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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.

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Soil Erosion and the Coffee Industry.*

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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

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which has been under coffee for a hundred years and which still exists as a productive agricultural unit.

Permanence of plantation crops. This feature of coffee cultivation in South India is perhaps more remarkable than appears at first sight. If we glance at the history of the great tropical 'permanent crops', we find that 'permanent' is perhaps hardly the right term. The coffee industry of Ceylon started and ended within half a century and left the succeeding tea industry with little more than a subsoil over considerable areas of the hills of Ceylon. In Brazil, the coffee industry has been based on the exploitation of fresh lands as the earlier plantations declined. Recent reports indicate that the great coffee industry which has grown up in Colombia in the last thirty or forty years is faced with declining production.

The other perennial crop industries in the wet tropics have hardly had time to show what degree of permanence they possess. The dangers inherent in such forms of agriculture are, however, sufficiently obvious now and there are clear signs of a realization of their importance in agricultural practice. There still remains much to be done, not only in applying conservation methods already known, but in investigating the means of ensuring a stable agriculture in the large areas of evergreen and monsoon forest which have been opened up for the increased production of tropical commodities during the last half century.

System of coffee cultivation and the problem of soil erosion. I believe that the system of coffee cultivation in South India represents one solution of the problem of a stable agriculture under the topographical, pedological and climatic conditions of the coffee growing areas. It is, of course, a particular solution applicable only to coffee (and also to cardamoms) but an examination of one solution may not be without interest in considering the general problem of soil erosion. Further, the solution is only a partial one and there are many ways in which the situation ought to be improved. The fact that the system is one which greatly minimizes soil losses must not be allowed to obscure the existence of danger points which demand special measures.

Although the first essential of an enduring agriculture must be a stable surface soil, protected against the dangers of soil erosion, it is an interesting paradox that the measures, which in a high degree provide this protection for coffee, were not introduced for this purpose at all. The result is that a considerable degree of protection against soil erosion has been incidental and the coffee planter is less alive to the dangers that still exist in certain areas and under certain conditions than he should be.

The system of cultivation in general use in South Indian coffee areas is, shortly, the culture of the crop plant under a continuous shade canopy, composed of a mixture of trees, many of which were constituents of the original plant association which had developed on the area prior to its cultivation. The mode of opening such land varies widely from a complete

clearing of the original jungle and planting shade along with the coffee to the simple undergrowthing and light thinning of the taller trees to permit the development of the young plants. Nowadays, the debris is normally burnt, but in the early days of coffee planting, a number of estates were opened without burning. It is perhaps not without significance that several estates opened in this way in the early days of coffee planting still exist as sound productive units, with no visible signs of serious soil deterioration

Undergrowth cultivation. The cultural treatment of coffee is normally conditioned by this system of what might be described as undergrowth cultivation. Coffee planters place great store by the preservation of the surface mulch which is built up from the leaf fall from the shade canopy. Soil cultivation with implements is comparatively restricted after the establishment of the young plants, though in this respect there is much variation in estate practice, depending to a considerable degree on the slope of the land.

Shade canopy and soil erosion. Under the shade, the coffee itself is planted closely, very much more closely than is normally the practice in other coffee growing countries, and the ground is covered by the coffee plants from a comparatively early age. From the point of view of soil erosion, this continuous shade canopy affords a very valuable protection against the beating action of the rain on the soil and at the same time reduces the effects of insolation in accelerating organic matter breakdown and reducing the soil's absorptive capacity for water. This protection is of course, further increased by the continuous cover of the crop itself Secondly the leaf fall from the shade provides a mulch which is of the utmost value, as has been shown by Lowdermilk in California, in reducing run-off considerably in excess of its absorptive capacity.

Erosion control in mature coffee plantations. In mature coffee therefore, erosion control is achieved to a considerable degree by natural methods—the utilization of a plant association approximating to quite a considerable degree to the natural vegetation of the areas, in which the crop is inserted, as it were. At the same time, it must be repeated that the value of the system has rarely been consciously attributed to its influence on the stability of the surface soil. This has resulted in a complete lack of recognition of the dangers which can arise from a failure to take additional precautionary measures under certain circumstances.

Erosion losses in young plantations. The main dangers arise in the early stages of opening land under coffee or in replanting old lands with new plants, and in the laying down of drainage which is frequently necessary. Under these conditions, the coffee industry has been slow to undertake conservation measures from a lack of understanding of the damage that can occur in a very short period of time.

Work in East Africa showed that in a coffee clearing on a slope of one in six and under a rainfall of between 60 and 80 inches without any contro

measures, the loss of soil amounted to 38 tons in two years or about 2½ per cent of the top foot of the soil. There is no reason to believe that losses of the same order do not occur in South India in newly opened land as the shade affords small protection at this stage and the rainfall and slopes often exceed those experienced in the experiment in question.

Erosion control measures rare in S. India. It is rare to see any measures for erosion control in coffee clearing in this country; planting and working is carried out up and down the slope, felled trees lie across the contours, cover crops are very rarely seen and only very recently has any interest been aroused in the use of green manure plant hedges. In only one district, where slopes are exceptionally steep, are any attempts at terracing common. Even the use of green manure hedges cannot be regarded as introduced as a measure of erosion control, since the emphasis is mainly on the provision of organic matter and of temporary shade. Contour ridging or box ridging such as is practised in East Africa is quite unknown.

Effects of erosion control measures are not spectacular. It is clear that much can be done in reducing the losses which undoubtedly occur in the early years of opening up coffee or when old areas are replanted. The great difficulty lies in convincing the planter of the damage that is taking place. The effects of erosion control may not be obvious nor the economic gains considerable. The results in the experiment quoted above are of interest in this respect. Where the erosion control measures depended on growing green manure hedges on contour bunds or on the provision of a cover crop, the check to soil losses was very great but the condition of the coffee in the dry season following the rains was noticeably better in the controls. This was traced to a lower percentage of soil moisture in the plots carrying the supplementary crops. To many planters, the immediate differences would bulk very much larger than prospective gains resulting from the soil retention, which could only be cashed in over a long period of years. Even where the control measures would not involve soil moisture competition, it is unlikely that any striking differences in growth and development would be visible for some considerable time and the cost factor would discourage a practice the value of which is not readily demonstrable. Herein lies the great problem of erosion control. In its spectacular manifestations, the damage done is obvious and calamitous. The spectacular manifestation is, however, the end product of a long series of invisible movements, the control of which means trouble and expenditure without any apparent return. The return comes in time in the maintenance of productivity and of the capital value of the land but unless the cultivation methods are very wasteful the differences may take a long time to show themselves.

Soil erosion not serious in South Indian coffee plantations. The situation is especially difficult in coffee, where with growth of the shade cover and the development of a litter of fallen leaf, the early losses are

checked and the damage done greatly slowed down. At the same time, the efficiency of the litter cover must be regarded as having been reduced by the damage done in the few years of exposure in the early stages of opening the land. At the same time, it must be pointed out that it is not easy to point to coffee areas in South India where a reasonable shade policy has been followed, which show serious signs of deterioration from soil erosion. Individual cases may occur on small areas where special circumstances play a part but speaking generally, I think it would be agreed by those familiar with South Indian coffee areas, that soil erosion plays a small part in determining the productivity of the land under this crop

Conclusion. In conclusion, therefore, it may be said that the system followed on most coffee areas in South India affords a substantial degree of protection against soil erosion. There seems no great need for elaborate measures for its control and on the whole, it seems that attention to the improvement of control by the use of vegetation will meet most of the needs of coffee cultivation. This requires most emphasis in connection with the opening up of land for coffee or the replanting of old land. Most of all, planters require education on the question of soil erosion so that special cases can receive prompt attention and that cultivation methods, especially trenching and draining, shall be carried out with the dangers of badly designed work in mind. There is no question that much can be done in opening new clearings by the effective disposal of debris along contours, carrying out weeding and other works along contours and by raising green manure crops at a very small cost to check the losses during the years before the shade and its litter become effective.

Some Correlations in the Appendages of the Indian Honey Bee.

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Introduction. That variations in honey bees are displayed not only in the average dimensions of their various appendages, but in the coefficients of correlations between such measurements as well, was indicated by Alpatov (1929). In the present paper are furnished the coefficients of correlation of the measurements of tongue, right forewing and right hind leg of four colonies of *Apis indica*, the variations in the biometry of which were reported previously (Ratnam, 1939). The data used for the present paper are the same as those used for the previous one.

Material and Method. The data relate to four colonies of *Apis indica*, which differed in the number of supers each had and in their honey storing abilities. About 50 nectar gathering bees from each hive were collected separately within a period of six days and killed immediately in cyanide bottles. They were numbered serially noting also the number of hive from which each bee was collected. Wings and leg were removed immediately