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Soil Erosion and Conservation of Moisture in Un-Irrigated Black Soils

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Lecture No. 1*

Soil Erosion is a subject that is receiving world-wide attention today. Although erosion has been going on for centuries, it is recognised that it has begun to assume serious proportions in recent years. America may be said to be the foremost country in the collection and dissemination of knowledge concerning this problem. Through a chain of experimental stations which deal exclusively with the problem of soil erosion in all its varied aspects, a large mass of data is collected and the results made available to the farmers through a series of scientific articles, pamphlets and other publications; wide publicity is given to such results. Farmers are encouraged to form soil conservation districts, which on co-operative lines practise the various control measures advocated by the officers of the Soil Conservation Service, under their expert guidance and advice. The Soil Conservation Service deals comprehensively with the problem of erosion from the agricultural, forestry, engineering and other points of view. The quantity of soil washed down the great river systems of America annually is computed in millions of tons of soil. Some of the erosion surveys of the United States as a whole showed that 35 millions of acres have already been destroyed; out of the 350 millions of acres under cultivation, 125 millions have lost most of their surface soil and 100 millions are eroding seriously. It is stated that at the present rate of soil and water depletion the fertile soil in America will be reduced in another 50 years to a fourth of what it is now. These are some of the results of the erosion surveys of the United States.

In India no such computations of the losses of soil fertility are yet available. According to Dr. L. Dudley Stamp, an authority on land utilisation matters, the problem of soil erosion in Africa is of recent origin, but is assuming very serious proportions as a result of the intensive exploitation of the land for purposes of agriculture. The native system of cultivation known as 'Bush fallowing', which is also called 'shifting cultivation', is best suited to the country. A period of cultivation is usually followed by a long period of fallow—usually 7 to 10 years, during which bushes and trees grow. These form a natural protection against erosion. It is only when the period of fallow is reduced and clean ploughing, clean weeding,

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extensive clearing and such other practices are introduced, erosion is excessive.

A knowledge of certain facts fundamental to the problem of erosion is essential for a proper understanding of the subject. Soil erosion is caused by the action of wind or water in motion. The average depth of soil in the world is estimated to be about 6 to 12 inches. At some places it is deeper and at others shallower. It is this thin layer of soil resting on a rocky core that is responsible for all plant growth and that supports all animal and human life. It is as essential for life on this planet as air, water or sunlight. It is therefore our primary duty to protect this layer of soil and see that its fertility is well preserved.

Under the natural undisturbed conditions, an equilibrium will be established between the climate of a place and the cover of vegetation that protects the soil layer. Vegetation, trees and forests retard the transportation of soil material and act as a check against excessive erosion. A certain amount of erosion, however, does take place even under this natural cover; but it is such a slow process that it happens at the rate at which soil formation takes place. Such erosion is called geological erosion and proceeds in a natural undisturbed environment. As opposed to this we have what is called accelerated erosion. When vegetation is removed and land put under cultivation the natural balance existing between the soil, its vegetational cover and climate is disturbed. The removal of the surface soil takes place at a much faster rate than it can ever be built up by the soil forming processes. Erosion is thus accelerated. When dealing with erosion on cultivated soils we are considering only this accelerated erosion.

The damage due to wind and water erosion assumes different degrees of importance depending on the locality. Whenever soils without a cover of vegetation in a dry state are exposed to high winds, we have wind erosion. The fine portions of the soil are lifted and carried to great distances. In India as a whole wind erosion is not as extensive as water erosion. Light soils are more susceptible to wind erosion than heavy soils. Along rivers like the Hagari and the Pennar in the black soil areas sand blowings are common. During summer, when the river is dry, high south west monsoon winds lift up the sand which is deposited on the black soils making them unfit for cultivation in the course of some years. If this is allowed to go on without hindrance much of the cultivable land will get covered up with sand annually.

The following remarks are mostly confined to the effects of water erosion which is the more serious and extensive type of erosion that occurs in the black soil areas of the Ceded Districts Two fundamental types of water erosion are the 'gullying' and the 'sheet erosion'. In the case of sheet erosion, movement of run-off water and eroded soil takes place in sheets, approximately the same amount of soil being removed from each place. When this moving mass assumes sufficient velocity it has a cutting action on the soil. A gully or a trench, as it were, forms at any small dent or depression in the field where this moving mass of soil and water collect at a high speed. The run-off water carrying the surface soil flows down the gully with ever increasing velocity. If the velocity of the run-off water is doubled its energy is increased four times and its cutting action is correspondingly increased ; its capacity to carry in suspension the soil material is increased sixty-four times The gullies tend to deepen and widen with every rainfall. They cut up agricultural lands into small fragments and make them unfit for cultivation in course of time. Of these two types of erosion, gullying is the more spectacular type while sheet erosion is the more insidious type, creeping on unnoticed. The destructive action due to sheet erosion may not be felt in the first few years. Only when, due to continuous erosion, the productive capacity of the land is diminished, we begin to realise that the fertility of the soil is being steadily lost. Sheet erosion usually ends in gully erosion. (Vide Fig. 1).

Let us now examine the chief causes of accelerated erosion in black soils. Run-off water and its speed on these soils are controlled by the following factors :

(1) the heavy nature of the soil and its physical condition ;
(2) the nature and distribution of rainfall ; and
(3) the slope of the country.

The black cotton soil or the *Regur* of the Madras Deccan is noted for its high clay content consisting of about 50 percent clay and 30 percent silt, the finest mechanical fractions of the soil. It is the fine colloidal clay that determines all the soil-water relations. It is highly retentive of moisture but on account of the heavy nature, the soil is slow to absorb rainwater. It is sticky when wet and hard when dry. These black soils have been shown by many workers to possess properties similar in many respects to the extensive group of black earths known as 'chernozems', one important difference being, however, that the chernozems are rich in organic matter while these soils are poor, consisting of only one to two per cent of organic matter. What happens when a heavy rain falls on these clayey soils ? The colloidal clay which might be visualised as a thin film existing round the mineral particles swells on wetting. Clay in the flocculated state assists in the formation of compound particles. This aggregation into compound particles known as 'crumb structure' is agronomically the most desirable structure. It offers the least resistance to the passage of implements ; allows water to percolate better to the lower layers. But when rain drops begin to beat on these crumbs or compound particles, apart from the mechanical action of pulverising, deflocculation of the colloids sets in due to the washing away or leaching of the electrolytes ; the crumbs deteriorate and the soil-water mixture flows on the surface as a viscous fluid. Consequent on the loss of structure the fine material flows into the pore spaces in the soil, clogging them and preventing any further percolation of rain water to the lower layers. Absorption is then limited to the rate at which percolation to lower layers can take place, which, however, is very slow. Thus the soil will not be able to absorb rain water as fast as it is received. The result is run-off.

The run-off carries away the surface soil with it. The amount of the run-off necessarily depends upon the intensity of rainfall. A heavy storm within a short interval might cause as much damage as all the other rains put together during the year. One of the factors conducive to excessive erosion in these soils is that there is no crop or other vegetation on the land during most of the period when the rains are received. The main *hingari* crops, cotton and sorghum, are harvested by March or April; between April and September or October, until the next sowings are done, the land is fallow. The distribution of rainfall is such that out of an annual precipitation of about 20 in. about 12 in are received in the quarter—August, September and October. It is only after the September rains are received that cotton is sown, sorghum being sown in October. Most of the rainfall is thus received only when the land is fallow. A few *mungari* or early crops like *korra* (Italian millet) and groundnut, if sown, are all the protection that the soil has against erosion consequent on the direct impact of rain. It is not also uncommon to receive a downpour of about 3 in. overnight. One or two such instalments of intensive rainfall occur every year. Added to these the land is slopy in nature. Thus the heavy type of soil, which does not allow rain water to be absorbed as fast as it is received, the undulating nature of the land and the fact that soil is exposed without any protective cover for most of the rainy period are the chief factors underlying accelerated erosion in black soils.

Losses of soil and water due to erosion can be measured accurately. A knowledge of this aspect of the problem is essential for an understanding of the magnitude of the losses. During the last five years soil and water losses due to run-off were studied at the Dry Farming Station, Hagari. Two plots 66 ft. by 8¼ ft. (area 1·25 cents) with a gradient of 1 in 80 were selected. On three sides the plots were enclosed by galvanised iron sheets, which project about a foot above the ground level. The run-off was collected in masonry cisterns (6 ft. × 4 ft. × 3 ft.) towards which the plots slope (Fig. 2). The volume of the mixture of soil and water that collected in the cisterns after each rain was measured. Samples of run-off waters were analysed for water and soil separately, from which the amount of water collecting in the cisterns by run-off and the amount of soil that it carries with it are calculated. The samples were also analysed for total salts, lime and nitrate nitrogen.

During 1937–38 both the plots served as duplicates, only hand-hoeing being done before the rainy season in both.

Any method by which the velocity of flow of the run-off waters could be minimised helps in reducing erosion. If small pockets or basins are formed, it will be an effective check against excessive erosion. The effect of 'scooping' on the control of erosion was investigated during 1938–39 and 1939–40. One of the plots had scoops formed in it before the rainy

Fig. 1. Gullying in black soils.

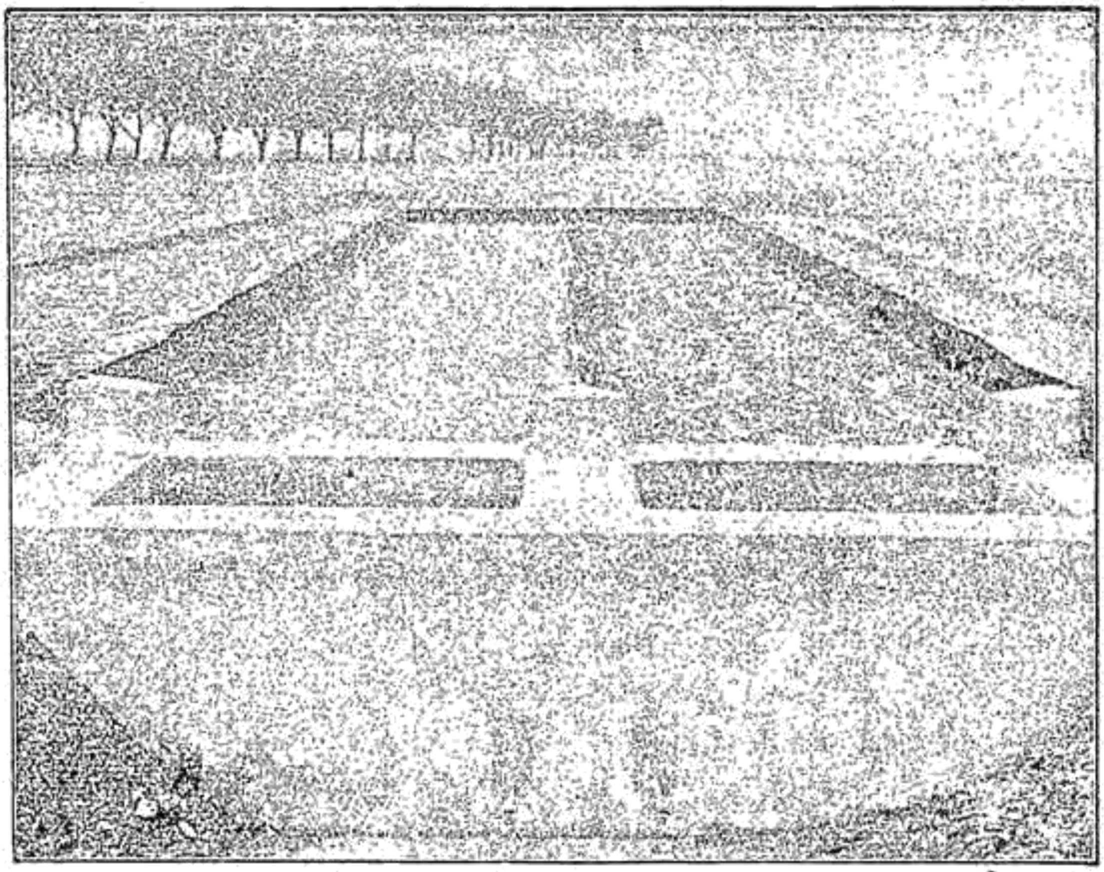

Fig. 2. Run-off plots at Hagari—control and scooped plots.

season, while the other was given hand-hoeing and kept as clean fallow. The latter served as control. The results obtained during the years 1937 to 1940 are given in the following table.

TABLE 1. Run-off results, 1937 - 40

	1937–38 Average of two control plots	1938–39		1939–40*	
		Control	Scooped	Control	Scooped
1. Number of days when there was run-off	11	13	10	16	10
2. Total rainfall on days when there was run-off in either of the plots–inches	9·16	15·66	15·66	8·36	8·36
3. Rain water lost–inches	4·00	7·52	3·29	2·73	1·34
4. Rain water lost—expressed as per cent of rainfall received	43·67	48·01	21·01	32·66	16·03
5. Silt washed off in tons per acre	6·58	9·86	3·60	7·35	2·44
6. Silt washed off in tons per acre per inch of rain water lost	1·65	1·31	1·09	2·69	1·82
7. Total salts lost in lb. per acre	100·60	132·86	95·79	65·00	41·72
8. Lime (CaO) lost in lb. per acre	2·45	20·07	16·79	5·46	2·62
9. Nitric nitrogen lost in lb. per acre	0·11	0·59	0·29	0·19	0·09

* Excluding data on two days when the run-off cisterns overflowed—rainfall being 3·82 in. and 2·61 in. within 24 hours on 10th August 1939 and 25th October 1939 respectively.

It is seen from these figures that in the control plot 44 and 48 per cent of the rainfall was lost by surface run-off during 1937 and 1938. Considerable amounts of silt were lost in the run-off waters. The soil losses amounted to 6·6, 9·9, and 7·4 tons per acre for a rainfall of 9·2 in., 15·7 in. and 8·4 in. respectively. Every inch of run-off water carried away 1·5 tons of silt per acre during 1937 and 1938. It was even more during 1939.

While the actual amount of run-off depends on the intensity of the rainfall and the slope of the plots, some of the American results reported from the Texas Experimental Station on run-off under agricultural conditions were 3 tons per acre per inch of rainwater lost. Grass was found to be 65 times more efficient in the control of soil losses and five times more effective in checking water losses than bare soil.

At the Sholapur Dry Farming Station, it was found that a clean fallow plot lost 25 tons of soil in one year for a rainfall of 14·8 in. when the run-off was only 5·8 in. The soil removed per inch of rainwater lost was 4·3 tons per acre under the same conditions of gradient and size of plot as at Hagari, while the corresponding figures for Hagari were 1·6 tons per acre during 1937 and 1·3 tons per acre during 1938. A plot in which weeds were preserved gave only 0·58 tons per acre or 1/50th of the losses in the clean fallow plot at Sholapur.

On an average, excluding days of very heavy rainfall as occurred in 1939, about 8 tons of soil per acre was lost by erosion in a clean fallow plot at Hagari, *i. e.*, about 16 cart-loads of fine silt.

Intense storms contribute most to run-off. A single storm on the 28/29th of September, 1938, for example, was responsible for nearly a third of the total loss of silt and a fourth of the total loss of water that occurred during the whole year.

	Rainfall, in inches.	Water loss in inches.	Soil loss in tons per acre.
28/29—9—1938	3·57	1·81	3·29
Whole rainy period of 1938	15·66	7·52	9·86

Such instances are very common when the scouring action of an intense downpour does great harm and removes much of the valuable surface soil.

When the soil is very dry and numerous cracks are present, even a heavy precipitation does not give much run-off. Run-offs recorded early in the season are very small; (e. g.) on 4th July 1939 for a rainfall of 1·14 in. the run-off was only 0·03 in. and the soil loss was 0·03 tons per acre. Run-off data recorded early in 1940—41, illustrating this point is given below.

Run-off data recorded early in 1940—41

Date	Rainfall in inches	Run-off in inches
7—6—40	0·49	0·10
10—6—40	0·52	0·26
13—8—40	0·97	0·02
13—9—40	0·87	0·04
Total.	2·85	0·42

Effect of scooping on the control of erosion It is seen from Table 1, that by scooping or listing the water losses are reduced from 7·5 to 3·3 in. and from 2·7 to 1·3 in. respectively for the years 1938-39 and 1939-40, while the soil losses for the same period were reduced from 9·9 to 3·6 tons per acre and from 7·4 to 2·4 tons per acre respectively. Scooping the land therefore considerably reduced the run-off and consequent losses by erosion. Data on a few occasions when the scoops were very effective in reducing run-off is given below.

TABLE 2. Extract of run-off data for 1938

Date.	Rainfall, in inches	Run-off in inches		Silt lost in tons/acre	
		Control	Scooped	Control	Scooped
6—8—38	1·89	1·12	0·26	1·259	0·409
18—8—38	1·62	0·92	0·15	1·020	0·185
22—8—38	2·39	1·31	0·71	1·570	0·842
24—9—38	1·18	0·60	0·03	0·492	0·036
25—9—38	0·81	0·39	0·09	0·215	0·032
Total	7·89	4·34	1·24	4·556	1·504

The reduction in the run-off in the scooped plot on these occasions of heavy rainfall is due to the mechanical obstruction to the flow of water which the scoops offer.

The total salts washed off the surface are not considerable; the weight of the top 6 in. layer of soil will be about 1000 tons per acre and 100 lb. in this is negligible.

Quality of the soil washed by the run-off waters The soil collected in the run-off cisterns was analysed for the physical and chemical composition. The results are given in the following table.

TABLE 3. Mechanical analysis of silt collected in 1937–38

Heads of analysis	Run-off silt	Soil 0 to 1 ft. layer
Clay (per cent)	56·8	44·9
Silt („)	26·9	17·1
Fine sand („)	8·5	15·7
Course sand („)	1·4	17·5

TABLE 4. Chemical analysis of silt collected in 1937–38

Heads of analysis	Run-off silt	Soil 0 to 1 ft. layer
Loss on ignition	7·14	3·12
Insoluble matter	63·95	75·49
Iron and alumina (Fe_2O_3, Al_2O_3)	20·95	13·19
Lime (CaO)	3·83	3·45
Magnesia (MgO)	1·52	0·92
Potash (K_2O)	1·28	0·29
Phosphoric acid (P_2O_5)	0·041	0·054
Nitrogen (N)	0 043	0·024

These figures for the analysis of silts collected in the run-off cisterns are typical of the data obtained year after year. The analysis of the soil from the top one foot layer is also given in the tables for purposes of comparison. The figures for the mechanical analysis show that the silt washed off the land consists of about 84 per cent of the fine fractions, clay and silt, while the original soil contains only 62 per cent. The difference is due to the fact that during the course of the washes the coarse particles settle out quickly and it is the fine material that gets lost The nitrogen content of the silt was 0·043 per cent while that of the soil was only 0·024 per cent. Potash in the silt was about four times that contained in the soil. Thus from all accounts the silt that is washed off the land is much richer than the original soil Much of the organic matter present in the surface soil gets lost; the loss on ignition for the silt being nearly double that for the original soil. The fertility of the soil is lost. A poorer soil is left behind. A healthy soil is the first essential for the production of a healthy crop. Loss in soil fertility results in a crop which is unhealthy and susceptible to disease.

Effect of a cover crop on the control of erosion During 1940-41 and 1941-42, the effect of a cover crop of groundnut on the control of erosion was studied in the above plots. Groundnut (A. H. 25), spreading variety, was sown in one of the plots early in June and it was harvested early in December. If timely rains are received for the sowing of a *mungari* crop like groundnut, it will be on the field practically throughout the rainy period and will be a good protection against erosion.

Table 5. Results of run-off for 1940-41

(Data from 13-6-40 to 13-12-40, the date of sowing and harvest of groundnut respectively, in one of the plots)

	Control clean fallow	Cropped with groundnut
1. Number of days when there was run-off	11	5
2. Total rainfall on days when there was run-off in either of the plots in inches	7·63	7·63
3. Rain water lost in inches	2·81	1·63
4. Silt washed off in tons per acre	1·83	0·98
5. Total salts in lb. per acre	102·61	62·48
6. Lime (CaO) lost in lb. per acre	19·12	7·93

The number of days when there was run-off was 11 in the clean fallow plot while it was only 5 in the cropped plot. Losses of water and soil are also reduced by nearly 50 per cent in the plot with the cover crop of groundnut. The effect of the cover crop in the reduction of the run-off is threefold: *viz.* (1) interception of the rainfall by the crop reduces the intensity of the rain drops reaching the soil; (2) the spread of the crop offers mechanical obstruction to the flow of water; and (3) absorption of moisture by the crop reduces the cropped plot to a drier state than the uncropped one and the soil will readily absorb the rain water when in a dry state. This will tend to lessen run-off. For these reasons losses of soil and water by surface run-off, in the plot with the cover crop of groundnut were reduced to nearly half those occurring in the control plot. As stated earlier, most of the rainfall is received in the period August to October, during the period when the *mungari* crops, if any are sown, are on the field. It will therefore be advantageous to have strips or belts of a *mungari* crop across the slopes during the rainy period, in areas which are subject to severe erosion.

Soil conservation measures The main principle underlying methods of control of erosion is to reduce the velocity of the flowing water If the velocity is reduced its amount naturally gets reduced. Methods of control of erosion may be either mechanical or biological. Bunding, listing or scooping and damming are the purely mechanical methods of control of erosion. The flow of run-off water is checked and greater time allowed for it to soak into the land. In cultural operations like ploughing the soil is brought into good physical condition for absorption. Ploughing on slopy land should never be done along the slopes as the furrows will form channels of drainage and run-off will be increased. On the other hand ploughing across the slopes greatly adds to the capacity of the soil to absorb rain water.

If all the rain water gets into the land there is neither run-off nor erosion. But this is impossible and we can try by various measures to minimise erosion. We have seen how scooping reduces losses due to erosion considerably. Bunding, as advocated by the Department of Agriculture, is a very simple operation and rain water is held well in the compartments. The "bundformer" which forms bunds about 7 in. high can cover about 10 acres a day, the cost of working being only about four annas per acre. Being an annual operation, it should become part of the preparatory cultivation like the working of the *Guntaka* or the blade harrow.

Bunding as advocated in the Bombay Presidency differs from the system of bunds formed by the "bundformer". They are high bunds, about 2 to 3 feet in height and provided with waste weirs for the flow of surplus water. They are more or less permanent improvements which will be of greater use in very slopy fields. In such fields contour cultivation offers one of the best means of controlling erosion.

Among the biological methods of control of erosion, cultivation of crops should be done in such a way that the maximum protection to the soil is offered for as long a period as possible, during the rainy season. Strip cropping is one of the best examples among the methods of biological control of agricultural erosion. Wide-spaced, clean-tilled crops like cotton offer the least resistance to erosion, while close-growing crops like *korra* or groundnut offer the maximum resistance to erosion. The principle of strip cropping is to alternate strips of erosion-permitting with erosion-resisting crops. Under the local conditions of Hagari, mixtures of *korra* and cotton are sown in the *mungari* season. These can easily be replaced by strips of *korra* and strips of cotton. Not only is this anti-erosive; but it was found that there was minimum of root competition in such an arrangement. Strips of *korra* alternated with strips of groundnut also form an efficient cover against erosion.

I have attempted to place before you the main factors which contribute to excessive erosion in black soils and the magnitude of the soil and water losses that occur due to surface run-off. One example of mechanical method of control of erosion (scooping) and one example of biological method of control of erosion (cover crop of groundnut) were studied in detail as to their effects on the reduction of run-off. The necessity for obtaining such data under different agronomic practices and under different soil and climatic conditions is obvious. Only a beginning has been made in the study of erosion losses. Conservation of moisture in dry areas should necessarily aim at minimising run-off. A more efficient use should be made of the rain water, by making as much of it as possible get into the soil. This aspect of the problem will be dealt with in the next lecture.