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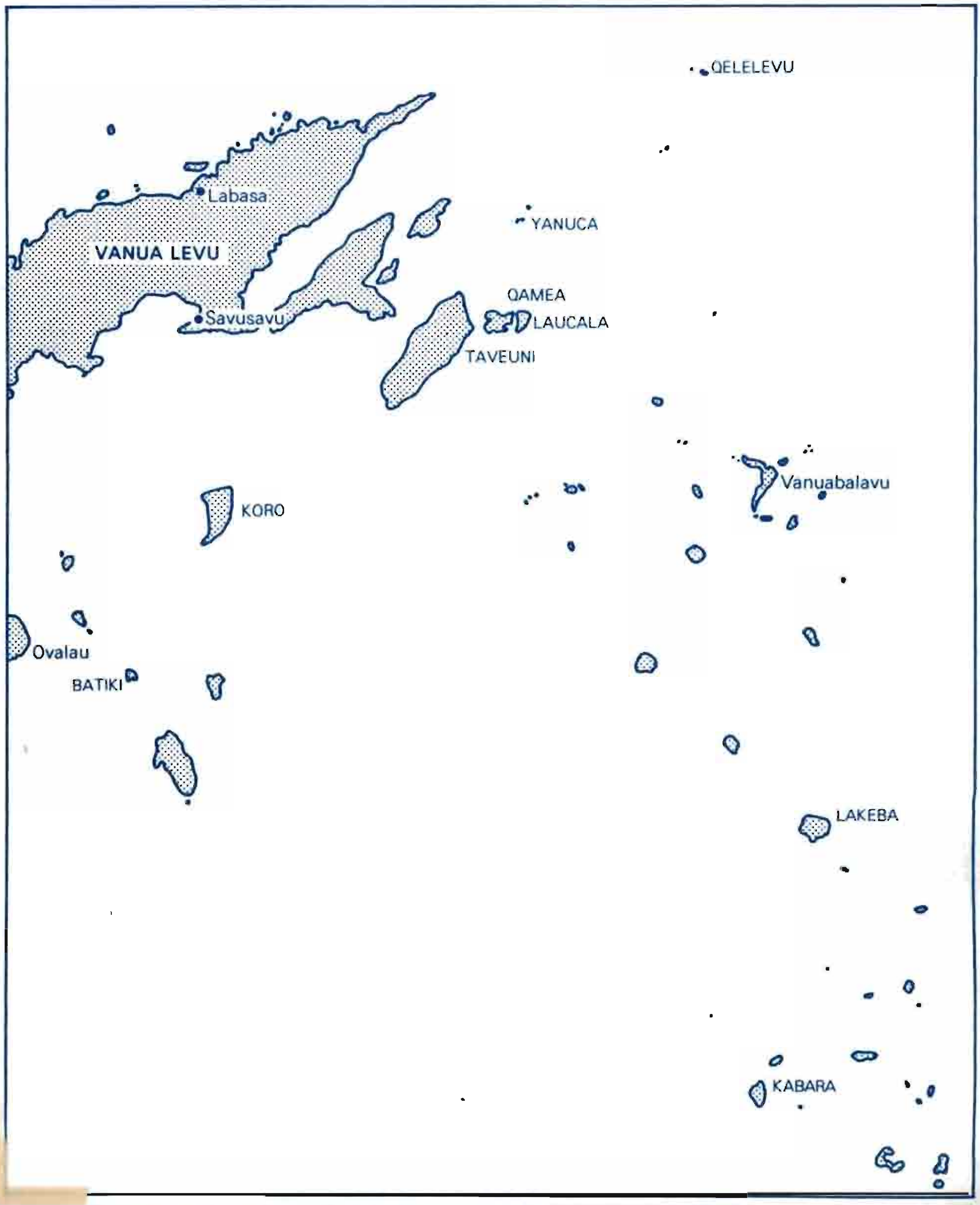
Project Working Paper No. 1 & 2

Population and Environment Project: Eastern Islands of Fiji

Denis & Salvat



UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION (UNESCO)

UNITED NATIONS FUND FOR POPULATION ACTIVITIES (UNFPA)

UNESCO/UNFPA PROJECT ON POPULATION AND ENVIRONMENT

IN THE EASTERN ISLANDS OF FIJI

(Man-and-the Biosphere Programme)

PROJECT WORKING PAPERS Nos. 1 and 2

PRELIMINARY PAPERS ON NATURAL RESOURCES

Bernard Denis; Bernard Salvat *et al.*

1. Bernard Denis: THE SOILS OF LAKEBA AND TAVEUNI

2. Bernard Salvat *et al*: THE ECOLOGY OF THE REEF-LAGOON COMPLEX OF SOME ISLANDS IN THE LAU GROUP

Published from the Development Studies Centre, Australian National University, Canberra, A.C.T.

July 1976

THE UNESCO/UNFPA POPULATION AND ENVIRONMENT PROJECT IN THE EASTERN ISLANDS OF FIJI: A DESCRIPTION

The UNESCO/UNFPA Project was conceived within the framework of the Man-and-the Biosphere Programme of UNESCO, and forms part of Project 7, 'The Ecology and Rational Use of Island Ecosystems'. It was designed as an international project, to be one of a series in different regions of the world, both to feed into, and to provide a measure of design for, national programmes of research into man/biosphere relations. After the agreement of the Government of Fiji was obtained in 1973, the project was funded in 1974, and research began later in the same year. Field work ran through 1975 until mid-1976.

The project has had twin objectives. On the one hand its purpose is to explore the scientific study of human activity in and on specifically defined environments. On the other hand it has also had the objective of providing researched guidelines for policy aimed at optimizing, within the limits of possibility, the satisfactions of life for the people concerned, within the context of rational use of environment. The objectives are not seen as in conflict; the same research programme feeds both aims, and we have sought to demonstrate that scientific research into population and environment can equally serve both 'pure' and 'pragmatic' ends, each being the better for the incorporation of the other. The two general reports of the project, to be published in the MAB Technical Notes Series, will reflect these two faces of our work.

The research team has represented the disciplines of human and physical geography, demography, soil science, marine biology, nutrition, agronomy and agricultural economics. Topics under review have ranged from the fields of soil and vegetation ecology and the impact of natural hazards, through studies of land use and land holding, detailed community studies and the economics of farm-decision making, to regionally-comprehensive studies of production and communication, historical demography and migration. This list is not exhaustive. The emphasis given to different topics, and hence different specialisms, reflects the problems identified in the particular area. The method of research has varied; community studies are best carried out by an individual researcher, but often several specialists have lived and worked together in the field, each pursuing his own line of interest, but constantly interacting, so that almost all members of the project have become aware not only of the work of their colleagues, but also of the methods used and the problems raised.

This project has had a smaller local component than we wished or had planned. In common with many developing countries, Fiji has only a limited pool of skilled specialists, and we were not able to secure the collaboration of certain persons from whom the project would have gained much. However, we have collaborated very extensively with the field and headquarters staff of three Ministries and have also collaborated, in a real sense, with the populations of the islands in which we have worked.

The design of the project has been governed by the resources available to us. We have carried out some general studies over the whole eastern island area, and several members of the project have been able to tour quite large areas of an oceanic region. However, we have concentrated our efforts principally on two islands, and have worked less intensively on three others. These five islands, respectively Taveuni, Lakeba, Kabara, Koro and Batiki, were chosen to reflect a range of physical types and also of economic development, and of distance - measured in the real terms of access - from the national centres.

For the most part the full evidence of integration of our work will appear only in the general reports. However, a great body of data and discussion cannot be presented in these reports, and we are thus also publishing a series of Project Working Papers, which will contain from one to three reports by individual specialists, or, in a few instances, the collaborative and integrated work of more than one. This series has limited distribution, and its primary purpose is to make our work available quickly in Fiji itself. All Project Working Papers are 'cleared' only with the Chief Technical Adviser; they therefore do not necessarily represent the views of UNESCO or UNFPA, or even of the project as a whole. Responsibility for all statements made and views expressed rests with the author.

Harold Brookfield
Chief Technical Adviser

EDITORIAL INTRODUCTION

This first issue of the Working Papers of the Project combines two basic-data papers concerning the natural resources of the islands. They present little discussion, and are essentially preparatory studies on which the final reports will expand. Because the material contained is, however, of great potential value to specialists within Fiji and in a wider scientific oecumene, they are published now in this series in order that results can be disseminated as speedily as is possible.

The first paper, by Bernard Denis, soil-scientist of the Centre ORSTOM at Noumea, presents initial data on the description and classification of the soils of Lakeba and parts of Taveuni. It is based on field work done in 1975, together with some preliminary analyses. Soil maps are not provided at this stage, since these are subject not only to the field work carried out in early 1976, but also to the results of more detailed analyses that are not even now complete. As is stated in the paper, these maps will be provided in a final report on the soil-vegetation complex of islands studied, due for completion late in 1976, and to be published in French and English by ORSTOM during 1977. However, the present report is of immediate interest not only for its own descriptions, but also as representing the first major attempt at correlation between the Wright and Tywford (1965) classification and the international (FAO-UNESCO) and French systems, and also as constituting the first comprehensive soil surveys in Fiji to be carried out on map scales larger than 1:100,000. The Wright and Twyford work is now more than twenty years old; we felt it timely that this project should contribute to the study of the natural resources of Fiji by including a soil survey incorporating the great advances in soil science made since that time.

The final report will not only elaborate this descriptive work, and present also work done on some other islands, but will be concerned also with two sets of problems in dynamic ecology. On the one hand is the effect of cultivation on soils: for this purpose the Project conducted yield measurements and soil fertility measurements, and collected land-use histories at the same sample sites. On the other is a specific dynamic problem concerning the evolution and amelioration of the barren fern-casuarina (talasiga) complex of Fiji, superbly exemplified on the island of Lakeba.

The second paper is written without data analysis, and was entirely written in Fiji itself, before the research team even left the field in April 1976. This reports a reconnaisance survey of the resources of the reef-lagoon ecosystems of a number of islands in the Lau group. It was carried out, on sub-contract to the Project, by Dr Bernard Salvat and a group of specialists engaged by him. Much is made in the literature of the Pacific about the resources of the circum-island reefs and lagoons;

clearly, they constitute a major part of subsistence resources, and are also subject to varying degrees of commercial exploitation. It was necessary to obtain some evaluation of the content and nature of these resources, and the conclusion drawn from the work of Salvat's group is one of great variability. The variability is, indeed, little if any less than the variability on land. Facile generalizations are therefore much more readily avoided.

It may be felt that the reconnaisance methods used by Salvat's group preclude any quasi-quantitative conclusions. However, a subsidiary object of this survey was to seek knowledge by relatively unsophisticated methods, without also the crudity of mass kills through the use of dynamite in order to obtain quantification. By means of a purposive visual sample, supplemented by instrumental observations, it was hoped to obtain results of sufficient precision to make possible statements concerning the nature and variability of reef-lagoon resources. With limited instrumentation, the same would be possible within the resources of most island countries. The final report will be the basis on which the success or failure of this experiment may be judged, but the preliminary report presented here is sufficiently revealing in its evidence of variability to suggest that the care needed in evaluating marine resources is no less than that required on land.

The authors acknowledge the specific help both groups have received from members of the Fiji Ministry of Agriculture, Fisheries and Forests. This has been very great, not only to these enterprises quite specifically within the domain of the Ministry, but also in all our activities. As Chief Technical Adviser of the Project, this is for me perhaps the most suitable place to acknowledge a volume and enthusiasm of collaborative interest among members of MAFF without which our project could not have achieved the half of what we have - we hope - succeeded in doing. It is therefore perhaps most appropriate that this first issue of a series of Project Working Papers should be devoted to matters entirely within their concern.

Maps accompany both reports. Those accompanying Salvat's paper have been redrawn in the Map Laboratory of the Department of Geography, Australian National University, by Mrs Val Lyon. Those accompanying Denis' report are copies of originals prepared in Noumea for an earlier version of the report in French. Being based on standard topographic sheets they also use the cumbersome orthography of Fijian names employed on those sheets. This is not the normal practice of the project, which is to use the standard Fijian orthography.

The whole of this issue has been typed and prepared for publication by Mrs Colleen Morton, assisted by Mrs Elizabeth Bray. Our debt to Mrs May Dudley for her help in arranging the cover design and printing is also most gratefully acknowledged. The cover design itself is based on a suggestion by Richard Bedford.

Both reports were prepared in French, Translation, except for a part of Denis' report, has been carried out by myself. In the case of Denis' report, this has been checked by the author and his colleague, Marc Latham. In the case of Salvat's report, it was decided to proceed directly to publication without this additional delay. The translator's apologies are therefore due both to the authors and to readers, for such inaccuracies and infelicities as quite clearly remain.

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(Man-and-the Biosphere Programme)

PROJECT WORKING PAPER No.1

THE SOILS OF LAKEBA AND TAVEUNI:

PRELIMINARY REPORT

Bernard Denis
(ORSTOM, Noumea, New Caledonia)

Published from the Development Studies Centre,
Australian National University, Canberra, A.C.T.

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Preamble

Following the agreement between ORSTOM and UNESCO concerning the participation of soil scientists of the ORSTOM centre in Noumea in the study of the soil-vegetation complex in the eastern islands of Fiji, three missions have been carried out. The first was a reconnaisance mission by M. Latham. The second was carried out between the end of August and the middle of October 1975, and is the subject of the present preliminary report. It had been intended to study soils on four islands, but both for practical reasons and because of their own interest, only two were retained in the programme: these were LAKEBA in the Lau islands, and TAVEUNI.

The final report will include soil maps and very complete analytical results but these latter will take some time: a completion date in November 1976 is envisaged. In order to avoid too long a gap between the mission and publication of results, this preliminary report is therefore prepared. It both presents general discussion of the geology, geomorphology and vegetation of the two islands, and also presents an account of the principal soil types encountered, together with some review of their spatial distribution and principal morphological characteristics. The account is based on field study supplemented by the use of air photographs.

Preparation of this account also facilitated design of the third mission, which was carried out between mid-January and the end of March 1976 by B. DENIS and M. LATHAM. This will be separately reported. Once we have the full results of soil analysis carried out in Suva, with the kind co-operation of the Research Division of the Ministry of Agriculture, Forests and Fisheries, and in the ORSTOM laboratories, we shall be able to refine certain aspects of the classifications, and also provide greater detail on the physical, chemical and agronomic characteristics of the soils studied. Two definitive maps will be prepared for each island (parts of the island in the case of Taveuni). The first will be a pedological map; the second will indicate the land-use potential.

Finally, I take this opportunity to thank all those who have helped in the work including Dr. Brookfield (Chief Technical Adviser), Mr. John Campbell (Project Assistant), and other members of the UNESCO/UNFPA Population and Environment Project, and equally the Fijian authorities and scientific personnel, especially those of the Department of Agriculture (MAFF).

LAKEBA

1. General Remarks

Lakeba is situated in the southeast of Fiji, in the Lau islands, at 178° East by 18° South, approximately 180 miles east of Suva. It is a rounded island with a small peninsula in the south. Its mean diameter is five miles, and its total area is 21.5 sq.miles (approx.50 km^2).

Geology Following F. Coulson, (unpublished) who has carried out the most recent survey, the island is mainly formed of a miocene volcanic complex, rocks being mainly andesitic and dacitic, with some basaltic flows. This formation is overlain by Miocene limestone on the northwest and west coasts, and in the southern peninsula. Geologically, two limestones are distinguished, the one foraminiferal, the other shelly, but this differentiation appears to have no effect on soil type. There are also quite large colluvial deposits in the valleys and sub-coastal areas, and alluvial plains in parts of marine origin.

Topography and Geomorphology Our own observations, and those of Twyford and Wright (1965) agree in describing the island as a single massif characterised by rounded summit forms. There is evidence of tilting along a north-south axis passing roughly through the centre of the island. In the western part the uplift of the airfield valley is especially notable, while in the east several valleys have been drowned, with formation of hydromorphic zones. Soil materials encountered are of colluvial and alluvial origin according to this same differentiation.

It is possible to distinguish several levels which are clearly recognisable on the ground and in aerial photographs:

(a) The central area, occupying the larger part of the island, with a highest point at 230m (720 ft). Hills are rounded mainly and their slopes overlap. Slopes are often steep (30% to 50%), falling from the two highest points directly to the sub-coastal colluvial areas in the north and south, and part of the east, and to quite extensive areas at lower altitude in the southeast and all along the west coast.

(b) Plateau areas, between 60 and 120m altitude. These occupy most of the western side between Nasaqalau and Tubou villages. There is also a smaller plateau near Waitabu, and a third, at only 20 - 30m, in the southern peninsula.

(c) Valleys, between 5 and 20 metres altitude. These are very variable in size, but extend toward the centre of the island as much as 2km or more from the sea. The largest are those of Tubou, Nukunuku and Yadrana. Materials encountered are in two classes. On colluvium of andesite material soils are often deep, and these areas are frequently occupied by coconuts. In the centre of each valley is generally found a mixture of colluvial and alluvial material in which mineral hydromorphic soils are often developed.

(d) Coastal Zones, flat topography, very gentle slopes. These cover quite a considerable area, occuring both at the foot of the hills occupying the larger part of the island, and in the mouths of valleys. The break of slope is often sharp. Both colluvial and alluvial materials are encountered. Colluvial deposits, formed from the basic rocks forming the core of the island, form a piedmont around the massif. Their extent varies from place to place, and they give place to alluvial deposits close to the shore. These alluvial deposits are sandy between Tubou and Vakano villages, but have a high clay content around the remainder of the island. These textural differences are related to the distribution of mangroves, and it seems possible that the clay-alluvial deposits represent former mangroves, subsequently elevated or stranded by a change in sea level. In the clay-alluvial areas there is an almost imperceptible gradient from colluvium, through non-hydromorphic alluvial soils, to hydromorphic alluvial soils. It is extremely difficult to draw boundaries within this zone.

Erosion seems most active on the ferralitic soils derived from andesites, the 'talasiga soils' of Twyford and Wright. Sheet flow is common, but there are also areas of strong gullying, including some coalesced gullies forming wholly eroded patches ('badlands') on the sides of some hills. These ferralitic soils are the main site of the present efforts of the Department of Forests (MAFF) in pine plantation; these have the effect of checking soil erosion, and also of ameliorating the condition of the surface horizon. Following Twyford and Wright (1965) Lakeba includes:

- 40% of steeply-sloping land
- 40% of gently-sloping land
- 20% of level ground.

Vegetation At this stage only a general discussion is provided, and greater detail will be found in accounts of particular soil types. Four main vegetal types can be distinguished:

(a) Fern-dominated treed savana. Ferns (Pteridium equisetum and Dicranopteris linearis) form the dominant ground cover, while Casuarina equisetifolia and Pandanus odorentissimus constitute the tree stratum. This formation is very widespread on the hills and on the plateau areas.

(b) Forest. Found on the hill summits, and in the heads of certain valleys.

(c) Reed-dominated savanna, with few trees. The reed-grass Miscanthus floridulus dominates this formation, ecnountered on steep slopes, and in areas of brown soils.

(d) Cyperacous bush. Encountered in the valleys on hydromorphic soils.

Climatology Twyford and Wright give the annual mean for Lakeba as 1890 mm. Only few data are available for temperature, but the regional mean for Fiji (approx. 77°F, with a seasonal range of 10° to 14°F) may be used. Relative humidity is high, of the order of 80% and 95% as extreme values, varying between seasons and between places. The following are monthly means for 22 years for Lakeba, from Twyford and Wright (1965):

	mm
January	228
February	203
March	247
April	210
May	159
June	101
July	88
August	114
September	98
October	117
November	167
December	159

There is no strongly marked dry season, but there is a notable diminution of rainfall between June and October. Droughts occur mainly in the latter season.

Land utilization Four main types may be noted in this preliminary report (much fuller accounts being available from other members of the project):

(a) food-crop cultivation in the valleys (wet and dry taro).

(b) food-crop cultivation and coconuts on the lower slopes of the reed-dominated savanna, and on the colluvial areas.

(c) coconuts with livestock on recent alluvial soils, the livestock being continuous or seasonal according to water-table fluctuations.

(d) reafforestation with Pinus Caribbea in the western part of the island. There are very few cultivated patches on the fern-dominated savanna.

2. The Soils of Lakeba

Available working materials

- Geological sketch at 1/10,000
- Aerial photograph at 1/12,500
- Draft map at 1/12,500 (watercourses, contours at 10 metres)
- Draft map at 1/25,000 (as above)

In this second section, an account is given of the different soil types encountered. For each we describe its topographic and geomorphological relationships, its principal morphological characteristics as determined in the field, and lastly its classification in the French and FAO systems. The relationships of these soil types to those identified in the Twyford and Wright survey will not be discussed here. The results of analyses may demand certain modifications, and hence this aspect is deferred to the final report. We discuss in turn:

- soils derived from volcanic rocks
- soils derived from limestones
- alluvial soils

<u>Soils dervied from volcanic rocks</u> (a) Ferralitic soils, weakly or moderately leached, rejuvenated, characteristic of hilltops on andesite (C.P.C.S.); HUMIC CAMBISOLS on hill summits on andesite (F.A.O.).

These soils are encountered on the generally rounded summits of the hills. They also occur on the upper slopes before giving place lower down <u>either</u> to brown soils on steep slopes where the main vegetation is reeds, <u>or</u> to other ferralitic soils on andesites, on gentler slopes where there is no change in vegetation. They are covered by a more or less treed savanna with numerous Casuarina and Pandanus; the density of the ground stratum varies from one summit to another, characterised by ferns (Pteridium and Dichronopteris) and some scattered reeds (Miscanthus floridulus). In certain cases a secondary forest has developed on the summits.

The soil profile is of type A1-B-BC. The A horizon is generally organic, dark brown, clayey, with always a fine to average blocky structure. Friable and porous. In different observations, depth varies between 10 and 20cm. Many roots.

Below is a B horizon, brown in colour, often with a thin density of andesite stones and gravels: Clayey. Consistently a fine blocky-structure. Porous and friable. Roots. Depth from 10 to 30cm.

Finally is a BC horizon, more reddish in colour and always of fine texture. Structure continues that of the underlying rock. Low porosity. Friable. Some roots. This horizon is between 30 and 50cm in depth. These soils are small in area, and not always easily represented even on a scale of 1/12,500. However, they have been represented wherever possible, since these small sites are often utilized for dry taro cultivation, and other subsistence crops.

(b) Ferralitic soils, heavily leached, rejuvenated with abundant evidence of erosion, on andesite slopes and hills (C.P.C.S.) FERRALITIC CAMBISOLS on andesite hills (F.A.O.).

Together with the brown soils which we discuss below, the area occupied by these soils covers the larger part of the island. In the west they occupy the whole hillslope area, while in other areas they are found intermingled with brown soils, which are confined to the steep slopes. Erosion is almost universal on this soil type. It takes the form both of sheet erosion, with formation of a staircase landform, and also of gullies and ravines, which can sometimes coalesce into 'badlands' by regressive development. The erosion seems to be due both to the physical characteristics of the soil itself, and also to the very sparse vegetation cover. Examples are easy to find: for example along the right-hand side of the road linking the airfield to the circum-island road, or on the slopes of hills rising to the small plateau dominating the airfield where an area of 'badlands' has developed. Even at this stage it seems certain that Pinus Caribbea plantations can only have a beneficial effect in stabilizing such soils.

Vegetation is a treed savanna of variable density, with numerous Casuarinas and a ground stratum partly formed of ferns, which provide a poor soil cover.

The soil profile is of type AB-B-C, or sometimes A1-B-C. Generally, the A horizon is shallow (less than 10cm), often having been truncated by erosion so that only a little-humified AB horizon remains. The texture ranges from silty-clay to clay; structure is very weak. This horizon is, however, porous, friable and roots are quite numerous. This is succeeded by a B horizon, often shallow but on gentle slopes attaining a depth of as much as 30 to 40cm. Rock fragments, of andesite, are often encountered. Texture is clay to clay-silt and structure is weak. Some roots.

Finally the soil passes into weathered andesite, brightly coloured red, yellow and violet. Onion-skin rock balls of 50 to 100cm diameter. Even though the physical and chemical properties of these soils seem average to good, the first need is clearly to fix the soils, so as to arrest erosion where it is already active, or to prevent it where it has just begun or is still absent. The afforestation with Pinus Caribbea already begun seems very essential not only to fix the soils, but also to ameliorate them by preventing the annual passage of fires. M. Latham's observations confirm this view.

(c) Ferralitic soils, heavily leached, clay impoverished, characteristic of the plateau areas on andesite (CPCS); RHODIC FERRALSOL on andesite, plateau situation (FAO).

The soil type is encountered on small level surfaces, plateau areas, situated around 100m altitude. These areas are always distinct, and easily identifiable on air photographs, but their location does not show any clear regularity; in general they are around the periphery of the central massif.

Vegetation is of variable density from place to place, especially the ground stratum; however the floristic composition is very similar to that of the soil types described above. Small areas have been planted with Pinus Caribbea.

Soils are always deep, and the parent rock, or even traces of the parent rock, is only encountered at a depth of about 2 metres. The topographic position has clearly played an important role in the formation of these soils; weathering has been able to penetrate deeply and the soils have not been truncated by erosion. Hence we have a profile of type A1-B1-B2 with fairly deep penetration of organic matter.

- A1 horizon, average depth 10 to 15cm, dark red, humified, sand-clay texture, weak structure. Friable, porous, permeable, with many roots.

- B1 horizon, also humified, dark red, with small ferruginous rock fragments. Sandy clay to sandy. Structure weakly, blocky to particular. Friable, very porous; fine roots. Thickness on average 30cm.

- Below this is a B21 horizon. Clayey; weakly structured subangular blocky. Friable. Poor porosity. Small black granules, most probably manganese.

- Finally a deep B22 horizon, clayey, more strongly structured than the overlying horizons. Friable, poor porosity. No roots.

It is not possible to offer a positive opinion concerning the utilization of these soils in the absence of data on their physical and chemical properties. The only advice than can be offered at this stage is continuation of the pine planting; a study of one site under two-year old pines indicates that these have a beneficial action on the structure of the A1 horizon.

(d) Brownish soils, brown eutrophic tropical in type, immature characteristic of steep slopes on andesite (CPCS); HUMIC CAMBISOLS on steep slopes in andesite (FAO).

These soils are characteristic of steep hillslopes over most of the island, with the exception of the western side where we do not find them. As we noted above, these soils are found in close association with the rejuvenated ferralitic soils of the gentler slopes around them; vegetation on these soils is totally different from that on the soil types described above. There is savanna with few trees, with a dense ground stratum composed of reeds (Miscanthus floridulus - GASAU) 2 or 3 metres tall. This sharp vegetation contrast facilitates the delimitation of these soils from aerial photographs. Essentially, the reed-savanna with few trees form a scatter of patches among the much larger areas covered by the Casuarina/Pandanus savanna which occupies the larger part of the rejuventated ferralitic soils on andesite (the TALASIGA soils of Twyford and Wright). This distinction is easily recognisable on aerial photographs, and is important; without it, separation of these two soil types would have been very difficult except where they have actually been recognised in soil pits. The profile is of type A1 (B) - (B)C:

- A1 horizon, humified, variable depth between 7 and 25cm, clayey, well structured in fine to medium blocky form. Porous. Friable. Very numerous roots.

- (B) horizon, with fragments and pebbles of andesite; clay-sand; well structured, medium to fine blocky in form. Very porous; friable; depth ranging from 15 to 35cm.

- (B)C horizon, with large areas of weathered parent rock, and numerous stones.

It would seem that the coconut groves (which extend up the hillslopes) and the food-crop gardens established on the lower reaches of these same slopes are all on such soils; the physical qualities of the soils, as observed on the ground, seem to be satisfactory. As observed in other countries, such soils generally have good chemical properties with a sufficient reserve of elements usable by cultivated plants. It therefore seems probable that these soils are capable of fuller exploitation, given adequate attention to preservation of the vegetation cover, by fallowing, in order to prevent erosion.

(e) Ferralitic soils, more or less leached, humified, formed on redeposited colluvial andesitic material, at the foot of the slopes (CPCS): HUMIC FERRALSOLS on andesitic colluvium, at the foot of the slopes (FAO).

These soils are developed at the bottom of hillslopes on material derived from the andesites. The areas are very small, and it is often not possible to map them even on the 1/12,500 scale. However, given that these soils are generally utilized, and are capable of cultivation given their physical qualities and ease of access, we are seeking to represent them on the map wherever this is possible.

These soils are related to the adjacent soil types: to the brown soils of the steep slopes; to the rejuvenated ferralitic soils on andesite; in some cases also to the sandy or clayey recent alluvial soils located along the sea coast.

Natural vegetation is often difficult to find. Much the greater part of the area occupied by this soil type is under coconuts, with a dense ground stratum covering the soil well. However there remain some trees within the coconut groves.

The soil profile is of type A-B-BC. Soils are in general deep, but there is significant variation in the depth of horizons:

- humified horizons, A1 to A3, are encountered in numerous profiles and have together a depth of from 30 to 40cm. The A1 horizon is generally 10 to 15cm deep. They are clayey, well structured of medium blocky form, sometimes of large blocky form. Porous. Friable to coherent. Very numerous roots.

- a deep B horizon, 50 to 100cm in depth. Clayey, with weak to strong structure, medium to large blocky in form; generally friable and porous. Notable are the universal clay coverings in the pores and on the aggregations. Again numerous fine to medium-sized roots.

- finally a transitional horizon to weathered parent material, BC, always deep, with large areas of altered parent material and andesite fragments. Texture is clay-silt to clay. Structure is weak. Poor porosity. Clay covering present as in the B horizon.

These soils are already well utilised; there are extensive coconut groves and areas of food-crop cultivation. Given their proximity to the villages and easy access, these areas seem likely to be used more and more in the future.

The presence of a deep humified horizon, and of numerous roots of the natural vegetation, together with the topographic situation, make these soils particularly suitable for food-crop cultivation. It is important to know if such cultivation, even with rotation, will however exhaust the mineral and organic resources of the soils after a certain time. It is not possible to be precise on this topic until analysis results are to hand.

(f) Ferralitic soils, more or less leached, characteristic of redeposited colluvium (CPCS); RHODIC-FERRALSOL on andesite colluvium (FAO).

These soils are of small extent, and were observed only at the foot of the hill above the hanging valley occupied by the airfield. They are found in pockets of varying size, always of considerable depth, confined between spurs on which rejuvenated ferralitic soils on andesite slopes give way to the deep ferralitic soils situated on the small plateau dominating the airfield.

The vegetation is very similar to that of the slope soils, i.e. a more or less treed Casuarina savanna with a very thin and patchy ground stratum. There is abundant evidence of erosion on the slopes.

Soils derived from limestone. As we noted in the introduction, limestones cover only a small part of Lakeba. They are confined mainly to the west coast and the small southern peninsula.

Three soil types have developed on this rock formation. Two are of very small extent while the third is found on the plateaux areas of low altitude which dominate the zones characterised by soils formed from coral-sand alluvium.

Vegetation on the first two types is a secondary forest; these are mineral soils associated with the brown soils of steep slopes. Vegetation on the third soil type is a more or less treed savanna of Pandanus and Casuarina, with ferns dominating the ground stratum and only few reeds. These areas are used for pine and coconut plantations. Because of its relatively large area, we describe this soil type in greater detail.

(a) Ferralitic soils, more or less leached, clay impoverished, characteristic of limestone plateau situations (CPCS); HUMIC FERRALSOLS on limestone plateaux (FAO).

The plateaus on which these soils are found lie along the west coast, where the soils lie adjacent to the hills. Soils derived from andesites (ferralitic soils) rejuvenated, essentially characteristic of slopes. These are deep soils, with a profile similar to that of the characteristically improverished ferralitic soils derived from andesites. The profile is of type

A1-A3-B2. However, morphological studies made in the field suggest that the organic matter content is higher in soils derived from limestone than from andesite. The sequence is as follows:

- A1 horizon from 10 to 15cm deep, sandy-clay, weakly structured of medium subangular polyhedric form. Permeable; friable; numerous roots.

- A3 horizon, more or less humified, without any coarse material, sandy-clay to clay, weakly structured, normally of subangular blocky form associated with a particular structure. Permeable, friable, porous. In different observations, depth ranges from 15 to 40cm.

- B horizon, thick, dark red, no large fragments, clayey, weakly structured of large blocky form. Friable; porous.

The topography of such soils is either planar, or only slightly undulating. Their extent is not negligible, and they are also characterised by fairly deep penetration of organic matter (generally to 40cm). The modification of texture between the A1 and A3 horizons, due to a diminution in the clay content, does not seem to constitute any obstacle to agricultural utilization. However, the structure is not very favourable, and might possibly be destroyed under intensive cultivation. At present some areas have been planted with pines, especially near the airfield. It seems that coconuts grow well. But without analytical data on the chemical characteristics of these soils it is difficult to be more precise about the possibilities of more extended utilization.

<u>The alluvial soils</u>. Among the alluvial soils, a clear distinction needs to be drawn between the non-hydromorphic and the hydromorphic sub-groups. In the first, we have soils developed on clayey alluvium and on sandy alluvium. Among the second sub-group we distinguish organic soils, partially organic soils, mineral soils and finally mangrove soils.

Non-hydromorphic alluvial soils. There are two distinct zones here. One, which extends along half the north coast, the west coast and a part of the south coast, is formed on sandy alluvium of marine origin. The other is formed on clayey alluvium, and occurs on the east coast and especially in the mouths of the Yadrana and Nukunuku valleys, and south of Waci-Waci.

(a) Immature soils, non-climatic in origin, carried on sandy marine alluvium (CPCS): CALCARIC FLUVISOLS on sandy marine alluvium (FAO).

These soils are encountered all along the shore on the three coasts listed above. For the most part they are under coconuts. The limit between these soils and the colluvial soils derived from andesites is often hard to establish, both because of some cloud shadows on the aerial photographs, and also the very faint break of slope encountered in certain places - for example between Vakano and Nasaqalau.

The profile is of Type A1-A3-C. The whole soil is sandy in texture, and the difference between horizons is due solely to penetration of organic matter which gives a colour range from brown-black (A1) to dark grey (A3). Structure is weak, granular to particular in the A1 horizon, fine blocky to particular form in the A3. These are very porous soils, of filtering action, and their cohesion ranges from very weak to nil, notably in the C horizon.

Generally, the organic matter penetrates to a depth of over 30cm before pure grey sand with shells is encountered. These soils are very suitable for coconuts, but should not be put under any other form of use, except for certain types of pine and eucalyptus, which are able to maintain their vegetative habit on such soils.

(b) Soils of marine clayey-alluvium; EUTRIC FLUVISOLS (FAO).

These soils bear close relationship to the soils under present mangroves, and most probably are derived from clayey material forming ancient mangroves, subsequently uplifted.

It is often difficult to determine the limit between colluvial and alluvial soils, because of the very slight break of slope in these coastal zones. Another cartographic problem arises in separating these non-hydromorphic soils from the hydromorphic soils found at the lowest levels on the edges of the present mangrove. Villagers have planted coconuts on these soils,and also maintain cattle on them. This is particularly the case in a zone several hundred metres wide in front of Yadrana. For these reasons, it has been necessary to combine the clayey-alluvial soils with the colluvial soils derived from andesite in preliminary mapping. In the final report, after verification on the ground, an attempt will be made to separate these soils, which are of considerable agricultural importance, and describe them in greater detail.

Hydromorphic soils. The area occupied by these soils is quite small, but they are often used, especially for irrigated taro. They have a very special significance from an agricultural point of view. They occur in a number of valleys between Tubou and Yadrana.

(a) Hydromorphic soils, organic, semi-fibrous, oligotrophic, on marine alluvium (CPCS); DISTRIC HISTOSOLS (FAO).

The main areas of this soil type are at the mouth of the Tubou-Levuka valley. To a depth of one metre, the profile is formed exclusively of organic matter, partly decomposed, with total absence of mineral elements. These latter, of fine texture, are encountered between 100cm and 280cm; they are sands containing numerous shells of all kinds, which increase in number with depth.

The entire profile is very wet, and the top 30cm are permanently saturated in spite of the fact that the water table may be at a lower level. Such soils are no longer used, and in the present state of decomposition of organic matter it would seem very difficult to bring them into use, even with a system of drainage; the absence of mineral matter suggests a serious disequilibrium in elements assimilable by plants.

(b) Hydromorphic soils, moderately organic, with acid humus on colluvio-alluvium (CPCS): HUMIC GLEYSOLS (FAO).

This soil type is encountered in the bottom of the Tubou valley, between hills on which are developed Humic Ferralsols on andesite colluvium, and Humic Cambisols on steep slopes in andesite. The secondary vegetation that arises is a thick, low bush, with ferns, convolvulus and cyperaceous plants. After drainage, these soils are used for irrigated taro cultivation.

The profile is formed of an A1 horizon (above water table), of partially fresh organic matter, silty in texture, granular in structure which is very weak. Below this is a gley horizon, bluish-grey in colour, clay-silt texture, and showing very many traces of hydromorphism; some andesite pebbles are encountered, and make it possible to determine the origin of colluvial and alluvial infilling material. Structure is quite strong, medium blocky in form; there are numerous very fine live roots. Finally, below 100-120cm the parent material is encountered, silty-clay in texture, marked with traces of vivid colour.

The use of these soils after drainage is easily explained. The organic material is in large measure decomposed, and the mineral elements impart cohesion and structure to the whole. The elements forming these soils are different from those of the organic soils; despite the very close topographic relationship of the two, their evolution and morphology are not identical.

(c) Hydromorphic mineral soil, weakly gleyed, on alluvial clays (CPCS); EUTRIC GLEYSOLS on alluvial clays (FAO).

These soils are encountered in the lower parts of valleys, such as those of Nukunuku and Yadrana. They are found in relation to colluvial soils or non-hydromorphic soils on alluvial clay, at slightly higher elevation. Vegetation is a savanna with very few trees, characterised by the SEKARAWA and the Rhizophora micronata typical of hydromorphic soils. These soils have the following profile:-

- A1 horizon, humiferous, red-brown, clayey, strongly blocky structured of form very fine to granular; porous; permeable; friable; very many roots.

- below this is a horizon with a mixture of orange-red iron hydroxide and deep grey stains (BG. G). Wet, clayey, massively structured, sticky. Some roots penetrate into this horizon.

- finally is a gley horizon (BG) wet, dark brown in colour, clayey; massively structured, very sticky, plastic. The water table is reached at 70cm.

Our information suggests that the water table fluctuates seasonally and that these areas may sometimes be submerged for varying periods of time. Certainly the water table may rise very close to the surface. Given good physical and chemical qualities, these soils are probably suitable for irrigated taro cultivation, at least over small areas with sufficient drainage to avoid soil-saturation when the level of the water table rises very close to the surface. An examination of these water table fluctuations would probably assist in establishing the scale of drainage required.

3. Conclusions

This first report on the soils of Lakeba has three principal objectives;

(a) to present an inventory of the soil-types present,

(b) to give a more precise impression of their distribution than is possible from the Twyford and Wright map, which is on a smaller scale, and

(c) to correlate the French and FAO classifications in order to facilitate relationships with maps made by other pedologists and agronomists.

This first mission has made possible an understanding of the importance of topography in soil distribution; a more precise account will be presented in the final report with the aid of certain representative soil-successions. The classification itself will also be made more exact once the results of physical and chemical analysis are available; it should be remarked that in the FAO-UNESCO classification some of the differentiations between diagnostic horizons call for statistical data. In the final report, we will also present correlation between the French (CPCS), FAO and UNESCO and Twyford and Wright classifications, in order to relate the work done by Twyford and Wright to our own. Analysis results will also make it possible to present the characteristics of each soil in precise terms, and will make possible corresponding information on their agronomic value. The second mission was carried out in January-February 1976. Physical and chemical measures carried out in the field, or to be undertaken in the laboratory, will permit the measurement of changes in the soil which result from cultivation; the soils chosen for this purpose are those mainly under food crops. During the second mission the soil map was verified in the field.

The mission of M. Latham (February-March) has been concerned with the problem of the Talasiga soils (FERRALITIC CAMBISOLS on andesite hills), and also with the effect of pine plantation in fixing and eventually ameliorating these soils. Physical and chemical measures were carried out of the same type as those undertaken on soils used for food-crop cultivation.

TAVEUNI

1. General Remarks

Taveuni is the third largest island in Fiji. It is situated directly on the 180th meridian and lies between latitudes of 16°40' and 17° south. It is separated by Somosomo strait (9km wide at the narrowest point) from the large island of Vanua Levu. The island is 42km long (26 miles) by 11.5km (7 miles wide): the total area is approximately 430km^2 (168 sq.miles).

Although a detailed geological survey of Taveuni has been carried out, its results have not been published. Only reconnaisance accounts are available. Twyford and Wright (pp.26-7) provide an adequate summary. The island is composed almost entirely of basic volcanic rocks, described by Rickard, (1965, p.20) as 'very young and fresh, highly vesicular, coarse augite-olivine basalts'. The volcanics of the northeastern sector are older, and the country here is quite heavily dissected; elsewhere the slopes approximate closely the natural slopes of the volcanoes, only slightly dissected.

A chain of approximately 120 craters and vents lies along the main axis of the island from SW to NE, and a subsidiary line with 6 major craters parallels this on the eastern side. While the origin of Taveuni may be in the Pliocene, the island is essentially a product of the Pleistocene. The older vents probably ceased activity in the late Pleistocene, but others continued into recent and very recent times (one to four thousand years), producing large areas of pyroclastics - scoria and basic volcanic ash, and vesicular lavas. The south of the island is largely covered by a mantle of volcanic ash, overlying very young basic volcanic rocks. These ash beds have a depth of 1 to 2 metres in the central-south, but diminish to a depth of a few centimetres near the coast. A number of very recent ash cones seems to be the origin of this mantle. Elsewhere, along the high central chain, the recent pyroclastics remained confined to the vicinity of the vents, although soils in this whole area are very deep.

The highest point of the island is the crater ULUIQALAU (1241m), one of the highest mountains in Fiji. A chain of craters with intervening small plateaux at an altitude around or above 1000m extends some 10km northeast from this point, terminating in the caldera-like basin of TAGIMAUCEA Lake. The present survey covered the north and the south of the island, but not the central area lying between a line joining Somosomo (west coast) and Pagai (east coast) on the north, and the Waimaqera-Salialevu road on the south. The two areas have very marked differences in topography and geology. The northern area is formed of older volcanics with little or no ash; the only remaining evidence of recent vulcanism in the soil is provided by residual blocks of scoria and lava which litter the surface and are found in the soil to varying depths. These originate from volcanic cones of the central chain, and are variable in distribution; other than by very meticulous ground survey it is very difficult to determine their pattern of distribution.

The southern area, by contrast, experienced vulcanism to a much later date; the ash mantle, and the alternating bands of lapilli and volcanic sand noted in certain profiles bear clear evidence of recent activity. We also encountered numerous blocks of lava and scoria pebbles, and vesicular lavas, all in much greater density than in the north. On the slopes of the ash cones themselves these unweathered elements are found within the soil, intermingled with ash, but almost never at the surface. On the shield-like slopes between the foot of the recent cones and the coast, by contrast, they litter the surface of the soil almost everywhere. It is, for this reason, much simpler to delimit the distribution of soil types in the south than in the north.

Geomorphologically and topographically there are also very marked contrasts between north and south. In the centre of the island there is a very regular slope from about 700 metres to the coast. Above this, an area of gentler slope separates the steep coastal fall from the more precipitous central chain. As we go northward, the height of the central chain diminishes, and some plateau-like areas emerge, at heights descending northward, to occupy the axis of high ground. Below these we encounter the same steep and regular slopes of the coastal fall as in the central part of the island. Toward the northern point, north of NARATA hill (410m), slopes become gentler.

However, while the upper portions of the eastern and western slopes have the same order of steepness, there are great contrasts in the coastal zone. On the western side the slopes continue uninterrupted to the sea, while in the east there is much more dissection higher up, and along the shore itself are some areas of low topography, such as the area between QELENI village and VUNIVASA estate. The only mangroves encountered on the Taveuni coast are developed here.

In the south of the island three principal zones can be distinguished:-

(a) recent volcanic cones, occuring as isolated hills or as groups of steep sided hills, ranging from 300 to 420m in altitude. The majority lie along the SW-NE axis.

(b) a piedmont zone around these cones, with a mixture of scoria and ash, but without rocks at the surface. Altitude is variable, but extends from the feet of the cones down to about 130-100m. In the extreme south, however, this landform continues to the coast.

(c) around this, beginning about an equal distance from the line of cones on both sides, is a zone of gentler slopes (a little steeper on the eastern side than on the western side), in which the whole surface is littered with volcanic rocks, often in very great density. Rocks are also found in the soil, often in such high density as seemingly to exclude all possibility of cultivation. An attempt to delimit the distribution of rock-density formed part of the work during the second mission.

Forest or traces of forest are found over the entire island, but dense high forest is now confined mainly to the centre of the island, and the whole central part of the eastern coast (RAVILEVU) which is extremely rugged, and uninhabited. Elsewhere we encounter:-

(a) coconut plantations, on estate and Fijian land, extending right around the northern coast and up to an altitude of 150-200m and sometimes higher than this. In the south, where slopes are gentler, coconut planting extends much further inland.

(b) food crop cultivation, extending more and more deeply into the interior to elevations as high as 520m along and beyond new roads.

(c) areas of former clearing, under secondary bush of various ages.

(d) areas under grass, and used for grazing cattle, at the back of large estates in the north and south of the island.

Survey was concentrated on the occupied areas and the adjacent forest margin. There are strong climatic contrasts, as demonstrated by the following table derived from Twyford and Wright.

Stations	Alt.	Situa.	No. Yrs.	J	F	M	A	M	J	Jl	A	S	O	N	D	Total
SALIALEVU	100 feet = 30m	Zone South and East Coast	33	401	474	437	521	587	483	386	400	517	539	488	485	5720
VUNA POINT	25 feet = 8m	Zone South and West Coast	35	327	341	302	311	272	183	183	185	195	275	230	315	3119
WAIYEVO	175 feet = 53m	Zone North and West Coast	49	294	312	300	277	221	129	80	113	122	179	212	278	2517
MUA	175 feet = 53m	Zone North and West Coast	35	311	355	335	335	256	138	115	143	153	191	254	315	2900

Table: Rainfall at some Taveuni stations (in mm).
(for Twyford, Wright 1965).

It is clear that:-

(a) there is no marked dry season

(b) there is, however, a notable reduction in mean rainfall in the June-September period on the western coast, and down the full length of this coast

(c) the contrast between the east and west coasts in total rainfall is very great: thus SALIALEVU has double the rainfall of VUNA POINT.

Available working materials

- published topographic map, contoured at 50 ft. (15.24m) intervals (Vanua Levu, sheets 15 and 16).
- aerial photography at 12,000ft (3650m) for 1967,
- geological work done but not published.

2. The Soils of Taveuni

In this preliminary report, we present a soil classification, using first field and analytical records, the major characteristics of each main soil group and their land uses. Some modifications may occur in the final report when the analyses will be completed.
Classification. As for Lakeba, FAO-UNESCO legend (1968-1974) will be taken as reference. It is shown in parallel with the French classification and Twyford and Wright in a following table. Two points will be developed:

- the choice of the Andosols as a major group,
- definition of the lower units.

(a) Choice of the Andosol great group. From a morphological point of view we have found some diagnostic characteristics, already observed in other recent volcanic areas. They concern mainly the B layer and are:

- a weak structure and cohesion of this horizon which forms a continuous and fragmented mass;
- a strong and very fine porosity;
- a smeary touch giving the appearance of a loamy texture;
- aggregation very poorly developed.

In order to confirm these observations, we carried out the Fieldes and Perrot (1966) test which permits one to identify the presence of Allophane*, a clay characteristic of andosols. It emerged that, while all soils in the south gave a strong positive reaction, results among the northern soils were variable, but almost never negative.

Taking geological, climatic and morphological considerations into account, it seems certain that the majority of Taveuni soils are in the Andosols or at least that andosolic character must

x This occurrence is confirmed by mineralogical analysis carried out by Twyford and Wright in 1959 in New Zealand.

occupy a relatively high level in the classification. However the physical and chemical analysis will allow us to go further into details in this classification. These soils are characterised by:

- a thick, well structured, humiferous horizon;
- a high organic matter level;

which set them into two first subdivisions of the Andosols, the MOLLIC and the HUMIC. The separation between Mollic and Humic Andosols rests on base saturation criteria, above or below 50%. According to the analytical records we obtained, we thought that the shallower soils could be saturated and so Mollic or Humic. The thicker and more weathered ones should be desaturated and so Humic.

(b) Definition of lower units. The major divisions of the FAO legend are of very little use in representing the differences in the soils of this island. So we used the lower division; the textural and the slope classes and the phases.

For the textural classes we took into account the presence of gravels in some soils, made of lapilli, so as to distinguish them from the fine textured soil form on basaltic flows.

The slope classes permitted us to distinguish level to gently undulating, rolling to hilly and strongly dissected to mountainous landscapes.

Distinctions were also made between a deep phase, a petric phase (soils showing the occurence of hard rock in the first 50cm) and stony phase (soils having big blocks of rocks in the profile and mostly up to the surface).

(c) Key for the soils of Taveuni.

Mollic or Humic Andosols.

- Coarse textured, rolling to hilly, on lapilli.
- Fine textured, steeply dissected, petric phase, on basaltic flows.
- Fine textured, gently undulating, deep phase, on basaltic flows.

Humic Andosols.

- Fine textured, steeply dissected, deep phase on lapilli.
- Fine textured, rolling to hilly, deep phase, on lapilli and basaltic flows.
- Fine textured, rolling to hilly, deep phase, on basaltic flows.
- Fine textured, rolling to hilly, petric phase, on basaltic flows.
- Fine textured, rolling to hilly, stony phase, on basaltic flows.
- Fine textured, gently undulating, stony phase, on basaltic flows.

(d) Correlation between the FAO legend and the French classification and the Twyford and Wright legend.

FAO-UNESCO Legend	French Classification	Twyford and Wright Legend
1. MOLLIC or HUMIC ANDOSOLS Coarse textured rolling to hilly on lapilli	ANDOSOLS, peu différenciés humiques, sur lapilli, de pentes et glacis de cones volcaniques	LATOSOLIC SOILS, without dry season, steep land or silt loam.
2. MOLLIC or HUMIC ANDOSOLS fine textured steeply dissected petric phase on basaltic flows	ANDOSOLS, peu différenciés, humiques, sur coulees basaltiques, de pentes de collines	LATOSOLIC SOILS, with weak dry season, steep land
3. MOLLIC or HUMIC ANDOSOLS fine textured gentle undulating deep phase on basaltic flows	ANDOSOLS, différenciés, saturés, chromiques, sur coulées basaltiques de zones peu vallonnées sans éléments grossiers	LATOSOLIC SOILS, with weak dry season, silt loam, and recent soils
4. HUMIC ANDOSOLS fine textured steeply dissected deep phase on lapilli	ANDOSOLS, différenciés, désaturés, chromiques, sur lapillis de pentes de cones volcaniques	LATOSOLIC SOILS, without dry season, steep land
5. HUMIC ANDOSOLS fine textured rolling to hilly deep phase on lapillis and basaltic flows	ANDOSOLS, différenciés désaturés, chromiques sur lapillis et coulées basaltiques, de zones peu vallonnées	LATOSOLIC SOILS, without dry season, steep land and with weak dry season
6. HUMIC ANDOSOLS fine textured rolling to hilly deep phase on basaltic flows	ANDOSOLS, différenciés, désaturés, chromiques, sur coulées basaltiques, de pentes de collines. sans éléments grossiers.	LATOSOLIC SOILS, with weak dry season, steep land
7. HUMIC ANDOSOLS fine textured rolling to hilly petric phase, on basaltic flows	ANDOSOLS, différenciés, désaturés chromiques, sur coulées basaltiques, de pentes de collines, avec éléments grossiers (inferieur a 30%).	LATOSOLIC SOILS, without dry season, steep land
8. HUMIC ANDOSOLS fine textured rolling to hilly, stony phase, on basaltic flows	ANDOSOLS, différenciés, désaturés, chromiques, sur coulées basaltiques de pentes de collines, avec éléments grossiers abondants des la surface	LATOSOLIC SOILS, with weak dry season, silt loam
9. HUMIC ANDOSOLS fine textured gentle undulating stony phase on basaltic flows	ANDOSOLS, différenciés, désaturés, chromiques, sur coulées basaltiques, de zones peu vallonnées, avec éléments grossiers abondants.	LATOSOLIC SOILS, without dry season, (middle north and East coast in south) With dry season (West coast in south).

<u>Soil Distribution</u>. Except for some very restricted areas of the sandy coastal plain and the mangrove, soils of Taveuni derive from volcanic material. Some places, especially in the south, are covered with a thick lapilli layer.

In the following section, the approximate localisation and extension of every soil are given. These often show some difficulties because the phases are distributed in a very heterogeneous way in the field and in the soil profile.

These characteristics do not seem to be linked to a topographical pattern but more to the recent volcanic activity. However, as we have not been able to consult the most recent geological studies, the soil boundaries are sometimes rather imprecise.

<u>Description of the major soils</u>. (a) Mollic and Humic Andosols, coarse textured, rolling to hilly, on lapilli.

They are mainly located on the southern part of the island, on slopes of recent volcanoes (1,000 to 4,000 years) and on some of their piedmonts. The original material is lapilli. These are unconsolidated rock made of gravel size elements. Natural vegetation is a dense forest. It has been cleared in many places for coconut plantation or gardens. Soils are normally shallow and are characterised by A-AC-C profile with:

- an A humiferous, loamy, well structured horizon of about 20cms;
- an AC, still humiferous, gravelly, poorly structured, very permeable horizon of 20 to 60 cms;
- a C, unstructured horizon, made of lapilli gravels.

As for similar New Hebridian soils, these seem well drained and resistant to erosion. Their water retention capacity is good despite the youth of the soil. From a chemical point of view, these soils look rich.

The deeper soils can be planted with arborescent crops such as coconut and the shallower ones with field crops such as yaqona, taro, cassava and kumala. Special attention will have to be given to these latter so as to prevent the exhaustion of the soils when they are under continous cultivation without fertilisers. On the steeper slopes erosion danger must be taken into account.

(b) Mollic or Humic Andosols, fine textured, petric phase, on basaltic flows.

Very few profiles of this type have been seen. They are located on steep slopes on the coastal plain in the southern part of the north zone. Natural vegetation is a secondary forest. Boulders may occur at the soil surface. The profile can be characterised by:

- its shallowness (30 to 40cms before reaching weathered rock, in joints;
- a humiferous, fine textured, porous horizon of about 10cms;

- the occurence in the following horizon (10 to 30cms) of coarse fragments, stones and gravels more or less weathered.

From a utilisation point of view, the major handicap is the generally steep slope and the presence of boulders from place to place. The weathered coarse rock fragments which occur in the profiles do not seem to be a constraint on root crops which do not penetrate too deeply. Coconut trees are sometimes also planted on these soils.

(c) Mollic or Humic Andosols, fine textured, deep phase, on basaltic flows.

These soils have been observed on the East coast (by Qeleni) and in the extreme north of the island on both sides of the air strip. They cover large areas used mainly for coconut plantation but also for root crops. Mean slopes are about 10% and the landscape is undulating. The soil profile is characterised by:

- a depth of 90 to 130cm before the weathered rock;
- the absence of coarse fragments in the whole soil profile;
- a humiferous penetration of 20 to 30 cms;
- a good general porosity.

The absence of coarse fragments, the depth of the pedon and the topographical situation are very favourable factors for cultivation on these soils. The chemical characteristics should reinforce this first favourable impression.

(d) Humic Andosols, fine textured, deeply dissected, deep phase, on lapilli.

These soils have been observed in juxtaposition with the (a) soil on the upper part of some volcanic hills on slopes of about 50%. Natural vegetation is a secondary forest. A savannah has developed in some cleared areas. They are characterised by:

- the depth of the pedon (deeper than the soils of the 3.1 unit);
- a humiferous, fine textured, porous horizon of about 20cms;
- a poorly structured with friable aggregate, porous underlayer;
- the absence of coarse material in their profiles.

Their use possibilities are similar to those of the (a) soil but they are deeper.

(e) Humic Andosols, fine textured, rolling to hilly, deep phase, on lapilli and basaltic flows.

These soils have been noticed mostly in the south of the island around the volcanic cones. But we have also found some of them in the northern part. On the soil surface, sca ttered boulders and stones from the basaltic flows may be seen. These soils are already very cultivated either with taro gardens or coconut plantations. The natural vegetation which must have been forest has disappeared. The soil profile shows:

- a depth of about 80cms without coarse fragments. Under this, a mixture of lapilli and fragments from basaltic flows can be observed;
- a humiferous penetration of 30 to 50cms;
- a good porosity with fine pores;

These soils seem to have a high organic matter level. They are very permeable, very porous and the root penetration can be noticed down to 40cms. Their original material is indicative of a high mineral reserve. Their agricultural possibilities are very wide.

(f) Humic Andosols, fine textured, in rolling to hilly landscapes, deep phase, on basaltic flows.

These soils have been observed in two main zones; one around Qeleni village from Waibula creek near Pagai to the north of Qeleni road; the other one on the west coast in the Nasilasila and Tuvurega estates. Some of the Vione road soils go into this unit. They are located on slopes ranging mainly from 15 to 30% but reaching sometimes 50% near the thalwegs. They are characterised by:

- the absence of coarse fragments in the whole profile;
- a humiferous, well structured, porous, permeable horizon of 15 to 20cms;
- a B, fine textured, with friable, very porous underlayer;

From an agronomic point of view, the restricting factor for this unit would be mainly the slope. Actually this does not seem likely to embarrass the users who plant taro gardens even on the steeper slopes. The soil preparation and the cultivation can only be manual and no signs of erosion have been seen. The vegetative state of plants appears very good and the yields obtained high according to informants. In the second mission, not reported here, we have investigated a possible depressive effect on the soil mineral reserve and on the physical state after years of continuous cultivation.

(g) Humic Andosols; fine textured, on rolling to hilly landscapes, petric phase, on basaltic flows.

They are located in the centre and the west coast of the northern part of the island. They cover an area limited by Qila road, Nasarata (Vione) road and the northern part of the Lagiloa plateau. In the south of the island they can be seen on undulating areas which extend by the volcanic cones.

They are very similar to the previous one; the main difference lies in the occurence of coarse material from basaltic flows under 30 to 40cms;. However these fragments represent rarely more than 30% of the soil volume.

This characteristic presents rather few constraints for the development of these lands as most of it must be cultivated manually because of the slope.

(h) Humic Andosols, fine textured, on rolling to hilly landscapes, stony phase, on basaltic flows.

These soils can be seen on hillslopes and are located in the northern part of the island at two major points:

- one on an area limited by the northern boundary of the Lagiloa plateau, the Nakaute creek on the east coast and the Nasilasila (Mua) estate on the west coast. It is surrounded by three zones without coarse material in the entire soil profile.
- a second area has been observed by Welagi village, including Nambeka estate on the west coast.

Their altitude ranges from 400 metres to sea level. Slopes vary between 10 and 25%. In most cases boulders can be observed on the soil surface. Their density is variable but always very high. The soil profile is characterised by:

- the occurence of coarse fragments, mostly of stone size (2 to 20cms) in the whole profile. Their concentration is very important, generally more than 50% in volume.
- a humiferous, fine textured, well structured, horizon of 15 to 20 cms. The coarse fragment percentage in this layer is at least 25%.
- a B horizon, well rooted in spite of the coarse fragment richness. This layer is highly porous with fine to very fine pores.

From a land development point of view, the major constraint for these soils is the high coarse material percentage, that occurs in the superficial layer as well as in the whole profile. This prevents any mechanical cultivation and restrains also manual cultivation in view of the enormous work demanded in land preparation. Only some soils, which have a coarse material percentage of less than 25%, can be used for field crops, if they are accessible and if their other characteristics are fair. Some coconut plantations can be seen but few field crops. At present, it seems better to leave these soils covered with the natural vegetation as there are plenty of other unused soils with little or no coarse material in them.

(i) Humic Andosols, fine textured, on gentle undulating landscapes, stony phase, on basaltic flows.

We have observed these soils in the north of the island on an undulating area above Qeleni road under secondary forest and in the south of the island on large undulating zones, on the west coast (Vuna Point) and on the east coast (Salialevu). These two places are almost entirely occupied by coconut plantations.

Soils have the same characteristics as the previous one except the topographical location.

This favourable location does not allow field crop cultivation because of the high coarse material level. But the cattle breeding under coconut trees are of a very high economic interest and could be expanded. This ultilisation may increase the sinking of the upper layer and so restrict the macroporosity.

Soil utilisation possibilities. As a summary of the remarks given for each soil unit, we have drawn up a table showing the soil utilisation possibilities of both parts of Taveuni. Agological value allows us to give a first approximation on the soil value. It is chiefly made on morphological and topographical criteria at the present stage.

The following table gives only indications and is only related to present crops cultivated in Taveuni. In the final report we shall try to suggest other crops which could fit into these ecological conditions.

3. Conclusions

It must be stressed again that the work reported here is only preliminary, and that the aim of this report is simply to give an account of the principal elements of the soils of Lakeba and Taveuni. The final report will take account of subsequent work, including:

(a) verification during the second mission (Jan-Feb 1976), especially on the delimitation of soil types on the map.

(b) analytical results, both physical and chemical. These will not only permit refinement of the classification, but will also provide an indication of the agronomic qualities of the soils, yielding numerical data which will be interpreted in relation to morphological and topographic criteria, and also to the present agricultural use of the soils.

For each island, this final report will be accompanied by a soil map, a map of land-use potential, and diagrams to facilitate understanding of the distribution of soil types.

However, the principal aim of the second mission was to study the evolution of soils under cultivation. Measures in the field, and samples for subsequent laboratory analysis, were taken at parallel sites, so far as possible identical in terms of soil type and topography, but representing cultivated and uncultivated plots. The location of these sites followed the earlier selection by Haynes and Brookfield of sites for the measurement of taro yields (October 1975 and January 1976). It will therefore be possible to compare sites on the basis of soil evolution under cultivation, given a comprehensive background of data on recent land-use history and present productivity. All this work, however, will be separately reported.

SOIL UTILISATION POSSIBILITIES

Agological Value	Soils	Topographic Criteria	Morphological Critera	Major Constraints	Utilisation Present	Utilisation Suggested
Very good	C and E	Soil C: Slopes average 10%. Soil E: Slopes from 10 to 25%.	Deep soils. Sparse coarse fragments. none in top 80cm of profile. Humiferous penetration 20 to 35cm. Structure: good, porosity: good.	Nil	Coconuts Taro Yaqona Cassava	Best to retain food crops in these areas. Avoid soil exhaustion by use of fallow rotation.
Medium	A	Medium slope usually about 10% (base of hills and undulating zones), but in places up to 50%.	Depth varies, with topography. About 35cm as pedon. Humiferous, well structured, porous horizon.	Some steep slopes. Good structure only in upper layer.	Coconuts on steeper slopes. Taro, Yaqona, Cassava, Sweet potatoes in undulating zones.	Avoid steep slopes; fallow rotation desirable.
Good	F and G	Hillslope areas. Usually 15 to 30% but steepening to 50% on slopes of thalwegs.	Deep soils belonging to unit 7. Coarse material less than 30% of whole column. Humiferous, well structured, A horizon.	Some steep slopes.	Some coconuts but mainly gardens planted after clearing secondary forest.	Fallow rotation desirable; avoid steep slopes.
Weak	B and D	Steep slopes (above 30%)	Shallow (soil D) to medium depth (soil B) soils. Humiferous, porous, A horizon. Sometimes coarse fragments on surface (soil B).	Steep slopes. Inaccessibility.	Soil D: food crops. Soil B: sparse coconuts.	Leave natural vegetation undisturbed.
Bad	H and I	80% of area covered by coarse fragments. Soil H: slopes less than 10%. Soil I: slopes 15 to 30%.	Coarse fragments account for 50% of soil volume throughout depth of profile. In some locations only 25 to 30% coarse fragments in first 20cm. Humiferous horizon: 15 to 20 cm.	Coarse fragments in profile and on surface.	Coconuts: especially in South of island.	Leave natural vegetation on soils with greater than 25% coarse fragments in first 20cm undisturbed.

Soils A to I refer to soil descriptions (a) to (i) at pages 20 to 23.

References

Brookfield, H.C. and Doreen Hart, 1966. *Rainfall in the tropical southwest pacific*, Australian National University, Canberra, Department of Geography publication G/3.

Brookfield, H.C., 1974. Background paper for discussion UNESCO/UNFPA, (18p.multi.) Suva.

-- 1974. Specification of subproject B2/C2 Soil-vegetation complex, Spiel 12 UNESCO/UNFPA, (3p.multi.) Suva.

Coulson, F., 1975. *Geological maps on 1/50,000 Vanois islands in eastern Fiji.* (Not yet published).

Fitzpatrick, E.A., Hart, D., Brookfield, H.C., 1966. 'Rainfall seasonality, in the tropical southwest pacific', *Erdkunde, 20. Supp. Band 3, p. 181-94.*

Ladd, H.S. and Hofmeister, J.F., 1945. 'Geology of Lau Fiji' - Bernice P. Bishop Museum Bulletin, 181.

Parham, J.W., 1972. *Plants of the Fiji islands,* 462p. + index, Government Printer, Suva.

Rickard, M.J., 1966. *Reconnaissance geology of Vanua Levu,* 1 map + text (Geological survey of Fiji).

Twyford, I.T. and Wright Acs., 1965. The Soil resources of the Fiji islands, 2 vol. (Vol 1 text, Vol 2 maps), Government Printer, Suva.