Reprinted from "Fiji Agricultural Journal," (Vol. 25, Nos. 1-2); March, 1954.

THE SOILS OF THE NAVUA PLAINS AND THEIR CHEMICAL STATUS

BY J. P. FOX* AND I. T. TWYFORD

During the course of the Reconnaissance Soil Survey of Fiji, the Navua Plains were surveyed between June 15th and June 19th 1953 inclusive. In the absence of aerial photographs, one inch to one mile topographic maps were used.

The Navua Plains lie on the lower Navua River. Navua township, near the centre of the plain, is 26 miles by road west of Suva. The plains extend about 10 miles along the south coast of Viti Levu from Lobau River to Taunovo Bay, They reach their greatest width, five miles, on a line south-east from the Navua Gorge to the sea, and have an area of approximately 20,000 acres.

The Plains are formed of debris and alluvium brought down from the hills by the Navua River. Former islands remain as isolated hills and provide useful refuge in times of flood.

As the Navua Plains are on the south coast of Viti Levu they experience frequent heavy rains and have an annual rainfall of approximately 150 inches.

The former vegetation was tropical rain forest but this has long been cleared for native gardens. Since the arrival of the European, large areas have been established in para grass and rice. Only the very infertile peats and sandy soils support rushes, sedges, ferns and stunted trees.

Recent soils are formed on alluvium which is constantly receiving additions of fresh material or has ceased to receive such additions so recently that the soil forming processes of leaching and weathering have not had time to develop distinct soil horizons. Where the alluvium contains high proportions of silt and clay which readily weather to release plant nutrients, fertile soils are found, but where the proportion of sand is high the material has had little time to weather and few plant nutrients are available. In addition with the rainfall as high as at Navua, permeable, sandy soils are rapidly leached of the few plants nutrients they possess.

Soils in which ground water frequently rises to the surface or lies just below the surface for long periods, develop characteristic properties. The most important of these are the presence of conspicuous red brown iron oxide stains and dark brown concretions of iron and manganese oxides. Such soils are named Gley soils. Gley Recent soils also receive additions of fresh material from floods as they retain some characters of a Recent soil.

The main problem in the utilization of the Gley Recent soils, which are usually fertile, is to control the amount of water in the profile. This usually means removal of excess water by drainage but for rice crops, abundant water is no problem. However, the coarse Tokotoko sandy clays contain so much sand and are so little weathered that they contain a very small reserve of plant foods.

Where conditions are extremely wet and water lies on or above the ground level for long periods, the oxygen in the soil and ground water is used up and plant remains do not completely decompose and gradually accumulate. Shallow lakes and swamps may in time be completely filled by partially decomposed plant remains. This material is called peat, and soils formed from it are called Organic soils because they have developed through the activities of organisms and not from the deposition of mineral matter. The properties of peat vary with the type of vegetation accumulating and with the source of water forming the swamp. If the groundwater is rich in minerals, sedge plants flourish and produce a fertile mellow peat. If the ground water drains impoverished soils and a high proportion is derived directly from rain water, as at Navua, rushes and mosses form the dominant vegetation and produce acid, very infertile peats.

The Navua Plains' soils are formed on alluvium from basalt, andesite, coarse-grained diorite, and gabbro rocks. Field textures range from clay loams to sands and peat. Five soils series were recognized and they may be classified as follows:—

Recent soils:—
 Rewa clay loam
 Navua clay loam.
Gley Recent soils:—
 Tokotoko clay loam
 Tokotoko sandy clay loam
 Deuba sandy loam and sand.
Organic soils:—
 Melimeli peat.

SOIL DESCRIPTIONS

Rewa clay loam is developed on levees along the banks of the Navua River and the small streams draining the adjacent hills. A representative profile is:—

10 ins. brown clay loam; friable; moderate, fine blocky structure; passing over one inch to

26 ins. + reddish brown clay loam; friable; very fine blocky structure.

This soil is free draining and fertile. It is intensively used for dairying, bananas and food crops.

Navua clay loam lies at a lower level than the Rewa clay loam. Surface drainage is impeded because levees prevent water from flowing to the river and streams.

A profile from ½ mile east of the Deuba River is:—

6 ins. brown clay loam; friable; distinct, abundant, fine reddish brown mottles; grading over 2 ins. to

30 ins. + reddish brown fine sandy clay loam; distinct, medium sized reddish brown and light grey mottles; plastic.

Profiles vary with the degree of gleying, and with increased gleying grey colours appear.

Navua clay loam is moderately fertile and is used for dairying and rice production.

Laboratory data are given in the table at the end. The two samples were from 1 mile along Vakabalea Road from Queens Road turnoff and from Wainadoi Valley just outside the area studied.

These data indicate that the Navua clay loams are particularly low in acid soluble phosphate. In the case of the Wainadoi sample, lime is also low. Trials are needed to establish the suitability of dressings of phosphatic manures other than superphosphate which is readily "fixed" by tropical soils and made unavailable to plants. (See section on phosphates.)

Tokotoko clay loam is developed on recent sediments where water tables are near the surface. A profile from the corner of Queen's Road and Tokotoko Road is:—

5 ins. light olive brown clay loam; few small yellowish red mottles along root hairs; plastic; very fine blocky structure.

10 ins. grey clay loam· distinct, many, medium sized yellowish red mottles; plastic, dries out hard.

10 ins. grey clay; plastic; occasional greenish grey mottles; *ON* grey clay; prominent, coarse, reddish yellow mottles; plastic.

Where conditions are very wet, profile colours are greenish or bluish grey; this soil type is fertile and widely devoted to dairying and rice production.

Analytical data are given in the table, the profiles being located:

(1) near the junction of Queen's and Tokotoko Roads and

(2) 2½ miles west of the Navua river on Queen's Road.

The figures indicate that Tokotoko clays are low in phosphate and lime but have an adequate potash figure. Applications of phosphate and ground calcium carbonate should raise rice yields and improve pastures for dairying.

A small area of *Tokotoko sandy clay loam* occurs in the Taunovo valley. These soils have been formed by the deposition of silt and clay on coarser sediments. They are intermediate in properties between the Tokotoko soils and the Deuba soils, being more liable to suffer from drought than the former, and more fertile than the latter.

A profile is:—

8 ins. dark grey sandy clay loam; plastic; moderate, fine and very fine blocky structure; faint, fine, many yellowish red mottles, particularly along root hairs.

4 ins. dark grey sandy loam; plastic; distinct, many, medium sized yellowish red mottles; grading to

20 ins. + bluish grey sands; non-plastic; slightly sticky.

A larger area of Tokotoko sandy clay loam occurs between Togoru Creek and Melimeli village. The soils here appear to be infertile and support a vegetation of coarse grasses and ferns.

A profile is:

0–15 ins. very dark brown sandy clay loam, weakly developed fine nutty structure, friable to plastic, boundary sharp

ON 20 ins. + pale olive sandy clay, plastic, faint medium sized yellowish red mottles.

The present land use is rough grazing only, but the remains of rice fields can be seen.

A sample from the east of Togoru Creek, Queen's Road, was analysed and the results are shown in the Table.

These figures indicate an acute lack of phosphate and lime, and topdressings of those amendments may be the means of bringing into production present waste land.

Deuba sandy loam and sand are formed on coastal deposits of alluvium brought down by the Navua River. These are coarse and siliceous, and a typical profile on them, from the east side of Togoru Creek is:—

16 ins. dark grey brown sandy loam; plastic; distinct, medium sized red brown mottles, common; passing to

20 ins. light yellow brown sandy loam; slightly plastic; distinct medium sized reddish yellow mottles, common;

ON bluish grey sand, containing some clay.

Textures range from sandy loams to sands, and around the swamp the soils become slightly peaty.

Deuba sandy loam is strongly acid and leached of plant nutrients, as shown by the following samples from 1½ miles east of Deuba Hotel, and 1 mile west of the Pix Plantations, Vunidilo, whose analyses are quoted in the Table.

These samples indicate that Deuba soils have a low base capacity exchange so that applications of phosphate and lime should enable the ready establishment of pastures and improvements in yields of cassava and other root crops. At present where conditions are too dry for rice production this soil supports weeds and rough pasturage.

Melimeli peat is formed where the coastal sand ridges have ponded lagoons in the Melimeli, Togoru and Wainisau streams. These lagoons have gradually filled with organic matter which has decomposed to peat. A profile from alongside an old tramline, one mile west of Melimeli is:—

8 ins. dark reddish brown peat; having a nutty structure on dry surfaces

10 ins. dark reddish brown peat; 1/3 fibrous matter. 2/3 gelatinous matter;

12 ins. dark reddish brown peat; 1/4 mushy root remains,

ON greyish sand.

The depth of peat ranges from 18 ins. to more than 36 ins. and the substrate is sandy. Access is difficult and the exact boundaries are not determined. At present they support a vegetation of rushes, ferns, sago palms, pandanus, and shrubby trees and are used only for rough grazing in dry periods. Analyses, as shown in the table, were carried out on samples 1 mile west of Melimeli village and from ½ mile on the north side of Queen's Road opposite Waimate beach.

Analytical data for peats should not be assessed in the same way as for mineral soils. Most of the nutrients are bound up in the organic matter and are unavailable to plants. Thus, the high figures for acid soluble phosphate are almost certainly not indicative of an adequate level and of no response to phosphatic fertilizing; likewise, the high exchangeable potassium does not imply luxury quantities of this element for plant food.

The main thing shown by the analyses is that the peats are very highly acid. The very low base saturation shows that large applications of fertilizer would be necessary before the peats could be considered as even moderately fertile, beside the problems posed by their extremely poor drainage, so that cultivation of these at present, would probably be prohibitively expensive.

LABORATORY INVESTIGATIONS

1. METHODS

pH was determined by a glass electrode using the standard soil: water ratio of 1:2·5, organic carbon by the Walkley-Black wet oxidation method, total nitrogen by a micro-Kjeldahl. "Available" phosphate was determined by a modified Truog method and total phosphate by a colorimetric procedure after fusion. Base exchange data were obtained by the use of neutral normal ammonium acetate, calcium and mangesium being separately estimated by "versene" solution, potassium by cobaltnitrite, and sodium by Kahane's procedure. Mechanical analysis was carried out by the International pipette method, the data being uncorrected for organic matter, and the other physical data were obtained from Keen-Raczkowski experiments.

2. OBSERVATIONS AND INTERPRETATION OF RESULTS

(a) *Introduction*

In a Soil Survey of the present nature, it is obvious that only a relatively small number of samples can be dealt with in the laboratory, hence the results are often not statistically highly significant. Thus only nine profiles from this area involving nineteen soil samples, were analysed. Navua plains however, is a moderately small area, compared with the total area of Viti Levu and viewed in this light, the sampling was rather more detailed than usual. Furthermore, the soils are all formed in roughly the same manner, constituting an interdependent association and so they have marked similarities. In the main, the two differences which separate them are textural, i.e. whether sands or clays, and the degree of poor drainage. All the soils analysed are in fact gleyed to some extent.

The chemical and physical properties of gleyed soils differ in many ways from those of freely drained soils. In general, poorly drained soils are rarely very acidic, they are not eluviated, so that the base status of the topsoil is usually similar to that of lower horizons.

The lack of oxygen which obtains under these conditions for at least six months of the year has two main effects; firstly, it reduces the soil population, so that decomposition of plant material is slowed up, causing a high soil organic matter content with a high carbon-nitrogen ratio, and secondly it makes for reducing conditions in the soil. Compounds like ferric phosphate are thus reduced to ferrous phosphate to some extent, which releases one phosphate ion per three ferric phosphate molecules reduced. In additions, the ferrous phosphate is more soluble than ferric phosphate, so that acid soluble phosphate tends to rise down the profile of a gleyed soil. However, the total phosphates are nearly always low.

(b) *Acidity and Base Exchange*

The soils of the Navua plains are highly acidic, and with a low base status. This is shown by low pH's and low base saturation percentages. With the exception of the Vakabalea profile of Navua clay loam, the base saturations are all less than 35 per cent and far lower in the sandy profiles than in the clayey profiles. Base exchange capacities also fall regularly with clay content, after allowing for that due to organic matter, and are in general for Fiji, moderate to very low.

LABORATORY DATA.

Field No.	Laboratory No.	Soil Type	Location	Depth	pH	Acid soluble P_2O_5 mgr/100gr.	Total P_2O_5 mgr/100gr.	Acid soluble RO Total P_2O_5	Per cent C	Per cent N	C/N	Total Exchangeable cations m.e./100gr.	Cation exchange capacity m.e./gr100	Base Saturation per cent	Calcium m.e. per cent	Magnesium m.e. per cent	Potassium m.e. per cent	Sodium m.e. per cent	Coarse sand per cent	Fine sand per cent	Silt per cent	Clay per cent	Texture Rating	Water holding capacity per cent
87	246	Navua clay loam	1 m. along Vakabalea Road from turn-off	0″–12″	5·05	0·2	126	0·16	4·7	0·27	17	16·05	30·4	55	11·1	5·2	1·47	0·32	0·5	34·9	29·0	33·4	clay	74·5
	247			12″–18″	5·35	0·0	21	0·0	0·7	0·04	18	18·7	27·0	69	13·0	5·1	0·43	0·64	15·9	38·6	18·0	24·4	sandy clay loam	65·3
88	248	Navua clay loam	Waidoi Rubber plantation	0″– 7″	4·85	0·0	94	0·0	4·0	0·15	27	8·5	26·2	32	4·9	3·5	0·82	0·48	1·05	24·3	34·8	36·4	clay	85·7
	249			7″–16″	4·85	0·4	97	0·41	1·8	0·04	42	10·0	25·1	34	5·5	3·0	0·25	0·50	1·6	23·0	35·5	40·7	clay	77·2
80	231	Tokotoko clay loam	Near junction of Queens and Tokotoko Roads	0″–15″	4·8	0·8	129	0·62	4·5	0·22	21	8·25	28·4	29	5·0	2·4	0·48	0·48	1·25	13·5	37·0	42·9	clay	81·5
	232			15″–20″	4·7	0·7	41	1·70	1·8	0·07	24	7·6	25·2	30	3·9	3·5	0·72	0·55	4·9	17·4	36·2	42·7	clay	75·5
81	233	Tokotoko clay loam	Queens Road 2½ m. W. of Navua River	0″–15″	4·75	0·8	158	0·51	3·5	0·23	15	6·4	24·0	27	3·1	2·9	0·82	0·49	0·7	15·9	36·0	43·1	clay	81·0
	234			5″–15″	4·9	1·1	153	0·72	2·4	0·12	20	7·3	26·3	28	3·3	3·7	1·01	0·46	0·9	14·9	36·6	46·0	clay	73·7
	235			15″–20″	4·8	1·0	84	1·19	1·1	0·05	21	5·9	21·3	28	2·8	3·1	0·51	0·62	0·6	22·7	31·6	45·8	clay	70·1
82	236	Tokotoko sandy clay loam	Togoru Creek, Queens Road	0″–15″	4·5	2·8	136	2·06	12·3	0·43	29	2·5	50·6	5	1·3	0·6	0·46	0·51	15·7	22·3	18·1	26·6	clay loam ..	95·6
	237			15″	4·8	0·0	47	0·0	5·0	0·06	80	2·7	18·0	15	1·4	0·9	0·36	0·68	41·0	20·1	14·2	22·1	sandy clay loam	62·4
83	238	Deuba sandy loam	1½ m. E. of Deuba Hotel	0″–12″	5·3	2·9	87	3·33	7·8	0·29	27	1·15	14·9	5	0·8	0·1	0·61	0·31	51·5	19·3	2·8	13·3	sand	68·0
	239			12″–18″	5·5	1·8	36	5·0	1·0	0·03	33	0·7	7·3	10	0·4	0·0	0·57	0·15	76·9	11·4	5·3	7·0	sand	46·1
84	240	Deuba sandy loam	1 m. W. of Pix Plantation Vunidilo	0″– 8″	5·15	2·3	77	2·99	7·4	0·35	21	0·8	10·1	8	0·6	0·1	0·49	0·00	66·5	12·5	14·2	9·7	sandy loam ..	49·1
	241			8″–14″	5·35	3·6	56	6·42	1·4	0·06	23	0·4	3·8	10	0·3	0·05	0·60	0·14	85·9	6·3	3·3	6·1	sand	35·0
85	242	Melimili peat	1 m, W. of Melimeli village	0″– 8″	4·2	6·6	118	..	54·8	2·05	27	14·4	105·6	14	9·2	4·8	1·4	1·7	..	..	..	..	peat	..
	243			8″–16″	4·15	2·1	113	..	63·9	1·90	34	12·9	122·0	10·5	7·4	5·2	1·1	2·0	..	..	..	..	....	..
86	244	Melimeli peat	¼ m. N. side Queens Rd. oppostie Waimate Beach	0″– 6″	3·7	23·5	175	..	56·6	2·12	27	3·1	139·4	2	1·3	1·6	2·1	0·67	..	..	..	..	peat	..
	245			6″–12″	3·9	2·9	73	..	65·3	1·78	37	5·7	141·0	4	2·5	3·0	1·4	0·65	..	..	..	..	peat	..

It is likely that leaching goes on to a certain extent in the drier months of the year, especially in the sands, and in this case the low base saturations can be explained, especially in view of the fact that a highly acidic vegetational association is present.

Pastures on such soils as these would therefore be expected to respond markedly to liming. It is not known how far rice is acid tolerant, i.e. what is the optimum soil pH for the growth of this crop, but it seems very likely that an increase in the calcium status of these soils would have a beneficial effect on rice, if only by release of phosphorus consequent on a rise in pH or by improvement of the soil structure, to mention only two other beneficial effects of liming. These conjectures can only be verified or disproved by properly designed field experiments.

(*c*) *Phosphate*

The interpretation of phosphate analytical data is very difficult. Two determinations are normally carried out, total phosphorus and that fraction soluble in n/100 sulphuric acid (Truog's method). The former undoubtedly constitutes the total phosphorus reserves of the soil and the latter is supposed to give an indication of that fraction of the soil phosphorus available to plants. However, workers in other countries have found that crop responses to phosphorus do not correlate very well in some cases with predictions using acid-soluble phosphorus figures.

The problem is further complicated by "phosphate fixation". This phenomenon is the rendering unavailable to plants of easily soluble phosphates in the soil. In general, a dressing of phosphate on a field as fertilizer calculated by phosphate requirements of the crop plant, gives very poor results. A 10 per cent utilization of a phosphate dressing may be considered as highly satisfactory even over 10 to 15 years.

The reason for this is that the phosphate anion combines to a greater or lesser extent in soils with various cations and other substances, the products of which are relatively insoluble and hence unavailable to plants. There are various mechanisms by which this happens and they differ between tropical countries and temperate countries. Differences in phosphate fixation, as it is called, are also found between freely drained soils and poorly drained soils as on the Navua Plains. Overseas experience indicates that the water logging of a dry soil lowers fixation to some extent and that in a particular profile the amount of fixation decreases with increase in depth and wetness. The rate at which this process takes place is, in general, fairly fast, so that phosphate added in a fertilizer dressing usually is rendered unavailable to plants before they can make full use of it.

Peat soils usually show high acid soluble phosphate but this would appear to be unavailable to plants since they usually respond to phosphate dressings.

To consider now the laboratory results for the Navua soils, it is clear that both the acid soluble and the total phosphates are very low, averaging (for the mineral soils) 1·2 mgr./100 gr. soil and 89 mgr./100 gr. soil respectively (compare the average for all soils analysed in the Soil Survey of Viti Levu, of 3·0 and 161 mgr./100 gr. respectively). The amounts of total phosphate decrease with decreasing clay percentages with some aberrations where there are high organic matter contents. This would seem to show that the clay (which includes the iron and aluminium oxides) is in most cases, still the predominant seat of fixation, as the acid soluble phosphates show no such correlation with clay content.

There are two obvious methods to overcome this to some extent:—

(*a*) by placing phosphate fertilizer as near the feeding roots as possible, such as in band dressings and

(*b*) by using substances which are relatively insoluble in themselves, but which continually release quantities of phosphate, usually by acid decomposition, which the plant roots in the vicinity can use immediately. Such substances are apatite and rock phosphate.

It is recommended that properly designed field trials on the phosphate fertilization of rice be laid down to decide what the optimum dressings are, and also to test the validity of the chemical methods used for phosphate estimations, and perhaps to design new ones.

(d) *Organic matter and nitrogen*

In general the soils are well supplied with organic matter, but the very high C:N ratios indicate the lack of decomposition under poorly drained conditions. The nitrogen contents are however, adequate despite the high C:N ratios, though how much of this is in an available forms, it is not possible to say. Rice typically responds to nitrogen.

(e) *Potash and Sodium*

The former nutrient, as indicated by the analytical data, is well supplied in Navua soils, and there should not be any serious need of potash fertili·er at present.

(f) *Mechanical Analysis*

No signs are detected from the sodium data of encroaching seawater, as might have been expected from the location.

The soils fall into three groups, those with above 30 per cent of clay, those with 20 per cent to 30 per cent and those with less than 15 per cent. Silt percentages are somewhat less than, and follow the trends of, the clay contents. The soils of the first and second groups would be, on a mechanical basis, therefore, the best for rice growing, as the sands of the third group tend to lose water very quiekly and may even be droughty in dry wheather.

(g) *Water holding capacity*

The amounts of water the soil can hold are very high, even the sands well supplied with organic matter. It appears that organic matter acts just like clay with regard to moisture retention and this fact increases the usefulness of the sands, so long as the content of organic matter is kept up.

CONCLUSIONS AND PROSPECTS FOR DEVELOPMENT

All the Navua and Tokotoko clay loams are being used for dairying or rice production except for about 750 acres in Melimeli Creek and 750 acres in the Lobau valley. The remaining areas of undeveloped land consist of approximately 3,250 acres of Melimeli peats, 2,000 acres of Deuba sandy loam and sand and 1,000 acres of Tokotoko sandy clay loam.

Mr. P. McNee, of the Irrigation and Drainage Department, Malaya, who was consulted by the Fiji Government on the prospects for the draining and irrigation of the Navua Plains, recommends a controlled drainage and irrigation programme for rice. The cost of this will be borne by the Colonial Development Rice Scheme Fund of £3 million.

The fertility requirements of rice are not fully known. However, experience in Asia shows that nitrogen as ammonium sulphate gives increased yields in almost every case, phosphate gives increased yields on deficient soils and it requires several years to bring the yield up to the maximum in spite of heavy dressings. Organic manures usually give responses, potassium only on iron leached soils of very low exchangeable cation content. Experiments in Asia on liming acid rice soils are not encouraging (see the Report of the second meeting of the Working Party on fertilizers of the International Rice Commission of F.A.O., May 1953).

The available chemical data indicate that these soils, compared with those at Sigatoka, are low in lime and phosphate, sometimes in magnesium. Fertiliser trials should be carried out on these soils to study the effects of ground limestone and phosphate manures, other than superphosphate, on pasture and rice production.

The peats offer difficulties in development because they are very close to sea level, and on draining they can be expected to shrink 9 inches to 24 inches below their present surface. In addition these soils are low in plant nutrients and will require expensive top-dressings for adequate production.

A possible method of reclamation is that of warping. This is the flooding of the low lying peaty areas with silt laden waters which, on being allowed to stand, deposit a thin layer of sediment. The process is repeated during and after each storm until a sufficient depth of fresh sediment has been built up to enable farming to be carried out.

The Melimeli Creek provides a suitable source of water and the main outlay involved is the construction of dykes to contain the flood waters.

It is suggested that the engineering possibilities of this method of reclamation be investigated both for the Navua swamps and the Toga swamp.

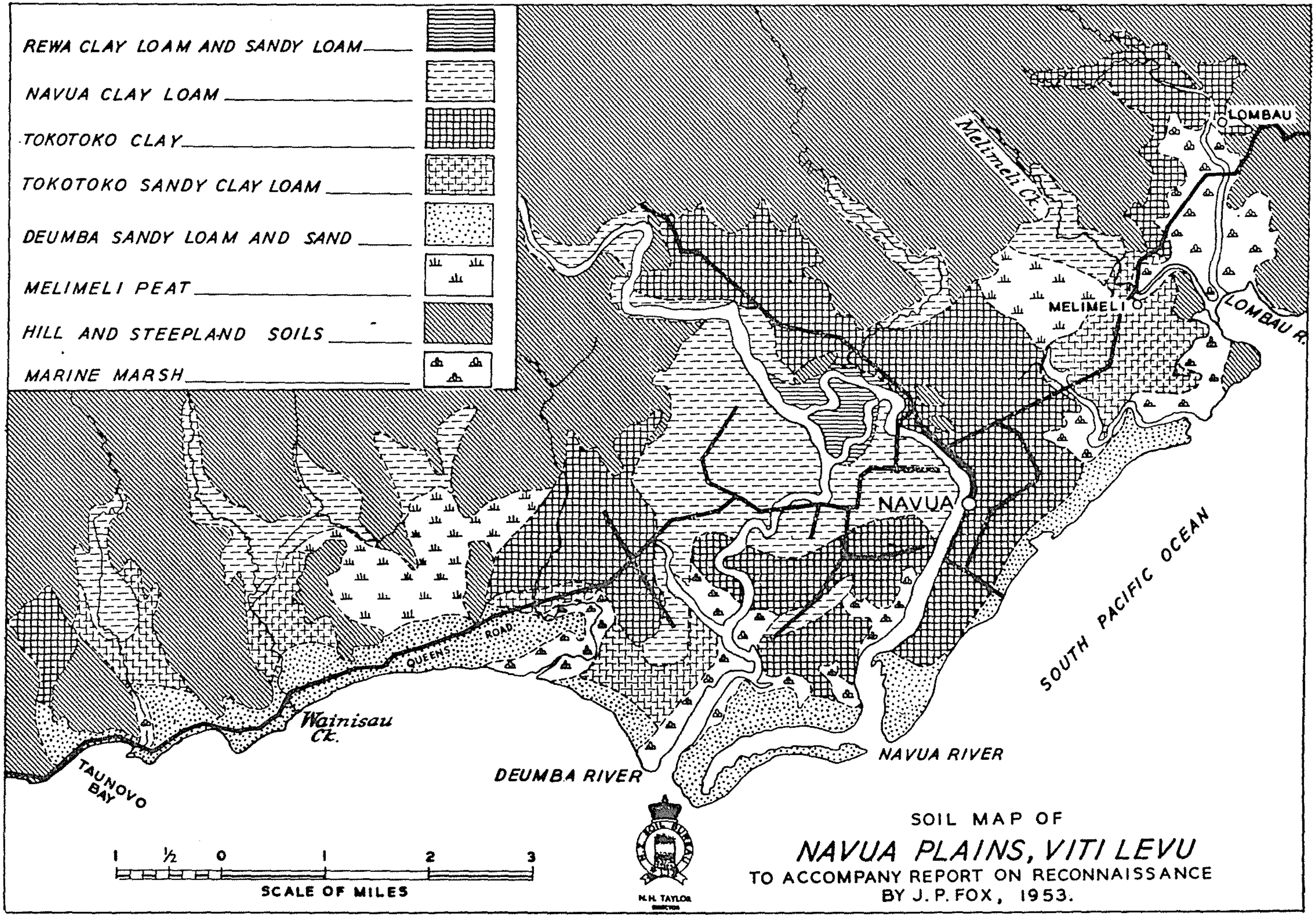
The Deuba sandy loam and sand are more readily drained, but being strongly leached they will also require lime, phosphate, and perhaps nitrogen dressings. Being sandy these soils are liable to become droughty should dry weather be prolonged. This could be offset by close regulation of the drainage ditches to use the available water to the best advantage. Such a method of farming requires considerable co-ordination of drainage, and this could be organized by a local board, suitably advised by a competent agriculturist. In addition such a board could act as a central agent for marketing, supplies of fertilizer and as a farm advisory agent.

Production from the Tokotoko sandy clay loam about Togoru Creek is limited at present by lack of plant nutrients. Experiments should be designed to demonstrate methods of raising fertility by topdressing particularly with lime and phosphate.

At present these soils have a high water table and could be used for rice production. Any lowering of water tables by drainage will make these soils free-draining, and thus more suited to pasture production than to rice production.

In addition to the development of further land, consideration should be given to methods of improving practices on the present holdings. One such aid would be a local board for controlling, maintaining and extending the present drainage system.

112/Q/54—100



SOIL MAP OF

NAVUA PLAINS, VITI LEVU

TO ACCOMPANY REPORT ON RECONNAISSANCE
BY J. P. FOX, 1953.