The study of land potential: an open-ended inquiry

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In the initial design of the Unesco/UNFPA Project in Fiji, one of the stated objectives was scientific description of the agrological qualities of the land resources, together with an estimate of their capacity to withstand and support cultivation. Added to this was an emphasis on the dynamics of change in the soil-vegetation complex, viewed as the expression of interaction between variable environmental conditions and the impact of changing human occupance. Following the conclusion of a mutually welcomed agreement between Unesco and ORSTOM, and approval of this agreement by the Government of Fiji, the present authors were charged with primary responsibility for this task, in collaboration with other members directly recruited by the project. Field work was carried out on five islands (Lakeba, Taveuni, Nairai, Batiki and Kabara) among which four were also studied from other points of view. In terms of their ecology, none of these islands was previously well-described. The major source on the soil and vegetation of Fiji (Twyford and Wright 1965) is concerned principally with the two main islands - Viti Levu and Vanua Levu - and discussion of the smaller islands is based only on reconnaissance. The islands chosen for study in the present project were selected on the basis of their representativeness in terms of the range of ecological conditions encountered in the eastern part of Fiji. Moreover, all had been heavily affected by human occupation, and hence were particularly appropriate for study in a pilot project within the Man and the Biosphere Programme of Unesco. On present evidence, it would appear that these islands were first populated by man about 3000 years ago[1]. Such occupation must be presumed to have initiated a range of environmental transformations, by clearing of the forest and use of fire. The 'talasiga' formation - the most extreme of a range of pyrophytic formations supported by very degraded soils - was either formed or greatly enlarged as a result of this interference. Soil erosion, and the creation of large areas of colluvium, may also be presumed to have arisen from, or been accelerated by, the interference of man with natural environmental process[2].

In so far as the team was concerned with evaluating the suitability of land for agricultural use, which was its pragmatic objective, the context had to be a search for the optimal production capacity of these environments, consistent with preservation or amelioration of ecosystems that are already in a very unstable condition. It was decided to base the work on the task of classification using the 'system for evaluation of soils' proposed by FAO (1976). Three stages of work are therefore involved:

- definition of ecological units;
- evaluation of the agrological qualities of land;
- evaluation of land-use potential, taking account of the consequences which any particular form of use might have on the environment.

[1] Based on work still in progress at the University of Auckland, and by this project.

[2] In Fijian, the term 'talasiga' means 'sun-burnt land' (Parham 1972). The term designates both a pyrophytic vegetation complex dominated by ferns, often in association with *Casuarina equisetifolia*, and also the very degraded and often eroded soils which support the complex. It is used in what follows as a generic term for a soil-vegetation complex which, while not limited to the eastern islands of Fiji, is particularly-well exemplified on some of these islands, outstandingly Lakeba.

Unesco, 1980. *Population-environment relations in tropical islands: the case of eastern Fiji.* (MAB Technical Notes 13).

The emphasis given to each of these stages varied according to the practical possibilities of access to islands, to knowledge of the environmental conditions as a whole, and to the purposes of the project, which was designed as a pilot study in this area. The approach adopted is represented diagramatically in Figure 1.

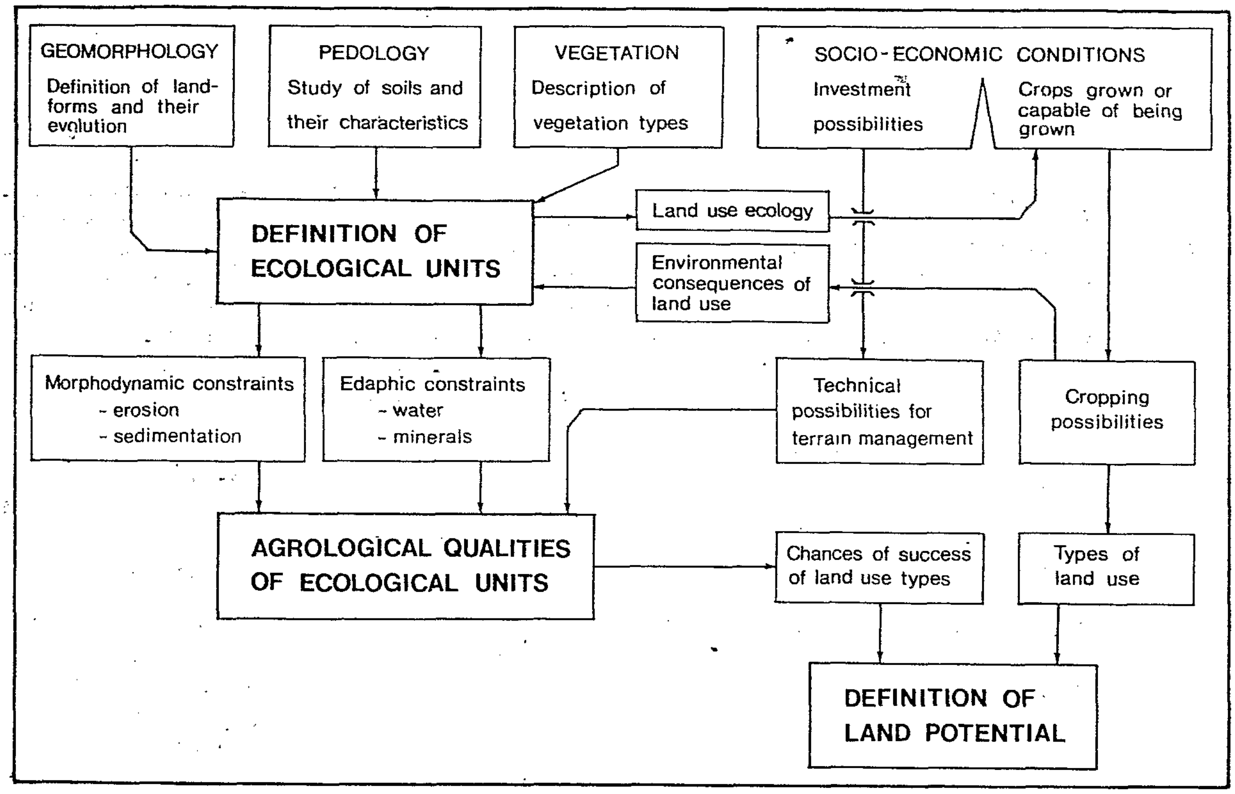

Figure 1. *Flow chart representing the method employed for the study of land potential*

I. THE DEFINITION OF ECOLOGICAL UNITS

The term 'ecological unit' is a compromise between the 'land unit' of most land-evaluation studies and the 'ecosystem' favoured by the Man and the Biosphere Programme. Many of the ecological units would in fact be congruent with natural ecosystems, being land units of relatively uniform environmental conditions capable of separate analysis in terms of their life-support systems, but to speak of ecosystems involves questions of bounding and the import and export of energy and matter, which are not faced in this work. For an essentially reconnaissance study, the term 'ecological unit' seems more appropriate. Even so, the task of defining such units demands a large input of new research, since these island environments are little-known scientifically, in view of their isolation and small size. Moreover, the environments of the different islands are very varied, and many elements are unique to particular islands. Within-island variation is often as marked as between-island variation. A short description of each island will introduce the disucssion which follows. That discussion is based primarily on Lakeba, the most complex of the islands studied from an ecological viewpoint, but draws also on conditions elsewhere in the archipelago.

LAKEBA

Although only 56 km^2 in area, Lakeba is an island of quite unusual ecological complexity. Basically, the island constitutes an andesitic massif of Miocene age, partly covered by Pliocene limestones, of which only fragments remain. In the present era, it experiences an oceanic tropical climate, with a mean rainfall at coastal sites of around 2000 mm/yr. A succession of somewhat different palaeoclimates, together with general uplift, has led to the formation of a range of morphological units, including bauxitic plateau areas, eroded hills, large colluvial zones in the valleys and lowlands, and alluvial coastal plains within which are quite numerous valley and sub-coastal swamps. A wide range of soils has evolved on these morphological units, among which the most maturely developed are the 'talasiga' soils (acric ferralsols and ferralic cambisols), while the least mature are the soils of the plains (eutric fluvisols, rendzinas, histosols and humic gleysols). Great diversity of vegetation is associated with these soil-landform complexes: dense forest, reed thicket, forb vegetation dominated by ferns (talasiga vegetation), and hydromorphic herbaceous vegetation. Notwithstanding its small size, the range of ecological units encountered in Lakeba exceeds the range encountered on any of the other islands visited.

BATIKI AND NAIRAI

These also are small volcanic islands, but of basaltic composition and Pliocene age. Batiki, the smallest island studied by the project, covers only 9 km^2, but Nairai covers 28 km^2. Both islands are hilly, and eutric cambisols, ferralic cambisols and a few areas of rhodic ferralsols are developed on the hills. Rendzinas are found on the coastal plains. Reed thicket dominates the slopes, but the small areas of plain, the valley bottoms and the summit area of Nairai carry forest vegetation. These two islands therefore constitute a younger and less diversified environment than Lakeba. They differ from Lakeba also in the relative importance of the ecological complexes. Eutric cambisols covered in reed thicket dominate these islands very much as Lakeba is dominated by the talasiga formation.

KABARA

Kabara is representative of a group of uplifted atolls, and occupies 52 km^2. In the northwest, however, is an outcrop of basalt of Pleistocene age. Three principal environments may be distinguished. Most of the island is formed of a limestone basin, sloping inward from the encircling ridge toward the centre, and containing some pockets of bauxitic soils (humic ferralsols); this whole area is covered in dense forest. Second is the small volcanic hill which carries the principal cultivated area, but where soils (eutric cambisols) are badly eroded. Third are the coastal plain areas of sand or rendzinas, which are mainly under coconuts. Kabara's environment is therefore quite simple, but very different from that of the other islands.

TAVEUNI

Taveuni is much the largest of the islands studied (264 km^2), and is not representative of any other island but itself. Geologically, it is the most recent in formation. Major eruptions have taken place within the past 3000 years, concluding perhaps within the past 1500 years, and the whole volcanic mass is of upper Pleistocene and Holocene age. The climate is unusually humid, mean annual rainfall exceeding 6000 mm in parts of the island. According to the age of the volcanic parent material, soils may be divided into an andic group and a ferralitic group with bauxitic tendencies. Except where cleared for coconuts or other cultivation, a dense forest covers the whole island to the summits. Taveuni is a young island, of fertile volcanic soils characterized by a dense rain forest with little or no evidence of degradation.

SUMMARY

The environments of these islands are varied, and contain distinctive elements. Because of its diversity, work on Lakeba alone occupied half the time alloted to the ecological survey in the field. Maps have been prepared for Lakeba at a scale of 1:25 000 and of parts of Taveuni at 1:50 000; sketch maps only were prepared for Kabara, Nairai and Batiki, at the 1:50 000 scale. Table 1 summarizes the main environmental characteristics of each island.

The three essential elements in the definition of ecological units are inquiries in geomorphology, soil science and the nature of the biota. They are all indispensable to an understanding of environment, its natural fertility and its dynamism. For each there are problems of classification, but especially of soils and vegetation. In order to facilitate international comparison, the FAO/Unesco (1972) system was used for classification of soils, and the Unesco (1973) system for vegetation.

Table 1. *Ecological characteristics of the islands studied*

ISLAND	AREA (km^2)	GEOLOGY	GEOMORPHOLOGY	SOILS	VEGETATION
LAKEBA	56	Andesites (Miocene)	Bauxitic plateaux	Acric ferralsols	Forb vegetation (talasiga)
			Eroded slopes	Humic and rhodic ferralsols	Forest and forb vegetation
				Ferralic cambisols	Forb vegetation
				Eutric cambisols	Scrub with reeds
			Colluvial zones	Chromic luvisols	Forb vegetation
			Alluvial plains and coastal plains	Eutric fluvisols	Coconuts and food crops
				Rendzinas	Coconuts and food crops
				Gleysols and histosols	Irrigated taro
		Limestone	Karst landforms	Humic ferralsols	Food crops and dense forest
				Lithosols	Food crops and dense forest
NAIRAI	28	Basalt (Pliocene)	Eroded slopes	Humic ferralsols	Dense forest
				Ferralic cambisols	Forb vegetation
				Eutric cambisols	Scrub with reeds
			Coastal plain	Rendzinas	Coconuts and cultivation
BATIKI	9	Basalt (Pliocene)	Eroded slopes	Eutric cambisols	Scrub with reeds
			Alluvial and coastal plains	Rendzinas and fluvisols	Coconuts and cultivation
KABARA	52	Limestone	Bauxitic plateaux	Humic ferralsols	Dense forest
				Lithosols	Dense forest
		Basalt (Pleistocene)	Eroded slopes	Eutric and chromic cambisols	Cultivation
					Cultivation
			Coastal plains	Rendzinas	Coconuts
TAVEUNI	264	Basalt	Cones, slopes and low-angle flows	Humic ferralsols	Dense forest and cultivation
				Ferralic cambisols	Dense forest and cultivation
				Humic andosols	Dense forest and cultivation

II. EVALUATION OF THE AGROLOGICAL CHARACTERISTICS OF ECOLOGICAL UNITS

Having defined the ecological units, the next step in an applied study such as the present is to determine more precisely their agrological characteristics. Study of three principal elements is involved:

- the edaphic constraints of the soil;
- the constraints of morphodynamic processes;
- the possibilities of rational management.

THE EDAPHIC CONSTRAINTS

Without experimentation, or data from experiments in closely comparable conditions elsewhere, approach to the study of these constraints has to follow a process of logical synthesis based on observation. The principal characteristic of the soil being determined, observation of the vegetation and of existing agricultural practice is then compared against these characteristics and evaluated. The biological activity of the soil was also tested, as an important measure of the quality of the soil-plant interface. In these islands, three pedological characteristics were deemed particularly significant in evaluating the edaphic constraints of the soil:

- depth of the natural root zone;
- availability of water to the plants;
- the chemical fertility of the soil.

Depth of the root zone. This is a basic variable in soil quality. The depth of the natural root zone determines the water and nutrition supplies available to cultivated plants. In these islands, shallow eroded soils are abundant, and this circumstance places strict limitations on the possibility of management. In all soil profiles this variable was observed with particular care.

Availability of water. The supply of water to plants is likewise a major determinant of vegetation growth. Even in these relatively humid climates, with mean annual rainfall generally in excess of 2000 mm, drought is often a limiting factor of considerable importance. A major part of the rainfall occurs during heavy and drenching showers, and flows some distance across the surface before being absorbed. Moreover, the dry season is often three or four months in length, and long dry periods occur in the rainfall records. Plants may be supplied with water by concentration of sheet flow as well as from water stored in the soil. The water reserve held in the soil is thus of major importance in drained situations, and was estimated using the formula developed by Hallaire (1961)[1]. Taking account of a mean evapotranspiration of around 100 mm/month, it emerges that drought stress can become a serious risk for plant life after only one month without rain on the majority of these soils (Table 2). Mineral deficiencies are notoriously difficult to evaluate in these environments, and their quantitative assessment demands experimental work such as has been carried out in the Cook Islands or the Kingdom of Tonga (Widdowson and Blackmore 1975; 1976). It would seem, however, that potassium deficiency is very likely to be a real constraint both on the ferralitic soils and the andosols. Moreover, it seems probable that phosphorous assimilation would be a problem on the andosols, following the work in similar locations by Quantin (1975), and Colmet-Daage and Lagache (1965).

Evidence of the biota and of existing cultivation

The above evaluation of chemical fertility is in large measure substantiated by observation of the natural vegetation and of present land use. Both the density and the floristic composition of the natural vegetation were taken into account. Estimation of vegetation density makes possible an approximation of the biomass, and by inference of productivity. It needs, however, to be complemented by floristic analysis of burned-over areas. Such floristic analysis often makes possible linkage between a recently-burned assemblage and an un-burned assemblage to which it corresponds, and facilitates correction of estimates concerning the productivity of the land.

Observation of land use, and the information provided by cultivators are very valuable sources of information, even though subjective. The project undertook field measurements of taro yield (Haynes 1976) and also estimates of coconut yields from secondary data (Unesco/UNFPA 1977; H.C. Brookfield, personal communication). These measures are not easy to interpret in view of uncertainties regarding cultivation methods, use of different varieties in the case of taro, and uncertain age of trees in the case of coconuts. They offer, however, the only available objective comparisons of agricultural crop productivity between different parcels of land.

A further method of judging the productivity of soils was therefore sought. The method employed was to evaluate the biological activity of soils through measurement of the release of CO_2 (Bachelier 1968). This method is very sensitive to variations in soil humidity, and comparison between sites is not possible except under equivalent humidity. Measurements were therefore made in the months of February and March 1976, at the height of the rainy season when soil humidity is almost constant at field capacity. Very

[1] $Q = \Sigma_{o}^{h+15} \frac{d}{10} (H_0 - H_1)\zeta$

Where:

Q = potential water reserve in mm
h = depth of the root zone in cm
d = bulk density of the soil
z = depth
H_0 = humidity at field capacity
H_1 = humidity at the wilting point.

interesting results were obtained (Table 2), corresponding well with other evidence. It emerges that soil fertility in these islands generally exhibits a direct correlation with organic matter content, the plant cover and level of biological activity. In the absence of data which could be extrapolated from other situations, the project relied on these field and laboratory observations in its attempt to define a scale of soil fertility.

The morphodynamic constraints

Erosion, sedimentation and the action of the sea all have an important bearing on the question of land capability. Erosion rates were estimated principally from sedimentary deposition in swampy areas, especially on Lakeba; only qualitative observations were possible elsewhere. The rate of sedimentation could be measured through C_{14} dating of samples obtained at different depths, and erosion rates were then estimated from the area of the upstream catchment. This work was reported in greater detail by M. Latham, P.J. Hughes and M. Brookfield in Brookfield 1979, and also in the final report to be published by ORSTOM. Erosion rates of at least 100-125 t/km^2/yr have been estimated both from forested and from talasiga catchments. These rates are high, but are comparable with those calculated from sites else-

Table 2. *Comparison between ground cover, soil characteristics of the A horizon and biological activity in Lakeba*

	ACRIC FERRALSOLS	HUMIC FERRALSOLS	FERRALIC CAMBISOLS	CHROMIC LUVISOLS	EUTRIC FLUVISOLS	RENDZINAS	HISTOSOLS	HUMIC GLEYSOLS	EUTRIC CAMBISOLS	HUMIC CAMBISOLS
Ground cover	Talasiga	Forest	Talasiga	Talasiga	Coconuts	Coconuts	Wet Taro	Wet taro	Reeds	Forest
Mean cultivable depth (cm)	100	40-60	20-40	100	100	100	Hydromorphic		30-40	30-40
Potential water reserve (mm)	80-95	120-140	50-70	120	140-160	(	Saturated	)	100	100
Physico-chemical characteristics (A_1 horizon):										
Texture	SL	A	SL	L	AL	S	A	A	A	A
Structural instability	0.3	-	0.6	0.6	0.1	0.4	-	-	0.4	0.4
Bulk density	0.65	-	0.70	0.87	0.83	0.86	0.52	0.57	0.82	0.80
Per cent carbon	3.0	4.3	3.3	2.9	5.7	8.3	13.5	12.7	2.8	6.0
Per cent nitrogen	0.15	0.3	0.18	0.14	0.42	0.63	0.13	0.35	0.21	0.55
pH	5.3	5.6	4.9	5.3	6.5	7.1	4.4	5.6	5.8	6.0
Exch. Ca^{++} (me/100g)	2.2	6.1	2.2	2.5	24.4	-	14.1	19.6	10.5	9.4
Exch. K^+ (me/100g)	0.3	0.2	0.55	0.4	0.3	0.5	0.18	0.64	0.76	0.33
Cation exchange capacity (me/100g)	30.7	27.6	22.4	26.0	45.0	-	50	50	29.2	23.7
Base saturation (per cent)	16	48.9	29.1	40.4	73	-	50	50	76	75
Phosphorous (per thousand)	1.4	0.2	1.4	2.1	2.4	1.8	1.2	1.3	2.1	0.7
Biological activity in mg of CO_2/m^2/hour (wet season)	20-40	-	15-80	35	184	120	240	235	108	138

where in the tropics (Trescases 1975; Roose 1975). Rapid erosion may also be observed qualitatively in the field, by the presence of a number of gullies on the hillsides and the numerous examples of deposition of weathered andesitic sands on the lower slopes.

Material eroded from the slopes is distributed along the valley floors. Carried in suspension in the streams, finer fractions are deposited in the swamps and on flood plains. Other sediments result from sheet erosion on the slopes and are deposited on land of lesser gradient to increase the depth of the colluvial formations. Some of these deposits are beneficial to soils situated in the lower part of forested catchments, or catchments with other upland soils of high fertility, and it is probably this supply of mineral fertility that explains the high value of the valley swamps of Lakeba, which have been regularly cultivated under taro for many generations. However, colluvial deposits are less often valuable, being mainly derived from upslope talasiga soils of very low fertility.

The effect of the sea on the coastal areas is discussed elsewhere in this collection by McLean, and is not further developed here.

Technical possibilities for terrain management

The constraints discussed above are capable of some reduction by proper management. Such control measures can only be on a modest scale in the short term, given the level of investment for rural development proposed in the current five-year plan for Fiji (Central Planning Office 1975), but a certain minimum level of investment is necessary if an increase in agricultural production is desired. Such investments are possible both in improving the edaphic qualities of the soils and in bringing the morphodynamic processes under control.

Improvement of soil quality. Improvements are possible both in the manner of working the soils, and also in soil enrichment by fertilization. With only limited exceptions, the soils of this region are presently worked manually. Tractor ploughing has been introduced in Taveuni, and initiated in Lakeba, and considerable expansion is possible. However, mechanization is significant only in so far as it can contribute to extension of the cultivated area and the introduction of new crops such as cereals, oil seeds, or improved pasture; slope remains a major constraint. The use of manure and fertilizers is certainly capable of more universal expansion. Both mineral fertilization and the use of green manure would permit an increase in yields and also would assist recuperation of infertile soils. Mineral fertilization is presently practised on a very small scale on Taveuni and Lakeba, but extension of these practices would demand both a programme of agricultural education, and a large investment.

Very little has thus far been done to manage the morphodynamic processes on these islands. Work is essentially confined to anciently-established drainage on Lakeba, and to erosion control on the volcanic hill in Kabara. Modern drainage in Lakeba is confined mainly to inland valley sites where the slope is greater and depredation by livestock less of a problem. Only a few of the formerly-drained sub-coastal swamps are still in production. It would seem that to bring the larger of these swamps back into use would now require major works. With the exception of limited patches of wet land on Taveuni, none of which are still in production, and small areas of Nairai and Batiki, the problems of drainage and irrigation are presently specific to Lakeba among the islands studied. However, there are much larger areas of swamp on the main islands, some formerly managed and others never managed, especially in the Rewa delta near Suva.

Erosion, on the other hand, is widespread throughout the eastern island region, yet the only example of effective anti-erosion measures seen is on Kabara. On this raised atoll, most cultivation is concentrated on the slopes and piedmont of the one volcanic hill. This hill has been heavily cultivated for a very long period, leading to severe erosion and truncation of the soil. The upper slopes are now partly circled by contour-line hedges of *Cyperaceae* which check run-off and so reduce erosion. Similar practices need to be introduced throughout all the other islands of the archipelago, wherever annual food-crop cultivation is carried out on steep slopes. Present land management is of a very minor order, and needs to be greatly extended in order to permit the better utilization of the soil resources of these islands.

III. DEFINITION OF LAND POTENTIAL

The definition of land potential is an essential basis for rational agricultural planning. In order to be effective, the capabilities of each ecological unit need to be evaluated in terms of the type of agriculture presently employed, or of alternative types which could easily be adopted. It is also necessary to estimate the impact of these land uses on the environment.

Evaluation of land potential

For each ecological unit, there exists a range of possible land uses compatible with the edaphic qualities of the soil and the morphodynamic constraints of the land. Observation of existing cultivation practices provides a useful guide, but there are also other cropping systems found elsewhere in comparable ecological conditions, which are either not practised, or scarcely at all practised in present-day eastern Fiji. These include cereal cultivation, oil seeds, coffee and oil palm cultivation. Such crops could be established on certain islands to provide more diverse sources of income, but their development would generally require a complete restructuring of the rural landscape and economy. Such remodelling affects principally the dominant position presently occupied by the coconut palm. Estate and smallholder groves of coconuts presently cover much the larger part of the best land on all the islands. The trees are often old, badly maintained, and of low yield. In cash terms, they offer a low rate of return per hectare, and their presence both inhibits the introduction of more rewarding crops and constitutes a brake slowing down moves toward diversification (Unesco/UNFPA 1977).

The resultant scheme is summarized in Table 3, where seven land-use systems are recognized, cross-classified within each ecological unit by four levels of capability: good, average, mediocre and poor. The object is to permit the planner to make a rational choice among the range of possibilities.

Consequences of land-use systems for the environment

Changes in the system of land use can often, however, lead to very unfavourable secondary effects on fragile natural environments. It has been remarked above that clearing and the use of fire, which followed the arrival of man in these islands, led in some islands to severe degradation. This was especially the case in those areas now occupied by pyrophitic vegetation complexes such as the talasiga and reed-thicket. More recent examples include the almost uncontrolled introduction of weeds and plant disease in the late 19th century, and modern clearance of the forests. No new introduction should ever be proposed without evaluation of its environmental impact, whether by comparison with known cases elsewhere, or by attempts at measurement on site. During the course of the project, three types of land use were examined from this point of view:

- changes in soil under semi-continuous taro cultivation;
- environmental changes under *Pinus caribaea* plantation;
- the effect of shifting cultivation on the environment.

Soils under taro. Soils which had been under almost continuous cultivation for up to ten years on Taveuni, and far longer on Lakeba, were examined by Denis; brief results were presented in the project's first general report (Unesco/UNFPA 1977) and will be expanded in the final report to be published by ORSTOM. The Taveuni soils were andosols and humic ferralsols; in Lakeba the sites were on gleysols and histosols, under irrigation and drainage. The object was to determine whether or not the absence of a fallow period had provoked soil degradation. Two pairs of sites were examined on each island; in each pair one plot had been continuously cultivated while the other was under very old regrowth. Physico-chemical characteristics (porosity, structure, pF, organic matter, pH, exchangeable complex, phosphorous) were examined together with the biological activity of the soil, using the method described above. On the richer soils no significant differences were observed in any of these indicators between the cultivated and uncultivated soils, a result which implies that intensification of cultivation is entirely feasible in these environments. However, this conclusion cannot be extended to be applied to the less stable soils; intensification on the latter would require fertilization and green manuring.

Soils under Pinus caribaea. A similar study was carried out to test the effect of *Pinus caribaea* plantations, which are becoming widespread on talasiga and other degraded soils in Fiji. The general view is that the plant-

Table 3. *An example of land classification for agriculture and forestry: the case of Lakeba*

ECOLOGICAL UNITS CLASSIFIED BY AGROLOGICAL QUALITY	POSSIBLE TYPES OF LAND USE: FIELD CROPS MECHANIZED	IRRIGATED CROPS	SUBSISTENCE CROPS	LOW-DEMAND CROPS, LONG FALLOW	IMPROVED PASTURE	TREE CROPS	FOREST PLANTATION
HIGH QUALITY, little erosion:							
- Alluvial and coastal plains Eutric fluvisols, now coconuts	+++	--	+++	--	+++	+++	--
- Swamps, Humic Gleysols, now grass fallow and taro	--	+++	--	--	--	--	--
MEDIUM QUALITY, little erosion:							
- Coastal plains, Rendzinas now coconuts	--	--	--	++	++	+++	--
- Swamps, Histosols and Gleysols now under swamp vegetation	--	++	--	--	--	--	--
MEDIOCRE QUALITY, liable to erosion:							
- Colluvial/alluvial terraces, Chromic Luvisols, now talasiga	++	--	--	++	+	+	++
MEDIOCRE QUALITY, serious liability to erosion:							
- Steep slopes, Humic Cambisols, now forested	--	--	++	++	--	+	--
- Lower slopes, Eutric Cambisols, now reed thicket	--	--	--	++	--	+	--
VERY MEDIOCRE QUALITY, little erosion:							
- Plateaux, Acric Ferralsols, now talasiga	--	--	--	+	+	+	++
VERY MEDIOCRE QUALITY, serious liability to erosion:							
- Hills and slopes, Ferralic Cambisols and Rhodic Ferralsols, now talasiga	--	--	--	--	+	++	++
LOW QUALITY, serious liability to erosion:							
- Very steep slopes, Humic Cambisols, now forest	--	--	--	--	--	--	--

Key to symbols: +++ highly suitable
++ suitable
+ low chance of success
-- land use type not suitable

ing of resinous trees degrades the environment, and several studies in Europe have demonstated the role of resinous trees in producing podzolization. As in the taro study, paired samples were measured, in each case one site being selected from a planted area, the other from a nearby area under its 'natural' cover. In addition to the physico-chemical and CO_2 measurements described above, observations were also made of the spontaneous ground flora.

This study, carried out on plantations from five to 15 years in age, yielded significant evidence of net amelioration of the soil in the planted areas; moreover, there was also an enrichment of the spontaneous ground flora. Positive consequences of pine planting on soil permeability have earlier been demonstrated by Bayliss-Smith (1977). It perhaps follows that the establishment of a continuous ground cover under *Pinus caribaea* is beneficial both to the soil and to the hydrological regime. At this stage, no significant tendency toward degradation of soil under the resinous trees could be discerned.

The effect of shifting cultivation. In view of the widespread development of impermanent field plots on steep slopes, it seemed also necessary to evaluate the effect of forest clearance for this type of agriculture. Shifting cultivation is probably of ancient origin in these islands, but there has been considerable recent extension due to the new marketing opportunities for taro and yaqona. Observation suggested that loss of soil from the slopes was a more significant consequence of these developments than degradation of the soil itself or of the vegetation. In Lakeba, it was possible to measure this erosion from the sediment deposited in a swampy area of the base of a partly forested hill, which has long been cleared and cultivated (Waitabu). This was not a completely satisfactory method, and sediment traps would have been preferable. Not only is it impossible to separate sediment derived from the gardened areas and the uncultivated slopes, but the amount of erosion is also under-estimated, since quantities of material in suspension are carried further downstream in floods. None the less, some indication is possible, and on the basis of preliminary results we estimate erosion in a partially-cleared basin at 1.24 t/ha/yr, or 8.3 cm/1000 yr. If this estimate is compared with the mean rate of deepening of tropical soils by weathering, estimated at between 0.5 and 5 cm/1000 yr (Leneuf 1959; Hervieu 1968; Trescases 1975), we would seem to have only a moderate rate of soil truncation. Any increase in the clearing of land for cultivation would, however, accelerate this rate of soil loss, as seems to have happened on the volcanic hill in Kabara.

The three examples cited above demonstrate the value of measurement of environmental change under human use of the land; simple application of conventional wisdom is not sufficient. However, it was not possible to go beyond the reconnaissance work described above in view of limitations of time and resources in this pilot project.

CONCLUSION

The study of the soil-vegetation complex within the Fiji project was designed to explore the dynamics of change, as well as to establish the basis for an evaluation of land resources in terms of their rational use: a range of field studies was therefore undertaken, calling not only on pedology, but also on geomorphology, sedimentology, agronomy and botany. Limitations of competence were encountered, for while project members were selected for their interdisciplinary interests[1], the primary expertise of the ecological team was in the field of pedology, and a full suite of specialists could not be made available to advise the team in the field. Existing documentation, in particular unpublished material provided by the geologists of the Mineral Resources Division, the pedological studies of Twyford and Wright (1965), the botanical studies of Parham (1972) and a good aerial photography coverage from high, middle and low altitudes for Lakeba, and middle and high altitudes for other islands, had to substitute as the base of inquiry. Further information was obtained from the local professional services - meteorology, agriculture and forests - and also from unskilled but well-informed guides in the field. The larger part of the botanical work, in particular, was achieved by relating vernacular names obtained in the field to the data provided by Parham (1972) and specimens in the Suva herbarium.

Inevitably, more questions were posed than were answered. The problems raised in the course of the ecological survey demanded solution through research in geomorphology, botany and palaeobotany: in particular, these problems required the establishment of a quaternary chronology for the Fijian region, an explanation of the evolution of bauxitic soils in Lakeba, and of the origin of the talasiga formation. Partial answers could be suggested, but each of these questions demands a whole research project to itself alone. Even the edaphic study of soils had to rest at a level of unsatisfactory generality. Foliar analysis would be necessary in order to detect deficiencies. Pot trials would also have been desirable. For all this the project would have required more specialists, more time, and more money.

Finally, study of the all-important impact of man on environment has to remain at an indicative rather than conclusive level. The survey could do no more than estimate the effect of forest clearance on slopes by shifting cultivation. Agronomic systems, and the problem of fallow periods and their successional vegetation had to be discussed without full analysis. Working in an untouched area, the project could do no more with its resources

[1] (Editorial footnote) The principal author of the present paper in particular was selected for this reason.

than outline the dimensions of answers to its questions. However, it has been possible to shed light on a number of aspects of the island environment, its natural qualities and also its vulnerability.

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Edited by H.C. Brookfield

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