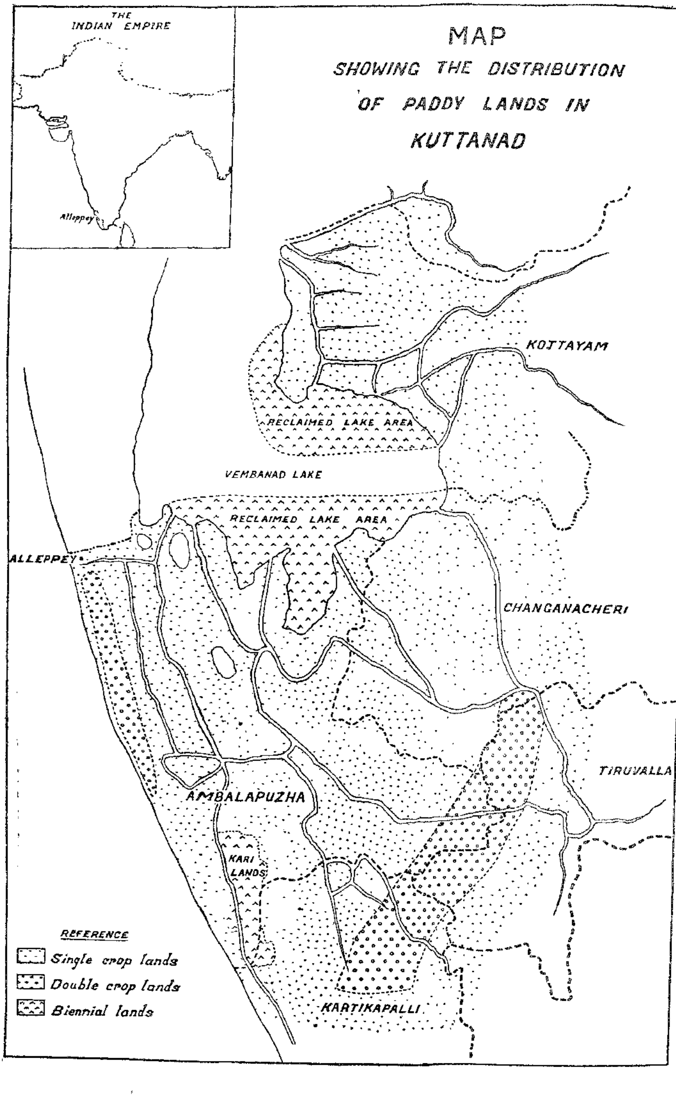
THE INDIAN EMPIRE
Alleppey
MAP
SHOWING THE DISTRIBUTION
OF PADDY LANDS IN
KUTTANAD
KOTTAYAM
RECLAIMED LAKE AREA
VEMBANAD LAKE
RECLAIMED LAKE AREA
ALLEPPEY
CHANGANACHERI
TIRUVALLA
AMBALAPUZHA
KARI LANDS
KARTIKAPALLI
REFERENCE
Single crop lands
Double crop lands
Biennial lands

SOME PECULIAR LOW-LYING SOILS OF CENTRAL TRAVANCORE.

By. T. R. Narayana Pillai and V. Subrahmanyan.

There is evidence that the area popularly known as *Kuttanad* was once a part of the Arabian Sea (K. Parameswaran Pillai, *Dept. of Agr. Travancore, Bull.*, 1924, 9). The land lies below sea-level, receives a high rainfall of about 150 inches and is subject to flooding by its numerous rivers and the sea. The slope is generally from east to west; and depending on locality, or farming enterprise, the cultivable area is under paddy (*a*) twice, or (*b*) once in the year, or (*c*) once in two years. Part of (*c*) is land reclaimed from a lake (*Vembanad*) and part from a marshy region (*Kari* land) which is peaty, and carries a characteristic vegetation.

Only on (*a*) is any crop raised during the monsoon months, June to October. The seeds are broadcasted during April and May when the land is generally dry. The rains begin soon after and the whole area passes under water and remains so till October, when the paddy is ready for harvest. If the opening rains are sudden and heavy, they uproot the plants and the crop fails entirely; but, if slow and steady, the seedlings withstand the flooding even if the depth of water exceeds 4 feet. The harvest is generally reaped when the land is under about 3 feet of water, and a yield of 1,200–1,500 lbs. of paddy per acre is obtained.

For the second crop on (*a*) and the only one on (*b*) and (*c*) the cultivation, which is begun either in late November or early December, is the same as elsewhere in the tropics with the following differences: (*a*) Shallow parts of the lake are reclaimed every alternate season by partitioning with high earthen walls and pumping out water into the main part of the lake until the level falls enough to permit cultivation; (*b*) The soil being wet and sticky, very little ploughing is possible; (*c*) Seeds are previously germinated and sown broadcast; (*d*) Owing to danger of early rains and consequent difficulty in drying, the straw is not cut but allowed to decompose in the soil. A yield of about 1,000 lbs. of paddy per acre is obtained.

Though Kuttanad remains one of the most fertile areas in the State, its yields are fast diminishing owing to disabilities such as (*a*) difficulties in cultivation, (*b*) unsuitedness of most chemical fertilisers, (*c*) danger of inundation with salt water, (*d*) decomposition of straw and sundry vegetation, (*e*) soil acidity and sickness, (*f*) plant diseases, and (*g*) visitation by grasshoppers and other insect pests.

A study of the soils was undertaken with a view to (*a*) determining the effect of the peculiar environment on their relative composition and character and (*b*) suggesting means for amelioration, and improvement of their yields. One of the authors (T. R. N. P.) toured the area in December, 1927; the collected specimens were air-dried and brought to Bangalore for examination.

EXPERIMENTAL.

Mechanical composition was determined by Robinson's pipette method as adopted by the Agricultural Education Association (*J. Agr. Sci.*, 1926, **16**, 123). The results have been recorded in Table I.

Although a number of soils were examined, only representative figures have been recorded in this and the following tables to clarify the main issues. Thus, A represents the average double-crop land; B, single-crop land; C, D and E, lake-area unreclaimed, or reclaimed 6 and 35 years ago respectively; also F, G and H, *Kari* land unreclaimed, and reclaimed about 6 and 40 years ago respectively. Where, however, differences between individual specimens of the same type exceeded those warranted by normal distribution, the maxima and minima of the ranges concerned have been recorded. Except when mentioned otherwise, the figures relate to surface soils only.

TABLE I.

Soil	Coarse sand	Fine sand	Silt	Fine silt	Clay	Hyg. moisture	Loss on ignition
A	7·95	17·32	9·08	17·20	22·92	9·54	14·63
B	7·09	20·23	9·06	16·50	26·13	9·33	10·42
C	2·34	39·54	8·25	11·50	19·00	6·49	9·41
D	2·77	47·20	7·13	9·88	15·50	4·65	8·82
E	20·70	37·60	4·50	7·50	15·75	4·63	7·70
F	14·07	0·55	0·75	7·75	11·25	27·90	33·10
G	5·05	12·00	8·00	15·50	28·25	11·65	17·20
H	22·90	21·35	10·00	14·50	13·75	8·60	6·10

The mechanical compositions of the average single and double-crop lands are similar, both being essentially light soils. The higher organic matter content of the double-crop land is probably due to the larger quantity of straw and other plant residues decomposing in it; but it does not appear to have affected the moisture retaining property which is nearly the same in both types of soil.

The lake-area is more sandy and contains less silt and clay than the other cultivated lands of Kuttanad. The portions under cultivation contain more of the coarser fractions than the unreclaimed ones, probably because the flood-water containing a large part of the lighter fractions is frequently pumped out. Since water is always plentiful, these soils are not likely to suffer from drought, although highly porous; but their composition suggests that they require considerable amounts of organic manures to replace the plant nutrients removed by flooding.

The remarkable differences between the three types of *Kari* lands should be attributed to cultivation, which prevents stagnation, facilitates proper aeration and provides adequate drainage. Whereas the unreclaimed portions are sticky, and contain considerable quantities of visible undecomposed plant residues which smoke and burn on ignition, the reclaimed areas are porous and contain only traces of undecomposed organic matter. The marked differences in composition between the wild and the reclaimed areas indicate that with the progress of cultivation the whole of *Kari* land can be brought to normal conditions except where proper drainage is impossible. The increased proportion of coarser fractions observed in the cultivated areas is probably due to (*a*) diminution of organic matter which, as observed on peat soils, appears to have become oxidised readily on being brought under cultivation and (*b*) draining of flood-water as in the lake-area.

The mechanical composition does not throw any light on the moisture or air-relations of the soils, because the latter (*a*) receive a high rainfall, (*b*) are almost always under water and (*c*) contain high percentages of organic matter, all of which factors modify greatly the physical properties of the soils concerned.

The mechanical composition of the sub-soils (9in.–3ft.) follows nearly the same order as that of the surface (Table II). Because they

TABLE II.

Soil	Coarse sand	Fine sand	Silt	Fine silt	Clay	Hyg. moisture	Loss on ignition
A	9·75	14·30	7·88	16·25	32·50	6·92	11·01
B	4·6	24·66	8·44	13·88	27·44	8·26	10·21
C	0·78	42·10	9·00	7·25	20·25	7·52	9·81
D	1·71	24·79	20·75	17·75	12·13	8·63	6·16
E	17·57	48·92	3·25	7·00	12·00	3·00	5·80
G	3·45	15·46	6·75	15·25	26·00	10·28	16·94
H	27·35	19·28	7·50	13·25	14·25	6·30	6·75

are not much affected by floods, they contain generally more of the finer and less of the coarser fractions than the surface soils. The plant residues occur largely in the surface soils and hence the sub-soils generally contain less organic matter and hygroscopic moisture than the former.

Saturation capacities for water were determined by Hilgard's method (cited from Hall, The Soil, 1921, 73), and were A, 66·15; B, 53·78; C, 55·04; D, 51·94; and E, 63·96 per cent. respectively. F, G and H absorbed no water even after standing for 24 hours. On further examination, it was observed that those soils contained a wax-like substance coating the soil particles and rendering them impermeable to water; investigation of this material is in progress. After its removal with ether, the soils absorbed water readily. The presence of the wax accounted also for (*a*) the very high percentage of hygroscopic moisture observed in F, the waxy film having rendered proper drying impossible by mere exposure to air, (*b*) the continued wilting of seedlings generally observed in the *Kari* lands even after a rain if preceded by drought. Its persistent occurrence in the soil forty years after reclamation suggests that, although other forms of organic matter are decomposed readily in the cultivated soil, the wax is highly resistant and causes considerable damage to the crop.

Saturation capacities of the other soils did not bear any direct relation to their mechanical composition. As in the *Kari* soils, however, it is possible that the nature rather than the quantity of organic matter may have influenced their water-absorbing properties.

TABLE III.

Soil	Available phosphorus as P_2O_5	Available potash as K_2O	Total nitrogen
A	135	14	2600
B	29	48	1580
C	13	120	1200
D	42	103	1050
E	83	100	400
F	210	30	2500
G	40	411	3900
H	27	10	1200

Nitrogen, Potassium and Phosphorus.

K. P. Pillai's figures (*loc. cit.*) showed that the total potash and phosphoric acid of the soils varied with locality. Since his figures for available phosphoric acid and potash were not complete, determinations were conducted on the different soils by Dyer's method (*J. C. S.*, 1894, **65**, 115). Total nitrogen was determined by the Kjeldahl method (Chemists' Year Book, 1927, 806) and nitrates by the phenoldisulphonic acid method (Harper, *J. Ind. Eng. Chem.*, 1924, **16**, 180) ; nitrates were absent. The results in parts per million (Table III) showed that all the cultivated soils excepting the double-crop lands were highly deficient in available phosphorus : but since even the latter become depleted with successive cropping, it may be inferred that Kuttanad soils will respond to phosphorus in an available form. The application of a suitable phosphatic manure will also (*a*) promote better root development thereby enabling the plants to withstand the heavy early rains, and (*b*) bring them to early harvest and thus greatly minimise the crop-failures so frequently experienced in Kuttanad.

Not all the soils were deficient in available potash. The double-crop and reclaimed *Kari* lands were poor and will respond to potash; but the single-crop and the lake-areas contained sufficient amounts to last for some years.

With exception of those from the lake-area, none of the soils were deficient in total nitrogen, but it is still possible that the major part is unavailable. Since there is no adequate technique for determining the availability of nitrogen in the soil, it will be necessary to carry out field trials, and to determine from the plant-growth and crop-yield whether the different types of soil will benefit by application of nitrogenous fertilisers.

The entire absence of nitrates from the soils must be due to (*a*) leaching of nitrates during monsoon months, (*b*) hindrance to nitrification by waterlogging (Subrahmanyan, *J. Agr. Sci.*, 1927, **17**, 429) and high percentage of soil moisture and (*c*) 'locking up' by micro-organisms in the decomposition of straw and other plant residues which are allowed to rot in the soil. Absence of nitrates should not, however, lower the agricultural value of the soil, because (*a*) the rice-plant responds more effectively to ammoniacal fertilisers than to nitrates and (*b*) nitrates, if present in more than minimal amounts, are reduced to nitrites, which are highly toxic to the rice-plant.

Reaction, Exchangeable Calcium and Lime Requirement.

The hydrogen-ion concentration of the soils was determined by Gillespie's method (*Soil Sci.*, 1920, **9**, 115), exchangeable calcium by Hissink's method (Chemists Year Book, 1927, 811) and lime requirement by the Hutchinson and McLennan method (*J. Agr. Sci.*, 1915, **7**, 75). The results (Table IV) showed that although most of the soils

TABLE IV.

Soil	P_H	Lime requirement Gms. CaO per 100 gms. soil	Exchangeable Ca Gms. CaO per 100 gms. soil
A	6·9–7·1	0·200	0·083
B	6·7-7·3	0·169	0·097
C	7 3	0·078	0·183
D	6·4–7·5	0·142–0·261	0·929–0·280
E	6·9	0·140	0·131
F	5·9	0·565	0·128
G	6·5	0·414	0·232
H	6·9	0·140	0·083

were slightly acid, their reactions, except in the case of the unreclaimed *Kari* land, were not such as would seriously affect plant growth. The reactions of the single-crop and the lake-area soils varied with locality and depended probably on the extent of (*a*) liming and (*b*) cultivation they received.

The acidity of the soils appears to be due to organic acids formed during incomplete oxidation of straw and other plant residues which decomposed in them. It was high in the unreclaimed *Kari* soil where undecomposed matter had accumulated in the marshes for years. The advance of cultivation by providing adequate drainage and aeration appears to have caused the organic acids to be rapidly oxidised and thereby brought about the marked improvement noticed in the reaction.

The cultivated soils were generally deficient in exchangeable calcium, probably owing to absorption by crop and loss by drainage. The abnormally large quantity noted in the recently reclaimed lake-area was due to shells of marine molluscs, occurring plentifully, and passing partially into solution on treatment with sodium chloride. The occurrence of appreciable amounts of exchangeable calcium in the different soils suggested that they were less affected by sea-water than the geographical conditions warranted. The cultivated soils were all deficient, and will improve with liming.

As observed by many other workers, there was a general agreement of sign, but no close relationship, between lime requirement and reaction of the soils. All the cultivated soils required lime, but only in moderate quantities. The high requirement of the unreclaimed *Kari* land was probably due to the large amount of free acid. There was a general negative correlation between exchangeable calcium and lime requirement of soils A, B, C and H, but the others, for reasons already stated, indicated the reverse.

WATER-SOLUBLE CONSTITUENTS.

To determine whether occasional inundations with sea-water had appreciably affected the water-soluble constituents of the soils (Chemists' Year Book, 1927, 830), estimations have been recorded as percentages in Table V.

TABLE V.

Soil	Chloride	Sulphate	Calcium oxide	Total solid	Alumina and ferric oxide
A	0·0022–0·0198	0·0016–0·0226	0·0018–0·0070	0·05–0 10	...
B	0·002–0·0154	0·0103–0·078	0·0018–0·0106	0·065–0·5	...
C	0·045	0·103	0·007	0·50	...
D	0·026–0·035	0·034–0·556	0·146–0·280	1·10–1·35	...
E	0·0088	0·0515	0·007	0·10	...
F	0·0617	2 307	0·44	3·375	0·575
G	0·0441	1·0609	0·1526	1·750	0·165
H	0·0133	0·0166	0·0142	0·175	...

The quantities of dissolved salts varied much with locality, but were not abnormal except on the unreclaimed *Kari* soil. Chloride, in particular, was uniformly low, thereby confirming the previous observation that the compositions of the cultivated soils were not affected by occasional inundation with sea-water. The heavy rains also might have washed out the soluble salts from time to time.

BACTERIAL NUMBERS.

To obtain an estimate of bacterial activity in the different soils, platings were made by Thornton's method (*Ann. Appl. Biol.*, 1922, **9**, 241). The average counts, in thousands, were:—A, 440; B, 350; C, 680; D, 355; E, 386; F, only fungi; G, 602; and H, 714. Excessive growth of fungi noticed in all the plates rendered counting difficult.

The very low counts of bacteria indicated that the soil conditions were not favourable to the growth and activity of those highly useful organisms. This was further confirmed by absence of nitrification and, probably, of nitrogen fixation bacteria because of the unfavourable reaction, in all the soils. The early appearance of large numbers of actively growing fungi on the plates indicated, on the other hand, that they (*a*) were favoured by the reaction and the presence of large quantities of straw and sundry vegetation, (*b*) occurred largely in the vegetative condition and (*c*) played an important part in the transformation of organic matter in the different soils of Kuttanad. The foregoing results also showed that, although Thornton's technique gives generally cleaner plates than most other count-media, it fails to keep down ready germination and rapid spread of fungi in some cases

DISCUSSION.

Although the general physical and physico-chemical characteristics of the soils of Kuttanad were not very different from those of most soils in other parts of the world, yet the natural conditions and the practised systems of agriculture bring them into a class by themselves. Because adequate cultivation and drainage are absent, and large quantities of straw and plant residues rot in them, they (*a*) contained much undecomposed organic matter, (*b*) were generally acid, (*c*) did not contain sufficient aerobic bacteria to bring about useful mineral transformations and (*d*) suffered from a large part of the nutrients being rendered unavailable by profuse vegetation of fungi.

Although rice-straw loses much of its feeding value after soaking under water, it still retains a large amount of cellulosic matter which, if properly utilised, can help to produce a useful synthetic fertiliser (Rege, *Ann. Appl. Biol.*, 1927, **14**, 1). A manure thus prepared will (*a*) be cheap to prepare because it will involve only the collection of waste materials from the soil and will involve no more labour in its preparation than that of occasional stirring, (*b*) become a convenient vehicle for the essential plant nutrients, (*c*) not be leached out by rains or drainage though the different nutrients will be readily available to growing plants, (*d*) contain no fresh decomposable matter and therefore neither turn acid nor encourage growth of undesirable organisms. If dung and cattle refuse, which are generally sold by Kuttanad farmers, be also added to the straw, the value of the manure will be greatly enhanced.

Although scientific advice for the preparation of the manure suited to each locality is to be preferred, a useful beginning can be made with that manufactured by the Agricultural Development Company (E.P., 219, 384), which works on a non-profit basis and therefore ensures the fullest value to the farmer. Adco contains, among other things, useful amounts of calcium, nitrogen and phosphorus, all essential to plant growth. It is quick in its action on rice-straw and converts it into a manure in about two months.

It should be possible to prepare the synthetic manure in the open during the major part of the year, but this may not be satisfactory if exposed to the exceptionally heavy monsoon rains which perhaps will remove the more useful portions. It will be advantageous either to prepare it only during the comparatively dry months or, if prepared during the monsoon, to protect it from being lixiviated.

The manure thus prepared may not supply all the lime required by the more acid soils. A useful scheme will be to apply burnt lime to such soils at the rate of 1–2 tons per acre soon after the summer harvest when the fields are comparatively dry. The liming should be continued until the reaction is corrected.

Although the essential nutrients will be released readily from the synthetic manure, it will be necessary to conduct a few preliminary field trials under the local conditions to determine the precise stage before or during plant growth at which the best results can be obtained.

SUMMARY AND CONCLUSIONS.

1. The natural conditions and the systems of agriculture practised on them place the soils of Kuttanad in a class by themselves, but a study of their physical texture and chemical composition showed that, with exception of the *Kari* lands, they are quite normal.

2. Defects such as acidity, non-availability of essential nutrients and inadequate bacterial activity were traced to accumulation of straw and other plant residues which, owing to difficulties in collection and drying, were generally allowed to decompose in the soil.

3. A scheme for correction of acidity, easy disposal and utilisation of decaying organic matter and improvement of soil fertility has been suggested.

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