziland the enactment of legislation by proclamation for the conservation and improvement of natural resources is under consideration, but so far as is known has not yet been brought into effect. The broad outlines of the legislation contemplate the setting up of Natural Resources Boards for the different districts and the provision of powers on lines broadly similar to those under the Nyasaland and Southern Rhodesian ordinances.

ADMINISTRATION

Full-scale conservation measures may affect the whole life of an agricultural community and involve drastic changes in agricultural practices and social conditions. Success depends, therefore, on a co-ordinated approach to the problem by the various agencies concerned ; these are numerous and include not only Departments of Agriculture, Forestry and Animal Health, but also other Departments of Government such as the Public Works, Health and Education Departments as well as the General Administration and often other agencies in addition. It depends also on overall land planning, it may require modification of systems of land tenure, and it must command the support and co-operation of the community. It must also be co-ordinated and harmonized with development plans in other directions.

Difficulties have arisen in the past owing to lack of collaboration between different agencies concerned with different aspects of development ; for example, erosion arising from overstocking may have been aggravated in places as a result of measures to control animal disease that have led to increases in the livestock population without corresponding increases in the food and water supplies necessary to their maintenance. The trouble, however, is not that such measures are wrong or undesirable, but that there has been lack of co-operation between the agencies charged with their execution and other agencies responsible for development in other directions.

Lack of co-ordination and lack of balance between authorities responsible for different aspects of agricultural development have been a fruitful source of difficulty. The existence of a number of separate departments all charged with related functions is inevitably bound to lead to unco-ordinated activity, conflict of ideas and consequent waste of money and effort. In some dependencies a tendency to create further separate agencies is in evidence,

and there is not always uniformity in the manner in which specific functions are allocated to individual departments. Thus in some African territories administration and investigations in regard to grassland management and the control of grazing are a function of the Department of Agriculture and in others of the Department of Animal Health.

One method of dealing with the difficulty is the appointment of Boards and Committees both for territories as a whole and also for districts and defined regions thereof, charged with the duty of advising on and in some cases the execution of development projects. In some of the legislation already described, provision of this description is included ; in other territories in which no legislation for conservation at present exists, development boards and committees have been appointed.

Another method of assisting overall co-ordination of various agencies of Government responsible for development is the setting-up of separate central administrative machinery to deal with departments concerned with development under a Development Secretary directly responsible to the Governor. This device has been adopted in a number of territories.

There is also need for co-ordinating policies between adjacent territories, and here the setting up of inter-territorial councils and boards such as have been established or projected for the East and Central African and West Indian Regions should prove of value.

The institution of separate departments for carrying out conservation programmes has also been suggested. Conservation, however, impinges directly on the work of many departments of government ; in its agricultural aspects it is intimately bound up with the devising and adoption of new and modified systems of agriculture which is the special province of Departments of Agriculture ; in other aspects it is equally closely associated with the work of other departments, notably in its forestry aspects with Departments of Forestry. The suggestion accordingly appears to be fraught with so many difficulties that it is to be questioned whether any really useful purpose would be served by adding yet another separate organization to the already over-long list of departments interested in questions of land use and development. As we have seen, one of the present difficulties is lack of co-ordination between the work of different agencies charged with convergent duties, and additions to their number are quite as likely to enhance difficulties as to remove them. On the agricultural side, therefore, there seems to be general agreement that soil conservation must continue to be part of the functions of the Departments of Agriculture, although separate sections or branches of departments may be instituted to deal with it. In certain of the Colonial dependencies, notably Kenya, soil-conservation branches of departments have already been inaugurated and in others soil-conservation officers have been appointed. In the discharge of their functions they work in close association with the district agricultural organizations and with local administrative authorities.

THE TRAINING OF OFFICERS FOR SOIL-CONSERVATION WORK

Experience has shown that officers engaged in soil-conservation work require special training, and this applies both to senior and junior staff. Since 1937 selected officers from Colonial Departments of Agriculture have from time to time been sent on missions to study soil-conservation practice in various parts of the world, notably in the United States of America. More recently, definite courses of instruction in soil conservation have been organized, notably through the United States Department of Agriculture which now offers special facilities for training in the subject; these are available, by arrangement through the appropriate authorities, for training officers from the Colonial dependencies. The course takes one year. The University of Witwatersrand in South Africa has also instituted a course of instruction in the subject. The full course occupies four years and leads to a degree. It is understood that shorter courses are also available. Recently officers from Colonial dependencies have been detailed to undergo one or another of these courses.

A conference of Directors of Agriculture held in 1946 expressed the view that all Colonial agricultural officers should receive adequate instruction in soil-conservation work as part of their training, and that facilities should be provided to enable serving officers to undergo short courses of training in the subject as circumstances permit.

In regard to the training of locally recruited junior staff, facilities for the general training of this class of officer already exist in many dependencies, and the inclusion of instruction in soil-conservation work therein should present no particular difficulties. In the Kenya proposals for agricultural development provision has been made for the institution of special centres for training the large number of locally recruited assistants needed for the programme of soil-conservation work that has been laid down. In Southern Rhodesia short courses on soil conservation are conducted which are open to officials and others of neighbouring territories.

RESEARCH

Reference has already been made to the need for research provision for soil surveys, fertility investigations and the working out of new agricultural systems. There is also need for investigation on the erodibility of soils and the rate at which erosion occurs under different soil and climatic conditions. It is true that a large amount of work on this subject is in progress in the United States of America, the results of which are available to Colonial workers, and are to a large extent applicable to Colonial conditions, at least so far as fundamental principles are concerned. The need remains, however, for investigations to ascertain how far methods require to be modified to meet local conditions. In particular there is also need for ascertaining the rate at which erosion is taking place under different conditions and the influence exerted by the various factors concerned. There is almost complete lack of this kind of data, and its absence has probably led to mistakes in the past.

For its successful prosecution soil conservation demands the expenditure of much money and effort. Mistaken premises and lack of sufficient data can lead to waste of effort and costly failures. Research and investigation can provide a reliable basis for assessing the possibilities and the prospects for success of methods in their local application and of measuring the results achieved. Adequate provision for it should be regarded as an essential part of conservation programmes.

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