https://doi.org/10.29321/MAJ.10.A04778

Relative Efficiency of Roots and Tops of Plants in Protecting the Soil from Erosion.*

By C. VIJAYARAGHAVAN, L. Ag.
AND
V. PANDURANGA RAO, M. A. (Madras); M. Sc. (Nebraska),
Dry Farming Station, Hagari.

Introduction. Since a plant cover, either natural or grown, is the main single controllable factor in erosion, an exact understanding of its effects is very valuable. Attempts to ascertain the rate of erosion of soil protected by both tops and roots of cultivated plants as compared with similar soil free from vegetation, are meagre. An immediate application of this knowledge is found in crop-growing. In the black-cotton soil tract of the Deccan where erosion of soil has become a serious proposition, it is important to know the erosion resistance efficiency of the several crops and crop-mixtures, growing in this zone.

In this tract only *mungari*[1] crops experience rains during their growing period. After the sowing of *hingari*[2] crops usually no further rains are received. These studies were made during the two seasons 1938—39 and 1939 – 40. As these pertain only to erosion, only crops which receive rain during their growth are included. Such of those *hingari* crops as figure in *mungari* mixtures only have been included in these experiments. In Section I a general survey of the relative efficiency of crops and crop-mixtures in protecting the soil from erosion is detailed. Section II deals with their relative efficiency at different stages of growth.

Technique. The technique adopted in these studies was that developed by Kramer and Weaver (1936) at the University of Nebraska, Lincoln, Nebraska, U. S. A. Stout frames 40 inches long and 20 inches wide inside and 4 inches deep were made of teak wood one inch thick. The corners were firmly reinforced outside, by angle irons held in place by screws. The frames were taken to the field and placed over samples carefully selected as representative of the area. Pairs of samples were taken only a few feet apart. Care was taken that the tops of all plants rooted inside the frame were included and those rooted outside excluded. Tops of plants immediately surrounding the frames were then removed. Care was exercised not to damage the plants within the frame. With a sharp mason's trowel the core of soil was cut to a depth of 4 inches around the frame in such a manner that the frame could be forced to this depth in the soil, holding firmly the enclosed sample. Laths nailed to the edges of the frame and between the rows of plants, were used to hold the soil in the frame when it was tilted. The frame was next undermined by digging the soil from the

---

* Paper read at the Twenty-ninth college day and conference, July 1940.

1. *Mungari*=*Kharif*=Early South west monsoon.
2. *Hingari*=*Rabi*=North east monsoon.

ends and, especially, from both sides in such a manner that a blunt wedge was formed from the soil core protruding beneath the frame. The frame was then carefully tipped on its side, but only after a sufficient excavation had been made so that the tops of plants like *setaria* or *sorghum* would not be crushed against the soil. The excess soil was removed and the bottom very carefully fastened in place while the frame lay on its side. The whole process, apparently so simple, was successfully accomplished after some experience. After the sample was secured, it was transplanted in a normal, erect position.

Since each sample contained 1·85 c.ft. of soil of approximately 175 – 200 lbs. in weight, securing it was arduous and painstaking work. The samples were lightly watered so that no dry soil remained. The frame was then placed lengthwise on a washing rack with a slope of 10°. A second frame of the same size but 12 inches deep was placed upon the first. It was held by a number of braces fitting over the frame beneath. A strip of wood ¾ inch wide was permanently fastened within the frame, one on the lower side of each wall, so that its edge protected the soil in the lower frame. Thus in eroding the soil no water came directly in contact with the sides of the lower frame until at least the upper 2 or 3 inches of soil were removed. A strip one inch wide had been removed from the lower end of the upper frame to permit surface soil to escape during this process, and 4 one-inch holes were bored in the lower end of the lower frame to furnish an exit for the water and eroded soil after the top of the soil had been worn away. Water was supplied from a 800 gallon tank on the top of a 40 feet tower, with the same hose and shower-bath nozzle and at a uniform distance of 2 feet from the surface of the soil. Care was taken to move the hose slowly back and forth in a regular manner so that the stream played for only an instant on any one portion of the soil. Two gallons of water were delivered from the nozzle per minute in 35 streams. Throughout the period of washing the soil, the head of water was maintained at practically the same level by two men operating continuously the hand pump connecting the tank.

The objective sought was to erode the whole surface of the soil as uniformly as possible until the entire sample disappeared. This was especially difficult to accomplish where the soil was protected by a plant cover. If all the soil had been eroded in places, obviously additional water on the bottom of the box would have merely prolonged the erosion time. Consequently, before this point was attained, a helper determined where ridges and columns of soil were holding longest and the operator directed the stream of water upon them. The necessary uniformity of method, essential to consistent results, was attained by the same investigator directing where the stream should fall.

Roots and other underground plant materials were caught upon a large copper screen with close meshes, attached near the end of the box and through which all of the water and eroded soil had to pass. The duplicate samples gave fairly similar results showing the accuracy of sampling. The

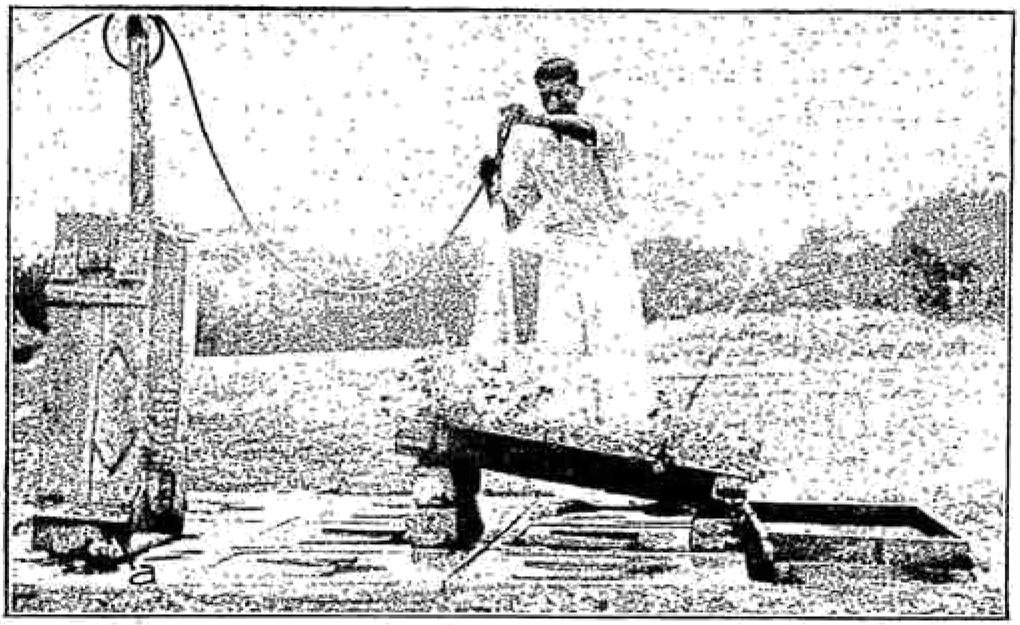

Illustration showing the technique adopted in studying the relative efficiency of crops in protecting the soil from erosion.

The second frame (a) is placed on the frame with the soil and crop while washing and is of the same size.

tops and roots of plants so secured were again carefully washed and each secured separately. The volume of roots in each sample was determined by displacement of water in a cylindrical graduate. The tops and roots were separately dried in a steam oven and the dry weights recorded after cooling in a desiccator.

I. Relative Efficiency of Crops and Crop mixtures in protecting the Soil from Erosion.

(a) *Sorghum—groundnut mixtures.* Sorghum and bunch variety of groundnut *(Arachis hypogea)* were sown in the following proportions: (1) sorghum—groundnut (1:1): (2) sorghum in between rows of groundnut. The groundnut crop was sown in August and sorghum in October and at the time of sampling the former was 90 days old and the plants 16 cm tall. The sorghum crop was 45 days old with a height of 23 cm. In the mixture in which sorghum was sown between rows of groundnut the time taken for completely washing the soil in the frames was 67 minutes. The erosion ratio for this mixture was 1:2*. In the mixture in which sorghum lines alternated with those of groundnut, the time taken was 63 minutes, the erosion ratio being 1:1·9. The effect of these mixtures in protecting the soil from erosion is similar.

(b) *Groundnut-pure (bunch):—* In the pure crops, groundnut grew to a height of 30 cm. and the plants were very bushy. This bushy growth, however, did not prevent water from reaching the ground through the interstices of leaves and branches. The soil was easily eroded as the root-system did not ramify the soil well enough to bind it. But for the soil protected by the lodged leaves and branches, the rest of it was easily eroded. All the soil was completely washed away in 112 minutes, the erosion ratio being 1:3·4.

(c) *Sorghum-pure :—* The plants were in shot blade with a height of 100 cm. Though the broad, swaying leaves considerably checked the beat of the water, the thin stand of the grain crop could not effectively prevent water from reaching the soil surface. Erosion occurred fairly quickly, though the thick crown roots held the soil for some time. The lodged leaves also protected the soil. All the soil in the box was washed away in 123 minutes, the erosion ratio working out to 1:3·7.

It will be seen that pure crops of sorghum and groundnut are more effective in protecting the soil than mixtures of these. This is so because pure crops are better and more vigorously grown than the crops sown mixed, and between the two pure crops there is not much to choose.

(d) *Setaria—cotton mixtures (1:1).* At the time of examination, the plants were 60—80 days old. Setaria (*Setaria italica*) plants had finished flowering, had 2—3 tillers per plant and were about 80 cm. in height.

* The time taken for completely eroding bare soil was 33 minutes. Assuming this time to be unity, erosion ratio for the several crops was calculated. For each set, paired samples were taken. The data are presented in the table I appended. These studies were made in 1938-39.

Cotton *(Gossypium herbaceum)* had just started flowering and the plants were 43 cm tall. Under the impact of water, the Setaria plants began to lodge. Gradually the plant cover settled closer to the earth as the hold of the roots was slowly weakened, but the process was slow. The mass of Setaria roots held firmly since the force of water was broken and erosion proceeded slowly. By the end of an hour the soil had been removed to the bottom of the box in only a few of the least protected places. Finally the soil between the rows gave way but the rows themselves held, each as a separate unit, and only after a long time was all the soil eroded. Though the cotton roots constituted a fourth of the weight and volume in the mixture, they were not so efficient in protecting the soil as they were stout and had sparse lateral branches; but the broad leaves of cotton were effective. In Setaria, the innumerable tillers and flowing leaves, combined with thick stand intercept a great deal of the falling water, thus breaking the force of the impact. This action is effectively reinforced by the dense crown roots at stem bases with their well ramified fine branch roots. The time taken for completely washing the soil was 108 minutes, the erosion ratio being 1:3·3.

(e) *Setaria--horsegram mixtures (2 Setaria:1 horsegram).* The Setaria plants were of the same size as those in the above mixture. Horsegram (*Dolichos biflorus*) plants attained a height of 18 cm. In this mixture, the soil was completely eroded in 2 hours and 32 minutes, with an erosion ratio of 1:4·6.

(f) *Setaria—groundnut (spreading) mixtures (1 : 1).* In these mixtures, the groundnut plants had foliage with a lateral spread of 32 cm. The Setaria plants were of the same size as those in the above mixtures. The lodged plants settled down on the spread haulms of groundnut forming such an efficient cover that erosion occurred very slowly. It took 3 hours and 38 minutes for all the soil to wash, the erosion ratio being 1 : 6·6. In this mixture, the efficiency of Setaria as a crop in protecting the soil against erosion, was greatly strengthened by the spread foliage of groundnut.

(g) *Setaria—pure.* The pure crop of Setaria had a very vigorous growth and it took 188 minutes of washing to completely erode the soil, with an erosion ratio of 1 : 5·7.

(h) *Cotton—pure.* The soil was completely washed away in 55 minutes, with an erosion ratio of 1 : 1·6. It will be seen that this is practically no better than bare soil. But in mixtures with Setaria, the erosion ratio rises to 3·3.

(i) *Groundnut (spreading)—pure.* In pure plots with spreading groundnut, all the soil was completely washed away in 164 minutes, with an erosion ratio of 1 : 5·0. In mixtures with Setaria, this ratio rises to 6·6, increasing the efficiency of the mixture. In the pure plots the stand was not so good. In spite of this, the spreading foliage protected the soil for a long time. If the stand were good, it is doubtful if the soil would have been eroded even after hours of washing. The leaflets afforded complete protection to the soil beneath them. The impact of the continuous beating

TABLE I. Relative efficiency of tops and roots of crop mixtures in protecting the soil from erosion.

	Age of plants.	No. of plants.	Height of plants.	Spread of plants.	Number of tillers.	Weight of shoot (dry)	Volume of roots.	Weight of roots (dry)	Erosion time.	Erosion ratio (bare soil = 1).	Remarks.
	days.		cm.	cm.		gm.	cc.	gm.	min.		
Bare soil	—	—	—	—	—	—	—	—	33	—	
Cotton pure	84	12·0	54·0	—	—	110·2	19	8·12	55	1:1·6	Flowering.
Sorghum-groundnut (1:1)											
groundnut (Bunch)	90	11·0	16·0	—	—	66·18	21	3·75	63	1:1·9	Pod stage.
sorghum	45	7·0	23·0	—	—	3·81	13	2·15			
Sorghum in between groundnut											
lines: groundnut (Bunch) ...	90	11·0	17·0	—	—	63·32	15	2·87	67	1:2·0	Pod stage.
sorghum	45	16·0	21·0	—	—	5·35	15	1·80			
Setaria—cotton (1:1)											
setaria	73	7·5	85·0	—	24	30·23	39	11·36	108	1:3·3	Flowered.
cotton	73	8·0	43·0	—	—	20·64	10	2·97			
Groundnut (Bunch) pure ...	90	18·0	30·0	—	—	106·87	20	4·59	112	1:3·4	Pod stage.
Sorghum—pure	66	9·0	100·0	—	—	216·17	127	31·72	123	1:3·7	Boot stage.
Setaria—horsegram (2:1)											
setaria	63	13·0	60·0	—	28	42·16	39	7·53	152	1:4·6	Pre-flowering.
horsegram	63	4·0	18·0	—	—	6·56	8	1·04			
Groundnut (spreading) pure ...	50	13·0	—	19	—	29·90	25	3·25	164	1:5·0	Pod stage.
Setaria—pure	83	26·0	84·0	—	38	174·10	66	21·16	188	1:5·7	Dough stage.
Setaria—groundnut (spr.) (1:1)											
setaria	63	7·5	66·0	—	20	35·24	38	7·35	218	1:6·6	Pre-flowering.
groundnut (spreading) ...	63	7·5	—	32	—	26·80	18	2·54			
Pillipesara (*Phaseolus trilobus*)-pure	—	—	—	—	—	127·95	70	12·75	390	1:11·8	Flowered.

water on the leaflets could be noticed in the etching on the leaf surfaces. Most of the upper epidermis was damaged and chlorophyll in places washed off, giving the leaf a patchy appearance. In spite of this, the soil protected by them was not eroded. Because of the poor stand, water gradually worked through the uncovered portions of the soil and undermined the protected soil.

(j) *Pillipesara*—(*Phaseolus trilobus*) *pure*:—The almost complete protection afforded to the soil by a spread plant cover is graphically demonstrated in this crop whose vines and leaves get inextricably tangled and clothe the surface of the soil. As in the case of groundnut, the chlorophyll was scoured from the leaf surfaces in patches by the beating water but the leaves and vines effectively protected the soil beneath them. As a consequence, very little soil was eroded even after six hours of washing, the water percolating through the holes being fairly clear, instead of being muddy. At this stage, the cover was disturbed to hasten the washing. After this, the soil was quickly eroded. The time taken for completely washing the soil was 390 minutes, the erosion ratio being 1 : 11·8. This would have been considerably longer were the plant cover not disturbed (Table I).

These studies reveal that mixtures of sorghum with bunch groundnut are not effective in controlling soil erosion. In fact they are as ineffective as a pure crop of cotton in affording protection to the soil among the crops studied. Mixtures of Setaria and cotton improve the situation slightly. Setaria-horsegram mixtures are considerably better than these. Setaria-groundnut (spreading) combination is the best among the crop mixtures. Pure spreading crops are clearly of advantage. Of the cereals, Setaria with its thick stand, numerous tillers, swaying leaves and panicles and the extensively branched root-system is a very efficient crop in conserving the soil. Though the broad flowing leaves of the single-stalked sorghum intercept and break the force of the falling water their thin stand is ineffective in protecting the soil. A pure crop of cotton protects the soil least. Naturally the loss due to erosion is highest in cotton fields. Sowing strips of cotton alternating with strips of Setaria reduces the severe root competition that exists under the present method of sowing and also helps in the conservation of the soil.

II. Relative efficiency of crops at different stages of growth in protecting the soil from erosion.

As it is common to receive rain at intervals during the growth of the crop in the *mungari* season, a knowledge of the relative efficiency of shoot and root at these stages will give accurate information regarding the damage done to the soil due to erosion were such plant cover not existent and also the protection afforded by the various crops at those stages of growth. The technique adopted was the same as in Section I. Paired samples were taken after each rain. Detailed data are presented in Table II. The respective ages of the crops after each rain together with rainfall data are given below:—

TABLE II Relative efficiency of crops at different stages of growth, against soil erosion.

Plant cover.	Number of plants.	Height of plants. cm.	Spread of plants. cm.	Numbr of tillers.	Volume of root. cc,	Weight of roots (dry) gm.	Weight of shoot (dry) gm.	Erosion time. min.	Erosion ratio (bare soil=1).	Rainfall received: in the interval (inches).	Rainfall received: prior to sampling (inches).
Bare Soil.	...	...	...	...	...	...	...	45	...	...	...
Cotton Pure.											
35 days old.	15·0	21·5	...	...	8·0	1·335	14·31	49	1:1·09	2·66	0·54
50 ,,	10·5	28·0	...	...	14·0	3·610	24·66	55	1:1·20	0·43	0·42
68 ,,	16·0	39·5	...	...	26·5	7·160	65·97	83	1;1 84	7·18	2·76
89 ,,	15·0	43·0	...	...	16·0	5·300	54·23	73	1:1·60	0·49	0·33
Setaria Cotton Mixtures.											
35 days old Setaria.	50·5	15·0	...	1	26·5	2·270	4·74	84·5	1:1·90	2·69	0·54
35 days old cotton.	10·0	14·8	...	...	2·5	0·480	3·94				
50 ,, Setaria.	15·0	31·5	...	1—4	26 0	4 430	12·81	100	1:2·20	0·43	0·42
50 ,, cotton.	8·5	20·0	...	...	7·0	1·750	10·84				
67 ,, Setaria.	20·0	48·0	...	...	17·5	3 160	12·49	140	1:3·10	7·18	2·76
67 ,, cotton.	10·0	24·0	...	...	9·0	2·580	14·77				
87 ,, Setaria.	14·0	53·0	...	1—2	9·5	2·650	18·09	135	1:3·0	0·49	0·33
87 ,, cotton.	11·0	31·0	...	...	9·0	2·720	14·89				
Setaria Pure.											
30 days old.	62·5	25·5	...	1—2	74·0	8·090	14·01	121·5	1:2·7	2·66	0 54
50 ,,	59·0	50 5	...	1—2	90·0	12·220	42·23	166·0	1:3·7	0 43	0·42
68 ,,	73·0	61 3	...	1—3	57·5	11·290	98·14	197·5	1:4 4	7·18	2·76
88 ,,	92·0	58·0	...	1—2	60·5	13·550	80·98	225·0	1:5 0	0·49	0·33
Groundnut (Spreading) Pure.											
35 days old.	13·5	...	37·5	...	30·0	4·850	42·82	109·5	1:2·4	2·66	0·54
50 ,,	20·5	...	33·0	...	42·5	6·730	55·18	129·0	1:2·9	0·43	0·42
68 ,,	15·0	...	40·0	...	54 0	9·360	109·02	163·5	1:3·6	7·18	2·76
90 ,,	17·0	...	45·0	...	47·5	10·630	160·21	240·0	1:5·3	0·49	0·33

TABLE III.

Age of Plants. (Days)	Rainfall received in the interval. (inches)	Rainfall received prior to sampling. (inches)
35	2·66	0·54
50	0·43	0·42
68	7·18	2·76
89	0·49	0·33
Total.	10·76	

(a) *Cotton pure.* Erosion time and erosion ratio at each stage are given below :

TABLE IV.

Age of plants. days.	Erosion time. minutes.	Erosion ratio.*
35	49	1:1·09
50	55	1:1·20
68	83	1:1·84
89	73	1:1·60

Though with the growth of the plant there is a slight increase in the erosion ratio, it is negligible. This is practically no better than bare soil. Thus at any stage of growth, cotton affords very little protection to the soil against soil loss.

(b) *Setaria – Cotton mixtures* (1:1). Inspite of the reduced growth due to severe root competition, the Setaria-cotton mixtures afford better protection, to the soil than a pure cotton crop. Below are given the erosion time and erosion ratios :—

TABLE V.

Age of plants. days.	Erosion time. (minutes).	Erosion ratio.
35	84·5	1:1·9
50	100·0	1:2·2
67	140·0	1:3·1
57	135·0	1:3·0

The crops in this mixture afford increasing protection with progressive growth in them. This increased efficiency at each stage is not due to the cotton but to the Setaria crop in the mixture. The extensive and dense root system in the soil and the numerous tillers with swaying leaves, break the force of falling water, reducing the soil loss. In the early stages of crop growth, the Setaria roots particularly bind the soil well.

(c) *Setaria—pure.* Because of its earliness, this crop develops and expands its vegetative organs quickly. In the early stages of the crop, the

* These studies were made in 1939–40. The time taken for completely eroding bare soil was 45 minutes. Assuming this time to be unity, erosion ratios have been calculated.

roots are very efficient soil binders, but in later stages the gradually expanding shoot also plays a dominant role The numerous leaves and tillers break the force of falling water and what little water that reaches the ground is further arrested and spread by the closely situated root crowns (as this crop is usually sown thick). The barriers that these rows of root crowns create are such that they remain intact even after all the soil is washed away. From the erosion ratios given below it will be seen that a pure Setaria crop protects the soil efficiently.

TABLE VI.

Age of plants. days.	Erosion time. (minutes).	Erosion ratio.
35	121·5	1:2·7
50	166·0	1:3·7
68	197·5	1:4·4
80	225·0	1:5·0

(d) *Groundnut (spreading)—pure.* Due to the spreading habit the leaflets almost lie on the ground and afford complete protection to the soil. Naturally, as the plant grows and puts on more foliage, its efficiency in protecting the soil increases. The impact of the continuous beating water on the leaves could be noticed in the etching on the leaf surfaces. Most of the upper epidermis was damaged and chlorophyll in places washed off, giving the leaf a patchy appearance. Inspite of its good spread on the ground, small portions of the soil were exposed. Erosion occurred due to the water working through the uncovered portions of the soil and undermining the protected soil. Data showing the increasing efficiency are given below:—

TABLE VII.

Age of plants. days.	Erosion time. (minutes).	Erosion ratio.
35	109·5	1:2·4
50	129·0	1:2·9
68	163·5	1:3·6
90	240·0	1:5·3

Summary. In the 'Black Cotton' soil of the Bellary District, where sheet erosion of the soil has become a serious proposition, it is important to know the erosion resistance efficiency of the several crops and crop-mixtures grown in this tract. A special technique developed by Dr. J. E Weaver of the University of Nebraska, U. S. A., was adopted in these studies. This consists in washing *undisturbed* soil taken out in a wooden frame (40″ × 20″ × 4″) under different plant cover with a steady jet of water delivered in a fine spray simulating rain and noting the relative time taken to erode the soil completely.

From these studies it is clear that spreading crops like Pillipesara (*Phaseolus trilobus*) sown pure or the spreading varieties of groundnut are clearly of very great advantage. The bunch variety of groundnut, though it has a

bushy top, is not efficient as the foliage is at some height from the ground and not spreading over it. Of the cereals, Setaria with its thick stand, numerous tillers and swaying leaves and panicles, is a very efficient crop in conserving the soil. In Setaria an extensively branched and dense root system also contributes a great deal in reducing the soil loss. Sorghum is generally sown thin when raised as a grain crop. Though the broad, swaying leaves intercept and break the force of falling water, the thin stand operates against their efficiency and, consequently, the sorghum crop affords poor protection to the soil. Cotton with its stout tap-root and sparse lateral root system protects the soil least. Naturally the loss due to erosion is highest in cotton fields. It is obvious from these studies that a farmer, who has the interest of his land at heart and who does not want to face the inevitable ruin should not sow cotton pure in any of his fields. It should be sown along with a soil-binding crop, preferably a spreading one. Since a food crop is to find a place in this mixture, Setaria may meet the situation. But the present mode of sowing this mixture has to be modified since it is not economical. Strip cropping may be done to reduce the severe competition in the root-systems and at the same time protect the soil against erosion. These studies also show that when pure crops which do not afford efficient protection to the soil are grown, a suitable mixed cropping which will be economically, ecologically and agronomically advantageous should be resorted to.

Acknowledgment. Our thanks are due to the Imperial Council of Agricultural Research for the financial aid afforded for carrying out these investigations.

Literature Cited.

1. Kramer, J. and J. F. Weaver. 1936. Relative Efficiency of Tops and Roots of Plants in Protecting the Soil from Erosion. *Conserv. Dept. Conserv. and Survey Divisn. Univ. of Nebraska, Bull.* 12, pp. 1—94.

Soil Erosion and the Coffee Industry.*

By W. W. MAYNE, B. Sc.,

Coffee Scientific Officer, Balehonnur, Mysore.

Introduction. I make no apology for addressing you today on the ecological conditions of coffee cultivation in South India, as they afford several interesting points on the management of hill lands under conditions of heavy rainfall; such areas, in fact, on which soil erosion is commonly seen in its most serious and spectacular form.

History of coffee industry. Coffee must be regarded as the oldest of the three main plantation crops in South India, its history as a plantation crop extending back to about 1840. Although many areas planted with coffee have been abandoned or given over to tea, there are considerable areas still producing satisfactory crops, which have been under cultivation for well over half a century. At least one estate in Mysore is known to me

* Paper read at the Twenty-ninth College day and conference of the M. A. S. U. July 1940.