SOIL AND CULTIVATION IN THE PAPUA NEW GUINEA HIGHLANDS: II. A COMPARISON OF INDIGENOUS AND SCIENTIFIC PERSPECTIVES.

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ABSTRACT

This is the second in a two part series of papers investigating the assertions of some Southern Highlanders that they do not inspect soil before clearing sites for cultivation. This paper assesses the status of their disclaimers through the analysis of the results of a survey of soil sites. A classification of soil resources is built up using multivariate techniques, by first assessing horizon variations, then constructing profile sequences, and finally combining these with clusters of site characteristics. A comparison of the resulting soil resource classification with indigenous assessments of, and agricultural use of soils reveals no apparent relationship, although there are some interesting soil-cultivation trends. The analysis fails to go beyond what local people assert about inspection of soils before cultivation, for there are apparently no observable patterns of properties by which they might assess agricultural potential.

Key words. Papua New Guinea, Southern Highlands Province, soil/site description, soil classification, multivariate analysis.

INTRODUCTION

The Wola of the Southern Highlands Province of Papua New Guinea say that inspection of soil does not figure in their selection of sites for cultivation, as related in Part I of this series of papers. In an attempt to assess the status of their disclaimers about soil appraisal, and to evaluate generally the standing of local soil knowledge, the results of a survey of soil sites conducted in the west of their region are presented and discussed here.

The sites surveyed occurred, by and large, on the local territories of two neighbouring *semonda* clan communities, situated adjacent to the Waga and Augu rivers, in Nipa District. It also included parts of the territories of other neighbouring *semonda* clan communities, particularly those with locations that had good examples of certain soil classes, such as sandy and gley soils, alluvial soils on extensive water-borne deposits (at lower altitudes in the vicinity of Lake Kutubu) and clayey soils on volcanic parent materials (Rutherford and Haantjens 1965; Bleeker 1983; Wood 1984; Radcliffe 1986). The total number of sites described was eighty-five.

The sites were not selected randomly, but with two aims in mind, related to the gardeners' unexpected disclaimers about soil appraisal. Firstly, to describe and classify the soils of the area according to a framework sympathetic to local perceptions and judgements, and secondly, to accomodate and appraise the affects of local land use and agriculture on the soils (Clarke and Street 1967; Wood 1979). In relation to the first aim, an effort was made to include in the survey sample representative examples of the different soil types identified in the area. And in relation to the second aim, sites were selected according to their vegetational cover and slope, in an effort to obtain representative coverage of different land uses, both past and present, and so allow for their impact on the soils.

Table 1 lists the classes of site distinguished according to land use, vegetational cover and slope, and the number of sites described in each class. While trying to obtain a representative sample of the soils in the survey region, by structuring the selection of sites according to the above guidelines to ensure the necessary distribution, sites were otherwise selected in a casual manner depending to some extent on local people's ideas of where would be a good place to look at a particular soil that met certain of the above criteria. Another factor that influenced the choice of sites was that a wide geographical spread of sites from around the region was more desirable than bunching in one locality, where this was comensurate with the above objectives. A final factor was that landowners did not object to me digging profile pits on sites (a consideration that applied to gardens only).

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Table 1. **Distribution of sites in soil survey sample according to land use, vegetation cover and slope.**

LAND USE			VEGETATION	SLOPE Steep	SLOPE Shallow	SLOPE Flat
Uncultivated land			Primary forest	6	6	
Uncultivated land			Wetland vegetation			2
Disturbed land	Cultivated long ago		Wetland vegetation			1
Disturbed land	Cultivated long ago		Secondary forest	5	7	
Disturbed land	Cultivated long ago		Cane grassland	5	7	
Disturbed land	Cultivated until recently	(long term gardens)	Grasses & herbs	2	6	2
Disturbed land	Cultivated until recently	(short term gardens)	Grasses & herbs	5	3	2
Currently cultivated land	Established long term gardens cleared from:	Primary forest	Crops			
Currently cultivated land	Established long term gardens cleared from:	Secondary forest	Crops	2	3	
Currently cultivated land	Established long term gardens cleared from:	Cane grassland	Crops	2	2	
Currently cultivated land	Recently cultivated gardens cleared from:	Primary forest	Crops	3	2	
Currently cultivated land	Recently cultivated gardens cleared from:	Secondary forest	Crops	3	1	
Currently cultivated land	Recently cultivated gardens cleared from:	Cane grassland	Crops	2	2	
Currently cultivated land	Recently cultivated gardens cleared from:	Wetland vegetation	Crops			2
Currently cultivated land	Recently cultivated gardens cleared from:	Bare ground (abandoned house site)	Crops			2

The sites and soils were described according to the Soil Survey of England and Wales procedure, as detailed in the *Soil Survey Field Handbook* (Hodgson 1976). The nominal depth of the profiles described was set at 50 cm, as the depth most relevant to an assessment of soil-related factors affecting agricultural land use, but this was often exceeded. The local description of the soil and assessment of its agricultural potential was supplied by those who assisted me, plus any other individuals who happened to be on site during the survey. They were asked to comment on the agricultural potential of the soil and to assess its status on a six-point scale (as very good, good, middling, poor, very poor, or waterlogged)[1].

DATA ANALYSIS

The data were subsequently programmed into an Amdahl 5860 and analysed multivariately using the SPSS-X computing package, employing ordination by principal components analysis, with cross-tabulation, factor analysis and cluster analysis (Cuanelo and Webster 1970; Goel and Gaikawad 1974; Webster and Burrough 1974; Webster 1977; Oliver and Webster 1987). The analysis distinguished between different classes of soils according to all the survey data, suggesting correlations that might help assess both the effects of soil status on local land use and of subsequent agricultural practices on the soils. And it compared these findings with indigenous soil judgements and perceptions, to assess the validity of assertions that the soil does not significantly influence and guide cultivation decisions.

The 'unearthing' of correlations between land use and soils, and local assessments of the cultivation potential of different soils, demands the classification of the soils described by profile and site. Firstly, different horizon types are defined, after assessing intra-horizon variations in soil properties. Secondly, different profiles are distinguished, as comprising different horizon sequences. And thirdly, these soil profiles are correlated with the site data to generate a soil resource classification. The strategy overall produces a classification of entire soils, as comprising sequences of defined horizons occurring in specified site locations. Finally, this soil resource classification is compared with land use and local assessments of soil-worth in an attempt to trace connections between cultivation practices and soil status.

HORIZON VARIATION

Any pattern to the variation in properties within horizons was assessed initially in a series of cross-tabulations of those pairs of soil properties that might reasonably be expected to show some correlation in their variation. While some evidenced a degree of correlation, the results were not conclusive, indicating that the horizons do not vary internally in any straightforward manner with certain properties varying regularly in relation to one another. The majority of properties showed a random distribution and no correlation. This lack of success was not surprising because if such an obvious variation in properties was present within horizons local people might be expected to comment upon it. We have to anticipate a more complex classification than one where only a few key parameters control class ascription. Principal components analysis was used to begin generating such a classification and assess what properties were responsible for the larger part of the variation within horizons (Rayner 1966; Webster 1977). The first three factors account for the greater part of the variation that occurs within each horizon.

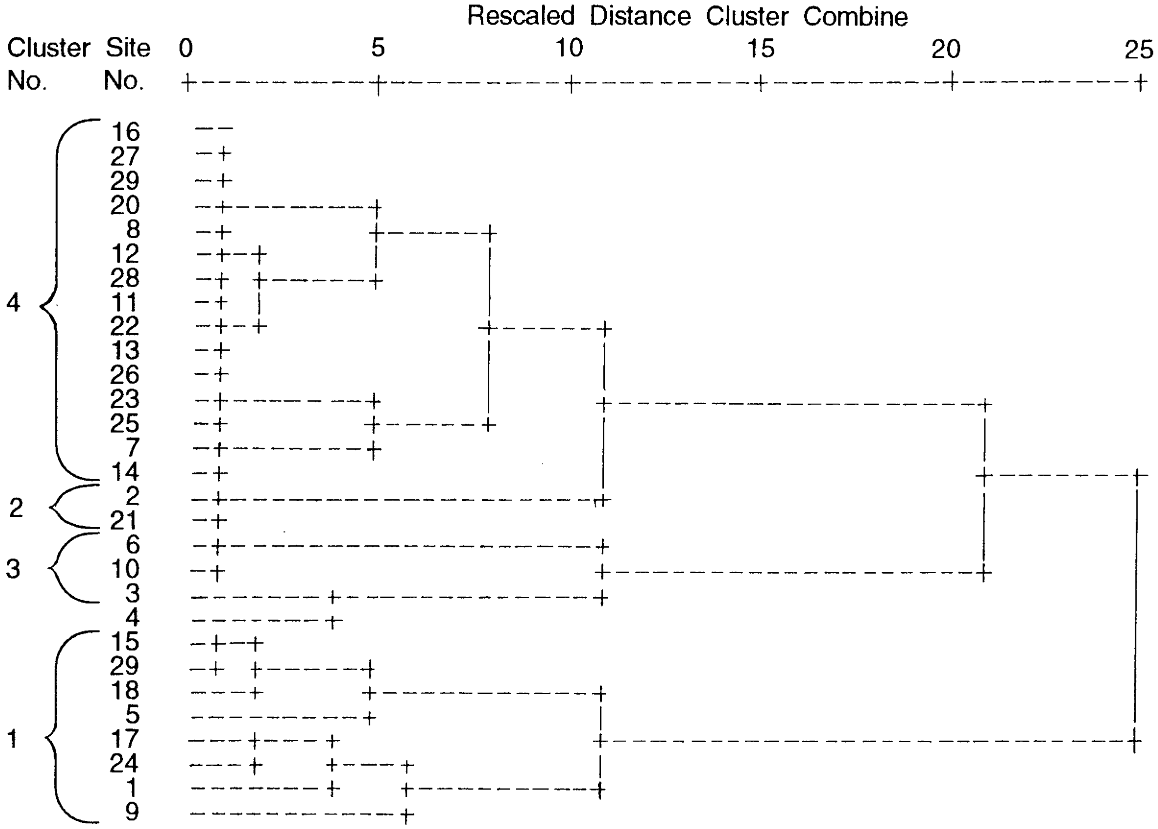
The HORIZON VARIATION is as follows:

HORIZON 1: **The first three principal components account for 50% of the variation (twenty-four factors were required to account for 100%). The first principal component represents stoniness, not merely the presence of stones but their abundance, size, shape and lithology, together with depth of the horizon, plus associated depth of rooting and abundance of roots. The second principal component represents colour (hue and value), which can possibly be associated tenuously with organic matter status, as they might be expected to vary in relation to one another. The third principal component represents texture. In summary, we can characterise the variation that occurs in horizon 1 as due principally to stoniness, thickness of horizon and depth of rooting, and differences in colour and texture.**

HORIZON 2: **The first three principal components account for 39% of the variation (thirty-four factors were required to account for 100%). The first principal component largely represents mottles, their abundance, size, contrast and boundaries. Of secondary importance are the related properties of texture and consistence (stickiness, plasticity and strength), to-**

Table 2. **Cluster dendrogram for horizon 1**

Dendrogram using Average Linkage (Between Groups)



gether with the structural properties of ped packing, shape and size. The second principal component represents stoniness (abundance, size and shape of stones). The third principal component relates to colour (value and chroma), together with the thickness of the horizon and the related property of rooting depth. In summary, we can characterise the variation that occurs in horizon 2 as due principally to differences in mottling, together with structure, consistence and texture.

HORIZON 3: **The first three principal components account for 53% of the variation (sixteen factors were required to account for 100%). The first principal component represents the related properties of texture and consistence (stickiness and strength), and organic matter status and colour (value and chroma), and to a considerably lesser extent stoniness (abundance, size and lithology of stones) and porosity (size and percentage of macropores). The second principal component represents mottles, their abundance, size, contrast and boundaries. And the third principal component relates to horizon thickness, and to a lesser extent to bulk density and acidity. In summary, we can characterise the variation that occurs in horizon 3 as due principally to differences in texture, consistence, organic matter status and colour, plus mottling and horizon thickness.**

HORIZON 4: **The first three principal components account for 37% of the variation (thirty-two factors were required to account for 100%). The first principal component represents mottles, their abundance, size, contrast and boundaries, and to a lesser extent stoniness (abundance, size and lithology of stones - the latter scoring high under factor 2). The second principal component relates to texture primarily. The third principal component relates to depth, abundance and type of roots, and to a lesser extent to colour (chroma and value - the former scoring high under factor 2), and poros-**

Table 3. **The mean/predominating properties for horizon 1 clusters.**

		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Thickness		6 cm (1.8)	4 cm (2.1)	2 cm (0.5)	7cm (1.8)
Boundary (1/2)		merging smooth 2,1 (50%)	smooth merging 2,1 (50%)	smooth 2,1 (50%)	sharp smooth 1,1 (33%)
Colour	: hue	5.6YR (0.4)	7.5R (0)	10.6R (1.2)	1.2YR (3.3)
	: value	2.9 (0.1)	2.0 (0.3)	2.3 (0.3)	2.0 (0)
	: chroma	2.1 (0.2)	2.5 (0.5)	2.5 (0.3)	2.1 (0.2)
Organic matter		H 3 (0.4)	H 3 (0)	H 3 (0.5)	H 3 (0)
Texture		sandy silt loam 3 (0.4)	silt loam 4 (0)	silt loam 4 (0)	silt loam 4 (0.3)
Stones	: abundance	<1% 1 (0.4)	1-5% 2 (0.7)	zero 1 (0)	1-5% 2 (0.5)
	: size	very small 1 (0.7)	small 3 (2.8)	- 0 (0)	very small & small 2 (0.8)
	: shape	rounded/sub-rounded 2 (1.6)	rounded 1 (2.6)	- 0 (0)	rounded 1 (0.8)
	: lithology	chert 1 (100%)	chert 1 (100%)	- 0 (0)	volcanic 5 (50%)
Soil water		slightly moist 2 (0.4)	very moist 3 (0)	very moist 3 (0.5)	slightly moist 2 (0.3)
Consistence	: stickiness	non-sticky 1 (0.4)	non-sticky 1 (0)	non-sticky 1 (0)	non-sticky 1 (0)
	: plasticity	slight 2 (0.4)	non-plastic 1 (0)	slight 2 (0.5)	slight 2 (0.3)
	: strength	very friable 2 (0.4)	very friable 2 (0)	very friable 2 (0.5)	very friable 2 (0)
Structure	: ped shape	granular 5 (88%)	granular 5 (100%)	granular 5 (75%)	granular 5 (53%)
	: ped size	medium 3 (0.7)	fine-medium 2 (0)	fine 1 (0.5)	fine-medium 3 (0.3)
	: ped grade	moderate 2 (0.4)	moderate 2 (0.7)	moderate 2 (0.5)	weak 1 (0.3)
	: packing density	low 1 (0)	low 1 (0)	low 1 (0)	low 1 (0)
Voids	: pore size	very fine, fine, medium 5 (0.7)	medium 7 (1.4)	medium 7 (1.5)	medium 6 (0.5)
	: pore %	3.13 (0.7)	5.0 (0)	5.0 (0)	4.20 (0.3)
Roots	: abundance	many 3 (0.4)	abundant 4 (0.7)	abundant 4 (0)	abundant 4 (0.3)
	: size	very fine, fine, medium (0.7)	very fine, fine medium, coarse (0)	medium (1.0)	very fine, fine, medium, coarse (0.3)
	: depth	6 cm (1.8)	4 cm (2.1)	2 cm (0.5)	7 cm (1.8)
	: type	fibrous 3 (50%)	woody, fibrous, freshy 7 (50%)	woody, fibrous, freshy 7 (70%)	woody, fibrous 2 (67%)
pH		5.10 (0.2)	5.05 (0.15	not measured	4.89 (0.08)

ity (size and percentage of macropores). In summary, we can characterise the variation that occurs in horizon 4 as due principally to differences in mottling and stoniness, texture, rooting, colour and porosity.

HORIZON CLASSIFICATION

Cluster analysis was used to create horizon classes (Rayner 1966; Webster 1977). The results of this agglomerate method, which creates a hierarchy from a similarity matrix by the nearest neighbour strategy, can be shown as a dendrogram or tree-diagram, on which the vertical lines represent distance in character space, and the horizontal lines correspond to the distance at which fusion occurs. The similarity measures relate to the above principal components, which give the properties that most differentiate between groups. The following discussion identifies four clusters per horizon, giving mean values and standard errors for the soil properties defining each cluster.[2]

The HORIZON CLASSES are as follows:

HORIZON 1 (Tables 2 and 3): The dendrogram indicates the presence of three major groupings, the larger of which can be divided at a considerably lesser distance into two groups, to give the four clusters required. The number of cases in these clusters is variable (at 2, 4, 8 and 15). They are differentiated largely by thickness, colour, stoniness and rooting, as follows:

Cluster 1: Thick (6 cm), dark reddish brown, virtually stoneless horizon with many fibrous roots throughout.

Cluster 2: Thin to thick (av. 4 cm), very dark reddish brown, very slightly stony horizon (small rounded chert stones) with abundant woody, fibrous and fleshy roots throughout.

Cluster 3: Thin (2 cm), very dark reddish brown, stoneless horizon with abundant woody fibrous and fleshy roots throughout.

Cluster 4: Thick (7 cm), very dark reddish brown, very slightly stony horizon (very small and small rounded volcanic stones) with abundant woody and fibrous roots throughout.

There is not a great deal of variation within horizon 1 on this analysis (even between the two main groupings of cluster 1 and clusters 2, 3 and 4) and the lumping of all such horizons into a single class called *waip* by the local people is understandable.

HORIZON 2 (Tables 4 and 5): The dendrogram indicates the presence of two major groupings, the larger of which can be divided at a considerably lesser distance into three groups, to give four clusters. The number of cases in these clusters is again variable (at 2,20,30 and 31). They are differentiated largely by thickness, colour, mottling, texture, consistence, structure and porosity (although the standard errors indicate considerable overlap between clusters in some of these properties - e.g. colour) as follows:

Cluster 1: Thick (21 cm), brownish black, scarcely mottled silt loam; slightly sticky, moderately plastic and friable; blocky and granular structured, medium packed acidic horizon of middling porosity.

Cluster 2: Average thickness (14 cm), dark brown scarcely mottled silt loam; slightly sticky and plastic and very friable; granular structured loosely packed acidic horizon of high porosity.

Cluster 3: Thick (17 cm), brown, faintly mottled silty clay loam; slightly sticky, moderately plastic and friable; granular and angular blocky structured medium packed acidic horizon of low porosity.

Cluster 4: Variable (av. 8 cm), greyish brown, unmottled silty clay loam; moderately sticky and plastic, and very friable; granular or angular blocky structured medium packed alkaline horizon of low porosity.

The differences between these horizon 2 clusters is again not large, as the standard errors demonstrate, and the lumping of all such horizons by the local people into a single category called *suw pombray* is reasonable (which they may qualify as necessary according to stoniness (*pombray araytol*), wetness (*pa pombray*) and sandiness (*muw pombray*)). The principal difference between the two main groupings (cluster 2 and clusters 1,3,4) is structural: a loosely packed soil of low density, poor coherence and highly porous crumb structure on

Table 4. **Cluster dendrogram for horizon 2. (Dendrogram using Average Linkage (Between Groups))**

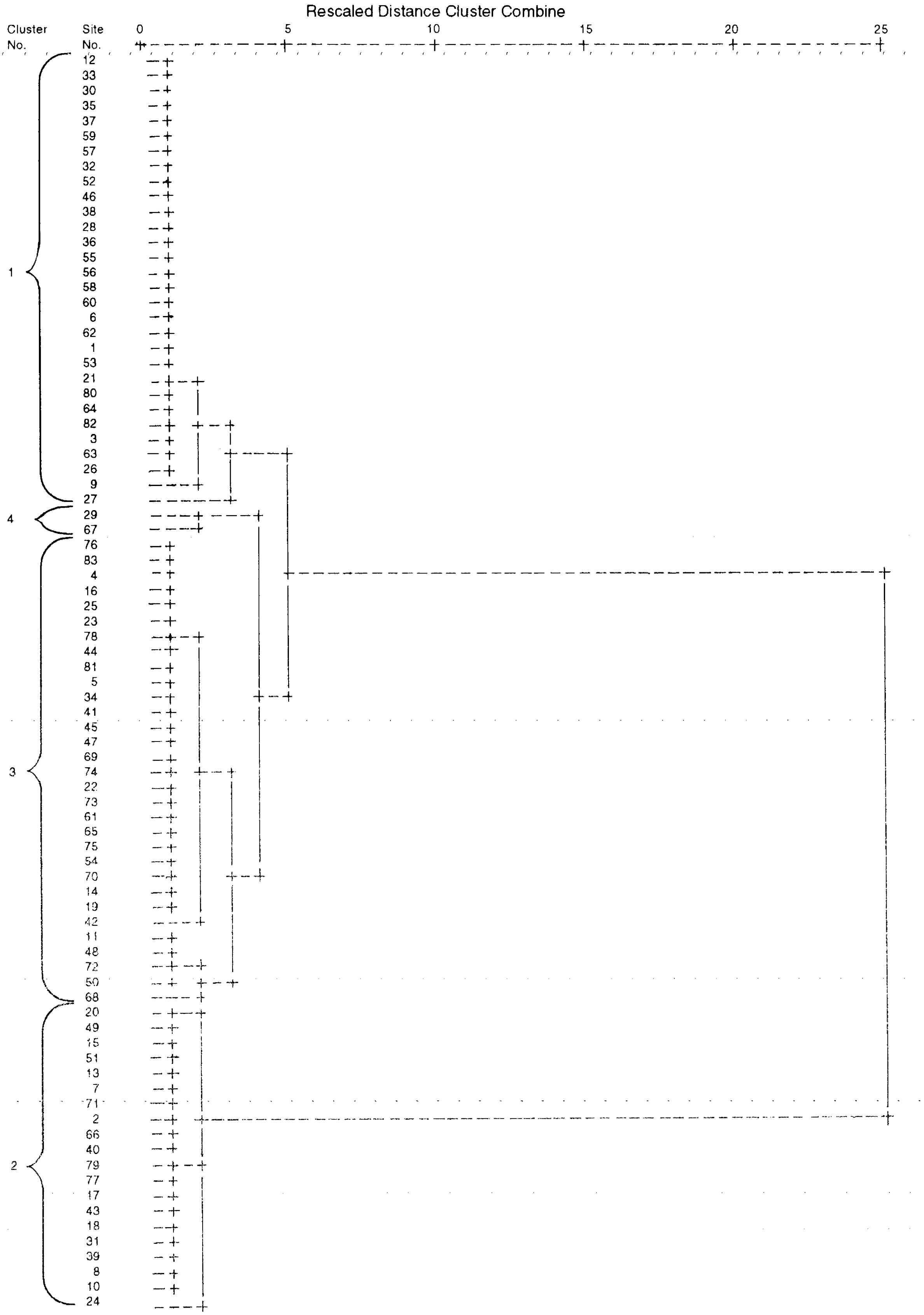


Table 5. **The mean/predominating properties for horizon 2 clusters.**

		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Thickness		20.5 cm (2.8)	13.7 cm (3.0)	17.3 cm (1.9)	8 cm (5.0)
Boundary	: (2/3;2/4)	merging smooth 2, 1 (60%)	merging smooth 2, 1 (45%)	merging smooth 2, 1 (55%)	merging smooth 2, 1 (50%)
Colour	: hue	7.1 YR (0.3)	6-9 YR (0.3)	7.5YR (0.3)	6.3 YR (1.3)
	: value	2.9 (0.1)	3.2 (0.2)	3.7 (0.2)	3.5 (0.5)
	: chroma	2.4 (0.2)	2.5 (0.2)	2.8 (0.2)	2.0 (0.9)
Mottles	: abundance	very few 0 (0.2)	very few 0 (0.2)	very few 0 (0.2)	none 0 (0)
	: size	extremely fine 1 (0.4)	- 0 (0.5)	extremely fine 1 (0.4)	- 0 (0)
	: contrast	- 0 (0.2)	- 0 (0.2)	fanint 1 (0.2)	- 0 (0)
	: boundaries	- 0 (0.2)	- 0 (0)	- 0 (0.2)	- 0 (0)
Organic matter		Intimate 2 (0)	Intimate 2 (0)	Intimate 2 (0)	Intimate 2 (0)
Texture		silt loam 4 (0.2)	silt loam 4 (0.5)	silty clay loam 5 (0.4)	silty clay loam 5 (0)
Stones	: abundance	1-5% 2 (0.2)	1-5% 2 (0.2)	1-5% 2 (0.2)	1-5% 2 (0.7)
	: size	small 3 (0.6)	small 3 (0.7)	very small, small, medium 4 (0.7)	very small 1 (0.7)
	: shape	subrounded & subangular 4 (0.4)	rounded & subrounded 2 (0.4)	subrounded & subangular 3.5 (0.3)	subrounded 3 (2.1)
	: lithology	chert 1 (81%)	chert 1 (60%)	chert 1 (62%)	volcanic 5 (100%)
Soil water		slightly moist 2 (0)	slightly moist 2 (0.2)	very moist 3 (0.2)	slightly moist 2 (0)
Consistence	: stickiness	slight 2 (0)	slight 2 (0.2)	slight 2 (0)	moderate 3 (0.7)
	: plasticity	moderate 3 (0.2)	slight 2 (0.2)	moderate 3 (0.2)	moderate 3 (0.7)
	: strength	friable 3 (0.2)	very friable 2 (0.2)	friable 3 (0.2)	very friable 2 (0)
Structure	: ped shape	angular blocky & granular 3 (67%)	granular 5 (50%)	angular blocky & granular 3 (61%)	angular blocky or granular 1, 5 (100%)
	: ped size	fine to medium 2 (0.2)	fine to medium 2 (0.2)	fine to medium 2 (0.4)	fine, medium, coarse 4 (0)
	: ped grade	moderate 2 (0.2)	moderate 2 (0.2)	moderate 2 (0)	moderate 2 (0)
	: packing density	medium 2 (0)	low 1 (0)	medium 2 (0)	medium 2 (0.7)
	: bulk density	1.05 g cm' (0.02)	0.96 g cm' (0.04)	1.13 g cm' (0.03)	1.15 g cm' (0)
Voids	: pore size	fine & medium 5 (0.4)	fine & medium 5 (0.5)	fine 3 (0.2)	fine & medium 5 (0.7)
	: pore %	2.0% (0)	5.0% (0)	0.5% (0.04)	0.5% (0)
Roots	: abundance	many 3 (0.2)	many 3 (0.2)	many 3 (0.2)	many 3 (0)
	: size	very fine, fine, medium 4 (0.4)	very fine, fine, medium 4 (0.5)	medium 5 (0.4)	very fine, fine, medium 4 (0.2)
	: depth	21 cm (2.9)	14 cm (2.9)	21 cm (2.2)	9 cm (5.7)
	: type	woody & fibrous 2 (40%)	fibrous 3 (40%)	woody & fibrous 2 (45%)	woody & fibrous 2 (0)
$CaCO_3$		<0.5% 0 (0.2)	<0.5% 0 (0)	<0.5% 0 (0)	1-5% 2 (2.1)
pH		4.99 (0.05)	4.85 (.04)	4.84 (.04)	6.15 (.035)
Pedogenic factors		not evident 0 (0)	not evident 0 (0)	not evident 0 (0)	not evident 0 (0)

Table 6. **Cluster dendrogram for horizon 3.**

(Dendrogram using Average Linkage (Between Groups)
Rescaled Distance Cluster Combine

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Cluster  Site    0         5         10        15        20        25
No.      No.     +---------+---------+---------+---------+---------+

            6     -+
           14     -+-+
            7     -+
           11     -+-+---+
           13     -+     |
1           1     -+-+   +-------+
            2     -+     |       |
            5     -+---+ |       |
           16     -+   +-+       +-------------+
           10     -----+         |             |
           12     -----+         |             |
            9     -----+         |             +-------------------+
3          15     ---------------+             |                   |
            4     -----+-------+               |                   |
2           8     -----+       +---------------+                   |
            3     -------------+                                   |
4          17     -------------------------------------------------+
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the one hand, and more packed soil of higher density and coherence, and less porous more aggregated blocky structure on the other.

HORIZON 3 **(Tables 6 and 7): The dendrogram indicates the existence of two anomalous sites, the others falling into two clusters, to give four. The number of cases in these clusters is consequently very variable (at 1, 1, 3 and 12), and their distribution is markedly skewed with 71% of the sample falling into one cluster. They are differentiated largely by thickness, colour, mottles, texture, stoniness, soil water, consistence, structure and porosity, and roots, as follows:**

Cluster 1: **Average thickness (23 cm), bright/ yellowish brown, mottled, very slightly stony (small subrounded chert), mineral, sandy clay loam; slightly moist, moderately sticky, very plastic and firm; fine through coarse angular blocky or angular blocky and granular structured horizon of low porosity and few roots.**

Cluster 2: **Thin (6 cm), brown, unmottled, slightly stony (very small to medium angular chert), humose sandy clay loam; very moist, moderately sticky and plastic, and friable; fine and medium granular and/or angular blocky structured horizon of low porosity and roots common.**

Cluster 3: **Average thickness (28 cm), dark reddish grey, unmottled, stoneless, humose silty clay loam; wet, slightly sticky, moderately plastic and very friable; fine through very coarse angular blocky structured horizon of low porosity and many roots.**

Cluster 4: **Thick (41 cm), dull brown, unmottled, stoneless, humose sandy loam; slightly moist and sticky, moderately plastic and very friable; fine and medium granular and angular blocky structured horizon of middling porosity and few roots.**

The differences between sub-types of horizon 3 are more marked than for the previous two horizons, although they may be more apparent than real given the skewed distribution. If we discount the markedly anomalous site, we can distinguish two major groupings (clusters 1, 3 and cluster 2), the principal differences between which relate to colour, stoniness, structure and rooting: on the one hand a more red-brown, nearly stoneless horizon with larger more aggregated peds and deep to fine roots, and on the other a more yellow-brown slightly stonier horizon with smaller less aggregated peds and shallower to very fine roots. This dual division parallels the identification of two principal types of transition horizon between top-soil and sub-soil by the local people (when they identify any at all). They distinguish between and name these horizons ac-

Table 7. **The mean/predominating properties for horizon 3 clusters.**

		Cluster 1	Cluster 2	Cluster 3	Cluster
Thickness		23.3 cm	6 cm	28 cm	41 cm
		(3.7)	(2.6)	(0)	(0)
Boundary		merging smooth	sharp irregular	merging smooth	-
		2, 1 (76%)	1, 3 (67%)	2, 1 (100%)	
Colour	: hue	8.7YR	9.2 YR	2.5 YR	7.5YR
		(0.4)	(0.8)	(0)	(0)
	: value	4.9	4.0	3.0	4.5
		(0.2)	(1.2)	(0)	(0)
	: chroma	5.5	3.7	1.0	4.0
		(0.5)	(1.2)	(0)	(0)
Mottles	: abundance	few	none	none	none
		1 (0.3)	0 (0)	0 (0)	0 (0)
	: size	very fine	-	-	-
		2 (0.9)	0 (0)	0 (0)	0 (0)
	: contrast	faint	-	-	-
		1 (0)	0 (0)	0 (0)	0 (0)
	: boundaries	sharp	-	-	-
		1 (0.3)	0 (0)	0 (0)	0 (0)
Organic matter		not evident	intimate	intimate	intimate
		1 (0.3)	2 (0.6)	2 (0)	2 (0)
Texture		sandy clay loam	sandy clay loam	silty clay loam	sandy loam
		7 (0.9)	7 (1.7)	5 (0)	2 (0)
Stones	: abundance	1-5%	6-15%	zero	zero
		2 (0.3)	3 (1.2)	1 (0)	1 (0)
	: size	small	v.small, small, medium	-	-
		3 (1.2)	4 (1.7)	0 (0)	0 (0)
	: shape	sub-rounded & subangular	angular	-	-
		3.5 (0.6)	7 (0)	0 (0)	0 (0)
	: lithology	chert	chert	-	-
		1 (63%)	1 (100%)	0 (0)	0 (0)
Soil water		slightly moist	very moist	wet	slightly moist
		2 (0)	3 (0.6)	4 (0)	2 (0)
Consistence	: stickiness	moderate	moderate	slight	slight
		3 (0.3)	3 (0.6)	2 (0)	2 (0)
	: plasticity	very plastic	moderate	moderate	moderate
		4 (0.3)	3 (0.6)	3 (0)	3 (0)
	: strength	firm	friable	very friable	very friable
		4 (0)	3 (0.6)	2 (0)	2 (0)
Structure	: ped shape	angular blocky + granular	angular blocky &/or granular	angular blocky	angular blocky & granular
		1,3 (100%)	1, 3, 5 (100%)	1 (100%)	3 (100%)
	: ped size	fine, medium, coarse	fine & medium	fine, medium, coarse, very coarse	fine & medium
		4 (0.7)	2 (0.9)	7 (0)	2 (0)
	: ped grade	moderate	moderate	moderate	moderate
		2 (0)	2 (0.6)	2 (0)	2 (0)
	: packing density	high	medium	medium	medium
		3 (0.3)	2 (0.6)	2 (0)	2 (0)
	: bulk density	1.22 gcm'	not measured	1.10 gcm'	1.20 gcm'
		(0.04)		(0)	(0)
Voids	: pore size	fine	very fine & fine	v.fine, fine, medium	v.fine, fine, medium
		3 (0.9)	2 (1.2)	4 (0)	4 (0)
	: pore %	0.25%	0.5%	0.5%	2.0%
		(0.06)	(0.2)	(0)	(0)
Roots	: abundance	few	common	many	few
		1 (0)	2 (0.6)	3 (0)	1 (0)
	: size	v.fine, fine	very fine	v.fine, fine	v.fine, fine, medium
		2 (0.3)	1 (0.6)	2 (0)	6 (0)
	: depth	35 cm	27 cm	66 cm	46 cm
		(4.0)	(5.2)	(0)	(0)
	: type	fibrous	fibrous	woody & fibrous	\fibrous & fleshy
		3 (58%)	3 (100%)	2 (100%)	4 (100%)
pH		4.85	4.67	4.80	4.90
		(0.04)	(0.07)	(0)	(0)
Pedogenic factors		not evident	not evident	not evident	not evident
		0 (0.3)	0 (0.6)	0 (0)	0 (0)

Table 8. **Cluster dendrogram for horizon 4.**

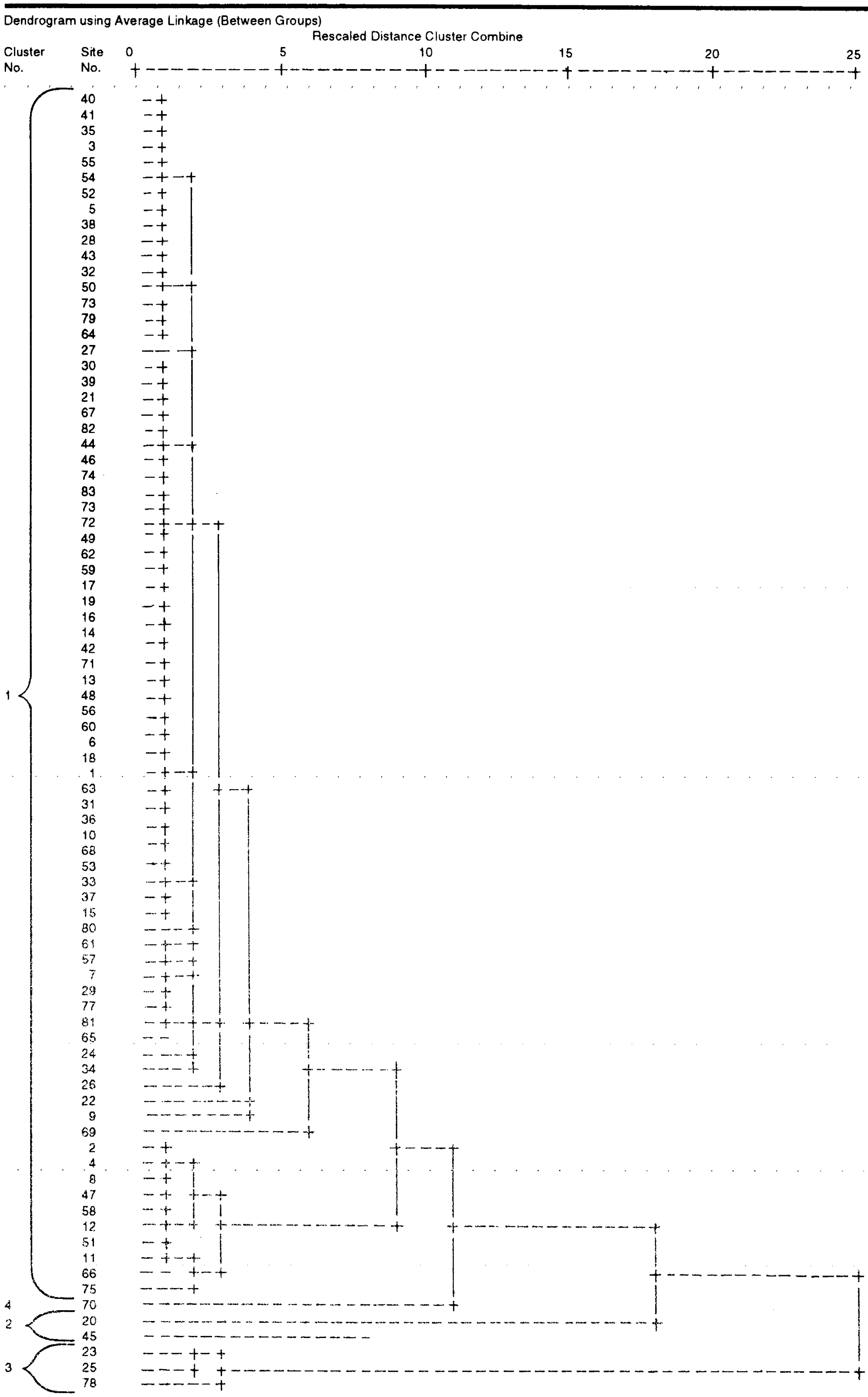


Table 9. **The mean/predominating properties for horizon 4 clusters.**

		Cluster 1	Cluster 2	Cluster 3	Cluster 4
Thickness		> 20 cm	> 20 cm	> 20 cm	> 20 cm
		(0)	(0)	(0)	(0)
Colour	: hue	8.3 YR	7.5 YR	1.7 YR	7.5YR
		(0.2)	(0)	(1.7)	(0)
	: value	5.8	4.5	5.3	7.0
		(0.1)	(0.5)	(0.3)	(0)
	: chroma	6.9	4.5	5.3	1.0
		(0.2)	(1.5)	(0)	(0)
Mottles	: abundance	few	few	few	very many
		1 (0.1)	1 (0.7)	1 (0.6)	4 (0)
	: size	v.fine, fine	v.fine, fine, medium'	fine	medium, coarse
		3 (0.5)	5 (5.0)	4 (2.9)	9 (0)
	: contrast	faint	faint/distinct	distinct	prominent
		1 (0.2)	2 (1.4)	3 (1.2)	4 (0)
	: boundaries	sharp	sharp	sharp	diffuse
		1 (0.10)	1 (0.7)	1 (0.6)	3 (0)
Organic matter		not evident	intimate	not evident	not evident
		1 (0)	2 (0.7)	1 (0)	1 (0)
Texture		silty clay	sandy clay	silty clay	sandy clay
		9 (0.10	8 (0.7)	9 (0.6)	8 (0)
Stones	: abundance	6-15%	16-35%	< 1%	1-5%
		3 (0.2)	4 (2.8)	1 (0.6)	2 (0)
	: size	v.small, small, medium	small & medium	v.small & small	v.small, small, medium
		4 (0.5)	5 (4.2)	2 (2.3)	4 (0)
	: shape	subrounded & subangular	rounded & subrounded	rounded	subrounded & subangular
		3.5 (0.2)	1.5 (1.3)	1 (0.4)	4 (0)
	: lithology	chert	volcanic	volcanic	volcanic
		1 (75%)	5 (100%)	5 (100%)	5 (100%)
Soil water		slightly moist	slightly moist	wet	very moist
		2 (0.1)	2 (0)	4 (0)	3 (0)
Consistence	: stickiness	moderate	very sticky	very sticky	very sticky
		3 (0.1)	4 (0.7)	4 (0)	4 (0)
	: plasticity	very plastic	very plastic	very plastic	very plastic
		4 (0)	4 (0.7)	4 (0)	4 (0)
	: strength	firm	firm	friable	firm
		4 (0)	4 (0)	3 (0.6)	4 (0)
Structure	: ped shape	angular blocky	angular blocky & granular	angular blocky	angular blocky
		1 (71%)	3 (100%)	1 (100%)	1 (100%)
	: ped size	fine, medium & coarse	medium & coarse	medium & coarse	fine, medium, coarse
		4 (0.2)	5 (1.4)	5 (2.3)	4 (0)
	: ped grade	moderate	moderate	moderate	moderate
		2 (0)	2 (0)	2 (0.6)	2 (0)
	: packing density	high	medium	high	high
		3 (0)	2 (0)	3 (0)	3 (0)
	: bulk density	1.32 gcm'	1.30 gcm'	1.47 gcm'	1.30 gcm'
		(0.02)	(0)	(0.2)	(0)
Voids	: pore size	v.fine, fine	medium	very fine	v.fine, fine, medium
		2 (0.2)	6 (1.4)	1 (0.6)	7 (0)
	: pore %	0.21%	2.0%	0.2%	0.1%
		(0.03)	(0)	(0.2)	(0)
Roots	: abundance	few	few	common	few
		1 (0)	1 (0)	2 (0.6)	1 (0)
	: size	v.fine, fine	v.fine through coarse	v.fine, fine	v.fine through coarse
		2 (0.2)	6 (0)	2 (1.2)	6 (0)
	: depth	41 cm	57 cm	64 cm	39 cm
		(2.2)	(5.0)	(2.9)	(0)
	: type	fibrous	woody, fibrous	fibrous	woody, fibrous
		2 (0.2)	6 (0)	2 (1.2)	6 (0)
$CaCO_3$		< 0.5%	< 0.5%	< 0.5%	0.5-1.0%
		0 (0)	0 (0)	0 (0)	1 (0)
pH		4.79	4.60	4.87	5.80
		(0.02)	(0)	(0.07)	(0)
Pedogenic factors		not evident	concretions	not evident	concretions
		0 (0)	1 (0)	0 (0.6)	1 (0)

Table 10. **Rationalised profile classification**

Profile class	Horizon 2 cluster(s)	Horizon 4 cluster(s)	No. of sites	Descriptive gloss
a.	1 3 4	1 2 4	58	coherent topsoil over orange clay
b.	2	1 2 4	20	looser topsoil over orange clay
c.	1 3 4	3	3	gleyed soils
d.	1 3 4	0	2	recent alluvial soils
e.	0	1 2 4	2	thin organic layer over clay horizon

cording to the dominance of properties from either the top-soil (horizon 2) above or the sub-soil (horizon 4) below as *pombray sha* or *hundbiy sha* (qualified further for stoniness by the term araytol where necessary). Their discrimination rests largely on colour differences.

HORIZON 4 **(Tables 8 and 9): The dendrogram indicates the existence of four variably sized clusters (of 1, 2, 3 and 77 cases), one overwhelmingly dominant, accounting for 93% of the sample. The cluster groupings are differentiated largely by colour, mottles, texture, stoniness, soil-water, porosity and root depth, as follows:**

Cluster 1: **Orange/bright yellowish brown, few to fine faint mottles, slightly stony (very small through medium subrounded chert), silty clay; slightly moist, low porosity, with few shallow (41 cm) woody and fibrous roots.**

Cluster 2: **Brown, few to medium to distinct mottles, moderately stony (small and medium rounded volcanic), sandy clay; slightly moist, moderately porous with few deep (57 cm) fibrous and fleshy roots.**

Cluster 3: **Greenish/bluish grey, few fine distinct mottles, almost stoneless, silty clay; wet, low porosity with deep (64 cm) fibrous roots common.**

Cluster 4: **Light grey, very many to coarse prominent mottles, very slightly stony (very small through medium subrounded and subangular volcanic), sandy clay; very moist, low porosity with few shallow (39 cm) woody and fibrous roots.**

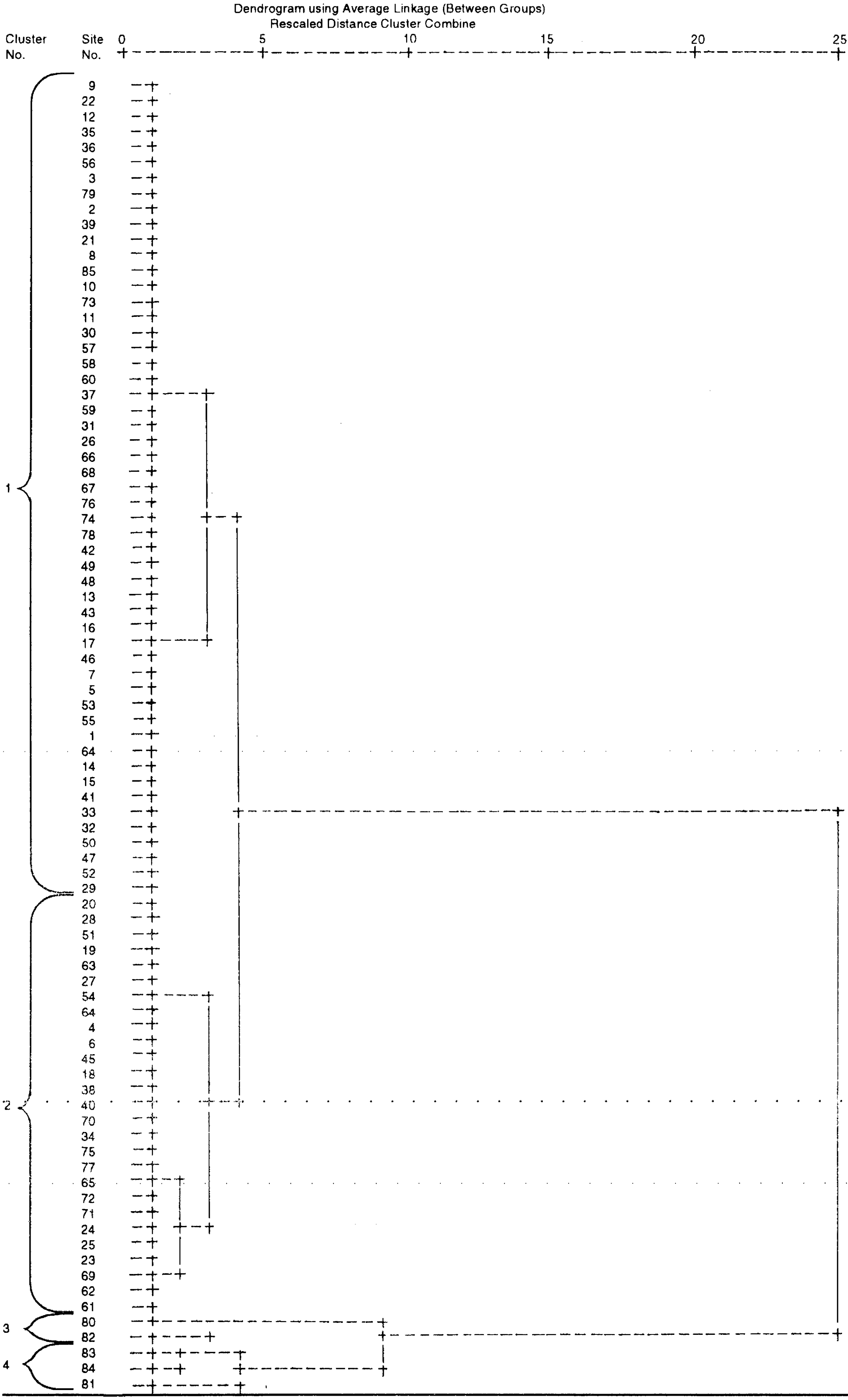
The cluster analysis separates some (though not all) of the anaerobic gleyed horizons from the aerobic ones, which parallels a local named discrimination, between gleyed horizons called *pa tongom* and aerobic ones called *suw hundbiy*. It is difficult to see any other similarities between cluster groups and local distinctions. According to this agglomerative analysis there is little variation in horizon 4 at most locations. When we consider the extensive range of properties by which we are differentiating between horizons, these horizons are more similar than dissimilar. The homogeneity of the horizon is demonstrated further when an attempt is made to divide it into more clusters.[3] At the five cluster level, differentiation between horizons depends almost exclusively on stoniness alone, the larger of the two new clusters generated being very slightly stony (1-5%) with small subrounded stones, and the smaller of them being very stony (36-70%) with large angular and subangular stones. This division parallels another distinction made by the local people, who regularly suffix a horizon designation with the word *araytol* or stony when the soil has a considerable stone content. The reverse of further division into smaller clusters is required however, if we are to come up with a manageable classification scheme, particularly given the fine distinctions made between some of the above horizon clusters and the small numbers of sites represented by them.

PROFILE CLASSIFICATION

When the horizon clusters are amalgamated together into profile sequences, a total of twenty-eight combinations results. These vary considerably in occurrence, fifty percent are represented by only one site. This classification is too cumbersome. It has too many classes defined by too many fine distinctions. It needs to be rationalised to a manageable scheme.

The following steps are taken to rationalise it: 1). Ignore horizon 1 because under cultivation it is a transitory horizon, it is lost entirely when a site is

Table 11. Cluster dendrogram for site parameters.



cultivated; furthermore, when present, this horizon evidences very little variation. 2). Ignore horizon 3 because it is a transition horizon that is often not present all all, and is infrequently identified by the local people. 3). Divide horizon 2 into two clusters; the cluster analysis justifies this with two major groups (comprising (i). cluster 2 and (ii). clusters 1,3,4). 4). Divide horizon 4 into two clusters; again the cluster analysis justifies this with two major groups (comprising (i). clusters 1, 2, 4 and (ii). cluster 3).

Only five of the eight possible rationalised horizon combinations occur together as surveyed PROFILE CLASSES (Table 10), as follows:

PROFILE (a): **Coherent, more clayey topsoil with aggregated less porous structure; over a slightly stony and moist, faintly mottled, firm aerobic orange clay subsoil. The most abundant profile in the region.**

PROFILE (b): **Looser, more silty topsoil with crumbly porous structure; over a slightly stony and moist, faintly mottled, firm, aerobic orange clay subsoil. The second most abundant profile in the region.**

PROFILE (c): **Coherent, more clayey topsoil with aggregated less porous structure; over a wet and distinctly mottled, very sticky anaerobic greenish-grey subsoil. A waterlogged and gleyed profile. An uncommon profile in the region.**

PROFILE (d): **Coherent, more clayey topsoil with aggregated less porous structure, extending to considerable depths (>50 cm). A recent alluvial profile. An uncommon profile in the region.**

PROFILE (e): **Thin organic horizon 1; over a slightly stony and moist, faintly mottled, firm aerobic orange clay subsoil. An uncommon profile in the region.**

SITE VARIATION

The generation of an overall classification of soil resources as perceived by the local people requires the combination of the above profile classes with site parameters. This demands firstly the establishment of some patterned variation between the sites surveyed. Again, a series of preliminary cross-tabulations of those parameters that might reasonably be expected to show some degree of relatedness in their variation evidenced surprisingly little patterning, other than the obvious. A subsequent principal components analysis of SITE VARIATION, gave the following results:

SITES: **The first three principal components account for 53% of site variation (thirteen factors were required to account for 100%). The first principal component represents the related factors of drainage and local relief, together with altitude. The second principal component represents the related factors of vegetation and litter form and depth. And the third principal component represents rock outcrops, and to a lesser extent surface evenness. In summary, we dan characterise the variation that occurs between sites as due principally to differences in their relief and drainage, altitude and vegetational factors, plus outcropping rock to a lesser extent.**

SITE CLASSIFICATION

The next step involves the creation of site classes. Again, a cluster analysis was used. The dendrogram (Table 11) indicates the presence of two major site groupings, both of which can be divided at a considerably lesser distance into two further groups, to give four clusters. The variation between the two major groupings (clusters 1 and 2, and 3 and 4) centres on differences in altitude and parent material, whereas variation between the two clusters comprising each of these major groupings centres largely on differences in aspect and slope, and to a lesser extent drainage, relief and vegetation.

The number of sites in each cluster varies considerably. The skewedness of the distribution of sites between the clusters reflects the overriding importance of higher altitude locations to the Wola. The greater part of their territory is in the highlands, the vast majority live and cultivate here. These site clusters are not as useful as they might be, the agglomerative program concentrating on the few strikingly different sites from lower altitudes at the expense of the more numerous high altitude sites. Doubling the number of clusters to eight to overcome this problem gives too many classes to produce a manageable classification when combined with the soil profile classes. It was decided to combine all the low altitude sites (<1500 m) into a single group of varied sites to overcome this problem. This reduces the site classes down to five, and possible soil resource classes to twenty-five. The

Table 12. **The mean/predominating parameters of site clusters.**

	Previous cluster 1		Previous cluster 2		Previous cluster 3 & 4
	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5
Altitude	2015 m (8)	1815 m (12)	1983 m (10)	1770 m (21)	1230 m (102)
Aspect	73° (9)	68° (7)	311° (12)	300° (16)	260° (57)
Slope	23° (2)	24° (2)	18° (3)	12° (4)	8° (8)
Slope form	straight (1 (83%)	straight 1 (70%)	straight 1 (56%)	straight 1 (73%)	straight 1 (100%)
Surface evenness	fairly even 1 (40%)	fairly even 1 (67%)	fairly even or hummocky 1, 3 (69%)	fairly even with obstacles 2 (46%)	fairly even 1 (80%)
Local relief	interfluve: ridge top or basin side 1, 2 (57%)	valleyside: middle to footslope 6, 8 (67%)	interfluve: ridge top or basin side 1, 2 (63%)	valleyside: footslope or bench 8, 9 (63%)	valleyfloor floodplain or valleyside bench 9, 11 (80%)
Drainage	normal 2 (0.2)	normal 2 (0.20)	shedding 1 (0.30)	receiving, run-off 3 (0.3)	receiving, run-off 3 (0.5)
Erosion	none 0 (35%)	none 0 (50%)	none 0 (44%)	none 0 (73%)	none 0 (60%)
Rock outcrops	none 0 (0)	none 0 (0.2)	none 0 (0.3)	none 0 (0)	none 0 (0)
Parent material	limestone 1 (96%)	limestone 1 (87%)	limestone 1 (94%)	limestone 1 (91%)	limestone 2 (60%)
Vegetation	secondary regrowth 2, 3, 4 (52%)	grasses or crops (sweet potato) 4, 7 (63%)	secondary regrowth 2, 3, 4 (63%)	secondary regrowth 2, 3, 4 (46%)	secondary regrowth or crops 2, 4, 7, 9 (80%)
Litter form	bare soil/tree leaves 1, 9, 10, 11 (52%)	bare soil 1 (33%)	bare soil/tree leaves 1, 9, 10, 11 (50%)	bare soil/tree leaves 1, 9 (64%)	tree leaves 9, 10, 11 (60%)
Litter depth	~ 1 cm (0.2)	~ 1 cm (0.2)	~ 1 cm (0.3)	~ 1 cm (0.6)	~ 1 cm (0.5)

Table 13. **Site classification by rationalised site clusters**

	Site cluster(s)	No. of sites	Descriptive gloss
(i).	1	23	high altitude, ENE facing, up-slope locations
(ii).	2	30	mid-altitude, ENE facing, down-slope locations
(iii).	3	16	higher altitude, NW facing, up-slope locations
(iv).	4	11	mid-altitude, NW facing, up-slope locations
(v).	5,6,7,8	5	low altitude, variable down-slope locations

resulting SITE CLASSIFICATION (Table 12) is as follows:

SITE (i). (Cluster 1): **Higher altitude (2000 m), east-north-east facing, steeply sloping, normally drained interfluve site on limestone, possibly supporting secondary regrowth.**

SITE (ii). (Cluster 2): **Mid-altitude (1800 m), east-north-east facing, steeply sloping, normally drained lower valleyside site on limestone, probably supporting grass or crops.**

SITE (iii). (Cluster 3): **Higher altitude (2000 m), north-west facing, steeply sloping, shedding interfluve site on limestone, possibly supporting secondary regrowth.**

SITE (iv). (Cluster 4): **Mid-altitude (1750 m), west-north-west facing variably moderately steeply sloping, receiving (with some run-off) lower valleyside site on limestone, possibly supporting secondary regrowth.**

SITE (v). (Cluster 5): **Low altitude (1250 m), variably north through west to south facing, level to steeply sloping, receiving (with some run-off), plane valleyfloor or bench site on volcanics or alluvium supporting secondary regrowth or crops.**

In summary, this classification divides sites by an interrelated series of parameters: altitude, local relief, drainage and slope. Higher altitude sites occupy up-slope locations on interfluves and upper valleysides, from which, steeper sloping, drainage is good due to rapid run-off. Mid to low altitude sites tend to occupy the lower down-slope locations on valleysides and floors which are more gently sloping and from which drainage is more likely to be poor (Table 13).

SOIL RESOURCE CLASSIFICATION

The final step in this investigation of the surveyed soil data requires the combination of the soil profile and sites classifications to generate an overall soil resource classification, which we can compare with local people's perceptions of, and agricultural use of, their land. Fourteen of the possible soil profile and site class combinations are represented (Table 14). Some of these SOIL RESOURCE CLASSES were represented in the surveyed sites considerably more often than others, occurring from twenty-one times down to once only.

Table 14. **The distribution of sites surveyed between soil resource classes**

	Site classes				
Soil profile classes	(i)	(ii)	(iii)	(iv)	(v)
(a)	16	21	11	8	2
(b)	7	8	3	1	1
(c)		1		2	
(d)					2
(e)			2		

Table 15. **The distribution of local assessment and land use classes between the soil profile and site components of the soil resource classes distinguished in this study.**

	Soil resource classes									
	Soil profiles					Sites				
	a	b	c	d	e	i	ii	iii	iv	v
Local assessment class:										
1. very good	10	2		2		2	5		2	5
2. good	15	3				7	5	3	3	
3. middling	6	2				1	6	1		
4. poor	12	6				4	8	5	1	
5. very poor	14	6			2	9	5	7	1	
6. waterlogged	1	1	3				1		4	
Land use class										
1. never cultivated	12	2	2		1	5	2	5	4	1
2. long abandoned garden	20	4				8	9	3	3	1
3. recently abandoned garden	10	6		1		5	6	4	1	1
4. sweet potato garden (inc. fallow)	14	8				5	13	2	1	1
5. taro garden	1		1	1					2	1
6. mixed garden	1				1			2		

SOIL RESOURCES AND LOCAL SOIL ASSESSMENTS

We are now in a position to assess the status of Wola assertions regarding their non-inspection of soil before cultivating it, by comparing the computer generated soil resource classes with local assessments of the cultivation value of the soils surveyed and the use to which they actually put the land. A cross-tabulation of local assessments of soils against the soil recources classes revealed no apparent relationship. It appears that none of the soil resources classes painstakingly distinguished correlates with any local assessment class, the very best and worst soils are likely to occur in almost all the soil resource classes. We cannot say that any of the classes in which the majority of soils surveyed fall represent better or indifferent arable soils. The exceptions have too few sites to allow us to draw reliable conclusions. But there are some trends noticeable upon inspection which merit comment (Table 15 - soil profile and site classes are separated to make comparison easier).

The soil profile class (a) 'coherent topsoil over orange clay' soil profile predominates over the entire spectrum of classes, except for (6). waterlogged soils. But the ratio to profile class (b) 'loose topsoil over orange clay' changes as assessment falls, from 4:1 for assessment classes 1 and 2 to 2:1 for classes 4 and 5. In other words, any soil resource class featuring loose topsoil is more likely to be judged an agriculturally poor soil.

The predominant sites in all local assessment classes, except for (6). waterlogged soils, are (i) 'high altitude ENE facing up-slope sites' and (ii) 'mid-altitude ENE facing down-slope sites'. The feature they have in common is aspect, and this complies with Wola assertions that the best arable land faces the sun to the north-east. The predominance of sites with this aspect reflects the non-random selection of the survey sample, which strived to accommodate all local land usages; hence it includes a large number of cultivated or once cultivated sites, which have this favoured aspect. But aspect alone is not sufficient to give a soil agricultural promise, and sites facing in a north-easterly direction cover the entire range of assessment from good to poor. The distribution of the next site class (iii) 'high altitude NW facing up-slope sites' between good and poor assessment classes further illustrates the importance of aspect, for these sites are twice as likely to occur in the poor classes 4 and 5 as they are in the good classes 1 and 2.

The low altitude sites (v) occur without exception in the first-class local assessment category. Although they are too small a sample to draw firm conclusions from, they reflect Wola assertions that sites occurring at lower altitudes are better, that crops grow more quickly there. They say that they avoid them because they fear sickness (notably malaria) and also because they are adjacent to the region of the Foi people whom they fear as sorcerers. Higher temperatures contribute to the perceived increase in agricultural productivity, but people attribute it in part to the occurrence of larger areas of favourable land too. A considerable part of this lower region has recent alluvial soils, and soils surveyed in this profile class (d) fall into the best local assessment class 1.

The soil profile class (e) 'thin organic layer over mineral horizon' predictably falls into the worst assessment class 5. And profile class (c) 'gleyed soils' predominates in local assessment class 6 of waterlogged soils suitable for taro cultivation. All the soils occurring in this assessment class fall as expected in the down-slope locations of site classes (ii) and (iv) where drainage is more likely to be poor. It is the uncommonly occurring alluvial, gleyed and skeletal soils that display a certain predictability regarding their local assessment; the majority of sites surveyed show scant pattern. Furthermore, it seems dubious to build an argument on the basis of local assessments of soil potential, when the people themselves both deny that they inspect the soil before they decide whether or not to cultivate it, and it is suggested that they are possibly unaware of any pedological judgements they make. We can overcome this objection to some extent by comparing the soil resource classes against land use.

SOIL RESOURCES AND LAND USE

The use people make of land is equivalent to their assessment of its worth in practice, rather than hypothetically (although this approach has shortcomings too, for we cannot simply equate cultivation of land with good soil, because the condition of the soil may have deteriorated under cultivation from what it was before clearance; nor can we equate recently abandoned plots with poor soil, because factors other than soil-related ones can prompt abandonment). The fourteen land use classes distinguished in the survey (Table 1) are too many for ready comparison and they are reduced to six for analysis (Table 15). Again, the initial impression of a cross-tabulation is that no land use predominates in any of the soil resource classes, which suggests that none of them are indicative of good or poor arable soils. But there are once more some trends worthy of comment.

The soil profile class (a) 'coherent topsoil over orange clay' again predominates over the entire spectrum of land uses. There is no indication that a larger proportion of the soils in this class are likely to be under cultivation rather than under secondary regrowth or primary forest, they are fairly evenly spread. The profile class (b) 'loose topsoil over orange clay' is not so evenly distributed, the figures suggesting that it is likely to be cultivated, with a ratio of 2:3 sites cultivated: uncultivated, compared to 1:3 sites cultivated: uncultivated for soil profile class (a). This contradicts the trend of the local soil assessment comparison where any class featuring the loose topsoil is more likely to be assessed as agriculturally poor. This may be explained, at least in part, by the larger proportion of (b) profile class soils coming from recently abandoned gardens (at a ratio of 1:2 recently abandoned sites to other land use classes, compared to 1:4 for profile (a) class soils). This suggests that a larger proportion of them might be judged as agriculturally tired soils on which cultivation has been stopped for an interval to allow them to recover. It is also likely that some of the soils under cultivation were showing signs of declining productivity, and with a large proportion of soil profile class (b) soils under cultivation there is an increased chance of them showing signs of becoming productively poor soils.

There is a wider spread of different land uses across the various site classes than across the soil profile classes (Table 15). There is perhaps a weak trend for down-slope sites to be preferred over up-slope sites for cultivation. The aspect preference is again evident, with a greater proportion of north-east facing sites under cultivation and north-west facing ones under natural vegetation. The land under primary forest and never cultivated covers the whole range of soil-site classes, indicating that none of the soil resource classes identified is either the product of cultivation nor is so preferred above others and widely used as to occur less commonly under virgin forest. It also suggests adequate availability of sites adjudged suitable for cultivation by the Wola. The low altitude soils also show an even spread over the land use range. The position with wet soils and sites under taro is not so clear-cut as might be anticipated, the multivariate analysis not assigning all wet soils to the gley class, some evidencing more properties akin to another class.

CONCLUSION

This comparison of local assessment and land use against a computer-generated soil resource classification evidences surprisingly little correlation where some might have been anticipated. We cannot tell the local Wola people, using the soil resource classification painstakingly built up by analysing data on their soils, what they might unwittingly look for in selecting a site for cultivation. The analysis has strived to identify a series of soil and site types, to uncover some hidden pattern underlying them that might relate to soil potential and cultivation use, and it has largely failed for the vast majority of soils to reveal anything other than a few trends, some of which are fairly weak and tenuous.

In some regards this may be deemed a negative result, the study be thought to have somehow failed. But only to those who assume the superiority of Western environmental scientific method, that it should come up with a more insightful and informed interpretation of soil resources than the people who for generations have successfully derived their livelihood by exploiting them. The analysis vindicates the opposite viewpoint, that the knowledge of local people is just as well informed. Regardless of efforts to generate a scientifically grounded appraisal of soil resources, this series of papers has failed to go beyond what the local people say about them. They see no point in inspecting soil closely before cultivating it, not because they are unaware of possible variations in fertility status, but because there are no observable properties, taken singly or in combination, by which they might classify and readily assess the agricultural potential of the majority of their region's soils.

Finally, and perhaps most importantly, this series of papers, demonstrating that a scientific survey and computer analysis cannot better local lore, lends support to those who advocate local participation in programmes of sustainable agriculture development (Eyben & Ladbury 1992). It shows that the proposition that experts should respect local knowledge and consult it closely, before they try to improve on it, has substance (Thomasson 1981; Chambers *et al.* 1989; Skoog *et al.* 1990) no matter how impossible that knowledge may first appear.

FOOTNOTES

[1] The Wola are familiar with such ranking procedures, having a series of linguistic markers to indicate gradations (e.g. *ebay ora* very good, *ebay* good, *ebay sha* middling, *kor* poor, *kor ora* very poor and *suw pa* waterlogged).

[2] In Tables 3, 5, 7, 9 and 12 each entry comprises two rows. The top row gives the cluster average for each soil property, and the lower row the mean class score and standard error, or where more appropriate, the class percentage. Figures outside brackets in the lower row are property mean class scores, or the predominant survey class number for non-averageable variables. These numbers refer to the list order of parameters in the *Soil Survey Field Handbook* (except for none/non-relevant which score zero). The figures inside brackets are either standard errors of the means, calculated as $\sigma / \sqrt{N}$ (the larger the standard error value the wider the mean distribution and the less representative the mean of any property for the entire cluster), or they show the percentage of the cluster falling in the predominant class listed. (percentages are used where properties vary non-linearly and discontinuously, and could not be sensibly averaged into means with associated standard errors). Properties which did not vary to any extent within a sample (e.g. cementation) or were entirely absent (e.g. mottles from horizon 1) were omitted from the analysis as having no effect on variance.

[3] At the five cluster level, the large cluster 1 divides into two groups comprising 10 and 67 sites. The larger of these clusters remains surprisingly resistant to further splitting, the next three divisions splitting off just one or two sites. The mean values and standard deviations of properties for the two groups generated with the splitting in two of cluster 1 further support the conclusion that the members of this large horizon 4 cluster are very similar on the whole, for they are almost identical for all properties except stones. On the basis of this analysis it was decided not to press the division of horizon 4 beyond four clusters, an urge prompted more by an aesthetic need to achieve a better numerical balance between clusters than by pedological considerations. It is common in soil surveys to find that one class of soil predominates in a region over others; the skewedness of this sample reflects nature's irregular distribution.

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