Local Perspectives of Forest Landscapes

A Preliminary Evaluation of Land and Soils, and their Importance in Malinau, East Kalimantan, Indonesia

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Cover photo:
Traditional cooperation in cultivating rice field is locally called 'senguyun' (Photo by Edmond Dounias)

Back cover photos (from left to right):
1. Shifting cultivation is a strategy used by local people in response to poor soil and weeds (Photo by Edmond Dounias)
2. Villagers use clay to dye rattan for basketry (Photo by Lini Wollenberg)
3. Soil from termite nest is sometimes used to treat stomachache (Photo by Imam Basuki)
4. Pak Aran Ngou from Langap village and CIFOR researcher Imam Basuki discuss soil properties in relation to natural vegetation and local land use choices (Photo by Douglas Sheil)

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Table of Contents

List of figures and tables

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Executive Summary

The preferences and perceptions of local communities are seldom obvious to others. As a result outsiders including private businesses, government agencies and development organizations, often make decisions that inadvertently harm to local people and their environment. Procedures to improve understanding are needed. The research documented here is part of a broader program linking local and outsider perceptions of landscapes, biota and land-resources. This report focuses on land resources and soils. Our goal is to clarify and summarize information that might facilitate, or be relevant to, the future development and management of the region.

Working with seven communities in the Malinau River Valley, Malinau District, East Kalimantan, Indonesia, we undertook a field study from 1999 to 2001. This approximately 2000-km^2 region includes elevations ranging from 100 m to over 700 m. The landscape is dominated by steep ridges that surround restricted alluvial plains and scattered swamps. The widest plains can be found on the riverbanks of downstream villages. Rocky exposures, swamps and extensive accumulations of organic debris occur locally throughout the larger region. Annual rainfall is nearly 4000 mm on the ground of 700 m above sea level, and a mean daily temperature is around 27˚C. Primary and secondary forests dominate general landscape cover; with swidden cultivation introducing localized rice and other crops. The region includes a diverse range of geological formations.

We selected and refine methods to examine terrain and soil conditions; describe the soil's physical, chemical, and biological properties; evaluate fertility, suitability for agricultural use, and its fragility and erosion risk; clarify local peoples' perceptions and priorities regarding land and soil; and better understand their land management practices. The full methods have been published elsewhere. The purpose of this report is to consider the data generated and their interpretation.

The research context is detailed in chapter 1. We underline the dearth of relevant background information, or indeed any past studies related to local soil conditions and land use. A better understanding of the region's land is needed.

The indigenous population includes various ethnic groups. We focused on the Merap and Punan people as these represent distinct and locally prominent cultures.

Settlements are exclusively riverside villages. Settled population densities in the upper Malinau are below one person per km^2. Agricultural fields, established by clearing forests or old fallow fields, tend to shift every year. Consequently, cleared land and re-growth dominates the view from main rivers and older roads. Forest concessions have surrounded the villages and their activities intersect the communities' forestlands. Land tenure has become highly politicized.

We describe our methods in chapter 2. Working with each of the seven communities in turn, we conducted field observations, and interviews with local informants and communities. Two hundred field-plots were surveyed. Plots were selected by stratification and with guidance from community members to cover as broad a range of site condition and histories as possible. We described soil profiles in-situ and recorded physical properties from each layer. Six hundred soil-samples (at 0-20 and 20-40 cm) were taken for various analyses (Puslittanak 1998). Analyses include measures of texture and bulk density as physical properties, and Al^{3+} (aluminum ion), base saturation, C (organic carbon), Ca^{2+} (calcium ion), CEC (Cation Exchange Capacity), Fe^{3+} (iron ion), K^+ (exchangeable-potassium ion), K_2O (available-potassium), Mg^{2+} (magnesium ion), N (total nitrogen), Na^+ (sodium ion), and P_2O_5 (available-phosphorus) as chemical. For the purposes of most analyses these are considered on a plot-by-plot basis (i.e. n=200).

Following introductory meetings informants were familiar with the overall aims and procedures of the study. For each sample an informant was interviewed regarding their perceptions of each site and the soil in particular. Additional individual and group interviews helped clarify specific topics.

An overview of the various analyses and data are provided in the first part of chapter 3. A review of site descriptions reveals that the parent materials observed in outcrops are diverse including volcanic, metamorphic, and sedimentary. Sedimentary formations are common, with sandstones and siltstones known to yield poor soils; and some localized limestones. Mixed alluvial deposits with larger stones and gravel are also widespread (section 3.1.1). Laboratory derived soil analyses proved relatively consistent and reliable (section 3.1.2 and 3.1.3). Most physical data are normally distributed, but most chemical data are not.

Five soil orders were encountered (section 3.1.4). Oxisols were by far the most prevalent being recorded at 145 sites, Ultisols, the most infertile type, were next with 24, while Entisols, Alfisols and Inceptisols were observed at 13, 10 and 8 sites respectively.

In section 3.1.5 we show that while the soils encountered were diverse, fertility was consistently low. This is because of low pH, limited cation exchange capacity, low organic carbon, phosphorus, and base saturation (Table i). The acidity of these soils tends to immobilize "macro" nutrients. Sample values for Oxisols, Ultisols, and Inceptisols reveal low Ca^{2+}/Al^{3+} ratios (median: 0.15; 0.09; 0.23) implying that aluminum toxicity will harm crop

Table i. Soil chemical characteristics from the sample sites (0-20 cm)

Characteristics	Unit	n	Mean	s.d.	Min/Max
H_2O pH	-	200	4.62	0.50	3.60/6.20
C	% d.m.	200	2.02	0.89	0.65/6.90
N	%	200	0.19	0.07	0.06/0.56
P_2O_5	ppm	200	13.02	36.89	1.20/472.10
K_2O	ppm	200	52.20	44.23	2.00/293.00
Ca^{2+}	me/100g	200	2.63	3.96	0.11/17.06
Mg^{2+}	me/100g	200	1.00	1.02	0.05/5.13
K^+	me/100g	200	0.15	0.09	0.00/0.62
Na^+	me/100g	200	0.10	0.11	0.00/0.82
CEC	me/100g	142	10.36	4.49	1.96/22.94
Base	%	142	33.38	30.91	3.00/100.00
Al^{3+}	me/100g	200	4.01	3.28	0.00/11.89
H^+	me/100g	200	0.42	0.37	0.00/1.94
Fe^{3+}	%	142	2.32	0.96	0.08/4.87

s.d: standard deviation, n: number of samples, Min/Max: lowest/highest reading plants. Agriculture generally requires more neutral pH levels though ash from burning may temporarily reduce this effect.

The least infertile soils were found on flood plain sites and in swampy areas. These soils were darker, richer in organic matter, and showed fewer signs of leaching. The most limiting soils are the fragile entisols: comprising both thin soils on steep slopes, and white sand-swampy areas. Such soils are relatively rare but maintaining vegetation cover in these sites is important as these areas have no productive potential and are easily degraded.

Results of land evaluation are provided in section 3.1.6. Using the criteria of the Indonesian Department of Agriculture that refers to permanent agriculture without fertilizers (Bina Program 1997), opportunities for sustained cropping for most obvious crops (without large-scale artificial inputs) are limited. Most land is entirely unsuitable for crops like pepper, coffee, cocoa, candlenut, rubber and oil palm (Table ii). A small number of alluvial flood plain sites appear suitable for growing field rice or coconuts. Such sites are already in use for cocoa, coffee and field rice giving little opportunity for expansion of sustainable agriculture. It remains possible that agroforestry or approaches employing regular inputs of fertilizer may offer some potential.

The main limiting factors varied according to crop and the site: poor drainage, high rainfall, shallow soil depth, coarse texture, steep slope, and rock presence (Table iii). We conclude that the area is unsuitable for sustaining these crops. Local communities can produce crops from these areas only because they use a shifting system with long fallows in which crop nutrition is derived from vegetation, through burning, rather than from the soil. These limitations on agriculture are likely related closely to the low population density.

Despite the limitations revealed by our analyses we must stress that if anything, we have overestimated the suitability of the wider region for sustained production of cash crops. Villages are located on or near the best land, and are the focus of much of our sampling. More distant sites, for example high on mountainsides, are underestimated in our survey and will usually have even lower suitability. We also under-sampled the plentiful very steep areas due to the difficulties involved. Factors known to influence local cultivation, such as floods, and hardpans, have not included yet in the formal evaluations, but are known to be problems. For example, the best soils occur in areas where flood damage risks are very real, and locally recognized. Given the low fertility of the soils in the region, agro-forestry approaches and application of fertilizers (including organic-matter and lime) appear necessary to obtain any sustained agricultural productivity – though as we note below the erosion hazard remains a severe limitation.

Samples from the area centered on Langap village were 'best' for most crops evaluated. This mainly alluvial region benefits from underlying volcanic rock, has good drainage and flat topography. The least suitable samples were found in the poorly drained soils with steep topography around Lio Mutai.

Soil erosion and compaction are examined in section 3.1.7 and 3.1.8. Soil erosion is noted even in primary forests, and the general erosion risk is high. Only 48% of our samples showed no evidence of erosion, 11.5% show sheet, 30% rill, and 10.5% gully erosion. Erosion occurs

Table ii. Number of sample sites' suitability class by crop (n=200)

Crop	Most suitable	Limited suitability	Marginal/unsuitable
Field Rice	4	11	185
Coconut	-	63	137
Pepper	-	-	200
Oil Palm	-	-	200
Cocoa	-	-	200
Coffee	-	-	200
***Hevea* Rubber**	-	-	200
Peanut	-	-	200
Candlenut	-	-	200

Table iii. Limiting factors of land suitability classes for sustained crop production in 200 sample sites based on standard criteria (see text)

Commodity	Limiting Factors						
	Depth	Drainage	Slope	Surface Rocks	Texture	Coarse Material	Rainfall
Field rice	too shallow/8	very impeded, quick/26	very steep/21	many rocks/3	coarse/2	dominant/10	-
Oil Palm	too shallow/8	very impeded, quick/73	very steep/22	many rocks/3	-	-	-
Pepper	too shallow/8	very impeded, quick/73	very steep/21	many rocks/3	coarse/2	dominant/10	-
Cocoa	too shallow/27	Impeded, quick/73	very steep/21	many rocks/3	coarse/2	dominant/8	-
Coffee	too shallow/27	Impeded, quick/109	very steep/21	many rocks/3	coarse/2	dominant/8	-
Coconut	too shallow/8	Impeded, quick/52	very steep/21	many rocks/3	coarse/2	-	-
Peanut	too shallow/8	Impeded, quick/52	very steep/21	many rocks/3	coarse/2	dominant/10	too high/200
Rubber	too shallow/27	Impeded, quick/110	very steep/21	many rocks/3	coarse/2	dominant/8	-
Candlenut	too shallow/27	Impeded, quick/73	very steep/21	many rocks/3	coarse/2	dominant/10	too high/200

An "-" means that this is not a limiting factor; /x means the number of plots where this is limiting

mainly in steeper areas – but such areas are the rule in the upper Malinau, where severe topography is common. A 40% slope limit marks the mandatory conservation requirements according to the law of Provincial Land Use Planning (Rencana Tata Ruang Wilayah Propinsi/RTRWP) of Indonesian Government Law, i.e. forestland on slopes over 40% cannot be converted. Yet, even among slopes of below 40%, our data shows that erosion demonstrably varies with relation to gradient (p-value= 0.001, Kruskal-Wallis) and with tree cover (p-value= 0.001, Kruskal-Wallis). So erosion risks remain high even in areas that may legally be converted – this argues a need for careful site-by-site appraisal and impact assessments if any large-scale changes are considered.

Timber harvesting has caused soil compaction. Bulk density is significantly higher in logged than unlogged sites (p-value= 0.004, LSD test, n= 32 vs. 56). The four sample sites with unambiguous reports of heavy machinery use are all included among the top 20% densest soil samples (exact probability p-value= 0.0016). The highest soil density values (>1.4 g/cm^3) occurred not only in logged areas (notably logging bays and extraction trails) but in old village areas too. In addition, soil hardening (hard-pan formation) was evident in nearly a third of plots.

Quite apart from the low fertility noted earlier, the limitations imposed by hardpans, potential erosion and by compaction pose further restrictions. These factors, especially the erosion risks, constrain land-use developments outside of the limited alluvial plains.

Result of interviews with local informants about their knowledge of soil, land, and land-use practices are presented in sub chapter 3.2. Local perceptions illustrate an intimate dependence of communities on their land for cultivation and for many other values. Merap people cultivate their staple foods and cash crops. Soil is also used for dye on rattan plaiting, sometimes for medicine and for building ovens. Punan people have similar soil uses although they posses only limited interest in cash crops. Land is also used for burial, and can also be designated as a site for specific roles. Such locations include those containing timber (timber for houses), bird nests (limestone outcrops), and salt springs. These special sites often have specific rules associated with them.

Perception differed within and between communities (section 3.2.1). This appeared to reflect cultures and experiences in utilizing land. Merap people revealed a more sophisticated nomenclature and evaluation of soils (20 terms to describe 79 plots) than the Punan (14 terms to describe 84, Table iv).

All informants agreed that the humus rich "black soils" (*tana tiem*) are the best soil, are fertile, and also easy to work with. Samples and community reviews show that the Punan generally use their best black soils, to cultivate field rice alone. Black soils are typically used by the Merap to cultivate field rice, corn, banana, peanut, sweet potato and cassava; while "swamp soils" (*tana toi pangkah*), "yellowish sandy soils" (*tana yie mieg*) and "red-dry soils" (*tana mla to'ou*) are viewed as infertile and are usually left as forest.

Merap and Punan interviewees clarified that vegetation and soil color are the principle criteria used to evaluate land quality, and suitability for cultivation. Dark soil, vigorous vegetation, friable soil, thick humus, deep soil, few stones, and level land are stated as indicators of good sites. Productive land is said to occur on alluvial plains and in still forested areas, while very poor land is associated with some swamps and steeper slopes. Ground on mountains and high ridges are perceived as not having any value for cultivation.

Local people use swidden systems because after only one year, field productivity drops and weeds generally become too strongly established to control (section 3.2.2). When land is no longer suitable for rice it either reverts to fallow (comprising mainly spontaneous vegetation) or is planted with hardier crops such as cassava, or sometimes fruit gardens. With recent cash crops, like coffee and cocoa, the Merap may sometimes clear land for these without an initial period of rice cultivation.

The Merap generally prefer to cultivate in groups as a way to maximize efficiency and share guard duties against animals. To establish field rice, people will choose and prepare

Table iv. Terminology used by local people to classify soils

Merap	Punan	Indonesian Glossary	English Glossary
Tiem	Punyuh	Warna Hitam	Black Color
Mla	Mengan	Warna Merah	Red Color
Mieg	Jemit	Warna Kuning	Yellow Color
Mbloa	Mpu	Warna Coklat	Brown Color
Bao	-	Warna Abu-abu	Gray Color
Toi	Cerouh	Warna Putih	White Color
-	Pekelet; Bulah	Warna Campuran	Mix Color
Yie	-	Berpasir	Sandy
Lumpuem	-	Agak Lengket	Moderately Sticky
-	Nyekadit	Lengket	Sticky
Ploug	-	Sangat Lengket	Very Sticky
Entat	Praeh	Tidak Keras	Not Hard
-	-	Keras	Compact
Lepeih	-	Tipis	Shallow
Petantaung	-	Datar	Flat area
Ngemura	-	Muara	Downstream
-	Awa	Hulu	Upstream
Matau	Batuh	Berbatu	Rocky
Piue	Pakat/Ancut	Akar	Small Roots
Pangkah	Pangka	Rawa	Swamp
Lohoya	Tukung	Hutan	Forest
'Ya	-	Subur	Fertile
Ta'aya	Jiet	Tidak Subur	Not fertile
To'ou	-	Kering	Dry

old fallow fields for cultivation or, if an old field is not available, they will seek suitable forest sites. We found three-principle form of Merap cultivation - field rice, various perennial crops, and fruit gardens. Land that has just been cultivated for field rice for six months (August to February) will usually be replanted by perennial crops such as peanut, soybeans, vegetables, corn etc. The Merap develop fruit gardens in accessible locations near their villages. Coffee and cacao are established in monoculture. Outsiders introduced these crops using intensive agricultural methods. Few local people now maintain those crops (mainly coffee) because of limited success. Floods have destroyed many of these gardens.

The Punan also undertake shifting cultivation although the process and motivation diverges somewhat from the Merap. In general they specialize less in agriculture, preferring instead to concentrate on gathering forest products. One reason for planting rice is the animals attracted, for hunting. In several cases these groups appeared reliant on buying and trading for rice imported from outside, and one Punan community suffered considerable food shortages during our survey period. The Punan have seldom attempted to establish cash crops (cacao, coffee, etc.). Fruit gardens are mainly located in old Punan villages.

Although the Punan did not traditionally specialize in agriculture, they are beginning to invest more in such activities. Lio Mutai, for example, is rapidly expanding their rice farming and is very proud of their rice self-sufficiency, despite their poor soils. The threat of soil erosion in the Punan communities is generally greater since they generally live in more mountainous areas and their fields tend to be on steeper slopes and on poorer soils.

Results of the study between standard technical assessment of soil and local peoples judgments are provided in sub chapter 3.3. Exploration using ANOVA and Mann-Whitney tests reveal that sites chosen for cultivation are significantly higher in silt content than non-agricultural land (p-value= 0.019), also pH (p-value= 0.002), N (p-value= 0.018), Ca^{2+} (p-value= 0.001), Mg^{2+} (p-value= 0.001), and base saturation (p-value= 0.001), but significantly lower for bulk density, Al^{3+} and H^+ (p-value= 0.003, 0.001, and 0.001; section 3.3.1).

Our sampling specifically sought to include a range of special sites - these are sites with swamp, salt springs, coal, limestone, old village, bamboo, and sago. Some of these areas (salt springs, old village, graveyard, fruit garden) have special cultural significance and are locally protected.

Sites with bamboo, limestone, and swamp contain more bases cation (including Ca^{2+}, Mg^{2+}, K^+, Na^+) than the rest. Others such as salt springs, coal and sago show no clear differences. Local and standard assessments of fertility generally agree that these special sites are not unusual. An exception is limestone, which appears infertile to local people.

Using samples from cultivation, fallow and we considered the relation between cultivation, time since abandonment and various characteristics. Dividing fallow-age into three groups (young 1-3 yrs, old 4-10 yrs, very old 11-40 yrs) and using forest observations as a control group, we found several characteristics differing significantly (Kruskal-Wallis, p-value<.05, table v) within the land use cycle. A specific measure of soil-carbon (C-ref, see main report for details), pH, available nutrients and base saturation (Figure i), increase after forest clearance. After fields are abandoned most measures initially decline for a year or two before rising again to approach forest levels. pH in contrast initially rises with burning, and then declines towards the prior forest condition.

Soil bulk density, and the density of large woody vegetation, decrease when the forest

Figure i. Base saturation (%) (0-20 cm) by stage in land use cycle

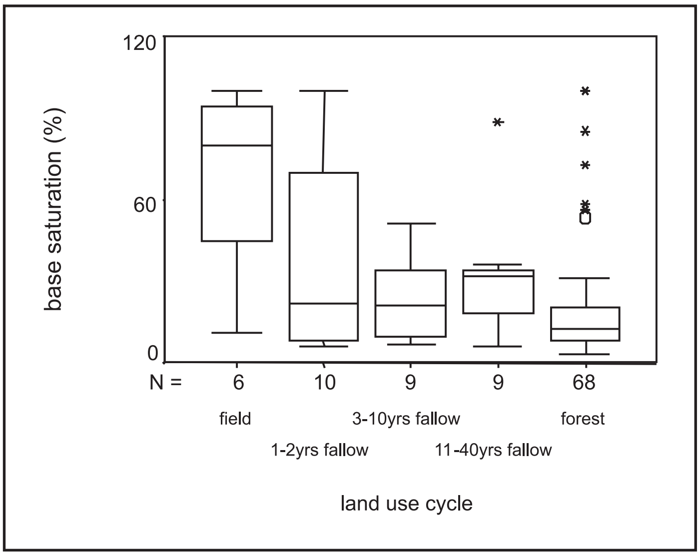


Table v. Surface soil (0-20 cm) characteristics by various local land use stage (Kruskal-Wallis, p<.05) (for *n* values see main report)

	Land use						*P*
	Forest	Agriculture	Fallow			Mean	
			1-2 yr	3-10 yr	11-40 yr		
Color-hue	4.124	4.500	4.273	4.375	4.462	4.223	***0.033***
Silt	36.483	42.900	35.909	45.313	36.692	37.935	***0.031***
Bulk density	1.064	0.897	1.105	1.022	0.993	1.045	***0.016***
Relascope	10.738	0.033	0.788	4.167	8.000	8.168	***0.001***
pH	4.406	4.940	4.645	4.656	4.662	4.516	***0.005***
C-ref.	0.518	0.678	0.512	0.580	0.648	0.548	***0.021***
Ca^{2+}	0.826	5.498	2.877	1.797	3.798	1.714	***0.001***
Mg^{2+}	0.606	1.870	0.904	0.842	1.268	0.810	***0.001***
K^{+}	0.138	0.295	0.124	0.148	0.160	0.151	***0.001***
Bases	1.657	7.775	3.975	2.898	5.328	2.767	***0.001***
B-sat.	20.294	68.167	35.900	25.333	31.111	26.039	***0.009***
Al^{3+}	5.577	1.956	4.412	3.327	3.166	4.740	***0.001***
H^{+}	0.514	0.206	0.280	0.417	0.448	0.456	***0.038***

is cleared and burned, but increase again after field abandonment. After three years of fallow, bulk density appears to decline once again, while woody cover continues to increase.

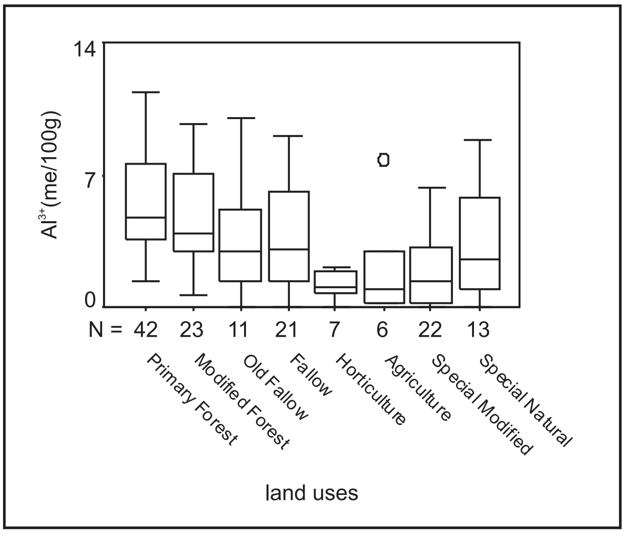
Oxisols, with probability of inclusion of some Ultisols, are the predominant soil type in the research area (n=145/200) allowing closer scrutiny. Several soil characteristics are non-randomly associated with landscape type (these landscape categories are used in our exploratory evaluations, and are fully explained in the main report). These characteristics are sand, Munsell hue, value and chrome, pH, Ca^{2+}, Mg^{2+}, base/nutrient saturation, Al^{3+} and, H^{+} (0-20 cm) (Kruskal Wallis, p <.05 $^{+}$; Figure ii for example of Al^{3+}).

We investigated how our technical evaluations relate to local land use choices. These studies are presented in section 3.3.2. Local informants were asked to choose one of four classes (e.g. not fertile, moderate, fertile, and very fertile) to describe each site relative fertility). Local fertility classes are significantly correlated with the following measured components: soil depth (p-value= 0.047), percentage of sand (p-value= 0.048), N content (%) (p-value= 0.002), Mg^{2+} content (me/100gr) (p-value= 0.02), H^{+} and the Munsell color components chrome (p-value= 0.01) and value (p-value= 0.01). These characteristics must be either directly or indirectly associated with criteria available to local farmers. This link appears clear for depth, sand percentage and color that are directly assessed but must be indirect for N content (%), Mg^{2+} content (me/100gr), and H^{+}.

The Merap assessment of soil fertility has a clearer relationship with our technical measurements than does the Punan system. Several standard characteristics of soil show significant differences among Merap's site assessments i.e. C, N, K^{+}, Ca^{2+}, Mg^{2+} (p-value= 0.032, 0.001, 0.041, 0.001 and 0.039 respectively by Kruskal-Wallis, n= 78).

Focus group discussions implied that flat land is generally considered more fertile than sloping land. Slope in the sample data is indeed significantly different among local

Figure ii. Al^{3+} by sample types



fertility assessment classes (df= 3, p-value= 0.023, Kruskal-Wallis, n= 197) where steep slopes are generally less fertile.

General sample types and local fertility assessments appear non-randomly related (Chi-square; n= 197; p-value= 0.004; coef. = 0.4). Samples of old village and area with bamboo, salt spring, sago and limestone that have been utilized are dominantly perceived as fertile sites. Agricultural and horticultural samples are usually perceived as having fertile soil.

Local fertility assessments are further investigated using an exploratory discriminant analyses in sub section 3.3.2.5. We included only five analytically suitable variables (slope, N, Mg, sand and H^+). We sought to detect variables that are able to reliably build classification functions for the local people's fertility assessment (4 classes, not fertile to very fertile). Only N and sand were selected as significant for the final model. This function was able to correctly classify 46.7% of all samples.

Comparisons between sample ranking based on local and standard land use evaluations are reported in section 3.3.3. Many measured soil characteristics significantly relate to local assessments of land suitability for rice, coconut and peanut (two classes of suitability; suit or not). For rice, soil characteristics such as N, P, clay, sand, CEC, Al^{3+}, Fe^{3+} and consistency, are significantly related (p-value= 0.036, 0.032, 0.004, 0.046, 0.032, 0.042, 0.001, 0.026 respectively by Kruskal Wallis). Further, local land suitability assessments are investigated using an exploratory discriminant analyses in sub section 3.3.3.4. We included only the four most correlated and relatively normal distributed variables (N, clay, sand and Fe^{3+}). Only Fe^{3+} was selected as significant for the final model. This function was able to correctly classify 71.1% of all samples.

The two main conclusions we draw from our analyses are 1) the limited opportunities for expanding non-forestry land-uses in the upper Malinau, and 2) the knowledge of local communities that provides viable livelihoods in the face of demanding local conditions. To illustrate the first point we refer to the fact that out of 200 diverse sample sites, not a single one appeared to offer potential for major cash crops such as oil palm, pepper, and coffee. To illustrate the second point we suggest that people have been able to live in this region only through a sophisticated ability requiring small scale shifting agricultural practices augmented by food from wild sources.

The understanding we have gained of both the limited opportunities presented by the soils of the upper Malinau, along with their crucial significance to the local people, provides a fundamental basis for examining any future land use in the region. The sustainability of the cultivation, the future of the forests, and the welfare of the people depend on good management that heeds this knowledge.

1. Introduction

When it comes to natural resources, the needs and priorities of local communities are seldom obvious to outsiders. Outsiders, whether they are private businesses, government agencies or development organizations, often have a poor understanding of how local communities value and manage their natural resources, a situation complicated by a lack of appropriate procedures to fill in these knowledge gaps. As a result, communities can often become the victims of poorly informed decision-making, a situation that often leads to both conflict and environmental degradation.

Conflicts regarding forestland management between communities and forest concessionaires, mining companies, or forest plantations have become a common phenomenon in Indonesia (Yasmi, 2002). This situation is symptomatic of a larger problem: unclear ownership of the forests, which tends to stimulate illegal logging activities. Many observers suggest that tropical forest management should ideally involve all stakeholders (James and Reed 1998). Breakdowns in relationships between local inhabitants and outsiders lend support to prescriptions, which call for multi-stakeholder management of forestland resources.

In many cases, local people have lived in forested landscapes for generations. They are far more dependent upon the natural resources in their surrounding environment than comparatively wealthy outsiders. As a result, local peoples' knowledge and viewpoints must be appreciated in forested land management. To foster this understanding, we need better ways of reflecting local priorities and values in forestland management.

The research documented here is part of a larger program seeking to link local and outsider perceptions of landscapes and resources. Overviews of the methods and some results have been published elsewhere (Sheil, *et al.* 2002; Sheil, *et al.* 2003).

The main objective of the research detailed here is to explore the current condition of land resources and to clarify how we might facilitate the inclusion of local community perspectives, values and priorities into a sustainable management regime. Within this framework, our detailed objectives are to develop a method of gathering land resource information, including local community perception of that resource; examine land and soil conditions; describe the soil's physical, chemical, and biological properties; analyze fertility, including suitability for agriculture, and degradation/fragility; clarify the local peoples' value and priorities on land resources; and better understand the land management practices undertaken by local people.

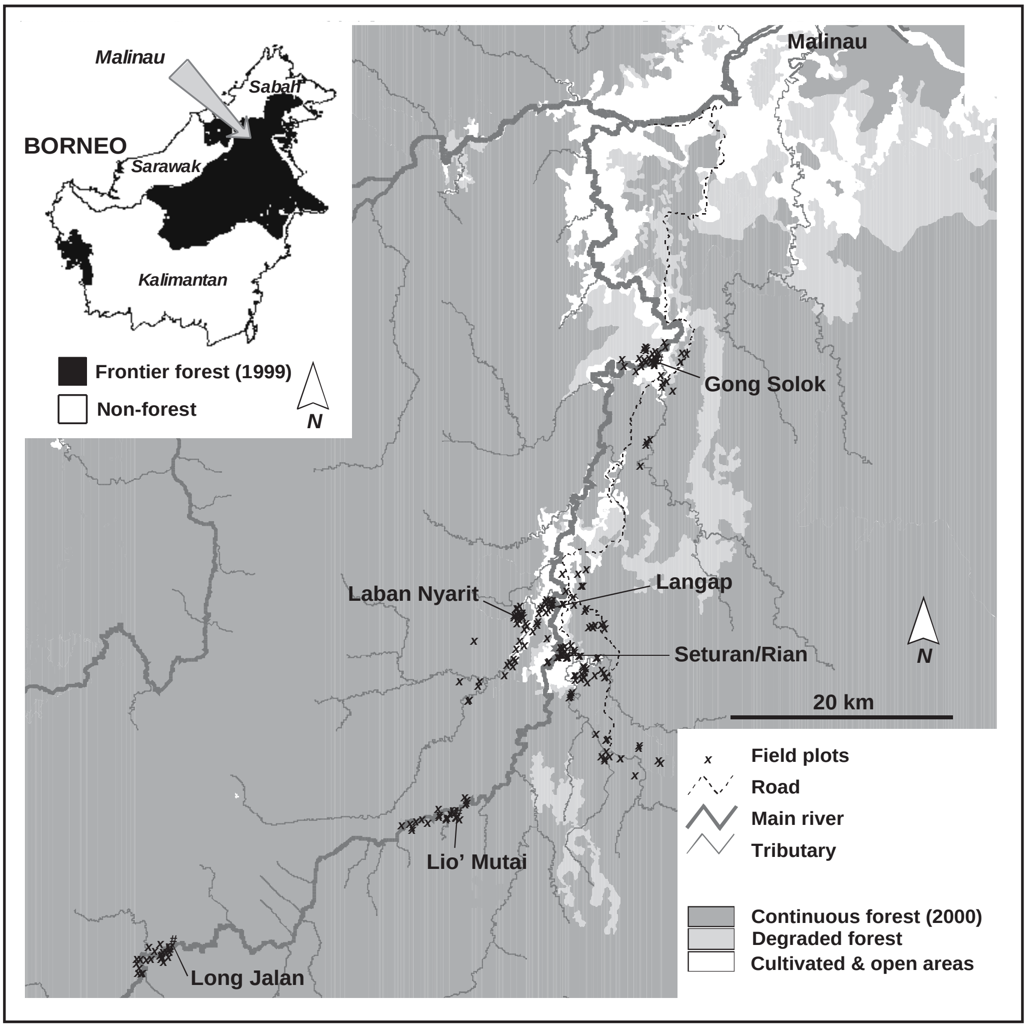
1.1 Study site

Our research was conducted in seven village territories along the upper reaches of Malinau River (Figure 1) of Malinau District, East Kalimantan. This approximately 2000 km^2 (Table 1) region includes rugged terrain with elevations ranging from 100 m to 700 m, annual rainfall of nearly 4000 mm, and a mean daily temperature of 27°C (anonymous 1997). Strong winds are rare but have occasionally been strong enough to fell large trees. Primary and secondary forest dominate the landscape with some patches of field-rice and small plantations of coffee and cacao present as well.

The Malinau area of East Kalimantan was, until recently, little known in terms of its habitats and vegetation. The area has long been viewed as part of Borneo's vast tropical wilderness (Schimper 1903, in Whitmore 1984). Little previous research has been conducted in the region, especially within our research area. It was, nevertheless, believed that the rugged forested landscape would have a high floral and faunal value. A major emphasis of our work has been to begin documenting this value, with explicit consideration of local needs and perceptions.

Until recent years access to the area has been by river. Today, however, several villages, including Gong Solok, Langap, Laba Nyarit, Punan Rian and Paya Seturan, are also accessible by road. Lio Mutai and Long Jalan, the villages furthest upstream, are still accessible only by boat. Three days by boat are needed to reach Long Jalan from Long Loreh village (the center of Malinau Sub-district), while one day is needed to reach

Figure 1. Research Site Map (from Sheil *et al.* 2002)



Lio Mutai. All these communities, except for Long Jalan, border active (1999-2002) logging concessions.

1.1.1 Local people

Population densities in the upper Malinau (ignoring any temporary company populations) are well below one person per km^2. Settlements are exclusively riverside villages. The indigenous population in the region is comprised of several ethno-linguistic categories, including Merap, Punan, Kenyah, Putuk, and Abai (Kaskija 2002). Such a diverse population hints at the complexity of the area's cultural life. Our research focused on the Merap and Punan people as representing two distinct and prominent cultures within the Malinau watershed.

The Merap, with a population of about 1100 in the Malinau region (1990), are one of the largest ethnic groups in the area (Kaskija 2002). They are socially stratified swidden cultivators. Locally they are also a politically influential group, with strong affinities to the more regionally powerful Kenyah.

The Punan have a smaller population of approximately 910 individuals (1990) in the Malinau watershed (Kaskija 2002). Although they have often been viewed as 'hunter-gatherers', the majority of the Punan today live in settlements. The number of Punan who regularly spend long periods in the forest has probably decreased in recent decades, but those that do are increasingly linked to a cash economy that involves trade in various forest products. Overall, the Punan have been less politically visible than Merap and have had less access to education. Literacy and abilities to speak Indonesian are lower, especially in the older generation. They also tend to be more reluctant to communicate with outsiders.

Both Merap and Punan communities hunt, fish, cultivate, and use the forests as a source of food, medicines and building and handicraft materials. A major difference between the two groups, at least until very recently, is that the Merap place great emphasis on rice farming, while the Punan have emphasized extractive forest-based activities.

1.1.2 Process of change

Malinau's people have been exposed to many changes in recent years, with mixed results. Notable among these is their increasing accessibility to the broader world. This is the

Table 1. Populations of survey villages

Village	Dominant Ethnicity	Main Religion	Total area (Km^2)	Households	Population	Inhabitants per Km^2
Gong Solok I	Merap	Catholic	324	44	208*	0.64*
Paya Seturan	Merap/Kenyah	Protestant	} 22**	25	116	} 7.05**
Rian	Punan	Catholic		9	39	
Langap	Merap	Catholic	469	99	415	0.88
Laban Nyarit	Merap/Punan	Protestant	256	29	138	0.54
Lio Mutai	Punan	Catholic	370	11	53	0.14
Long Jalan	Punan	Protestant	748	31	114	0.15
Total			2189	248	1083	0.49

* Gong Solok I disputes territory with Gong Solok II. The area also includes some Punan families—the total population in this territory may be more than twice this figure.

** These two communities share a territory.

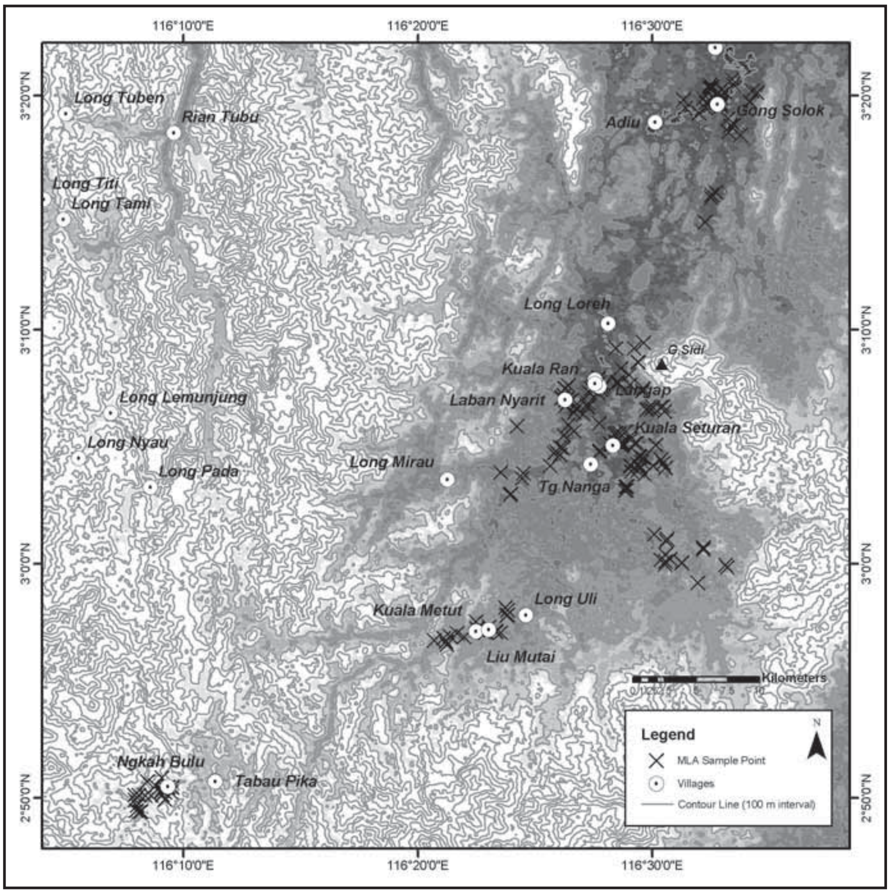
result of both new roads and the introduction of boat engines, beginning in the 1980s. These developments have exposed the communities to many distant forces while also increasing trading opportunities.

Today, outside traders buy gaharu/eaglewood (*aquilaria* spp.) and other products from villagers and, in turn, sell clothes, tools, cigarettes and in some cases, basic foodstuffs. Another recent development has been the creation of general stores in larger villages from which local people can buy many of their daily needs.

Various government programs and clinics in the larger and more accessible communities now provide health care. Improvements in access to education mean that abilities in reading and writing and even in spoken Indonesian have greatly improved. However, schools have reduced the involvement of young people in many traditional activities.

Other important changes in recent years include the use of chain saws for clearing fields. Roads are now a major determinant of which areas are cultivated, while in the past rivers served this role. Agricultural options have increased; local farmers appear willing to innovate and are often curious to learn about crops they have heard of or to talk to outsiders about their ideas. We have occasionally seen local people using chemicals in their fields – a type of small-scale experimentation by wealthier farmers. 'Sawah' (wet) rice is not local to the area but has been tested in several wetter places by some Merap farmers. Government agencies (Dinas Pertanian dan Perkebunan) have attempted to introduce new crop varieties and management techniques. Additional encouragement has come from the agricultural development programs (HPH Bina Desa) conducted by concessionaires through training programs and pilot projects. Various church and mission-led development programs have also played a role. New crops, pesticides, and fertilizers are thus becoming familiar – though this is truer for communities who specialize in farming (notably Merap and Kenyah in the lower areas of the Malinau) than for remoter Punan settlements.

Figure 2. Topographic map of River Malinau catchment



Note: Darker is lower

In addition, there has been some increase in animal farming. Cattle have been introduced on a very small scale in some locations but do not appear popular (seen in Seturan, Loreh and Laba Nyarit), while chickens are more widespread and are often traded. Penned domestic pigs are now seen in some communities closer to Malinau (e.g. Langap, Gong Solok). Domestic animal wastes are not used for agriculture. There has been some discussion of fish farming in downstream areas.

Despite their interest in adopting innovative approaches, local attitudes to these changes are not always positive. In many cases communities complain that the crops they have been encouraged to plant do not grow well in local conditions. For example, cacao plantations require special management and seem prone to pests and disease under local conditions.

1.1.3 Land

The forested landscape of the area is mostly very rugged, and is dominated by hills and ridges that surround restricted alluvial plains and scattered swamps. The widest plains can be found on the riverbanks of downstream villages (e.g. Paya Seturan, Langap, Laba Nyarit, and Gong Solok). An extensive swamp is located near Langap, with an underlying layer of sandy material. An ancient volcano (Mount Sidi) dominates the landscape near Langap village, approaching an altitude of 700 m above sea level. Rocky exposures, swamps and extensive accumulations of organic debris occur locally throughout the region.

Within the vast forested landscape, local people have been using the land for settlement; agriculture (mainly) swidden (dry) rice though including some cassava and local experiments with maize and with *sawah* (irrigated/wet) rice, fruit gardens, small plantations; recreation; hunting; and as graveyards. Agricultural fields, established by clearing forests or old fallow fields, tend to shift every year. Consequently, cleared land and young fallow re-growth dominates the view from main rivers and older roads. Forest concessions surround the villages. Their activities intersect the communities' forestlands and, not surprisingly, tenure is one of the most politicized matters in the area.

1.1.4 Geology

The geological map of The Land Resources of Indonesia (RePPProT 1990) shows that the Malinau River region is among the most geologically heterogeneous in Kalimantan. It contains sedimentary, alluvial, metamorphic and volcanic elements and a number of mineralogical anomalies. Old, weakly metamorphosed and sedimentary rocks underlie most of the area, with some enclosed irregular plains overlaid by younger volcanic activity. More detailed geological knowledge of the region appears fragmentary or is protected by commercial interests.

The Physiographic Map of The Land Resources of Indonesia (RePPProT 1990) highlights four physiographic types in the research area: non-alluvial plain, alluvial valley, hills and mountains. Geological fractures and volcanism were involved in these formations (RePPProT 1990). *'Melange'* formations are part of the geological composition of the area and result from a *subduction* process between continental and oceanic plates. This *'Melange'* results from a geological mixing of extant materials, in this case of diverse origins, scraped off the down-going oceanic plate, which to some extent explains the considerable variation in rock types observed (e.g. river pebbles).

The most comprehensive geologic survey of the region available to us (Direktorat Jenderal Pertambangan Umum [DJPU] 1982) describes the Malinau River region as composed of the 'Malinau' and 'Langap' sedimentary formations and the Mount Sidi volcanic structure. Included in these formations are quartz sandstone, volcanic tuff, clay stone, limestone, siltstone, and coal. Tuffs were believed to be formed by volcanic activities of Mount Sidi as described in previous work by the Indonesian Department of General Mining (Departemen Pertambangan Umum) and Bureau de Recherches Geologiques et Minieres (BRGM) of France between 1979 – 1982 (DJPU 1982).

This report (DJPU 1982) also provides greater detail on some specific and relevant areas, which we summarize here. The upstream course of the Malinau River (Long Jalan and Lio Mutai) is deeply embanked in hard sandstones, and sandy siltstones are almost continuously exposed. Starting five kilometers before the confluence with the River Rian (Tanjung Nanga) and extending downstream, the morphology becomes flatter, with some outcrops of soft clayey-sandy tuffs. Only the volcanic relief of Mount Sidi (700m) breaks this flatter alluvial terrain. Conglomerates that are essentially made up of poorly rounded sandstone pebbles, some white quartz, quartz gravel and biotite granite, occur upstream of Seturan tributary (Paya Seturan). Along the Ran River, a brown limestone unit and a typical limestone breccia over 30 to 40 m wide made up of reef limestone debris appears, starting with thin beds of sandy ochre to brown limestone, conformable with the previous Malinau sandstone. Three kilometers north of Loreh village, sandstone beds are found. In the Langap formation coal occurs below the surface at varied depths (and has been exploited at a large scale near Long Loreh). Further down river, argillites (clayey siltstone) and soft sandstones occur as far north as Gong Solok Village. Though such detailed information is unavailable for most of the area, it clearly contains a diverse and complex geology.

1.2 Past work on soils

Given the region's remarkable geological heterogeneity, great diversity in soil properties is expected. However, the available information does not clarify whether this is, in fact, the case. For example, the soils of the Malinau region are detailed within the main report and maps of the RePPProT (1990). This program was conducted over five years by compiling previous land classification information and associated soil data. The soil in each land system is presented according to the dominant types derived from existing land studies and maps of different scales. The reliability of this information is largely unknown.

RePPProT (1990) explains that the Malinau River watershed is characterized by several *orders* of soil which were classified using *Soil Taxonomy* (Soil Survey Staff, 1987, *order* denotes a class at the highest level), i.e. Inceptisols, Ultisols, and Spodosols. According to this source, Inceptisols found in Kalimantan have slightly altered soil horizons from which some bases, specifically iron and magnesium, have been lost. They are generally infertile, having been derived from sandstones and shales. Ultisols constitute most of the widespread red-yellow soils: colors that reflect leaching of bases and clay. These acidic soils, which have medium to fine texture and weak structure, appear typical of the rolling lowland plains of Kalimantan (Donner 1987). Spodosols normally form in cool temperate climates from acidic parent materials with minimal exposure to erosion and usually possess impeded subsoil drainage. They are strongly weathered and are characterized by medium to very coarse textures, extremely poor drainage, and by subsoil accumulation of iron and humus compounds. The soil map which accompanies the RePPProT report (1990) implies that the Malinau region is typical of the interior of Kalimantan but whether this was based on data interpolation or assumption is unclear.

The most detailed previous evaluation of East Kalimantan's soils known to us is provided by Voss (1983). Though the coverage of the province is quite extensive in his study, the interior was not included in the detailed soil maps. Indeed, while the Malinau area is shown in Voss's soil map 1 (Voss 1983, page 36), the research area is shown in white with the statement "soil data insufficient." In part this reflects an understanding that the area had a low potential for maintaining agricultural production by possible immigrants and was thus of little interest to the transmigration program (Indonesian Department of Transmigration Project).

No fine scale accessible information on Malinau's soils appears to exist. Current broad scale information remains a poor basis on which to assess longer-term land-use options, especially given local variation. A much better understanding of the region's land is urgently required. In particular, the need to link such site information with local needs and preferences needs to be addressed, and its implications recognized. This is the aim of our research.

2. Research Methods

2.1 Sampling design and data collection

Two hundred research plots were established in the study area during four separate periods from November 1999 to December 2000. These four periods are referred to as Multidisciplinary Landscape Assessments (MLA) 1 through 4 (Table 2). In addition, two other work periods, each for one month, were undertaken to check and expand upon local perceptions of the land.

The field plots were located using systematic sampling methods informed by local people's valuation, site characteristics, and map units (see Sheil *et al.* 2002). The recording of basic physical land characteristics at each site was based on standard procedures and terminology (Jurusan Tanah 1991).

Each sample plot was 40 m in length, on which a "mini-profile" and two augur samples were taken. These provided both the quantitative data analyzed in the laboratory and the qualitative data collected from interviews with local farmers.

2.2 Soil observation in the field

2.2.1 Auguring

Using a *Belgi* augur (Figure 3), with a diameter of 10 cm, two soil samples were taken in each plot. Augur samples were taken 10 m from each end of the 40 m length of the plot (Figure 4). Samples were taken in 0.2 m cores down to a depth of 1.2 m. In the event that a soil layer was too shallow to allow a 1.2 m sample to be taken, the sample's depth was noted. Each core layer was then described by texture and color (using the Munsell soil color chart).

2.2.2 Profile

A mini profile was dug in the center of each plot. This hole was approximately 1 m long, 0.5 m wide, and 0.6 m deep and provided enough

Table 2. Field work phases by time period and village location

MLA Phase	Period	Location
MLA 1	November to December 1999	Paya Seturan and Rian
MLA 2	April to June 2000	Langap and Laba Nyarit
MLA 3	July to September 2000	Long Jalan and Lio Mutai
MLA 4	October to December 2000	Gong Solok

space for direct observation of the horizon layers. Characteristics such as depth, moisture regime, color, texture, structure, consistency, matrix node, pores, and vegetation roots were examined according to the method outlined by Suwardi and Wiranegara (1998) and noted in a description form (Table 3). Soil pH was measured in the field using MERCK pH universal indicator paper in order to choose the appropriate procedure for Phosphorus analyses. If the plot was flooded or waterlogged, another augur sample was used in place of the profile.

2.2.3 Collected samples

Composite samples were collected by both profile and augur approaches, but 'undisturbed' (bulk density) samples (see below) were collected only from the profile study.

Composite samples were created by mixing all three samples according to depth (0-0.2 m or 0.2-0.4 m). If there was less than 0.2 m soil depth, the sample was taken only from the upper depth (0-0.2 m). If the site was flooded, the sample was taken from three augur samples. Samples from depths of 0.4 m to 1.2 m were left after noting their texture and color.

Each sample collected was approximately 1 dm^3. The samples were air-dried and roots and any other fibrous materials manually extracted. They were sealed in plastic bags for transport to the *Soil and Agro-climate Research Center* (*Puslittanak*) laboratory in Bogor, Indonesia, where the soils were sieved (2 mm) and oven-dried at 105°C, before chemical analysis.

'Undisturbed' soil samples were taken from the mini profile (0-0.2 m depth) using a stainless steel ring sample with a volume of 167,5 cm^3. From these samples, water content and bulk density characteristics were later measured in the laboratory (as described in Puslittanak 1998).

2.3 Laboratory Measurements

Following standard procedures (Puslittanak 1998) soil samples were analyzed for chemical properties:

1. pH value (KCl and H_2O procedures)
2. Organic Carbon (Kurmis procedure)
3. Total Nitrogen (Kjeldahl procedure)
4. Available Phosphorus (= P_2O_5, by Bray I procedure)
5. Available Potassium (= K_2O, by Morgan procedure)
6. Exchangeable bases, base saturation, cation exchange capacity (CEC), acidity, and Aluminum, and Iron content (this series of evaluations follows the sequential steps of "NH_4OAc/ 23rd procedure", of Puslittanak 1998)

Figure 3. Belgi augur used in the study

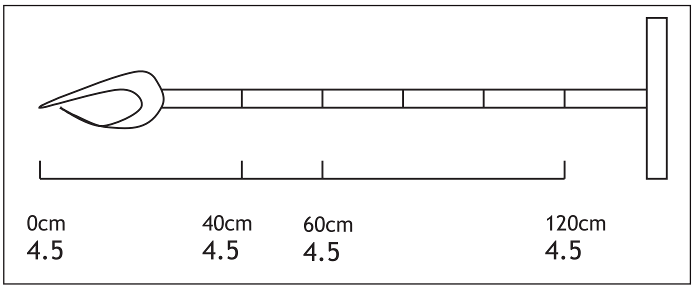


Figure 4. Auguring core (●) and mini profile site (■) in the Research Plot

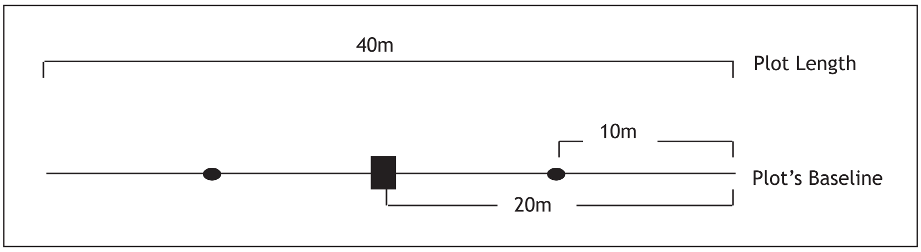


Table 3. An example of field observation results from the mini profile

Page 1

Soil data sheet									
Sample	*139*		Date	*21*	*11*	*00*	Inputted by	*Imam Basuki*
Location	***Ipa Lo'o Iben***		Booker	*Imam Basuki*			Checked by	*Doug Sheil*
Checked by	*Arifin*		Original/Copied?	*O*			File name	*H:\Laporan\MLA\All*
Written on back	Y	N	This is page	*1*	of	*2*	Backups?	*File copied? Y*

Parent Material: *Sediment*	**Drainage:** *Slow* / **Water table:** *>1m*	**BAF** *9 8 9*	**Sample Type:** *Fruit Garden*	**Site Name:** / **Map Number:**		**Surface pH:** *7*	**Erosion: -**		
Horizon Symbol	**Depth (cm)**	**Color**	**Texture**	**Structure**	**Consistency**	**Matrix Node**	**Soil Pores: Micro**	**Soil Pores: Macro**	**Root**
I A	*0-40*	*10YR6/6*	*SiCl*	-	-	-	-	-	-
I C	*40-*	-	-	-	-	-	-	-	-
II A	*0-40*	*10YR5/4*	*SCl*	-	-	-	-	-	-
II C	*40-*	-	-	-	-	-	-	-	-
III A	*0-30*	*10YR5/4*	*SCl*	*ab;1cm;m*	*Friable*	*Stone, 40%*			*s-m;m,b-f*
III C	*30-*	-	-	-	-	-	-	-	-

Page 2

No.	Land Characteristics	No.	Land Characteristics
1.	Surface Condition: *Rock 10%*	2.	Landform: *Hilly; Slope*
3.	Temperature Regime: *Iso-Hipertermik*	4.	Moisture Regime: *Udik*
5.	Classification:	6.	Land Suitability for………………………

No.	Question (Indonesian)	Question (English)	Answer (Indonesian/English)
1.	Sebelumnya lahan ini digunakan untuk apa saja? Hutan/Kebun/Ladang/Sawah/Lainnya….	What was the former use of this land? Forest/Garden/Fallow/Paddy/Other….	*Hutan (**Forest**)*
2.	Apa nama dari jenis tanah ini? Berdasar Lokasi/Warna/Tekstur/Lainnya…….	What is this soil's name? Based on Location/Color/Texture/Others….	*Tano Batuh/P (**Stony**)* *Batuan (**Stoniness**)*
3.	Apa ciri-ciri dari jenis tanah ini?	What are this soil's characteristics?	*Tipis tanahnya dan berbatu (**shallow and stony**)*
4.	Cocok untuk apa tanah ini digunakan? Mengapa? Hutan/Kebun/Ladang/Sawah/Lainnya…..	What kind of use is this land suitable for? Why? Forest/Garden/Fallow/Paddy/Other…	*Hutan (**Forest**)* *Tidak baik untuk ladang karena berbatu (**because its stones are not good for ladang**)*
5.	Bagaimana cara mengelola tanah ini (bila digunakan untuk berkebun/ladang/sawah)? Dibakar/Dibabat/ Dibajak/Lainnya….	How do you prepare this kind of land for cultivation? Burn/slash/Other….	*Dibabat; tebang; mekup; bakar; tugal (**slash; cut; dry; burn; holed**)*
6.	Seberapa suburkah tanah ini?; Berdasar apakah?; Jika tidak subur, bagaimana cara mengatasinya?	How fertile is this land? Based on what indicator? What do you do if it is unfertile?	*Subur; Warna dan gembur (**fertile; based on color and consistency**)* *Ditinggalkan (abandon it)*
7.	Apakah tanah ini mudah/sulit diolah? Jika sulit, bagaimana cara mengatasinya?	Is it easy or difficult to cultivate this land? What do you do if it is difficult to cultivate?	*Sulit karena berbatu (**difficult because of the rocks**)* *Ditinggalkan (**abandon it**)*

Physical characteristics were assessed as follow (Jurusan Tanah 1991):

1. Texture (pipette procedure)
2. Bulk Density (gravimeter procedure)
3. Total Pores (gravimeter procedure)

In the first phase (MLA 1, n=32 sites) only, physical data such as 'strength' and 'gravel content' and basic chemical data such as total P and K were analyzed. In later surveys those characteristics were disregarded in favor of more plant-relevant data gathered by field observation and other analyses.

The consistency of the laboratory results was examined with five duplicate samples from both MLA 1 and MLA 3. Thus, for most quantified variables there were 10 repeated observations. Exceptions are Fe^{3+}, total base, CEC, and base saturation, in which case there were only five samples. This exception occurred because the first survey (MLA 1) was a test phase and this specific type of data was not initially gathered. This was also the case for 'potential-P' and 'potential-K' (as they were changed after the first survey to 'available-P' and 'available K', which are more relevant to plant nutrient availability).

Classification was determined using criteria from Soil Taxonomy (Soil Survey Staff 1998) including: depth of horizon, color, texture, structure, matrix node, drainage, C-org, N, CEC, base saturation, exchangeable bases, and Al^{3+} content. If one plot contained more than one soil type (this occurred on at least five occasions), it was classified on the basis of composite sample analyses.

2.4 Fertility Evaluation

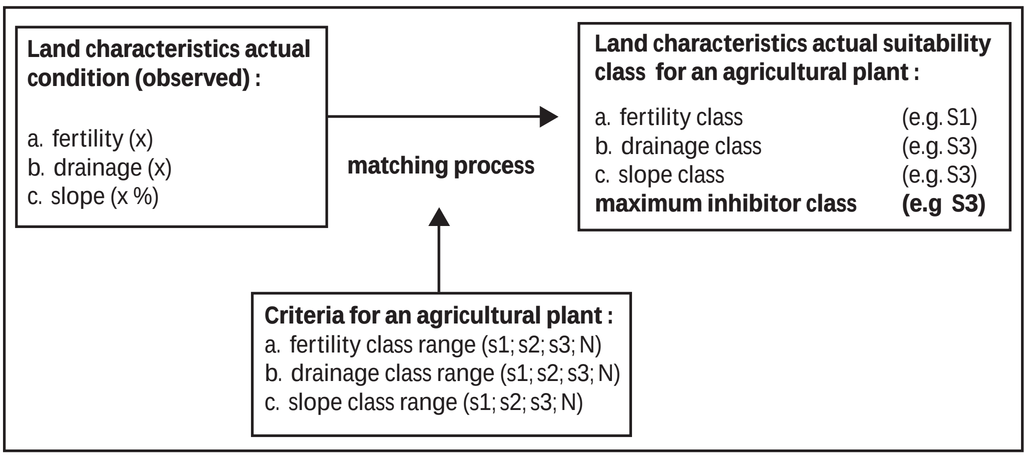
Soil fertility was assessed using two methods. The first was to asses the *critical value* indicators of nutrients which is the optimum level of an element needed for plant growth (Sumner 2000). These values are approximations, as differences in soil and crop types also have an influence on actual fertility. Specific characteristics assessed here are pH, P_2O_5 (ppm), and K^+, Ca^{2+}, Mg^{2+}(me/100g).

The second approach used chemical indicators, outlined by Staf Peneliti (1983), to assess fertility. These are: CEC (me/100gr), Base Saturation (%), P_2O_5 (ppm), K_2O (ppm), and C-org (%). The value of each factor was then translated to an ordinal scale of 1 to 5 and used to classify fertility. *Available* rather than *potential* P and K were used, as these are more relevant to actual fertility.

2.5 Land Evaluation

Land evaluation refers to an area's potential for specific land-uses. Land and soil qualities, such as drainage and nutrient content, can play a significant role in determining the appropriateness/suitability for a chosen activity. Each sample plot was evaluated for its potential for sustained (i.e. no fallowing) production under seven crops: upland-rice, oil palm, black pepper, coffee, cocoa, candlenut, and *Hevea* rubber (Figure 5) using the Standard Indonesian Department of Agriculture classification procedures (Bina Program, 1997). Upland-rice was evaluated because of local preferences and experiences using it. Oil palm was included

Figure 5. Site matching method



due to the considerable interest in developing plantations around East Kalimantan, and pepper, coffee, cocoa, candlenut, rubber due to their potential profitability. For a number of criteria, such as flood risk, we lacked adequate and accurate information for the study area. Our assessments by ignoring these additional criteria may overestimate land suitability.

For each plot the *primary limiting factor* was used to determine the plot's suitability. That is the factor or measure that is most unsuited to the crop in question. Each plot was then rated highly suitable (S1), moderately suitable (S2), marginally suitable (S3), or permanently not suitable (N). S2 land has "light limiting factors and only requires minimum input in order to support a sustainable yield of a selected crop". S3 land (marginally suitable) has "considerable limiting factors and requires sizeable inputs in order to support a sustainable yield of a determined crop." N land is considered "permanently unsuitable" land that is "neither economically nor biologically sustainable for a selected crop." (Bina Program 1997).

The evaluation/matching process between plot site characteristics and crop requirements was carried out using a Boolean logic formula in Microsoft Excel. This process is outlined below.

Formula-1. Example of the Boolean logic (using MS-excel logic) to construct a formula for the land suitability class values of cationic exchange capacity (CEC)

Land Characters	Land Suitability Class for Pepper			
	S1	S2	S3	N
CEC (me/100g)	>16	£ 16		

= IF (CEC = "","", IF (CEC >16, S1, IF (CEC <= 16, S2,0)))

This means that if CEC is >16, the maximum possible land suitability class for pepper will be S1 or "very suitable". Such criteria are applied until all characteristics have been evaluated. Then suitability is determined using the lowest rated characteristic.

2.6 Local Perceptions of Land

2.6.1 Field Informants

Local informants - generally experienced farmers recommended by village leaders and or local community meetings - were used as 'local experts' to evaluate each plot and help us understand how local people assess land fertility, classify soils and judge suitability for crops. Attention was also paid to how land was managed.

Ethnicities varied by village between Merap, Punan, and Kenyah communities (see previous Table 1). Kenyah informants were only utilized in Paya Seturan (MLA 1), while the rest of our informants were exclusively Merap and Punan. There is inadequate Kenyah data for most of the land-use assessments.

Though we would have liked to work with both men and women, this proved impossible due to difficulties finding female informants willing to work with the team.

All informants were familiar with the overall aims and procedures of the study. For each sample location, one informant was interviewed using a fixed questionnaire with a semi-structured approach (see previous Table 3). The questions were drafted with simplicity and clarity in mind and generally required short answers. If the answer was unclear, the question was explained and repeated until a consistent answer was provided. "I don't know" was accepted as an answer when necessary.

Informants were paid for their participation with reference to prevailing local rates (Rp. 20.000, which is equal to US$ 2.20 per day).

2.6.2 Villages

Communities were also interviewed about land and soil as part of a larger village meeting. Members of the local community were grouped by age and sex. During these meetings each group was asked to help develop a map that represented local geography and natural resources, including soil types.

Local community members were also interviewed informally, both individually and through group discussions, in order to gather additional insights on local cultivation systems and land fertility and verify information gathered from the field.

2.7 Statistical Methods

Various exploratory methods were used to examine the data. Given the diverse nature of the sample sites we found it convenient to use eight classes to simplify some of these, as listed in Table 4.

Statistical analyses were carried out to compare and contrast local people's knowledge and standard data between and within the two datasets and to underline possible linkages. SPSS version 9.0 and Microsoft® Excel© were used. The analytical methods are noted with the results in the following sections.

Table 4. List of summary categories used to classify sample locations for exploratory analysis

Land Cover and Uses	Explanation
PF (Primary forest)	Forest that has never been greatly modified. This includes forests that have never been logged, cut, slashed or modified by fire, wind or flooding. If the primary forest is of 'special character' (on limestone, coal, shallow soil, swamp, at salt spring or has sago) and is restricted in extent, it is listed as 'Special-Natural' (see below).
MF (Modified forest)	Forest modified by humans (e.g. logging) or natural causes (e.g. wind gusts, floods, landslides). If the forest has been logged, cut, slashed or modified by fire, wind or flooding, it is labeled 'Modified' and is given one of the following subtypes: logging (lo), pole cutting (p), wind (w), drought (d), fire (fi), flood (fl), under storey slashing (u). See also SM.
OF (Old fallow)	Previously cultivated area abandoned more than 10 years ago. Old fallow is generally dense woody re-growth.
YF (Young fallow)	Previously cultivated area abandoned less than 10 years ago. A sub-code indicates 'years since cultivation'.
H (Horticulture)	Perennial crops (often cash crops). If a garden or plantation is not at the same time part of an old village site, the label 'Horticulture' is given. The following sub-codes are used in addition: fruit garden (f), cocoa (cc), and coffee (c).
A (Agriculture)	Cultivated in the year of survey. Generally used for plots that were cultivated or tended at the time of sampling, with additional sub code for the type of crop: rice (r), cassava (m), beans (k), or an (s) for swampy locations. Note that plots that were recently burned (less than two months since) were avoided.
SN (Special-natural)	Vegetation located in a special site or with special characteristics, usually very localised, and never modified by humans. If primary forest is of 'special character' (e.g. on limestone, coal, rock, swamp, at salt spring or has sago) and is restricted in extent, it is labeled 'Special-Natural' and is given one or more of the following subtypes: swamp (s), salt spring (ss), coal (co), limestone (li), shallow soil (sh), sago (sa).
SM Special-modified	Vegetation at a special site or with special characteristics, but modified in some way. This category is similar to SN, but better matches the definition for 'Modified forest'. This includes other sites of restricted and/or special character like old village sites (ov), graveyards (g), or bamboo stands (b).

3. Results and Discussion

Our evaluation of Malinau's land is divided into three parts: the first focuses upon a standard, or 'soil scientists', assessment, the second investigate local people's perceptions, and the third offers a comparison of the two.

3.1 Standard Assessment

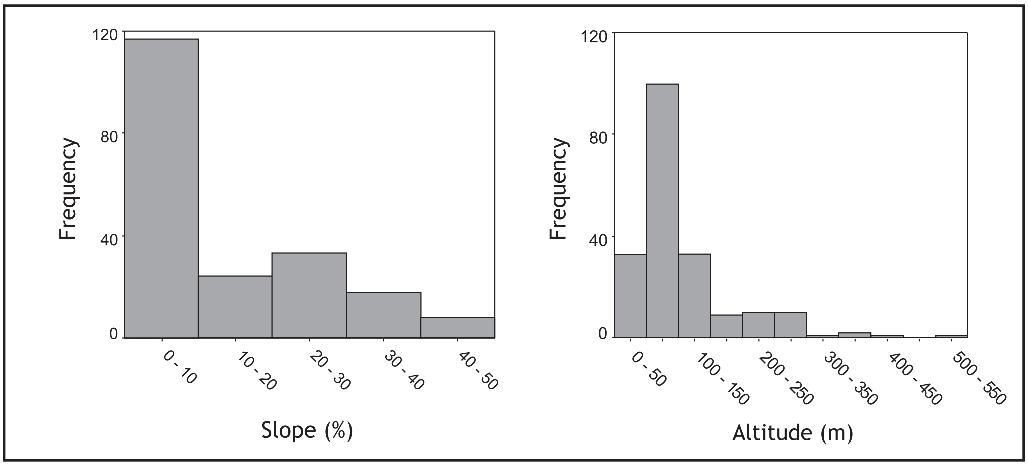
This section describes the results of an examination of our field and laboratory measurements using standard assessment procedures.

3.1.1 Site conditions

Selected sites are biased towards flatter terrain (figure 6). This is a practical reflection of the difficulties of sampling on severe slopes, but also emphasises areas that are accessible, and useful, to local communities. Local people prefer level areas for their settlements, agricultural fields and gardens.

Flatter terrain is more common alongside lower stretches of the Malinau River as flood plain near Gong Solok, Langap, Laba Nyarit and Seturan villages. In contrast, upstream villages like Lio Mutai and Long Jalan, occur in steep terrain. In reality we note that much of the local terrain, is very steep, and inaccessible. These sampling biases need to be born in mind while considering our various data analyses.

Figure 6. Distribution of slope and altitude amongst the 200 sample sites



Several stone outcrops were found through consultation with local community members as "special sites." Access to some locations was not possible due to terrain, distance and local sensitivities. This was particularly problematic in accessing certain limestone areas since they are mostly associated with bird's nests, a valuable - and protected - commodity.

From our observation of soil profiles and stone outcrops (85 sites recorded), we know that the parent materials are diverse. The main rock type observed in our field sites was sedimentary (e.g. n=12 for sandstone). Such sandstones are known to yield poor soils, as the predominantly quartz-based minerals release few plant nutrients. Tuffs, sulfuric rock, limestone, clay stone and siltstone also occurred in accordance with past geological surveys (survey report of DJPU 1982, see section 1.1.4).

Tuffs found on a riverbank near Langap seem to provide more fertile soils. Clay-stone was occasionally found in low areas near Langap and Long Jalan (i.e. near water springs and tributaries, n=5). Siltstone was found in steep areas of riverbank near Long Jalan and as outcrops near Laban Nyarit (n=2). Limestone occurs as weathered outcrops near Seturan and Gong Solok region (n=2). Sulphuric rocks and coal were observed in the vicinity of a few samples near Langap (e.g. River Todok) and near Seturan (e.g. River Rian). All of these rock types, except limestone, generally yield acidic soils.

3.1.2 Statistical Test for Consistency of Laboratory Analyses

The consistency of laboratory analyses was explored using duplicate samples. For all soil characteristics, rank correlation tests showed a positive correlation among duplicates, although this relationship is very poor for KCl-pH, and Na^+, and weak for CEC, and exchangeable-K (Table 5).

There is a shift in the distribution of values between duplicates for C/N, Ca^{2+} and base saturation (Wilcoxon signed rank test). The variance between duplicates as a proportion of the variation among samples is reported as the ratio 'sb/sa' (the standard deviation of the difference between duplicates as a proportion of that among different samples). This ratio indicates inconsistency in several measured variables. The poorest measurements relate to KCl-pH and to CEC; and the best to Mg^{2+} and Ca^{2+}. The poor KCl-pH, K^+, and Na^+ results are partly due to the limited variation found among the duplicated samples (i.e. KCl-pH from 3.6 to 4.4 units; K^+ from 0.0 to 0.62 me/100g; and Na^+ 0.0 to 0.82 me/100g). The poor CEC data may relate to the small-scale heterogeneity of natural variables (e.g. organic matter that can cause significant differences in CEC levels within a single sample). High C-content can also disturb CEC analyses, thus differences in unevenly mixed samples could explain these discrepancies. Physical measures, such as texture, appear to be highly consistent.

The statistical analysis of these duplicates suggests that the laboratory analyses are largely consistent and that the data are acceptable, although there are concerns with KCl-pH and CEC. CEC is a major factor for soil classification and land evaluation, making any errors potentially important to our analysis.

3.1.3 Evaluation of Laboratory Measurements Result

3.1.3.1 Physical Characteristics

Bulk density and texture were measured. Bulk density helps indicate the degree of weathering on the parent material and likely receptivity for root penetration, as well as helping clarify soil types. Texture helps identify soil type and describe a soil's sensitivity and potential for erosion. Taken together, these measurements can also reveal compaction.

Bulk density, clay and silt particles show a roughly normal distribution while sand particles display a more skewed distribution (Figure 7). Sand particle data show that most observations are centered on low values for both the surface and sub surface layers. Most samples have a sand particle component of less than 29.2%. Data distribution of all soil particles shows clayey loam and finer texture soils dominating the samples.

The Bulk Density figures only present 193 data points from 200 plots (Table 6) seven plots were dominated by organic material and are unsuitable for evaluation. Such organic material is always characterized by very low bulk density (< 0.1 g/cm^3). Analysis of the texture of subsurface soil presents 198 data points (the two shallow plots were omitted).

Table 5. Statistical assessment of soil data quality control

	Sand	Silt	Clay	H_2O pH	KCl pH	C	N	C/N	$_1P_2O_5$	$_1K_2O$	$_2P_2O_5$	Ca^{2+}	Mg^{2+}	$_2K^+$	Na^+	CEC	Base sat.	$_3Al^{3+}$	$_3H^+$	Fe^{3+}
n	10	10	10	10	10	10	10	10	5	10	10	10	10	10	10	5	5	10	10	5
sb/sa	0.42	0.42	0.43	0.83	1.63	0.57	0.55	0.31	0.09	0.67	0.63	0.25	0.10	1.00	0.93	1.57	0.34	0.34	0.55	0.85
Spear-man.	0.82	0.93	0.86	0.76	0.19	0.90	0.65	0.90	0.90	0.55	0.78	0.82	0.98	0.51	0.19	0.70	0.90	0.98	0.75	0.90
p	**0.001	**0.001	**0.001	*0.01	0.59	**0.001	*0.04	**0.001	*0.04	0.10	*0.01	**0.001	**0.001	0.14	0.59	0.19	*0.04	**0.001	*0.01	*0.04
Z Wil	-0.21	-0.42	-0.24	-0.87	-0.61	-1.07	-0.26	-1.99	-0.67	-1.07	-0.76	-1.78	-0.65	-0.64	-0.35	-0.67	-2.02	-1.58	-0.25	-0.67
p Wil	0.84	0.67	0.81	0.39	0.54	0.28	0.80	*0.05	0.50	0.28	0.44	0.07	0.51	0.52	0.72	0.50	*0.04	0.11	0.80	0.50
p sign	1.00	1.00	1.00	0.34	1.00	0.75	1.00	0.11	1.00	0.75	0.34	*0.02	0.51	1.00	1.00	1.00	0.06	0.34	0.75	1.00

[1] available form of P and K nutrient (solution, adsorbing complex, and minerals source) analysis
[2] exchangeable form of P or K nutrient (solution source) analyses recommendation
[3] non-active (adsorbing complex source) acidity of soil
b sat : base saturation
n : pairs of duplicated data amount
Spearman : rank correlation value
p : significance probability of correlation
sb/sa : standard deviation between duplicates over standard deviation among different samples.
Z Wil. : Z value of Wilcoxon signed ranks test
p Wil. : significance probability from Wilcoxon signed ranks test
p sign : significance probability of sign test
* significant at p=0.05
** significant at p=0.01

These physical measurements are listed by plot in Appendix 2, and the relationships between these and other measured variables are explored in Appendix 1.

3.1.3.2 Chemical Characteristics

Data on chemical characteristics used to classify soil, and to evaluate land fertility and suitability for agriculture is presented in Table 7. These variables reveal the outcome of weathering processes on the parent material and organic matter characterizing the sampled research area. This includes the relative proportion of elements, reaction status, capacity of nutrient absorption and nutrient saturation.

Iron (Fe^{3+}) content, CEC and base saturation data of the surface layer only include 142 samples since this information was not collected during the first phase of the survey. Subsurface Fe^{3+} content data includes only 141 values for the same reason and the fact that one additional-plot was too shallow.

All chemical data for the area appear far from normally distributed (except for Fe^{3+} content). Extremely high values are found within the phosphorus (2 plots) and potassium (4 plots) data range (Figure 8). These extreme phosphorus data were derived from plots that have associations with river floods and were located alongside the Ran and Malinau Rivers.

In general our samples confirm the description of Bornean soils in MacKinnon (1996): they are low in fertility and nutrient-holding capacity depends mainly on humus content.

As with the physical data, all the chemical characteristics are listed by plot in Appendix 2 and the relationships with other measured variables are explored in Appendix 1.

Figure 7. Example of soil physical data with normal and non-normal frequency distributions

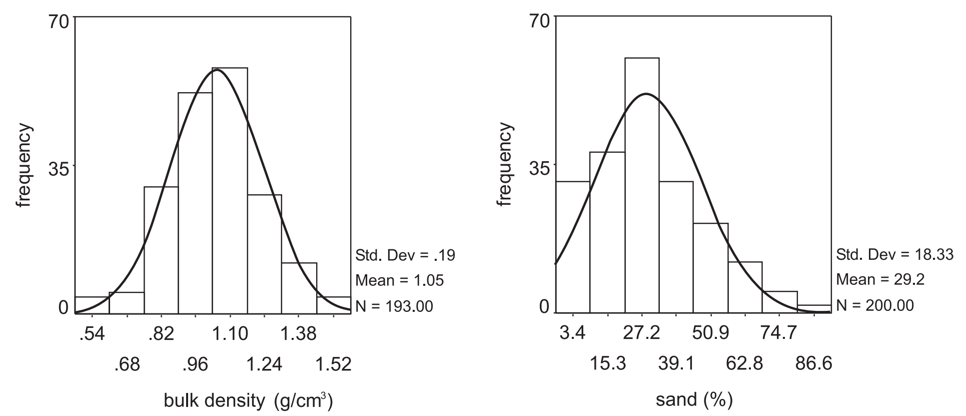


Table 6. The statistics of soil physical characteristics

Layer	Characters	Unit	n	Mean	Mode	s	Range	Min/Max	Skewness
Surface	**Bulk Density**	g/cm^3	193	1.05	1.02	0.19	1.07	0.51/1.58	0.03
(0-20 cm)	**Sand**	%	200	29.24	27.00	18.33	88.00	1/89	0.66
	Silt	%	200	38.28	31.00	11.91	69.00	5/74	0.10
	Clay	%	200	32.48	33.00	11.12	73.00	6/79	0.41
Sub Surface	**Sand**	%	198	28.18	23.00	17.40	85.00	1/86	0.80
(20-40 cm)	**Silt**	%	198	37.27	46.00	10.87	67.00	6/73	-0.11
	Clay	%	198	34.56	25.00	11.23	73.00	7/80	0.08

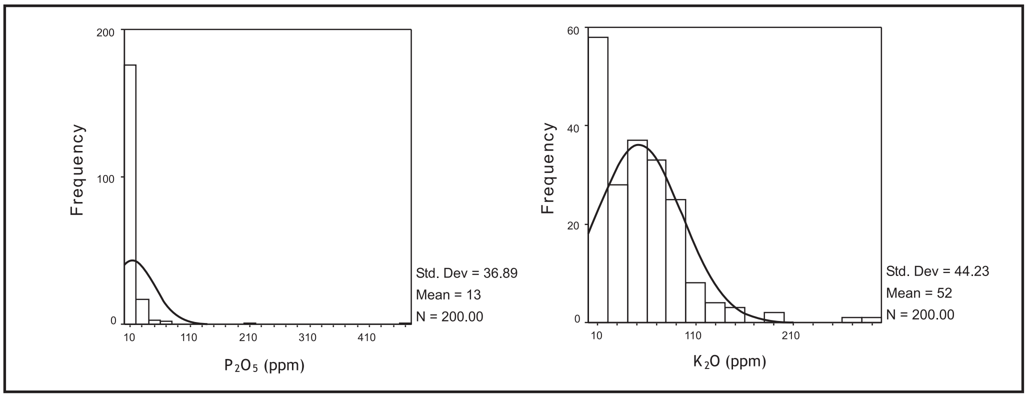
Note:
s: standard deviation
n: number of samples
Skewness: a measure of the asymmetry of a distribution. The normal distribution, or any symmetric distribution, has a skewness of zero. A distribution with a positive skewness has a right tail and a negative skewness has a left tail. (SPSS 9.0)

Table 7. Statistic of soil sample chemical characteristics

Layer	Characteristics	Unit	n	Mean	Mode	s	Range	Min/Max	Skewness
Surface	H_2O pH	-	200	4.62	4.40	0.50	2.60	3.6/6.2	0.85
(0-20 cm)	C	%	200	2.02	1.33	0.89	6.25	0.65/6.9	2.01
	N	%	200	0.19	0.20	0.07	0.50	0.06/0.56	1.29
	P_2O_5	ppm	200	13.02	4.30	36.89	470.90	1.2/472.1	10.62
	K_2O	ppm	200	52.20	8.00	44.23	291.00	2/293	1.99
	Ca^{2+}	me/100g	200	2.63	0.26	3.96	16.95	0.11/17.06	2.08
	Mg^{2+}	me/100g	200	1.00	0.17	1.02	5.08	0.05/5.13	1.50
	K^+	me/100g	200	0.15	0.08	0.09	0.62	0/0.62	2.13
	Na^+	me/100g	200	0.10	0.02	0.11	0.82	0/0.82	2.95
	CEC	me/100g	142	10.36	7.66	4.49	20.98	1.96/22.94	0.51
	Base saturation	%	142	33.38	100.00	30.91	97.00	3/100	1.10
	Al^{3+}	me/100g	200	4.01	0.00	3.28	11.89	0/11.89	0.60
	H^+	me/100g	200	0.42	0.00	0.37	1.94	0/1.94	1.23
	Fe^{3+}	%	142	2.32	0.08	0.96	4.80	0.08/4.87	-0.11
Subsurface	H_2O pH	-	198	4.62	4.30	0.44	2.30	3.7/6	0.88
(20-40 cm)	C	%	198	1.12	0.68	0.78	6.23	0.16/6.39	3.39
	N	%	198	0.12	0.10	0.05	0.34	0.03/0.37	1.30
	P_2O_5	ppm	198	11.71	4.10	68.68	958.70	0.5/959.2	13.50
	K_2O	ppm	198	37.10	4.00	36.53	291.00	2/293	3.18
	Ca^{2+}	me/100g	198	1.95	0.52	3.29	22.52	0.05/22.57	2.84
	Mg^{2+}	me/100g	198	0.78	0.13	0.86	3.31	0.05/3.36	1.50
	K^+	me/100g	198	0.10	0.08	0.07	0.52	0/0.52	2.62
	Na^+	me/100g	198	0.13	0.00	0.20	1.54	0/1.54	3.71
	CEC	me/100g	141	9.05	4.71	4.06	23.55	1.3/24.85	0.62
	Base saturation	%	141	28.66	100.00	28.84	98.00	2/100	1.44
	Al^{3+}	me/100g	198	4.35	0.00	3.32	20.85	0/20.85	1.00
	H^+	me/100g	198	0.45	0.00	0.40	2.41	0/2.41	1.49
	Fe^{3+}	%	141	2.47	1.58	1.04	4.64	0.08/4.72	-0.21

Note:
s: standard deviation
n: number of samples
Skewness: a measure of the asymmetry of a distribution. The normal distribution, or any symmetric distribution, has a skewness of zero. A distribution with a positive skewness has a right tail and a negative skewness has a left tail. (SPSS 9.0)

Figure 8. Distribution of soil sample phosphorus and potassium data (ppm, 0-20cm depth) by sample frequency



3.1.4 Soil Diversity

Five soil orders were identified in the sample area: Oxisols, Ultisols, Alfisols, Inceptisols, and Entisols. These are distributed differently among the sampled local community territories and underlie various sample types (see Table 8).

In regard of our assessment that did not measured soil layer characteristics deeper than 40 cm we made a careful examination of this through auger core, i.e. texture and color. This help us assessing phenomenon happened within deeper layer that will be important in term of classification, i.e. clay accumulation classifying Ultisols.

Variation in physical and chemical characteristics was found among and within the soil types in the research region. These variations relate to parent materials and local management activities. Some important general characteristics were low nutrient availability, acidic pH, and poor capacity of adsorbing and supplying nutrients for plants (CEC). Nutrient availability has been depleted by natural leaching processes, sometimes augmented by human activities, and are reflected by low pH values and low availability of soluble nutrients.

Poor CEC conditions are probably most affected by the clay type that formed in the area and by limited organic material. CEC is determined largely by the mineral structure of clay reflecting surfaces available for nutrient adsorption and release, and buffering. The CEC of most samples was found to be low despite the facts that clay dominates particle size distribution within the research area. This implies clay types, such as Kaolinite, with limited CEC (Hardjowigeno 1987).

We found hardpans in the upper 60 cm in 47 of 142 sample locations (note: this was not explicitly recorded in the earliest surveys "MLA 1"), a figure which should be seen as conservative since pans may occur at greater depths. Pans usually form by local deposition of specific elements. Their colors can be traced to iron and/or aluminum compound enrichment common in old soils in tropical regions (Burnham in Whitmore 1983). The reddish or brownish structures were recorded as hard and compact in a range of 1-20 cm thick.

The presence of continuous hardpan can act as an impermeable layer that limits root penetration, which ultimately will stops plant growth (Burnham in Whitmore 1983). The compact structure can decrease infiltration and impede subsurface drainage. This can increase erosion risks by increasing run off and contribute to landslides. The presences of pans can severely limit land-use options so the high proportion of pans recorded in our plots must be noted. This restriction is not an explicit criteria used in the land evaluation procedures adopted below. As such, factors have an important role in wise land utilization and further evaluations appear warranted.

The following sub-section describes the various soil orders, including their distinctive characteristics and the usage of each type recorded in our samples.

3.1.4.1 Oxisols

Oxisols are generally quite deep and possess a distinctive reddish color. They are generally old and strongly weathered and, despite high clay content, possess very low CEC (<16 me/100g). Oxisols have low pH, and limited fertility because of low nutrient availability. These acidic conditions suggest high soluble aluminum levels - a situation detrimental to agricultural uses, and further limiting productive use (see later).

Oxisols occur on both level and sloping sites throughout the region. However, those found on steeper gradients are generally less fertile than those found in flat alluvial regions (Table 9). Flat areas have a higher level of pH, base/nutrient saturation and have lower content of al^{3+} than those in hilly areas.

Oxisols are the most common order in Malinau and were found in 145 of all plots within the study area (72.5%). They occur in most locations, except those that are waterlogged. 45 of the 145 Oxisols (31%) plots were used for agriculture (including fallow, old fallow and horticulture).

In regard of qualitative assessment of deeper soil layer, we admit that there is probability to have a misclassification on this dominant soil type. This type has similar properties to Ultisols and the differentiating factor could be happen in those deeper layer. But if this is happen, the consequence would be lesser potential use in regard to the worse condition of Ultisols.

Table 8. Associated land cover and uses with soil orders per village

Village	Total Plots per Village	Order	Plots per Order	Sample Types
Gong Solok	38	Oxisols	24	Agriculture; Young Fallow; Horticulture; Modified forest; Old fallow; Primary forest; Special modified; Special natural;
		Ultisols	5	Young Fallow; Old Fallow; Modified forest
		Alfisols	5	Young Fallow; Horticulture; Modified forest; Old fallow; Special modified
		Entisols	1	Primary forest
		Inceptisols	3	Agriculture; Modified forest; Special natural
Langap	32	Oxisols	25	Agriculture; Young Fallow; Horticulture; Modified forest; Old fallow; Primary forest; Special modified; Special natural
		Ultisols	3	Modified forest; Primary forest
		Entisols	4	Modified forest; Special modified; Special natural
Laban Nyarit	30	Oxisols	27	Young Fallow; Modified forest; Horticulture; Primary forest; Special modified
		Ultisols	1	Young Fallow
		Entisols	1	Agriculture
		Inceptisols	1	Special modified;
Lio Mutai	21	Oxisols	18	Young Fallow; Modified forest; Old fallow; Primary forest; Special modified; Special natural
		Entisols	2	Special modified; Special natural
		Inceptisols	1	Primary forest
Long Jalan	21	Oxisols	15	Agriculture; Young Fallow; Modified forest; Old fallow; Primary forest; Special modified;
		Ultisols	1	Primary forest
		Entisols	3	Modified forest; Special natural
		Inceptisols	2	Primary forest;
Paya Seturan	58	Oxisols	36	Agriculture; Young Fallow; Horticulture; Modified forest; Old fallow; Primary forest; Special modified; Special natural;
		Ultisols	14	Agriculture; Young Fallow; Primary forest; Special modified; Special natural
		Alfisols	5	Young Fallow; Horticulture; Special natural
		Entisols	2	Special modified; Young Fallow
		Inceptisols	1	Special natural

3.1.4.2 Ultisols

Ultisols are generally black/red with a loamy texture. These are old, weathered soils. They always have a clear depositional layer (B-horizon) of clay with low base saturation. Leaching leads to acidification (average of H_2O-pH is 4.5), low inherent fertility and, in our samples, a low (c. 20%) base saturation.

Ultisols provided the lowest values of most chemical characteristics among all those surveyed. These include low H_2O-pH, carbon and nitrogen content, nutrient availability, CEC and base saturation. Aluminum toxicity is likely to occur since these ions dominate the exchangeable cations. In terms of fertility, it is the poorest order found in the sampled area.

Ultisols are relatively rare in Malinau, and were found mostly in the peneplain area of Paya Seturan, Langap and Gong Solok.

Table 9. Mean chemical composition of Oxisols in two slope classes

	n	clay	pH	C	N	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	Al^{3+}	H^+	Base sat.
		%	-	%	%	me/100g							%
Slope <15%	94	32.82	4.70	2.09	0.19	2.68	0.96	0.12	0.10	9.21	2.69	0.26	36.13
Slope >=15%	51	39.83	4.46	1.92	0.20	1.26	0.76	0.15	0.11	11.98	6.08	0.46	19.02
t-test[a]	145	**0.002	**0.001	0.356	0.885	**0.003	*0.016	0.351	0.425	**0.001	**0.001	**0.001	**0.002

[a] Only clay, C, K^+, Na^+, CEC, Al^{3+}, H^+ of all characteristics that were tested using parametric method.

* Difference is significant at 0.05 level

** Difference is significant at 0.01 level

Seven of our 24 Ultisols plots had been used for cultivation (agriculture, fallow and old fallow).

3.1.4.3 Alfisols

The distinctive black coloration of Alfisols and its friable consistency make it easy to recognize. Though physically similar to Ultisols, their base-saturation in the depositional layer is higher (it is defined as more than 35%).

They were found mostly in flat area of Paya Seturan, Gong Solok and Labanyarit. This includes two limestone outcrop sites, and a graveyard. Despite of their high base saturation (>35%), CEC and pH values are low (7me/100g and 4.8) and could limit cultivation.

Six of ten Alfisols plots had been/were used for agriculture (including fallow, old fallow and horticulture) and generally viewed as quite fertile by locals. The Seturan plot (plot number 34) was near a bird's nest cave, around which the owner prohibits human activities from taking place. The other site was a valley near Gong Solok (plot number 189) where local people were afraid to cultivate due to the presence of 'spirits'. Both sites, therefore, have special local significance and were left undisturbed.

3.1.4.4 Entisols

Entisols are distinguished by their shallowness and lack of a depositional layer. These are 'very young' soils developed from weathering on steep slopes or of deposition in flooded areas. They show a high value (69%) of mean base saturation with very low capacity for cation exchange. This means that base cations/nutrients saturate the complex of soil particles in high proportion but are not enough to support agricultural plant growth.

Entisols show the highest mean value of available K 93.45 ppm (Table 10). The source of this K_2O is unknown but seems to relate to the parent material of K^+ enrichment (probably mica). Despite high K^+ other nutrients are low, thereby limiting fertility.

Entisols were found in 13 of the sample plots (6.5%). They were recorded in the flood plain around Langap and Gong Solok, in the swamps near Paya Seturan and Long Jalan, and the sedimentary slopes near Long Jalan and Lio Mutai. Their high mean base saturation seems to offer good potential for cultivation. However, given their tendency towards shallowness, and taking into account local flood risks in the areas involved, local people often judged the Entisols unsuitable for cultivation, and agriculture had only occurred in two sample sites (including fallow).

3.1.4.5 Inceptisols

Inceptisols are reddish/yellowish in color with a sticky texture. The key trait is their relative youth and limited leaching, which is seen in the limited physical differentiation of their profiles. However, despite an apparent physical uniformity in our samples, their chemical properties are varied, with implications for their fertility. This variation can probably be best understood in terms of parent material, land-use history, drainage and topography.

Inceptisols occur on both level and sloping area throughout the region. However, Inceptisols found on steeper gradients are generally less fertile than those found in flat alluvial regions. Flat areas generally have a higher pH (4.9 vs. 4.1) and base/nutrient saturation (37% vs. 13%). Average base saturation is quite low (23.7%), but higher than in Ultisols (see Table 10). Among other soils, they have highest value of CEC but poor in nutrient content. Similar to Ultisols, aluminum toxicity is likely.

Inceptisols are said to be the commonest soils in Kalimantan (see MacKinnon 1996), but we found them very few in Malinau. They are the fewest order encountered in the research area. They were found in six villages and present in 8 of the 200 plots (4%). Only 1 of the 8 Inceptisols plots was used for agriculture.

3.1.5 Fertility Evaluations

Fertility is a dynamic condition that determines how well the soil will support plant growth (Sumner 2000). Evaluations of fertility were made for each research plot. The results have clear implications for land use.

Soil fertility studies were undertaken using the indicators summarized in Table 10. Fertility evaluation using Staf Peneliti (1983) procedures found 23 plots of very low fertility, 173 of low fertility and 4 of moderate fertility. In this process, unmeasured CEC values (58 plots from MLA phase 1) were approximated using the sum of bases (ions of K^+, Na^+, Ca^{2+}, Mg^{2+}) and potential acidity (ions of Al^{3+} and H^+), which serves as a *de facto* measurement of 'effective' CEC for each plot. By this method, base saturation values of those plots can also be derived using the following formula: base saturation = ($\sum$ bases) / 'effective' CEC.

Table 10. Mean sample values of chemical properties of each soil order (0-20 and 20-40 cm)

Soil Order	Sample Characteristic Mean Values													
		pH	C	N	C/N	P_2O_5	K_2O	Ca^{2+}	CEC	Al^{3+}	H^+	Bases	Base Sat.	Clay
		-	%		-	ppm		Me/100g					%	
Oxisols (145)/a	Mean	4.61	2.02	0.20	10.51	15.58	63.71	2.13	10.28	4.00	0.34	3.25	29.54	35.52
	Min.	3.60	0.69	0.06	5.00	1.70	2.00	0.11	1.96	0.00	0.00	0.40	3.00	10.00
	Max.	6.00	5.56	0.42	27.00	472.10	152.00	16.44	22.94	11.34	1.56	20.29	100.00	65.00
Oxisols (145)/b	Mean	4.67	1.14	0.13	9.17	16.10	44.05	1.58	8.73	4.24	0.34	2.46	27.22	35.53
	Min.	3.70	0.16	0.03	4.00	0.50	9.00	0.10	1.30	0.00	0.00	0.29	2.00	9.00
	Max.	6.00	6.39	0.33	36.00	959.20	152.00	13.08	15.51	11.60	1.54	16.86	100.00	55.00
Ultisols (24)/a	Mean	4.64	1.58	0.15	10.10	13.47	51.60	0.98	7.95	4.23	0.40	1.62	23.00	25.30
	Min.	4.20	0.76	0.10	8.00	6.00	23.00	0.20	3.41	1.43	0.01	0.43	9.00	18.00
	Max.	5.20	2.41	0.20	14.00	61.40	88.00	2.69	18.15	10.68	1.01	3.92	46.00	37.00
Ultisols (24)/b	Mean	4.69	0.72	0.09	7.80	6.08	41.80	0.56	7.45	4.88	0.34	1.08	16.60	33.00
	Min.	4.40	0.33	0.06	6.00	2.90	19.00	0.10	3.00	2.01	0.02	0.39	10.00	23.00
	Max.	4.90	1.66	0.15	11.00	19.40	72.00	1.09	18.28	10.61	0.87	1.88	31.00	53.00
Entisols (13)/a	Mean	5.03	2.12	0.19	10.40	18.37	102.30	3.98	9.05	1.29	0.16	6.05	67.10	25.90
	Min.	4.50	0.65	0.07	8.00	4.30	28.00	0.92	2.92	0.00	0.00	1.70	16.00	6.00
	Max.	6.20	5.32	0.40	13.00	72.40	293.00	12.66	15.37	5.40	0.34	15.19	100.00	47.00
Entisols (13)/b	Mean	4.89	1.39	0.15	8.80	14.82	83.30	2.55	8.41	2.62	0.25	4.03	47.90	32.60
	Min.	4.40	0.68	0.08	5.00	1.60	20.00	0.61	2.72	0.00	0.03	1.09	11.00	10.00
	Max.	5.90	3.59	0.26	14.00	67.50	246.00	9.96	13.42	7.72	0.84	12.65	100.00	50.00
Alfisols (10)/a	Mean	4.96	1.39	0.13	10.40	11.30	64.00	4.23	7.32	0.70	0.18	5.85	71.80	18.00
	Min.	4.40	0.97	0.11	7.00	4.70	28.00	1.05	4.56	0.00	0.11	1.60	32.00	13.00
	Max.	5.60	2.06	0.15	14.00	20.80	109.00	7.15	11.71	1.18	0.24	9.98	100.00	26.00
Alfisols (10)/b	Mean	4.68	0.72	0.10	8.40	7.38	36.20	3.39	8.15	2.38	0.22	4.87	56.40	27.40
	Min.	4.30	0.49	0.04	5.00	3.20	19.00	0.79	3.36	1.28	0.11	1.33	40.00	17.00
	Max.	5.20	1.20	0.19	15.00	15.60	48.00	5.90	14.43	3.20	0.32	8.04	74.00	39.00
Inceptisols (8)/a	Mean	4.47	3.06	0.31	9.29	15.49	138.57	3.01	19.42	7.46	0.77	4.82	23.71	47.00
	Min.	4.00	1.70	0.20	8.00	4.20	62.00	0.32	16.42	0.00	0.05	1.13	6.00	36.00
	Max.	5.90	6.90	0.56	12.00	45.80	279.00	13.68	22.83	11.89	1.94	19.44	94.00	55.00
Inceptisols (8)/b	Mean	4.50	1.87	0.20	8.57	7.80	99.57	2.48	17.97	8.00	0.98	3.71	21.00	44.29
	Min.	4.00	0.60	0.10	6.00	2.70	43.00	0.26	16.05	0.62	0.03	0.85	5.00	34.00
	Max.	5.60	4.61	0.37	12.00	26.40	293.00	10.09	24.85	11.99	2.41	13.05	75.00	55.00

Note: **(x)/a** = sample number by 0-20cm layer
(x)/b = sample number by 20-40cm layer

The highest fertility was found on sites that were flat and influenced by water: two sites were located on the riverbank and the others in swampy areas. These soils were dark (blackish to brownish), rich in organic matter, and showed few signs of leaching.

In general, the samples are acidic, with an average pH of 4.6 (standard deviation of 0.5). According to Hardjowigeno (1987), such acidity tends to immobilize “macro” nutrients (e.g. nitrogen, phosphorus, potassium, calcium, magnesium, and sulphuric required quite significant quantities by plants). In contrast, “micro” nutrient solubility (i.e. iron, manganese, zinc, cuprum, and cobalt, only required in very low amounts) tends to be high but leaching depletes some of these nutrients. Dissolved aluminum, and sometimes manganese (depending on mineral composition), can reach levels toxic to crops.

The risk and adverse impact of Aluminum toxicity on root growth and function increased from 50 to 75 to 100% as the soil solution Ca^{2+}/Al^{3+} ratio decreased from 1 to 0.5 to 0.2 (Cronan and Grigal 1995; in Sumner 2000). According to this our Oxisols, Ultisols, and Inceptisols with Ca^{2+}/Al^{3+} ratios of (median: 0.15; 0.09; 0.23) are toxic in aluminum. Agriculture generally requires more neutral pH levels than what we recorded. The forest vegetation, we presume, is better adapted to these conditions.

CEC of most samples were low (<17me/100g) compared to the Staf Peneliti (1983) standard. Such soils have limited potential to absorb and release nutrients to supply plant needs, as is confirmed by the low base/nutrient availability (Table 10). Together this implies low nutrient availability and low fertility.

In conclusion, the general capacity to support agricultural plant growth in the areas we examined appears very low, a condition resulting from low pH, CEC, nutrient availability and nutrient/base saturation levels. This can be attributed to the prevalence of nutrient poor, quartz-based (sandstone) parent materials and prolonged exposure to a climate that promotes leaching. Despite this scarcity, potassium sometimes occur in significant quantities (i.e. Inceptisols and Entisols), which is probably due to the local presence of younger enriching minerals, perhaps mica, or the deposition of mixed alluvial materials.

3.1.6 Land Evaluations

An evaluation of the land for possible commercial plantation crops, using the criteria of the Indonesian Department of Agriculture (Bina Program 1997), resulted in more than half the plots falling into the ‘N’ classification (cocoa 50.5%, peanut and candlenut 100%, coconut 36%, coffee and rubber 64%) (see Table 11 and 12). Most of the remaining plots are S3 land, while very few plots fell into S1 (4 plots for field rice) and S2 categories (11 plots for field rice, 63 plots for coconut). Plots that were categorized in the S1 and S2 classes (for field rice) are all utilized for rice cultivation, and are slightly limited by poor CEC. They were found on an alluvial area within Paya Seturan, Langap and the Laba Nyarit region. Plots of S2 class for coconut were found in all villages but mostly in Paya Seturan and Langap (but never in steep areas).

‘N’ (permanently unsuitable) plots are considered to be neither economically nor biologically sustainable for a selected crop. While this classification reflects commercial rather than subsistence cultivation, these figures confirm that the research region is unsuitable for large-scale oil palm, pepper, cocoa, rice cultivation, etc.

The S3 class samples have some serious limiting factors that would require substantial, and costly, inputs to allow a sustainable yield (Table 13 and 14). S2 class samples are slightly limited by poor CEC and, together with S1 samples (which have no limitation), offer the potential for rice cultivation.

The main limiting factors varied according to crop and the site tested but they include: poor drainage, high rainfall, shallow soil depth, coarse texture, steep slope, and the presence of rock. Poor drainage is a particularly important factor since it determined the N class of many sites, (e.g. 80% of oil palm’s N class), while rainfall specifically limited the suitability of candlenut and peanut within the area.

How can we conclude that the area is unsuitable for crops, like peanuts that are already grown locally? The main answer is that local production is invariably based on a small-scale swidden-fallow cultivation system in which nutrients are managed by cutting and burning the forest with long fallow cycles which allow for woody regrowth and nutrient recovery. Over any prolonged period of repeated cultivation crops decline

Table 11. Land evaluation criteria for cultivation of oil palm; pepper; and upland rice for marginally suitable (S3) and not suitable (N) classes

Land Characters	Suitability Class of Oil palm		Suitability Class of Pepper		Suitability Class of Rice	
	S3	N	S3	N	S3	N
Mean Daily - Temperature (°C)	20-22 32-35	<20 >35	-	>34 <20	20-22 32-35	<20 >35
Rainfall (mm)	1250-1450 3500-4000	<1250 >4000	3000-4000 1500-2000	<1500 >4000	1250-1450 3500-4000	<1250 >4000
Relative Humidity (%)	-	<50 >100	-	<50 >100	-	<50 >100
Dry months (month/s)	3-4	>4	3-4	>5	3-4	>4
Drainage	Impeded, Quite Quick	Very Impeded, Quick	Impeded, Quite Impeded	Very Impeded, Impeded	Impeded, Quite Quick	Very Impeded, Quick
Texture	Quite Coarse	Coarse	Fine	Coarse	Quite coarse	Coarse
Coarse Material (%)	35-55	>55	35-55	>55	35-55	>55
Depth (cm)	25-50	<25	30-50	<30	25-50	<25
Peat Depth (cm)	140-200	>200	140-200	>200	140-200	>200
Peat Maturity	Hemic, Fibric	Fibric	Hemic, fibric	fibric	Hemic, fibric	fibric
CEC (me/100g)	-	-		-	-	-
Base Saturation (%)	<35	-	<35	-	<35	-
H_2O pH	<4.2; >7.0	-	<4.0; >8.0	-	<4.2; >7.0	-
Organic C	8-10	>10	8-10	>10	8-10	>10
Salinity (dS/m)	3-4	>4	8-10	>10	3-4	>4
Alkalinity	-	-	15-20	>20	-	-
Sulfidic Depth	60-100	<60	40-75	<40	60-100	<60
Slope (%)	16-30	>30	16-30	>30	16-30	>30
Erosion Hazard	Heavy	Very heavy	Heavy	Very heavy	Heavy	Very heavy
Flood	F2	>F3	F1	>F2	F2	>F3
Surface Rocks	15-40	>40	15-40	>40	15-40	>40
Stone Outcrops	15-25	>25	15-25	>25	15-25	>25

Source : Wahid and Ujang 1986 in Biro Perencanaan 1997.

Table 12. Distribution of samples by suitability classes for selected crops

Agricultural Crops	Samples Within Suitability Classes of Selected Crops (n=200)			
	S1	S2	S3	N
Field Rice	4	11	133	52
Oil Palm	-	-	107	93
Pepper	-	-	108	92
Cocoa	-	-	99	101
Coffee	-	-	72	128
Coconut	-	63	64	73
Peanut	-	-	-	200
Candlenut	-	-	-	200
***Hevea* Rubber**	-	-	72	128

Table 13. Limiting factors of land suitability classes for agricultural uses in sample plots

Commodity	Limiting Factors						
	Depth	Drainage	Slope	Surface Rocks	Texture	Coarse Material	Rainfall
Field rice	too shallow/8	very impeded, quick/26	very steep/21	many rocks/3	coarse/2	dominant/10	-
Oil Palm	too shallow/8	very impeded, quick/73	very steep/22	many rocks/3	-	-	-
Pepper	too shallow/8	very impeded, quick/73	very steep/21	many rocks/3	coarse/2	dominant/10	-
Cocoa	too shallow/27	Impeded, quick/ 73	very steep/21	many rocks/3	coarse/2	dominant/8	-
Coffee	too shallow/27	Impeded, quick/ 109	very steep/21	many rocks/3	coarse/2	dominant/8	-
Coconut	too shallow/8	Impeded, quick/ 52	very steep/21	many rocks/3	coarse/2	-	-
Peanut	too shallow/8	Impeded, quick/ 52	very steep/21	many rocks/3	coarse/2	dominant/10	too high/ 200
Rubber	too shallow/27	Impeded, quick/ 110	very steep/21	many rocks/3	coarse/2	dominant/8	-
Candlenut	too shallow/27	Impeded, quick/ 73	very steep/21	many rocks/3	coarse/2	dominant/10	too high/ 200

An "-" means that this is not a limiting factor.

Table 14. Potential improvements for limiting factors

No.	Limiting Factor	Improvement	Local effort on agriculture
1.	Too shallow	Bund	Not used
2.	Quick or impeded drainage	Organic Material; Drains	Planted on higher and drier sites
3.	Steep slope	Terrace; contour planting	Used in some areas
4.	Surface rocks	Clear (when loose)	Planted in between rocks
5.	Texture (too coarse or too fine)	Organic Material	Longer period of planting upon too fine texture
6.	Physical barriers (stones/pan)	-	Not used

in yield and reduce the intrinsic productivity of land. In local cultivation fields cleared for rice generally provide only one-years worth of production before reverting to a fallow state.

Local people have a good reasons to look for and find areas, perhaps of less than a single hectare where land properties are better than elsewhere – thus they may occasionally be able to grow good coffee, cocoa etc. However, such a strategy is not viable for any large commercial enterprises.

It is true that oil palm may be able to establish and grow locally (e.g. an individual plant grows by the old site of Langap). However the establishment of such palms is not a good indication of their economic viability, as the seasonal availability of moisture is vital to good fruit initiation and production – our analyses show that conditions in Malinau are simply not suitable.

Furthermore, there is good reason to suppose that we have overestimated the suitability of the region for cash crops. This is because villages are located near the best lands, and are the focus of much of our sampling. We specifically try and put sample in cultivated areas even though such fields are a tiny proportion of the whole region. More distant sites, for example high on mountain sides, are underestimated in our survey and are likely to have still lower suitability.

Importantly, other factors indicate that the situation may be even worse than the evaluation system used above indicates. As mentioned earlier, hardpans and aluminum toxicity are widespread (1/3 of our samples) in the study area but have been ignored in the standard land evaluation, despite the fact that they may have considerable consequences for land-use. Hardpans can limit root penetration, reduce infiltration and impede subsurface drainage with negative implications for cultivation. High levels of hardpans, the prevalence of flooding on the best alluvial soils, and the high costs of transport will all reduce viable options still further. We are pessimistic about opportunities for agricultural expansion and intensification.

Overall, we found that the Langap region has the most suitable sites (S1-S3) of all plots studied in the village for most of the crops tested (i.e. rice 88%, pepper 70%, oil palm 73%, coffee and rubber 42.4%, cocoa 63.6%, coconut 81.82%; sample sites/n=33) (see Appendix 3). This region is underlain by old volcanic rock, has good drainage and flat topography. The least suitable sites (of all plots studied in a village) for the test crops were in the Lio Mutai region (i.e. rice 60%, pepper 30%, oil palm 35%, coffee and rubber 20%, cocoa 30%; coconut 50%; sample sites/ n=20). This region has poorly drained soils with steep topography.

3.1.7 Erosion

Erosion is a crucial concern in land-use planning. Neglect can lead to considerable negative impacts. Erosion reduces soil depth, and removes organic matter and plant nutrients concentrated in the soils upper layers. These factors, along with simultaneous increases in soil compaction and reduced permeability, lead to reduced productivity and future potential (Young 1990). It also threatens the quality of cathcment functions including water quality, fisheries and other aquatic resources, and can in some circumstances lead to life-threatening land-slides. Loss of top-soil also involves loss of the biological components that maintain soil fertility and recovery. Even moderate levels of erosion can deplete plant nutrients, a factor that is crucial when soils are inherently poor as is the case in much of Malinau.

In our study just over half of the sample sites revealed signs of erosion. Three types of erosion were distinguished based on visible evidence, which includes deposited soil particles (inter-rill), shallow channels (rill) or deep channels (gully). Given the hilly topography and high rainfall, rill erosion was found to be the dominant type (see Table 15). Gully and sheet/inter-rill types were less frequent and found in roughly equal numbers. Scores applied according to erosion type were used as pseudo-quantitative expressions of the erosion magnitude (scored here as sheet=1, rill=2, and gully=3 respectively. Note, these weights are used for presentation only and have no formal ratio or interval meaning).

Table 15. Erosion type, frequency and percentage within research plots

Type	Frequency	Percent
None	96	48.0
Sheet	23	11.5
Rill	60	30.0
Gully	21	10.5

Sample types were found to have a weak but still significant association with evidence of erosion (Cross-tab, p= 0.001). Interestingly, modified forest, primary forest and old fallow sample sites reveal the highest percentages of erosion evidence (Table 16, note: this is not specifically related to tracks and pathways) while, in contrast, special-modified and agricultural land have the least. There are two reasons that may be involved in explaining these patterns. First, agricultural land is generally flat, while the remaining forestland predominates on sloping areas (Figures 9a, 9b and 9c). Our data also shows a relatively stronger correlation between erosion and slope than between erosion and 'relascope counts' (our measure of woody plant cover, Table 17). The second reason is the age of the signs recorded. Erosion signs seen in a forest may reflect many years of limited soil loss, but the physical process of clearing and cultivating fields may obliterate such signs – even though tillage is not part of the process.

Old fallow lands have a higher percentage of erosion evidence than agricultural lands due to their steeper slope. Old fallow occupies different locations in the current landscape even though old fallow is of course ex-agriculture land.

We found that erosion largely occurs in steeper areas of hills and along riverbanks. More importantly, the type of erosion varied significantly even among slopes of 0 – 40% gradient and among those with an average relascope of 0 – 12 (ANOVA, p=0.001) (see Table 18; Figure 10). Such slopes fall below

Table 16. Erosion evidence by sample types

No.	Sample Types	Erosion Type				
		None	Sheet	Rill	Gully	Percent
1	**Primary Forest**	16	8	26	7	71.93
2	**Modified Forest**	6	5	13	8	81.25
3	**Old Fallow**	6	1	4	2	53.85
4	**Fallow**	15	4	6	2	44.44
5	**Horticulture**	7	1	2	1	36.36
6	**Agriculture**	8	1	1	-	20.00
7	**Special Modified**	23	2	3	-	17.86
8	**Special Natural**	15	1	5	1	31.82

Table 17. Rank correlation between erosion and slope; erosion and *relascope*; and slope and relascope using Kendall's tau

		Slope	Relascope
Erosion	Coef.	**.333	**.293
	p-value	.001	.001
	n	200	200

		Relascope
Slope	Coef.	**.217
	p-value	.001
	n	200

** Correlation is significant at the .01 level
Relascope: average value of plot's relascope count

Table 18. Comparison test of slope and basal area estimation among erosion types using ANOVA

		Slope	Relascope Count Avg. (Factor = 10)
Erosion	df	3	3
	p-value	**0.001	**0.001
	n	200	200

** difference is significant at the .01 level

the 40% limit, which marks the mandatory conservation requirements according to the law of Provincial Land Use Planning (Rencana Tata Ruang Wilayah Propinsi/RTRWP) of Indonesian Government Law (see detail at *http://www.kimpraswil.go.id/ditjen_ruang/nspm/PP47-1997.htm*).

In conclusion, the evidence of erosion within our samples was primarily caused by the steepness of the slopes in the study site. Even intact forest and older fallow areas reveal a high degree of natural erosion.

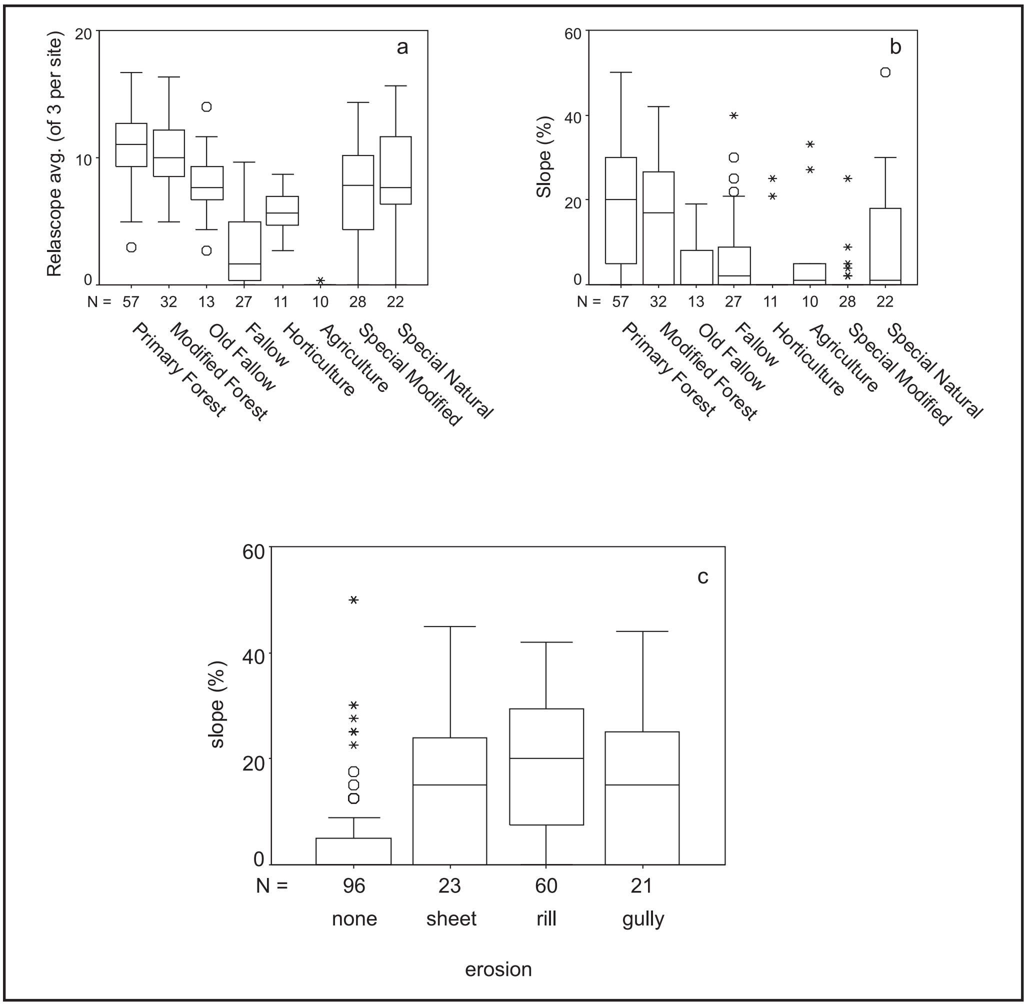
3.1.8 Compaction

Compaction can result from the impact of management and site intervention (Sumner 1999). In agriculture, for example, the application of heavy equipment and repeated tillage activities reduces soil porosity and can damage its structure. Under compacted conditions plants suffer from poor root development, leading to sub-optimal growth. Compaction also increases run-off and exacerbates erosion.

In Malinau, soil compaction was observed following both logging and extended land-clearing activities. The level of compaction was explored using bulk density values of measured samples. When samples are grouped by sample types they differ significantly in their bulk density (Anova, p-value = 0.003). Bulk density is significantly different between primary and modified forest (Figure 11; p-value = 0.004, LSD test) and between primary forest and the special modified samples (p-value = 0.04, LSD test).

The highest bulk density values (>1.4 g/cm^3) were scattered, occurring both in upstream (Lg. Jalan/n=2 and Lio Mutai/n=2) and downstream locations (Langap/n=2

Figure 9. Summary of samples by (a) relascope average estimation, and by (b) slope (%); and (c) slope against erosion types



and Gg. Solok/n=1). The most compacted soils are often found in sites modified by human activities: logged areas, logging bays, extraction trails, and old village areas. They were observed in places affected by human activity, e.g. logged forest (on swampy [1] and better drained ground [3]), bamboo forest, fruit garden, and old fallow. Such high values suggest increased clay concentrations, loss of organic matter, decreased porosity and/or exposure of hardpan surfaces.

Skid trails formerly used for logging activities in most villages were observed to be poorly vegetated, both in terms of overall growth and diversity. The four sample sites with unambiguous reports of heavy machinery use are all included among the forty densest samples in the 200 sites (exact probability p-value = 0.0016). This data, viewed in conjunction with the vegetation and site histories, implies that site recovery in such locations can be very slow.

Further analyses of bulk density distribution among villages were made to understand general picture of compaction phenomena through the region. This process used sample types as factor to describe their distribution within a village. Despite of no clear difference found in downstream villages (Paya Seturan, Rian, Langap, Laba Nyarit and Gong Solok), plots of Long Jalan and Lio Mutai villages show clear evidence of contrast bulk density values formed among sample types that cover hilly landscapes (Figure 12). Primary forest soils generally retain lower bulk density than other sample types except for a few agriculture (in Long Jalan) and special-natural (in Lio Mutai) sites. The only agricultural samples in Long Jalan were in steep areas near the settlement. The special-natural sampled area of Lio Mutai

Figure 10. A summary of erosion types according to slope (%) and basal area estimation (*relascope* count averages)

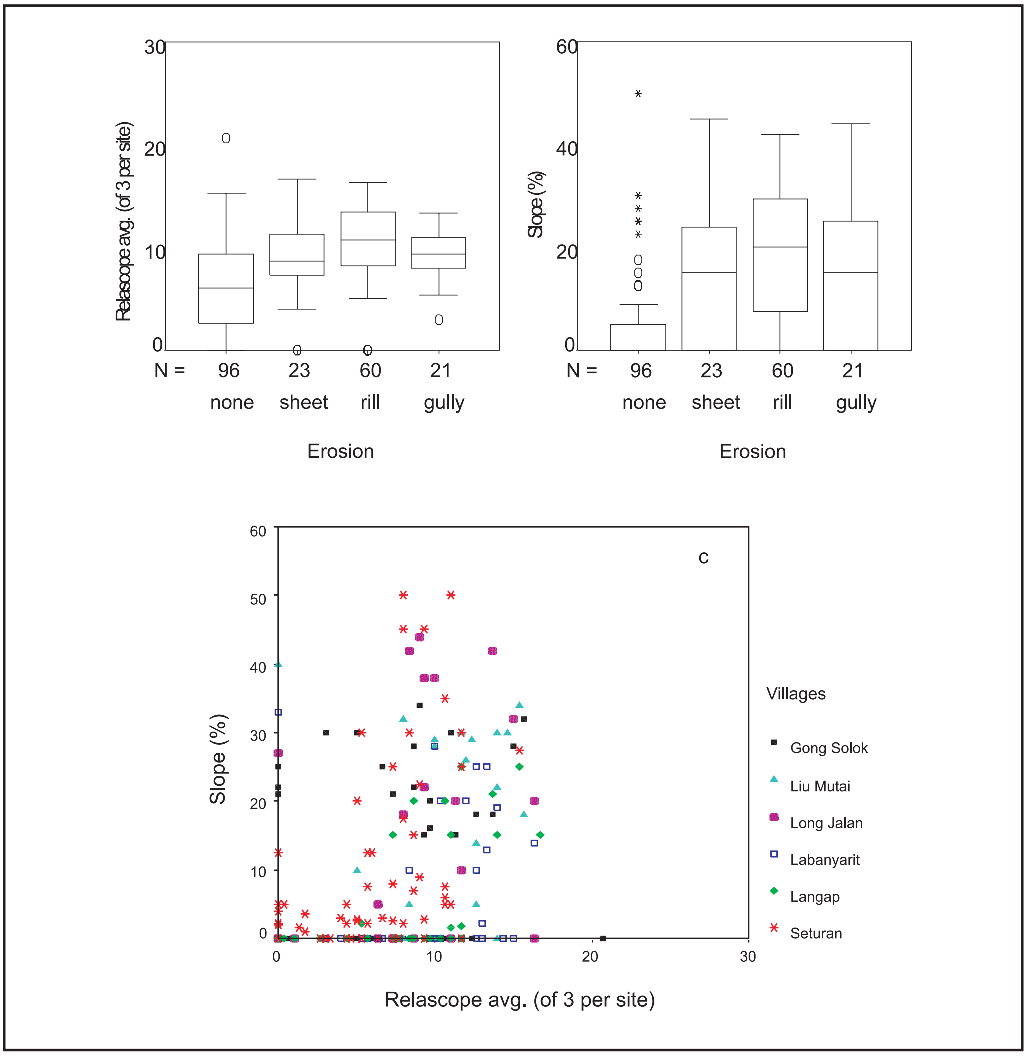


Figure 11. A summary of soil bulk density by sample types

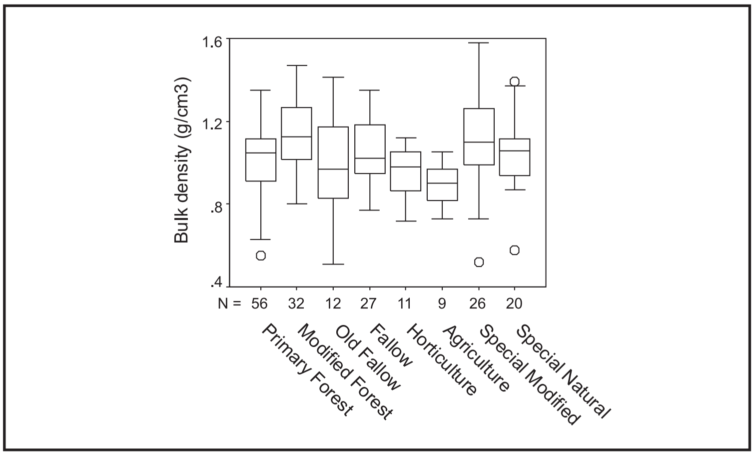


Figure 12. Summary of bulk density value among sample types in (a) Long Jalan and (b) Lio Mutai villages

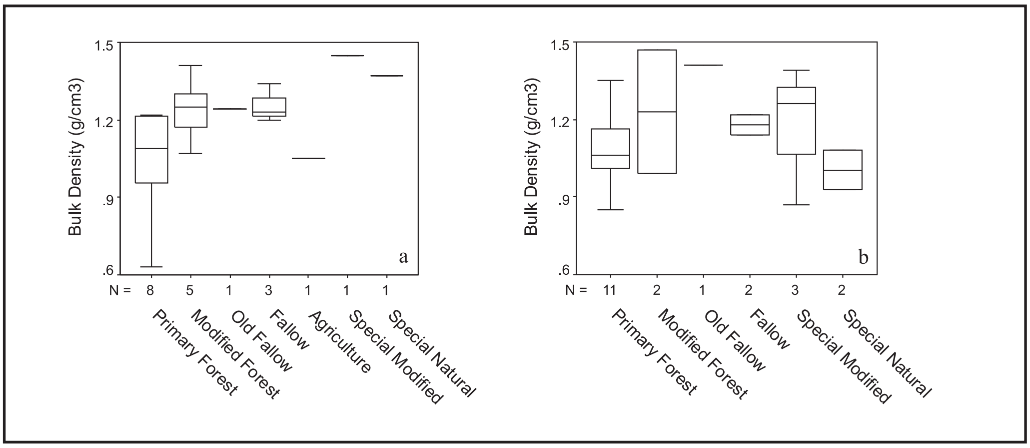


Table 19. Soil characteristics used by local people

Category	Characters
Color	Black; Gray; Yellow; Brown; Red; White; Mixed
Texture	Sandy; Not Sticky; Quite Sticky; Sticky; Very Sticky
Consistency	Not Hard; Friable; Quite Hard; Hard;
Stoniness	Rocks
Location	Forest; Swamp; River Mouth
Slope	Flat; Sloping
Humus	Thick; None
Fertility	Good; Poor

Number of plots = 200
Number of respondents = 25 in semi-structured interviews, plus about 100 in focus group discussions and local community meetings.

was located near a water spring and in an undisturbed forest. These results imply that compaction tends to occur as a result of land clearing activities in the forest either by direct human impact or by the effect of rain.

3.2 Local Assessment

3.2.1 Local People's Knowledge

Local knowledge represents an immensely valuable database on how local communities interact with their changing environments (Puffer 1995). When such management appears relatively sustainable such knowledge is may give critical insight to plan for sustainable development (Warren 1992, 1993). Despite this, local knowledge has rarely been recorded or critically assessed (Winklerpins 1999).

We attempted to describe and seek understanding of local views and choices about land, sites and soils as characteristics that help determine options and preferences, especially with respect to cultivation. This is a crucial part of our larger project to look at local perceptions of landscape values (Sheil *et al.* 2003). In our effort to examine and record local knowledge of soil and land management, farmers were asked to describe and discuss the soil types in all the sample locations (see Table 19). This information was then compared against laboratory analyses results (presented in the next section) and technical descriptions, in order to determine any relationship between the two systems.

Not surprisingly, local people generally have a good knowledge of the characteristics that define a soil's properties. They use this understanding along with other criteria to make land-use decisions. The characteristics recognized by the local population are outlined in the tables below. In each case, care was taken to ascertain a clear definition of each element

Table 20. Local people's terminologies used to classify soil by language

Merap	Punan	Kenyah	Indonesian Glossary	English Glossary
Tiem	*Punyuh*	*Saleng*	Warna Hitam	Black Color
Mla	*Mengan*	*Bala*	Warna Merah	Red Color
Mieg	*Jemit*	*Bila*	Warna Kuning	Yellow Color
Mbloa	*Mpu*	-	Warna Coklat	Brown Color
Bao	-	-	Warna Abu-abu	Gray Color
Toi	*Cerouh*	*Pute*	Warna Putih	White Color
-	*Pekelet; Bulah*	-	Warna Campuran	Mix Color
Yie	-	*Ahit; A'bu*	Berpasir	Sandy
Lumpuem	-	-	Agak Lengket	Moderately Sticky
-	*Nyekadit*	*Pulut*	Lengket	Sticky
Ploug	-	-	Sangat Lengket	Very Sticky
Entat	*Praeh*	-	Tidak Keras	Not Hard
-	-	*Mahing*	Keras	Compact
Lepeih	-	-	Tipis	Shallow
Petantaung	-	-	Datar	Flat area
Ngemura	-	-	Muara	Downstream
-	*Awa*	-	Hulu	Upstream
Matau	*Batuh*	-	Berbatu	Rocky
Piue	*Pakat/Ancut*	-	Akar	Small Roots
Pangkah	*Pangka*	*Bawang*	Rawa	Swamp
Lohoya	*Taong*	-	Hutan	Forest
'Ya	-	*Tihgah*	Subur	Fertile
Ta'aya	*Jiet*	-	Tidak Subur	Infertile
-	-	*Bengaheng*	Tanpa warna hitam, putih dan merah	No presence of black, white & red color
To'ou	-	-	Kering	Dry
-	-	*Panas*	Panas	Hot

of local people's terminology. The basic system of knowledge is comparable with those noted elsewhere in the region (Sindju in Sorensen 1997) and represents a more comprehensive classification scheme than those reported in other countries, such as the Philippines, Ghana, and Peru (Kauffman 1996).

We found that local knowledge of soil varies both within and between ethnic groups. The Merap appear to have a richer vocabulary and conceptual framework than the Punan. Table 20 provides a list of terms used to describe soil.[3] The Merap used 20 terms to describe 79 plots, while the Punan and the Kenyah used 14 and 12 terms to describe 84 and 34 plots, respectively[4]. Since knowledge levels differ within each village, and depend on the particular respondent, the following tables and evaluation reflect only a fraction of overall local community knowledge.

3.2.1.1 Assessment of Soil Type and Taxonomy

We found that local people differentiated land and soil types based on several characteristics: color, texture, consistency, surface rock, humus, vegetation cover, and perceived fertility. The main criteria relate to visual assessments; but some local people also rely on other senses, feeling the soil with their hands or digging with a metal blade. For example, one means of testing for 'stickiness' – associated with black fertile soils – is to stick a knife into the ground and see whether soil sticks to the blade when it is withdrawn. Though many informants demonstrated this particular test, investigators were told that this was an old-fashioned approach, used more for demonstration than diagnosis. While attributes such as taste and smell are used to help classify the soil in other parts of East Kalimantan (E. Wollenberg, pers. com. 2001) and in other countries (Concepcion 1997),

[3] Note that plot numbers and types differed between ethnic groups, a situation that causes some bias in these summaries.
[4] Three other plots which were described by Putuk-related informants are not included.

these were not noted during any interviews. The following summaries of local knowledge represent a synthesis of results from field samples as well as extensive discussions with focal groups and local experts in each Merap and Punan community.

All soil types start with the root term *tana* (Merap and Kenyah) or *tano* (Punan), meaning soil, which is followed by one or more adjectives describing the distinguishing characteristics. A single modifying adjective refers to the generic type, while two qualifying adjectives refer to a specific type. For example, *tana tiem* (Merap), *tano punyuh* (Punan) and *tana saleng* (Kenyah) all mean 'black soil' and represent the generic level. *Tana tiem* was divided into at least four sub-specific (Merap) categories *(tana tiem bao, tana tiem mla, tana tiem blouh* and *tana tiem petelat*).

We found that the Merap distinguish at least 20 generic soil types, while the Punan note at least 14 (see Table 21-23). The Merap recognize a further 19 specific categories, while the Punan do not appear to recognize any such sub-categories. (The limited sample data show that the Kenyah have at least 12 generic and five specific types, but there were no interviews with Kenyah to expand upon this sample).

3.2.1.2 Assessments of Fertility

Communities determine land fertility by analyzing both the physical characteristics of the soil and its associated vegetation, in contrast with local people of other tropical regions, such as those in Africa, who do not use explicit vegetation indicators (Corbeels *et al.* 2000). In all cases, field respondents were asked to determine the fertility for a sample using the following four point scale: very fertile, fertile, moderately fertile and not fertile. Though the scale is inherently subjective, the interviewer provided guidance to ensure some consistency between respondents and previous samples. (For example, if the respondent said that the sample-site is "fertile", we would then ask him what he based his reply on.)

The characteristics consistently identified by informants as useful for assessing fertility in field samples are:

Color. Generic black soils (*tana tiem*/M, *tana saleng*/K, or *tano punyuh*/P) are generally classified as "very fertile" or "fertile". White sandy soils (*Tana toi*/M) are judged as "not fertile". Red soils (*Tana mla*/M, *tana bala*/K or *tano mengan*/P) possess a more variable fertility and cover the entire spectrum of fertility categories.

Consistency. Friable soils are often viewed as "very fertile", while moderate stickiness is an indicator of "fertile" land. In general, however, *consistency* is a less distinct sign of fertility and is normally used in conjunction with other indicators. In Merap communities, older men use knife blades to assess a soil's consistency.

Stoniness. In general, a high rock content indicates that the land is "not fertile".

Vegetation. The presence of *Koordersiodendron pinnatum* (*kayuh arau*/ P&M), *Elmerilia tsiampacca* (*blefunyou pakuh*/P or *lefunyau*/M) and *Alpinia gelabra* (*klengkuh temping*/P or *teitei parai*/M) are considered as indicators of "very fertile" soil. Bamboo is believed to mark "fertile" areas on riversides. Soils that are "not fertile" are indicated by limited vegetation growth. However, in apparent contrast with research elsewhere in the region (e.g. Sindju in Sorensen 1997), plant indicators were not given much emphasis by the field informants.

Soil depth. Shallow soils (< 20cm depth) were considered either "moderately fertile" or "not fertile".

Slope. Steepness generally decreases the likelihood of fertile soil.

Humus presence. The presence of surface humus (layer of decayed litter) is viewed as an indication of fertility.

Crop productivity. Farmers often used a ratio of seed to yield as a measurement of an area's suitability. This can then be used as a means of comparison between different areas. The Merap use a yield of 200-tins/hectare from three tins of rice to indicate a "very fertile" category of soil (a tin is a roughly eight kilogram-tin locally used as a container for keeping seed), while the Punan quoted a yield of about 150 tins of rice from four tins of seed to indicate a "fertile" soil. A yield of 3.5 tins of rice from three tins of seed yielding was reported by one older informant to represent a soil that is "not fertile."

Table 21. Generic and specific soil types assessments in Merap communities

No.	Generic-Type	Specific-type	English Glossary
1	***Tana Mieg***	-	Yellowish
		Mieg Mla	Reddish Yellow
		Mieg Bao	Grayish Yellow
		Mieg Mbloah	Brownish Yellow
		Mieg Kunyie	Greenish Yellow
		Mieg Meko	Strong Yellow
2	***Tana Tiem***	-	Blackish
		Tiem Bao	Grayish Black
		Tiem Mla	Reddish Black
		Tiem Blouh	Brownish Black
		Tiem Petelat	Soft and Black
3	***Tana Mla***	-	Reddish
		Mla Mieg	Yellowish Red
		Mla Lumpuem	Brownish Red
		Mla Tiem	Blackish Red
		Mla To'ou	Dry and Red
4	***Tana Bao***	-	Grayish
5	***Tana Toi***	Toi Bao	Grayish White
		Toi Pangkah	White Swamp
6	***Tana Mbloa/Lumpuem***	-	Brownish
7	***Tana yie***	-	Sandy
		Yie Tiem	Black Sandy
		Yie Mieg	Black Sandy
		Yie Toi	White Sandy
8	***Tana Lohoya***	-	Forest
9	***Tana Pangkah***	-	Swamp
		Pangkah Lohoya	Swampy Forest
10	***Tana Lepeih***	-	Shallow
11	***Tana Ya***	-	Good
12	***Tana Ta'aya***	-	Infertile
13	***Tana To'ou***	-	Dry
14	***Tana Entat***	-	Soft
15	***Tana Ngemura Ran***	-	Ran River Mouth
16	***Tana Mohoya Talaye***	-	Forest Root
17	***Tana Matau***	-	Stony
18	***Tana Ploug***	-	Very Sticky
19	***Tana Petantaung***	-	Flat Plain

N= 79

In later interviews with local community members, we verified that the main characteristics involved in determining fertility are vegetation and soil color. Good vegetation structure is an easily identifiable sign of a site's fertility, a view which can be confirmed by observing if the soil is black.

Such observations seem to be generalized throughout the humid tropics. For example, the Machiguenga in Amazonian Peru also go to great trouble to locate areas with black and sticky soils, qualities that, while rare, are highly desirable for their (limited) cultivation (Johnson 1989).

3.2.1.3 Assessments of Land Evaluations

Local suitability assessment (Suitable/Not Suitable) for several agricultural crops were derived from answers to questions such as "What kind of use is this land suitable for?" and "Why?" There are, of course, different individual perspectives on land suitability, which vary according

Table 22. Kenyah's assessments of generic and specific soil types

No.	Generic-Type	Specific-Type	English Glossary
1	***Tana Pute***	-	Whitish
2	***Tana Salang***	-	Blackish
		Salang Bala	Reddish Black
		Salang A'bu	Sandy Black
3	***Tana Bala***	-	Reddish
4	***Tana Bila***	-	Yellowish
5	***Tana A'bu***	-	Sandy
		A'bu Pulut	Sticky Sandy
6	***Tana Ahit***	-	Sandy
		Ahit Salang	Black Sandy
		Ahit Pute	White Sandy
7	***Tana Bengaheng***	-	A without black, white or red color
8	***Tana Bawang***	-	Swampy
9	***Tana Mahing***	-	Hard
10	***Tana Pulut***	-	Sticky
11	***Tana Tihgah***	-	Good
12	***Tana Panas***	-	Hot

N= 34

Table 23. Punan's assessments of generic soil types

No.	Generic-Type	Specific-Type	English Glossary
1	***Tano Pekelet***	-	Mix Color
2	***Tano Jemit***	-	Yellowish
3	***Tano Mpu***	-	Brownish
4	***Tano Mengan***	-	Reddish
5	***Tano Bulah***	-	Mix Color
6	***Tano Punyuh***	-	Blackish
7	***Tano Ancut/Pakat***	-	Humus
8	***Tano pangka***	-	Swampy
9	***Tano Jiet***	-	Infertile
10	***Tano Awa***	-	Upstream
12	***Tano Batuh***	-	Stony
13	***Tano Nyekadit***	-	Sticky
14	***Tano Praeh***	-	Soft

N= 84

to experience, environmental context and ethnicity. For example, some informants felt that the soil texture defined land suitability for a specific crop while others felt that color was more important.

3.2.1.3.1 Merap

All informants agreed that "black soils" *(tana tiem),* with their high organic matter content, are fertile and easy to work with. Black soils are typically used by the Merap to cultivate field rice, corn, banana, peanut, sweet potato and cassava; while "swamp soils" (*tana toi pangkah*), "yellowish sandy soils" (*tana yie mieg*) and "red-dry soils" (*tana mla to'ou*) are infertile soils and usually left uncultivated (Tables 24 and 25). Like farmers in the Philippines (Concepcion 1997), in their recent attempt to develop sawah, the Merap generally sought out very sticky soil (*tana ploug)* that was usually found in some waterlogged sites or poorly drained areas.

3.2.1.3.2 Punan

Samples and local community reviews show that the Punan generally use their best soils, *tano punyuh* (black soils), to cultivate field rice only. In contrast, the Merap use their

Table 24. Agricultural use options associated with Merap soil types (Langap)

No.	Generic Type	Specific Type	Agricultural Uses
1	***Tiem***	-	Banana, Sweet Potato, Peanut, Field Rice, Fruit Garden
		Tiem Bao	Fruit Garden, Field Rice
2	***Mbla***	-	Field Rice, *Citronella sp.,* Peanut
		Mbla To'ou	None
3	***Mbloa***	-	Fruit Garden, Field Rice
		Mbloa Tiem	Peanut, Water Spinach, Corn, Papaya, Taro, Fruit Garden
4	***Mieg***	***Mieg Kunyie***	Field Rice, Peanut, Corn, Fruit Garden
5	***Toi***	***Toi Pangkah***	None
6	***Bao***	-	Sawah, Field Rice
7	***Lohoya***	-	Field Rice
8	***Yie***	***Yie Tiem***	Fruit Garden
		Yie Toi	Field Rice, Sawah, Water Spinach

Table 25. Agricultural use options associated with Merap soil types (Gong Solok)

No.	Generic Type	Specific Type	Agricultural Uses
1	***Tiem***	-	All Crops
		Tiem Petelat	All Crops
		Tiem Mla	All Crops, except for Pepper and Potatoes
		Tiem To'ou	Field Rice, Fruit Garden, Horticulture
		Tiem Bao	Field Rice
		Tiem Blouh	Coffee, Cocoa
2	***Mbla***	-	Fruit Garden, Field Rice
		Mbla Mieg	Field Rice, Fruit Garden, Sweet Potato
		Mbla Lumpuem	Field Rice, Coffee, Cocoa, Fruit Garden
		Mbla Tiem	Field Rice, Fruit Garden
3	***Mieg***	-	Fruit Garden, Coffee, Cocoa, Sweet Potato, Field Rice, Corn
		Mieg Mbla	Field Rice, Fruit Garden, Coffee, Cocoa, Sweet Potato
		Mieg Mbloah	Field Rice, Coffee, Cocoa, Sweet Potato, Corn
		Mieg Bao	Field Rice, Garden of Coffee, Cocoa
		Mieg Kunyie	Field Rice, Garden of Coffee, Cocoa
4	***Matau***	-	Field Rice, Peanut, Fruit Garden
5	***Toi***	***Toi Bao***	Fruit Garden, Meritam (*Nephellium* sp.), Durian (*Durio* sp.), Langsat
6	***Bao***	-	Field Rice, Sawah
		Bao Entat	Field Rice, Fruit Garden, Sweet Potato
7	***Yie***	***Yie Tiem***	Beans, Fruit Garden, All crops
		Yie Mieg	None

"black soils" (*tana tiem*) to cultivate a wide variety of crops. The *tano pangkah* (swamp soils) are perceived by the Punan informants to be suitable for sawah (as they have seen it practiced by the neighbouring Kenyah and Merap), even though the communities have not utilized it themselves. *Tano batuh,* a shallow rocky soil, is hard to work and is generally left uncultivated. The only example of *tano ancut* was found in a sacred place and was not available for cultivation. A summary of the Punan's different soil classes and their uses are described in Tables 26, 27, and 28.

3.2.2 Agricultural practices and soil management

The information presented in this section was developed mostly through focus group discussions and personal interviews. It also draws from issues raised by informants regarding field samples. The general patterns

Table 26. Agricultural use options associated with Punan soil types (Laba Nyarit samples)

No.	Generic Type	Agricultural Uses
1	***Pangkah***	Sawah, Field Rice
2	***Bulah***	Field Rice, Fruit Garden
3	***Jemit***	Fruit Garden, Sweet Potato
4	***Mengan***	Fruit Garden, Field Rice
5	***Mpu***	Fruit Garden, Field Rice, Peanut
6	***Pekelet***	Field Rice
7	***Punyuh***	Field Rice

Table 27. Agricultural use options associated with Punan soil types (Long Jalan samples)

No.	Generic Type	Agricultural Uses
1	***Pangkah***	Sawah
2	***Jemit***	Sweet Potato
3	***Mengan***	Field Rice, Sweet Potato, Sugar-cane, Taro
4	***Batuh***	None
5	***Pakat***	Field Rice
6	***Nyekadit***	Field Rice, Sweet Potato, Taro

Table 28. Agricultural use options associated with Punan soil types (Lio Mutai samples)

No.	Generic Type	Agricultural Uses
1	***Ploug***	Sawah
2	***Bulah***	Field Rice, Sweet Potato, All Crops
3	***Jemit***	Field Rice, Sweet Potato, Banana, Corn, All Crops
4	***Mengan***	Field Rice, Sweet Potato
5	***Pekelet***	Water Spinach, Taro, Field Rice
6	***Batuh***	None (shallow soil) Sweet Potato (deep soil)
7	***Ancut***	None

of agriculture and soil management differ little from those found elsewhere in the interior of Borneo (e.g. Sorenson & Morris 1997), although there is no apparent experience of relying on water buffalo. The principle cultivation is "dry" or "field rice", and a swidden system is required since sustainable cropping is not viable.

3.2.2.1 Merap

From our interviews we learned that the communities use swidden systems because after only one year, field productivity drops and weeds become strongly established. As a result, local people find it more effective to simply clear new land rather than continue working increasingly unproductive soil. In the case of '*tana tiem*' (black soil), however, some local people reported that they could use the land to cultivate rice for three to five years, a duration which justifies more intensive weeding. When land is no longer suitable for rice it either reverts to fallow (comprising mainly spontaneous vegetation) or they plant it with hardier crops such as cassava, or sometimes fruit gardens. With some more recent crops, like coffee and cocoa, land may be cleared for these without an initial period of rice cultivation – this last choice is especially prevalent on steeper land considered less suitable for rice (e.g. Gong Solok).

The Merap generally prefer to cultivate in groups as a way to maximize efficiency and sharing guard duties so as to minimize disturbance by animals. They usually form a group of family members, or close relatives, numbering 2-10 people.

Local people establish new fields from forests in several steps ('merimba'[5]). They first seek out a fertile site using indicators such as vegetation structure, leaf color, and soil color. Though initial selection of sites generally involves only men, women play a nearly equal role in the subsequent discussion in which the final choice is determined. This process takes several days.

After finding a suitable location, they divide the area up, establishing field borders for each member of the group, and they then begin clearing the land cooperatively ('senguyun'[6]).

The size of the fields depends on each family's needs and abilities. Typical fields are about 2 hectares. After the perimeter has been agreed to, families will slash the understorey until the field is clean of it. Large trees are often wounded and de-barked, although some (mainly fruit and honey species) are purposely protected. Some larger trees may be left standing but are eventually killed by burning the woody material purposely gathered at their base – though most groups now have chainsaws and do not find clearing to be as labor intensive as it was for their predecessors. The dead vegetation is allowed to dry for several weeks before being burnt, but the exact timing depends on the weather, which is closely monitored. If the burning is less than complete, the farmers will gather the remaining material together in an effort to re-burn it. The planting then starts after about two weeks when the ash is cool enough for seeding or after the first rain.

Rice cropping activities include preparing holes for seeding, weeding, establishing pest traps, harvesting, and carrying the yield to the 'lumbung'. Pest traps are made using available material in the village and fields. This includes metal wire, e.g. for pigs, monkeys, and deer, and rattan for birds. Men are exclusively responsible for establishing pest traps and carrying the yield, while women are responsible for protecting the crops from weeds and pests. They work together on other activities and are assisted by children in the harvesting.

To establish field rice, local people will prepare old fallow fields (5 to 10 years old) for cultivation or, if an old field is not available, they will go to the forest in search of new agricultural fields.

We found at least three main types of agriculture/horticulture in Merap fields - field rice, some perennial crops, and fruit gardens. Land that has just been cultivated for field rice for six months (August to February) will usually be replanted by perennial crops such as peanut, soybeans, vegetables, corn, etc. The Merap develop fruit gardens in accessible locations near their villages. These gardens are established from old fallow and are passed down through the family. Local people mix local fruit trees species and varieties within their garden.

Coffee and cacao are exclusively established in monoculture gardens. Outsiders introduced these fruits using intensive agricultural methods. Today, however, there are only a few local people who still maintain those crops (mainly coffee) because of limited knowledge about how to increase productivity and to keep the fruit safe from pests and disease. We also noted that floods from the Malinau River have destroyed many of these gardens.

3.2.2.2 Punan

The Punan also undertake shifting cultivation, although the process and motivation diverges somewhat from the Merap. In general, the Punan specialize less in agricultural, preferring instead to concentrate on gathering forest products. For example, many communities collect valuable gaharu or birds nests, and some individuals prefer to specialize in rattan and rattan-based crafts. While shifting cultivation is practiced, it is largely small scale and for local use. Informants told us that one reason for planting fields of rice was because of the animals they attracted, which made for good hunting. These groups appeared reliant on buying and trading for rice imported from outside, and some Punan communities, like those living in Rian, suffered considerable food shortages during our survey period.

Fruit gardens are located in old Punan villages. In contrast with the Merap, the Punan have not attempted to establish any intensive gardens of cash crops (cacao, coffee, etc.).

[5] "Merimba" is the local word for the process of making fields from the forest.
[6] "Senguyun" is a common local word for activities to help other people work for which they get paid in money or labor. This kind of activity is not limited only to 'merimba' but is also used for building a house, wedding ceremonies, welcome ceremonies, etc.

The threat of soil erosion in these communities is generally greater since the Punan generally live in more mountainous areas and their fields tend to be on slopes and on poorer soils. The productivity of the Punan's fields is much lower than their ethnic neighbors.

Although the Punan did not traditionally specialize in agriculture, there are signs that their communities are beginning to invest more in such activities. Lio Mutai, for example, is rapidly expanding their rice farming and is very proud of their self-sufficiency.

3.2.2.3 Kenyah

The Kenyah are cultivators of 'sawah' and swidden. They seem to have much in common with the Merap, with whom they are heavily intermarried. In our surveys they were the only respondents eager to establish sawah (wet rice) (Paya Seturan).

3.2.2.4 Other uses of soils

Soil has been used for activities other than cultivation, e.g., crafts, cookery and medicinal. Punan use earth from swamps or river sides to dye rattan black – this is done by boiling the rattan with soils and vegetable ingredients from a tree (kayuh deng/P). Many upstream villagers build stoves from loam (sticky soils). Some local people still use specific earths – mainly termite mound clays from the forest and under houses — for healing stomach complaints in children. Red soil is sometimes used to dye Merap funeral clothing (Langap and Gong Solok). People seem aware that some rocks and crystals have value and try and sell large quartz crystals to visitors. Some stones are believed to have magical properties (noted in Gong Solok). Coal is occasionally burned for smoke (as is fire wood) as a mosquito repellant (Seturan).

3.3 Standard and Local Assessments

Agrawal (1995) suggests that separating local and scientific knowledge marginalizes the contribution and value that local knowledge can make. We wish to recognize and include both forms of knowledge, so it is therefore important to characterize their relationship and recognize what they share and how they differ. As a contribution to such an overview we here compare our technical sample data with local information that includes management history, potential use, stated preferences, and the characters used on local diagnosis. We recognize that such analyses privilege the technical data (Winklerpins 1999), and emphasize that local knowledge does not require our technical corroboration to be valid or important. Indeed, as local land-use decisions will continue to be made on the basis of local knowledge, this must continue to be a significant body of information whatever the relationship with scientific approaches.

3.3.1 Land use

The relationship between local people's land management activities (slash, cut, burn, cultivation, fallow) and measured soil characteristics was explored. From a soil science perspective we expected that agricultural activities like burning would affect the chemical and physical composition of the fields. Clearing done on slopes would also increase the potential for erosion. Promising sites for producing high agricultural yields are usually alluvial areas.

The relationship between sample types (see previous section 2.7) and measured soil surface (0-20 cm) characteristics was explored using comparison tests and association measurements.

Sites that were used for agriculture [e.g. old fallow (OF), young fallow (YF), horticulture (H), and agriculture (A)] were generally found on flatter ground (Table 29). Agriculture and horticulture plots were found to have a higher value of Ca^{2+}, Mg^{2+}, H^+, pH, K_2O, and base saturation, and lower value of Al^{3+} than other sample types. As a result, these two sample types appear more fertile than others.

Comparison tests show that soil surface characteristics (e.g. bulk density, clay, pH, C, Ca^{2+}, Mg^{2+}, K^+, base saturation, Al^{3+}, and H^+) are significantly different among the sample types[7] (Table 30 and 31).

In addition, sample types and some soil surface characteristics are strongly associated (e.g. Ca^{2+} (chi-square, p-value = .001, eta = .506) and base saturation (chi-square, p-value= .047, eta = .535), while some others (e.g. silt, K_2O, Mg^{2+}, K^+, and Na^+) are weakly associated (chi-square, p-value <. 05, eta. < .5) (Table 32, Figure 13).

[7] See Table 4 for a review of the eight categories of sample type.

Table 29. Description of soil (0-20 cm) characteristics by sample types

Sample types	Soil Char.	N	Mean	Soil Char.	N	Mean	Soil Char.	N	Mean	Soil Char.	N	Mean
PF	**slope**	57	18.4	**P_2O_5**	57	8.7	**Na^+**	57	0.08	**Base-**	38	15.5
MF	(%)	32	16.1	(ppm)	32	8.6	(me/100g)	32	0.10	**Sat.**	30	26.4
OF		13	5.2		13	7.5		13	0.11	(%)	9	31.1
YF		27	7.1		27	9.6		27	0.10		19	30.9
H		11	4.2		11	24.7		11	0.16		8	66.9
A		10	6.9		10	8.2		10	0.15		6	68.2
SM		28	1.7		28	32.4		28	0.10		19	53.7
SN		22	9.8		22	9.9		22	0.22		13	40.7
Total		200	11.0		200	13.0		200	0.08		142	33.4
PF	**BD**	56	1.05	**K_2O**	57	46.5	**Clay**	57	36.4	**Al^{3+}**	57	6.2
MF	(g/cm^3)	32	1.16	(ppm)	32	60.2	(%)	32	32.6	(me/100g)	32	4.5
OF		12	1.10		13	46.2		13	35.0		13	3.2
YF		27	1.07		27	49.6		27	32.5		27	3.8
H		11	1.02		11	52.5		11	30.5		11	0.8
A		9	0.90		10	89.9		10	32.3		10	2.0
SM		26	1.15		28	48.6		28	28.4		28	2.3
SN		20	1.07		22	49.5		22	26.9		22	3.2
Total		193	1.05		200	52.2		200	32.5		200	4.0
PF	**pH**	57	4.3	**Ca^{2+}**	57	0.7	**Sand**	57	27.4	**H^+**	57	0.32
MF		32	4.6	(me/100g)	32	1.1	(%)	32	30.3	(me/100g)	32	0.47
OF		13	4.7		13	3.8		13	28.3		13	0.44
YF		27	4.7		27	2.2		27	26.0		27	0.31
H		11	5.1		11	7.5		11	25.0		11	0.25
A		10	4.9		10	5.5		10	24.8		10	0.13
SM		28	4.9		28	4.8		28	32.8		28	0.24
SN		22	4.7		22	3.3		22	36.5		22	0.47
Total		200	4.6		200	2.6		200	29.2		200	2.46
PF	**C-org.**	57	2.0	**Mg^{2+}**	57	0.5	**Silt**	57	36.1	**Fe^{3+}**	38	2.30
MF	(%)	32	1.7	(me/100g)	32	0.7	(%)	32	37.1	(%)	30	2.25
OF		13	2.2		13	1.3		13	36.7		9	2.42
YF		27	2.0		27	0.9		27	41.5		19	2.70
H		11	1.8		11	2.3		11	44.5		8	2.81
A		10	2.4		10	1.9		10	42.9		6	2.01
SM		28	1.9		28	1.4		28	38.9		19	2.33
SN		22	2.5		22	1.0		22	36.6		13	0.32
Total		200	2.0		200	1.0		200	38.3		142	0.47
PF	**N**	57	0.21	**K^+**	57	0.13	**CEC**	38	11.2			
MF	(%)	32	0.17	(me/100g)	32	0.13	(me/100g)	30	9.4			
OF		13	0.20		13	0.13		9	9.6			
YF		27	0.19		27	0.14		19	10.4			
H		11	0.20		11	0.13		8	9.7			
A		10	0.27		10	0.31		6	12.9			
SM		28	0.19		28	0.13		19	9.5			
SN		22	0.20		22	0.15		13	11.0			
Total		200	0.21		200	0.13		142	10.4			

Table 30. Comparison of soil (0-20 cm) characteristics among sample types using ANOVA

Characters	n	Sum of Squares	df	Mean Square	F	[a]p-value
BD	193	0.747	7	0.106	3.263	**0.003
Clay	200	2183.172	7	311.881	2.668	*0.012
Silt	200	1334.796	7	190.685	1.361	0.224
CEC	142	118.319	7	16.902	0.831	0.563

* Difference is significant at the .05 level
** Difference is significant at the .01 level
[a] Difference pattern can be assessed through previous Table 29

Table 31. Comparison of soil (0-20 cm) characteristics among sample types using Kruskal-Wallis

Characters	n	df	[a]p-value
H_2O pH	200	7	**0.001
C	200	7	*0.046
N	200	7	0.079
P_2O_5	200	7	0.203
K_2O	200	7	0.364
Ca^{2+}	200	7	**0.001
Mg^{2+}	200	7	**0.001
K^+	200	7	**0.009
Na^+	200	7	0.057
Sand	200	7	0.444
Base saturation	142	7	**0.001
Al^{3+}	200	7	**0.001
H^+	200	7	**0.001
Fe^{3+}	142	7	0.611

* Difference is significant at the .05 level
** Difference is significant at the .01 level
[a] Difference pattern can be assessed through previous Table 29

Another assessment relied on simplified sample classes. Two groups were defined — *used* and *unused* land — to differentiate agricultural activities from the others. The *used* group consists of all agriculture, horticulture, fallow and old fallow classified locations, while all others fall into the *unused* group (note: under these definitions, modified forest and special modified fall into the *unused* category). These groups were compared using two different methods. Those soil characteristics with a near normal distribution (Table 33) (e.g. bulk density, Fe^{3+} and texture component of silt and clay) were evaluated using ANOVA. Non-normal data were evaluated using Mann-Whitney.

The used group has higher silt, pH, N, Ca^{2+}, Mg^{2+}, and base saturation, but lower bulk density, Al^{3+}, and H^+-content than the unused group (Table 34, 35).

Table 32. Significant association between sample types and soil (0-20 cm) characteristics

Characteristics	N	Sample Types	
		[a]p-value	eta
K_2O	200	*0.049	0.222
Mg^{2+}	200	**0.003	0.478
K^+	200	*0.042	0.377
Na+	200	*0.039	0.370
Silt	200	*0.047	0.217

* Difference is significant at the .05 level
** Difference is significant at the .01 level
[a] Difference pattern can be assessed through previous Table 29

Further analyses demonstrated that only base saturation is weakly associated with sample type (chi-square, p-value = .037, coef. = .21). Base saturation seems to be linked to local preferences of land utilization (see detail in previous section 3.2.2), along with other factors such as soil color, natural vegetation growth, and cooperation (derived from focus group discussion with local community member). In other words, local management activities appear to have a significant relation to and effect on soil characteristics.

Land clearing, especially burning can increase fertility by releasing nutrients from vegetation ash (Hairiah, *et al.* 2001). However, the resulting gains in fertility are only a short-term phenomenon since ashes will typically only release nutrients for a single season and compacted surface soils will decrease a root's abilities to penetrate the soil. In addition, the compacted surface also increases the risk of erosion.

3.3.1.1 Special sites

Special sites within our overall sample scheme were initially grouped into *special natural* and *special modified* (these are sites with swamp, coal, limestone, old village, bamboo, and sago). Most of those sites (salt springs,

Table 33. Normality test of soil (0-20 cm) characteristics by *Used* and *Unused* group using Kolmogorov-Smirnov

Characteristics	*unused*			*used*		
	Statistic	df	p-value	Statistic	df	p-value
H_2O pH	.117	139	.000	.108	61	*.077
C	.172	139	.000	.114	61	.048
N	.082	139	.024	.158	61	.001
P_2O_5	.379	139	.000	.366	61	.000
K_2O	.120	139	.000	.156	61	.001
Ca^{2+}	.315	139	.000	.229	61	.000
Mg^{2+}	.227	139	.000	.231	61	.000
K^+	.161	139	.000	.207	61	.000
Na^+	.203	139	.000	.150	61	.002
Al^{3+}	.101	139	.002	.176	61	.000
H^+	.150	139	.000	.167	61	.000
CEC	.092	100	.035	.110	42	*.200
Base Saturation	.253	100	.000	.183	42	.001
Fe^{3+}	.078	100	*.137	.084	42	*.200
Bulk Density	.066	134	*.200	.101	59	*.200
Clay	.056	139	*.200	.093	61	*.200
Sand	.076	139	.048	.103	61	*.177
Silt	.052	139	*.200	.064	61	*.200

* Data is close to normally distributed

Table 34. Comparison test of soil (0-20 cm) characteristics between *Used* and *Unused* group using ANOVA

Characteristics	n	df	Mean Value		F	p-value
			Unused	*Used*		
Bulk Density	193	1	1.10	1.04	5.769	*.017
Clay	200	1	34.91	34.05	.018	.894
Silt	200	1	37.00	39.93	5.569	*.019
Fe^{3+}	142	1	2.31	2.49	.289	.592

Note: * Difference is significant at 95% confidence interval

Figure 13. Scatter of significant associations between sample types and soil (0-20 cm) characteristics

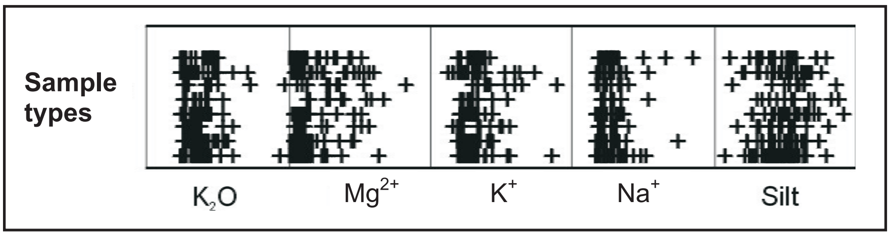


Table 35. Comparison of soil (0-20 cm) characteristics between Used and Unused land by Mann-Whitney

Characteristics	n	df	Mean Rank		Mann-Whitney	p-value
			Unused	*Used*		
Sand	200	1	104.99	90.27	3615.500	.098
H_2O pH	200	1	92.15	119.53	3078.500	**.002
C	200	1	97.16	108.11	3775.000	.218
N	200	1	94.12	115.04	3352.500	*.018
P_2O_5	200	1	103.73	93.14	3790.500	.233
K_2O	200	1	98.63	104.76	3979.500	.490
Ca^{2+}	200	1	87.96	129.07	2496.500	**.000
Mg^{2+}	200	1	89.80	124.89	2752.000	**.000
K^+	200	1	95.33	112.28	3521.000	.056
Na^+	200	1	96.42	109.80	3672.000	.131
CEC	200	1	71.11	72.42	4101.500	.714
Base Saturation	200	1	65.22	86.44	2596.500	**.000
Al^{3+}	200	1	110.12	78.57	2902.000	**.000
H^+	200	1	105.94	88.11	3483.500	*.045

Note:
* Difference is significant at the .05 level
** Difference is significant at the .01 level

Table 36. Comparison of soil characteristics between "special" (s) and "non-special" (n) land types

Soil characteristics	Mean			
	surface layer		sub-surface layer	
	non (n=107)	special (n=29)	non (n=107)	special (n=29)
Clay	*35.93	*30.14	*36.97	*32.41
Sand	*26.00	*32.79	*24.11	*28.86
Silt	38.07	37.07	38.92	38.72
Bulk Density	1.08	1.11	-	-
pH	4.59	4.84	4.63	4.85
C	1.93	2.15	1.02	1.35
N	0.20	0.19	0.13	0.13
P_2O_5	10.75	32.15	6.96	43.45
K^+	69.29	69.45	47.18	59.69
Ca^{2+}	1.87	3.88	1.24	3.33
Mg^{2+}	0.87	1.28	0.68	0.94
K^+	0.14	0.14	0.09	0.11
Na^+	0.10	0.13	0.08	0.19
CEC	10.59	10.06	9.19	9.06
Base	*2.98	*5.43	*2.09	*4.57
Base saturation	*28.23	*47.86	*23.27	*44.45
Al^{3+}	*4.38	*2.57	*4.83	*2.87
H^+	0.36	0.33	*0.37	*0.34
Fe^{3+}	2.43	2.12	*2.65	*2.09
Relascope	8.74	9.00	-	-

* Difference is significant at the .05 level

Table 37. Comparison of mean soil characteristics between "special" sites and others (combined) by Kruskal-Wallis

	Bamboo		Limestone		Salt springs		Swamp		Coal	
	Bamboo	other	Lime stone	other	Salt springs	other	Swamp	other	Coal	other
	(n=5)		(n=3)		(n=4)		(n=17)		(n=5)	
Surface Layer Characteristics Mean value by site type										
Bulk Density	1.106	1.046	1.020	1.048	1.150	1.046	1.042	1.049	1.028	1.048
Relascope	6.733	8.027	6.333	8.020	7.917	7.997	7.136	8.101	9.867	7.947
Clay	28.200	32.590	30.000	32.518	29.000	32.551	*24.500	*33.466	28.400	32.585
Sand	27.200	29.292	14.333	29.467	35.750	29.107	*42.091	*27.652	33.200	29.138
Silt	44.600	38.118	*55.667	*38.015	35.250	38.342	*33.409	*38.882	38.400	38.277
pH	*5.360	*4.597	4.867	4.613	5.075	4.607	4.659	4.611	4.760	4.613
C	1.832	2.023	2.050	2.018	1.975	2.019	*2.847	*1.916	1.756	2.025
N	0.218	0.194	0.223	0.194	0.195	0.195	0.204	0.194	0.152	0.196
P_2O_5	8.980	13.128	*1.867	*13.194	14.875	12.986	*16.059	*12.649	12.300	13.043
K_2O	38.000	52.564	*9.667	*52.848	78.750	51.658	51.227	52.320	*86.200	*51.328
Ca^{2+}	*10.322	*2.436	*10.257	*2.517	2.203	2.642	*2.244	*2.681	1.170	2.671
Mg^{2+}	*2.860	*0.957	0.773	1.008	1.770	0.989	0.905	1.017	0.422	1.019
K^+	0.176	0.152	0.193	0.152	0.153	0.152	0.118	0.157	0.168	0.152
Na^+	0.092	0.105	0.097	0.104	0.210	0.102	*0.146	*0.099	0.158	0.103
CEC	13.485	10.318	-	10.363	8.785	10.409	*7.479	*10.808	7.266	10.476
Bases cation	*13.450	*3.649	*11.320	*3.781	4.335	3.885	3.413	3.954	1.918	3.945
Base saturation	*96.500	*32.479	-	33.380	57.000	32.696	*46.789	*31.309	28.200	33.569
Al^{3+}	*0.394	*4.103	3.252	4.022	1.956	4.052	*1.777	*4.287	3.145	4.033
H^+	*0.119	*0.430	0.451	0.421	0.210	0.426	0.280	0.439	0.207	0.427
Fe^{3+}	2.910	2.311	-	2.319	2.366	2.318	*1.295	*2.477	2.444	2.315
Sub-Surface Layer Characteristics mean value by site type										
Sand	31.400	28.093	11.333	28.436	26.333	28.205	*41.273	*26.540	25.800	28.238
Silt	41.200	37.166	48.333	37.097	36.667	37.277	*32.773	*37.830	46.200	37.036
Clay	27.400	34.741	40.333	34.467	37.000	34.518	*25.955	*35.631	28.000	34.725
pH	5.260	4.604	5.067	4.613	4.667	4.619	4.691	4.611	4.880	4.613
C	1.008	1.119	1.023	1.118	0.870	1.120	*2.010	*1.005	0.840	1.124
N	0.156	0.124	0.140	0.125	0.133	0.125	0.130	0.124	0.148	0.124
P_2O_5	5.400	11.875	*1.767	*11.864	6.933	11.785	*10.345	*11.882	4.980	11.885
K_2O	27.200	37.358	*7.000	*37.564	41.000	37.041	33.091	37.602	*62.400	*36.446
Ca^{2+}	*6.620	*1.834	*11.827	*1.803	0.807	1.972	1.750	1.980	0.734	1.986
Mg^{2+}	*2.200	*0.745	0.520	0.786	0.603	0.785	0.894	0.768	0.256	0.796
K^+	0.128	0.100	0.113	0.101	0.087	0.101	*0.076	*0.104	0.126	0.100
Na^+	*0.480	*0.118	0.060	0.128	0.080	0.128	*0.213	*0.116	0.046	0.129
CEC	10.015	9.039	-	9.053	8.393	9.067	*6.306	*9.481	6.526	9.146
Bases cation	*9.428	*2.797	*12.520	*2.818	1.577	2.986	2.933	2.969	1.162	3.011
Base saturation	*95.500	*27.698	-	28.660	22.000	28.804	*49.105	*25.475	18.400	29.037
Al^{3+}	*1.220	*4.434	2.847	4.376	4.730	4.347	*1.988	*4.648	2.934	4.390
H^+	0.282	0.457	0.483	0.453	0.407	0.454	*0.274	*0.475	0.272	0.458
Fe^{3+}	2.900	2.459	-	2.466	2.253	2.470	*1.118	*2.676	2.760	2.455

* Difference is significant at the .05 level

graveyard, fruit garden) are treated in quite specific ways and are sometimes locally protected.

Do these sites differ in soil characteristics when compared to the other, non-special, sites? Yes, special sites generally reveal coarser, denser soils, higher nutrients and higher pH (p-value = 0.001, Kruskal-Wallis, Table 36).

Sites with bamboo, limestone, salt spring, swamp and coal show various different soil characteristics compared to other samples (Table 37). Surprisingly, local informants views and standard assessments generally agree that these sites are, even when considered by their specific properties, not distinct with respect to their fertility. Only limestone is judged by local people to have lower fertility, while laboratory assessments imply no clear distinction.

In terms of fertility and suitability for rice, special sites are not distinctly different to other sites – whether judged by local informants or using standard assessment procedures (Table 38). We note that special sites are regarded as important for cultural and other reasons, rather than for agriculture.

3.3.1.2 Fallow land

Shifting cultivation is a sustainable system, provided that the fallow is long enough to

Figure 14. Relations between some soil characteristics and the land use cycle stage

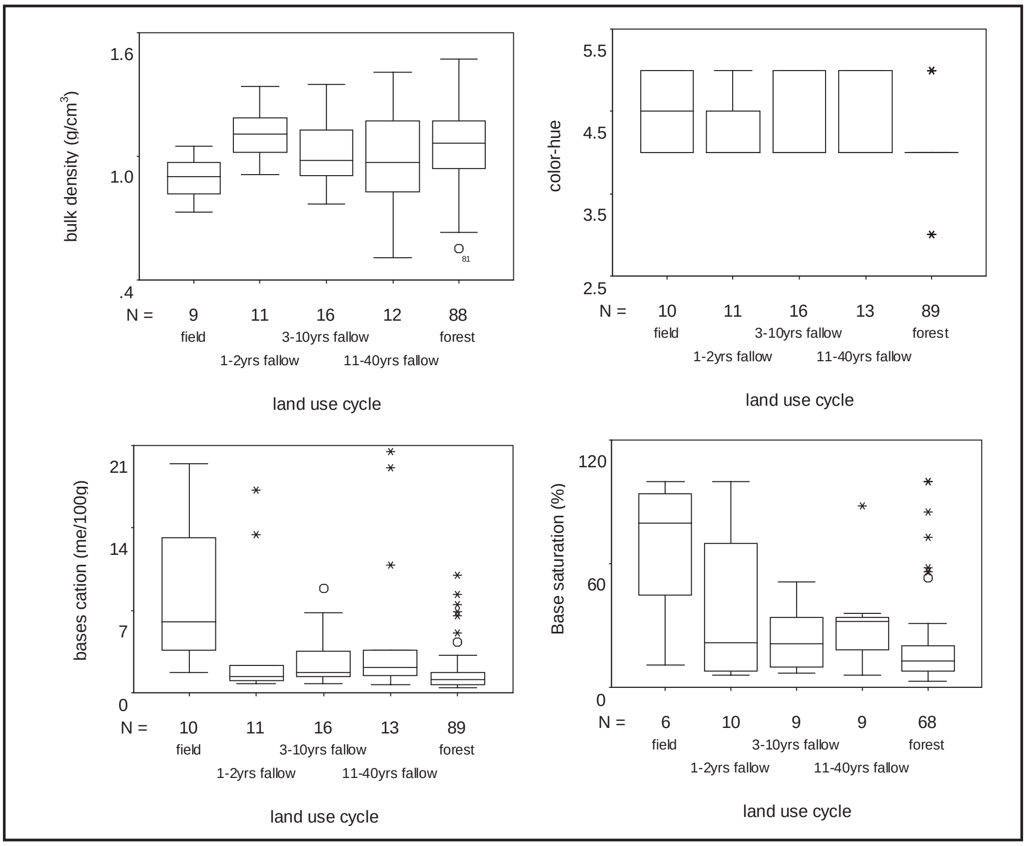


Table 38. Comparison of local and standard assessment of land fertility and suitability between special sites and other sites (combined) using Kruskal-Wallis

	Local Assessment		**Modern Assessment**	
	Fertility	**Suitability for rice**	**Fertility**	**Suitability for rice**
Chi-square	3.26	3.53	0.45	1.06
Df	1	1	1	1
p-value	0.071	0.060	0.501	0.304

Table 39. Soil characteristics by local land use cycle stage

	Land use						*P*
	Forest	Agri culture	Fallow			Total/ mean	
			1-2 yr	3-10 yr	11-40 yr		
			Surface Layer (0-20cm)				
Color-Hue/n	89	10	11	16	13	139	***0.033***
mean	4.124	4.500	4.273	4.375	4.462	4.223	
Silt/n	89	10	11	16	13	139	***0.031***
mean	36.483	42.900	35.909	45.313	36.692	37.935	
BD/n	88	9	11	16	12	136	
mean	1.064	0.897	1.105	1.022	0.993	1.045	***0.016***
Relascope/n	89	10	11	16	13	139	***0.001***
mean	10.738	0.033	0.788	4.167	8.000	8.168	
pH-H_2O/n	89	10	11	16	13	139	***0.005***
mean	4.406	4.940	4.645	4.656	4.662	4.516	
C-ref1/n	89	10	11	16	13	139	***0.021***
mean	0.518	0.678	0.512	0.580	0.648	0.548	
Ca^{2+}/n	89	10	11	16	13	139	***0.001***
mean	0.826	5.498	2.877	1.797	3.798	1.714	
Mg^{2+}/n	89	10	11	16	13	139	***0.001***
mean	0.606	1.870	0.904	0.842	1.268	0.810	
K^{+}/n	89	10	11	16	13	139	***0.001***
mean	0.138	0.295	0.124	0.148	0.160	0.151	
Bases/n	89	10	11	16	13	139	***0.001***
mean	1.657	7.775	3.975	2.898	5.328	2.767	
B-sat./n	68	6	10	9	9	102	***0.009***
mean	20.294	68.167	35.900	25.333	31.111	26.039	
Al^{3+}/n	89	10	11	16	13	139	***0.001***
mean	5.577	1.956	4.412	3.327	3.166	4.740	
H^{+}/n	89	10	11	16	13	139	***0.038***
mean	0.514	0.206	0.280	0.417	0.448	0.456	
			Sub-surface Layer (20-40)				
Color-Hue	89	10	11	16	13	139	***0.025***
mean	3.966	4.450	4.273	4.313	4.385	4.104	
Color-Value/n	89	10	11	16	13	139	***0.005***
mean	5.652	4.950	5.182	5.656	5.577	5.558	
Ca^{2+}	89	10	11	16	13	139	***0.002***
mean	0.724	2.842	1.959	1.346	2.153	1.179	
Al^{3+}	89	10	11	16	13	139	***0.012***
mean	5.812	3.488	4.759	3.703	3.185	5.073	

restore soil conditions to a similar state as in previous cultivation-fallow cycles (Young 1990). In Malinau, fallow land is relatively common in the more accessible areas and contributes 20% of our sample sites. These range from 1 to >60 years old.

We briefly examine soil and land characteristics for sites in cultivated and fallow area using forest data as a comparison. From our interviews we know that local people prefer to use older fallow (over 3 years) for cultivation as yields are better.

Our analyses find two dominant (non linear) patterns (figure 14): a drop followed by a slight rise (e.g. base-saturation) and an increase followed by a lower decline (e.g. bulk density) Dividing the fallow ages in to three groups we found that many soil characteristics are affected and differ significantly over land use (Kruskal-Wallis, p-value<.05, table 39) reflecting soil dynamic within local landuse cycle.

We found that C-ref. (total carbon corrected using a pedotransfer function developed in Sumatera to examine cultivation impacts, see Hairiah 2004), pH, available nutrients and base saturation level increase immediately after the forest is cleared and burned (agricultural fields). After the fields have been harvested and left for one or two years these characteristics have dropped to lower levels than in forest. On the third and later years they rise again reaching levels close to and usually slightly above the forest levels. pH may be a slight exception as after the intial rise associated with burning it declines near continuously towards its forest condition.

Bulk density and relascope (that is large woody cover) have similar initial relations to the land use cycle. They decrease after the forest is cleared and burned. They increase again immediately after the field harvested and left. After three years fallowed, bulk density decreases again while woody cover (relascope) continues to increase, to achieve their initial condition. Similar results for bulk density and carbon dynamics are reported by Suprayogo *et al.* (2004) in coffee plantation development associated with forest clearence in Lampung, Sumatera.

That more tree cover is associated with older fallow is not unexpected. As local people shift their villages several times, the observation that the older fallows are at greater distances from current villages is also easily explained.

Viewed in general, our result suggest that relatively high levels of nutrients result from forest clearing and burning that produce available bases cation of the organic matter-ash. This also increased pH, base saturation, and CEC, while decreasing the level of bulk density and acid cations. Young fallow soils show rapid decreases of fertility relative to agriculture fields which are interpreted as due to nutrient and organic matter loss during the planting season and harvesting. In young fallow we see a switch from desirable cations like potassium to undesirable H^+ and Al^{3+} ions. Finally, soil fertility increases as the forest itself recovers.

Local people report many problems trying to cultivate young fallow (1-2 years after harvested). These relate to infestation by weeds, low yield and a noted difficulty in seed holes and planting in the hardened soils.

Overall we see that local people depend on vegetation from forest or fallow land to serve as a reservoir of vital nurients that by burning can improve the soils and make them suitable for cultivation. These reservoirs take time to replenish, and swidden agriculture is only viable in much of Malinau due to the low populations density and long fallow period. The productivity of local land use is greatly limited by the dynamics of the soil and forest (fallow) system.

3.3.1.3 Sample type and Oxisols

Oxisols are the main soil type in the research area. As such, we arguably require a better understanding of these soils, especially their fertility following forest clearance.

An independency test (chi-square) was applied to clarify the association between Oxisols' characteristics and sample type grouping. Chemical and physical characteristics were included, while sample types were divided between used and unused (see section 2.7 for details). The results showed that silt, K_2O, Ca^{2+}, Mg^{2+}, K^+, Na^+, and base/nutrient saturation of the surface layer characteristics are significantly associated with sample type (Pearson chi-square <.05, Eta < .5). Some subsurface characteristics are also associated with sample type such as silt, Munsell value and chrome, Ca^{2+}, Mg^{2+} and base saturation (Pearson chi-square <.05, Eta <.5).

Used and unused samples were compared to clarify their differences, including overall soil physical and chemical attributes. Since much of the characteristic data of Oxisols was not normally distributed in both groups, different evaluation methods (ANOVA or Kruskal-Wallis) were applied depending on the data distribution. The two groups were found to be significantly different ($p < .05$) with respect to surface Munsell hue, bulk density, pH, N, Ca^{2+}, Mg^{2+}, K^+, base saturation, and Al^{3+}. They were also significantly different in terms of subsurface color-hue, P_2O_5, and Ca^{2+} (Table 40 and 41). Given our mode of sampling it is unclear whether these differences are due to the impacts of local cultivation activities or if local people have simply selected the most appropriate sites among Oxisols for land cultivation. Further research is required to assess these possibilities.

Table 40. ANOVA comparison of Oxisols' characteristics between *Used* and *Unused* samples

Soil Layer	Characteristic	n	df	Mean value		F	p-value
				Unused	Used		
Surface	**Clay (%)**	145	1	33.23	34.76	0.603	0.439
	Sand (%)	145	1	29.79	24.38	3.052	0.083
	Silt (%)	145	1	36.98	40.87	3.830	0.052
	N (%)	145	1	0.18	0.21	5.301	*0.023
	CEC (me/100g)	109	1	10.20	10.45	0.086	0.770
	Fe^{3+} (%)	109	1	2.34	2.46	0.357	0.551
Subsurface	**Silt (%)**	145	1	36.88	39.78	2.237	0.137
	Clay (%)	145	1	33.33	33.56	0.014	0.906
	Fe^{3+} (%)	109	1	2.45	2.75	1.705	0.194

* Difference is significant at the .05 level

Table 41. Comparison test of Oxisols' characteristics between Used and Unused plots using Kruskal-Wallis

Soil Layer	Characteristics	Unit	n	df	Mean value		Chi-Square	p-value
					Unused	Used		
Surface	**BD**	g/cm^3	141	1	75.91	60.17	4.499	*0.034
	Munsell Hue	-	145	1	67.69	84.80	7.997	**0.005
	Munsell Value	-	145	1	74.80	69.00	0.661	0.416
	Munsell Chrome	-	145	1	73.20	72.56	0.008	0.930
	pH	-	145	1	67.70	84.78	5.166	*0.023
	C	%	145	1	70.04	79.58	1.600	0.206
	P_2O_5	ppm	145	1	76.07	66.18	1.722	0.189
	K_2O	ppm	145	1	71.22	76.96	0.579	0.447
	Ca^{2+}	me/100g	145	1	63.60	93.88	16.125	**0.001
	Mg^{2+}	me/100g	145	1	65.12	90.51	11.346	**0.001
	K^+	me/100g	145	1	68.18	83.72	4.278	*0.039
	Na^+	me/100g	145	1	70.04	79.57	1.606	0.205
	Base saturation	%	109	1	49.98	66.56	6.342	*0.012
	Al^{3+}	me/100g	145	1	78.68	60.38	5.894	*0.015
	H^+	me/100g	145	1	74.94	68.68	0.691	0.406
Subsurface	**Sand**	%	145	1	75.54	67.34	1.184	0.277
	Munsell Hue	-	145	1	67.80	84.56	6.237	*0.013
	Munsell Value	-	145	1	76.18	65.92	2.090	0.148
	Munsell Chrome	-	144	1	72.03	73.53	0.043	0.835
	pH	-	145	1	71.29	76.79	0.535	0.464
	C	%	145	1	77.15	63.78	3.146	0.076
	N	%	145	1	73.48	71.93	0.042	0.837
	P_2O_5	ppm	145	1	77.73	62.49	4.088	*0.043
	K_2O	ppm	145	1	75.43	67.60	1.080	0.299
	Ca^{2+}	me/100g	145	1	67.60	85.01	5.341	*0.021
	Mg^{2+}	me/100g	145	1	69.11	81.66	2.773	0.096
	K^+	me/100g	145	1	73.40	72.11	0.030	0.863
	Na^+	me/100g	145	1	71.00	77.43	0.740	0.390
	CEC	me/100g	109	1	56.80	50.86	0.810	0.368
	Base Sat.	me/100g	109	1	52.26	61.30	1.886	0.170
	Al^{3+}	me/100g	145	1	76.43	65.38	2.149	0.143
	H^+	me/100g	145	1	73.22	72.51	0.009	0.925

* Difference is significant at the .05 level
** Difference is significant at the .01 level

Table 42. Comparison test of Oxisols' characteristics among sample types using ANOVA

Soil Layer	Characteristic	n	Sum of Squares	df	Mean Square	F	Sig.
Surface	Clay (%)	145	2375.79	7	339.40	3.13	**0.004
	Sand (%)	145	5709.88	7	815.70	2.96	**0.006
	Silt (%)	145	2602.33	7	371.76	3.31	**0.003
	N (%)	145	0.04	7	0.01	1.47	0.182
	CEC (me/100g)	109	35.24	7	5.03	0.31	0.949
	Fe^{3+} (%)	109	7.19	7	1.03	1.10	0.367
Subsurface	Silt (%)	145	2494.81	7	356.40	3.39	**0.002
	Clay (%)	145	2220.78	7	317.25	3.09	**0.005
	Fe^{3+}(%)	109	11.78	7	1.68	1.51	0.174

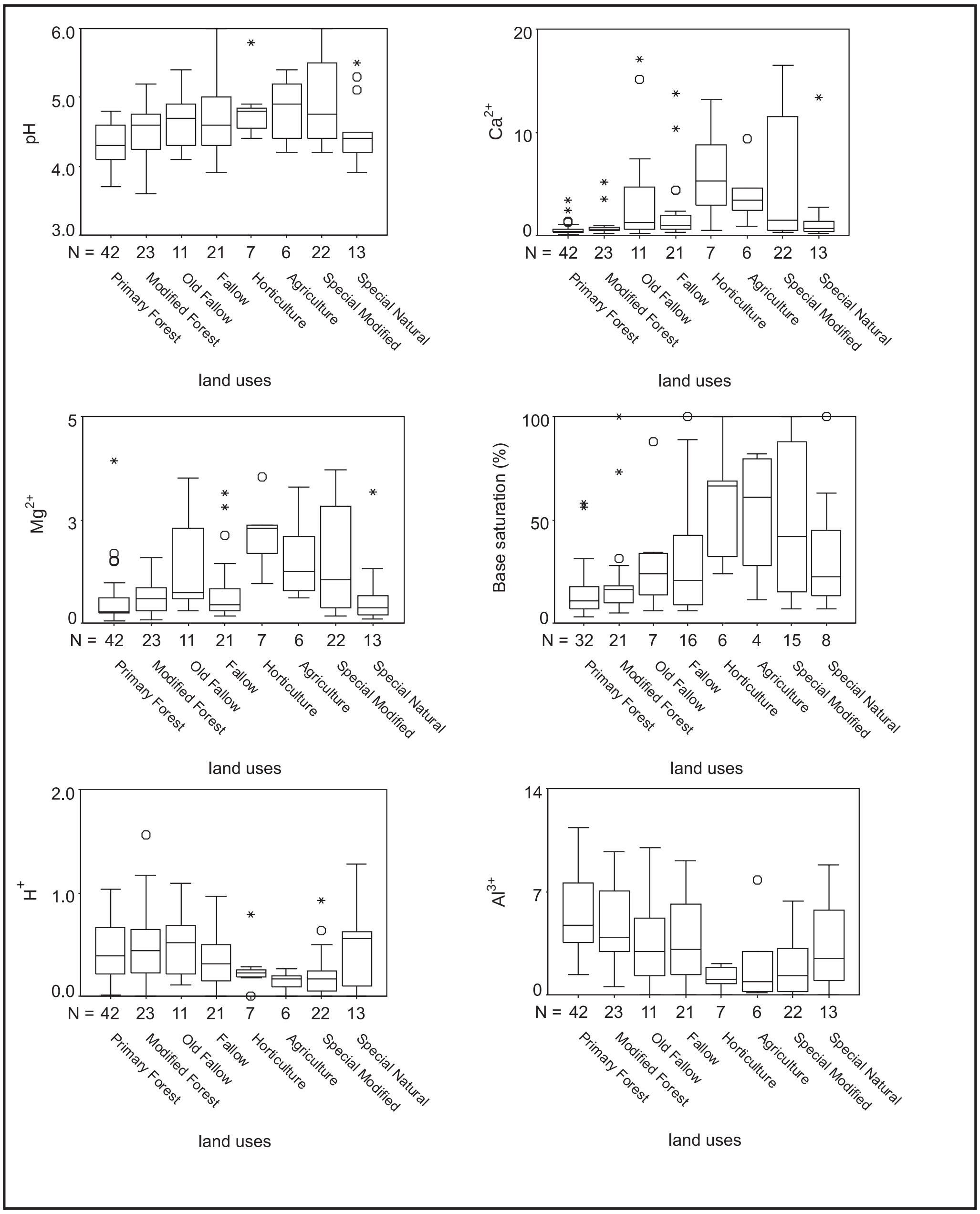
*   Difference is significant at the .05 level
** Difference is significant at the .01 level

Table 43. Comparison test of Oxisols' characteristics among sample types using Kruskal-Wallis

Soil Layer	Characteristics	Unit	n	Chi-Square	df	Asymp. Sig.
Surface	BD	g/cm^3	141	12.953	7	0.073
	Munsell Hue	-	145	12.275	7	0.092
	Munsell Value	-	145	10.807	7	0.147
	Munsell Chrome	-	145	22.845	7	**0.002
	pH	-	145	24.945	7	**0.001
	C	%	145	7.209	7	0.407
	P_2O_5	ppm	145	9.625	7	0.211
	K_2O	ppm	145	7.183	7	0.410
	Ca^{2+}	me/100g	145	41.122	7	**0.001
	Mg^{2+}	me/100g	145	33.685	7	**0.001
	K^+	me/100g	145	10.762	7	0.149
	Na^+	me/100g	145	8.269	7	0.309
	Base saturation	%	109	26.760	7	**0.001
	Al^{3+}	me/100g	145	39.166	7	**0.001
	H^+	me/100g	145	21.130	7	**0.004
Subsurface	Sand	%	145	19.383	7	**0.007
	Munsell Hue	-	145	15.477	7	*0.030
	Munsell Value	-	145	18.712	7	**0.009
	Munsell Chrome	-	144	32.271	7	**0.001
	PH	-	145	12.743	7	0.079
	C	%	145	11.250	7	0.128
	N	%	145	13.077	7	0.070
	P_2O_5	ppm	145	18.375	7	*0.010
	K_2O	ppm	145	9.564	7	0.215
	Ca^{2+}	me/100g	145	19.706	7	**0.006
	Mg^{2+}	me/100g	145	22.194	7	**0.002
	K^+	me/100g	145	2.541	7	0.924
	Na^+	me/100g	145	7.994	7	0.333
	CEC	me/100g	109	6.253	7	0.511
	Base saturation	%	109	21.123	7	**0.004
	Al^{3+}	me/100g	145	33.671	7	**0.001
	H^+	me/100g	145	10.733	7	0.151

*   Difference is significant at the .05 level
** Difference is significant at the .01 level

Figure 15. Chemical characteristics of Oxisols that are significantly different among sample types (p = .01; n = PF [39], MF [18], OF [9], F [18], H [8], A [5], SN [14], SM [14]; total = 125)



Note:

O Outlier: Cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box. The box length is the interquartile range.

* Extremes : Cases with values more than 3 box lengths from the upper or lower edge of the box. The box length is the interquartile range.

Table 44. Distribution of soil surface (0-20 cm) characteristics by local classes of fertility

Characteristics	Local Fertility	N	Mean
Slope (%)	Very Low	26	13.04
	Low	39	14.21
	Moderate	61	9.73
	High	10	9.70
Bulk Density (g/dm^3)	Very Low	26	1.11
	Low	39	1.09
	Moderate	61	1.06
	High	10	1.16
Relascope Count Avg. (basal area measure)	Very Low	26	8.60
	Low	39	9.38
	Moderate	61	8.40
	High	10	9.50
Clay (%)	Very Low	26	34.35
	Low	39	34.72
	Moderate	61	34.82
	High	10	34.70
Sand (%)	Very Low	26	26.54
	Low	39	31.38
	Moderate	61	26.26
	High	10	22.70
Silt (%)	Very Low	26	39.12
	Low	39	33.90
	Moderate	61	38.92
	High	10	42.60
H_2O-pH	Very Low	26	4.65
	Low	39	4.51
	Moderate	61	4.73
	High	10	4.79
C (%)	Very Low	26	2.06
	Low	39	1.81
	Moderate	61	2.09
	High	10	1.65
N (%)	Very Low	26	0.18
	Low	39	0.18
	Moderate	61	0.21
	High	10	0.20
P_2O_5 (ppm)	Very Low	26	12.75
	Low	39	7.58
	Moderate	61	22.54
	High	10	8.15
K_2O (ppm)	Very Low	26	70.27
	Low	39	62.18
	Moderate	61	75.05
	High	10	66.00
K^+ (me/100g)	Very Low	26	0.14
	Low	39	0.13
	Moderate	61	0.15
	High	10	0.13
Na^+ (me/100g)	Very Low	26	0.12
	Low	39	0.10
	Moderate	61	0.11
	High	10	0.10
Ca^{2+} (me/100g)	Very Low	26	1.49
	Low	39	1.54
	Moderate	61	2.97
	High	10	3.62
Mg^{2+} (me/100g)	Very Low	26	0.82
	Low	39	0.82
	Moderate	61	1.06
	High	10	1.48
CEC (me/100g)	Very Low	26	10.04
	Low	39	10.22
	Moderate	61	10.96
	High	10	9.88
Base Saturation (%)	Very Low	26	27.58
	Low	39	27.00
	Moderate	61	36.00
	High	10	50.30
Al^{3+} (me/100g)	Very Low	26	4.38
	Low	39	4.18
	Moderate	61	3.88
	High	10	2.75
H^+ (me/100g)	Very Low	26	0.45
	Low	39	0.36
	Moderate	61	0.32
	High	10	0.20
Fe^{3+} (me/100g)	Very Low	26	2.03
	Low	39	2.49
	Moderate	61	2.38
	High	10	2.58

Oxisols' characteristics among the eight original sample types were also compared. This was intended to identify the inherent difference within this soil type and their relevance to local people. Data was examined from all the traits, both normally (including surface clay, sand, silt, N, CEC and Fe^{3+}, and for sub-surface's silt, clay, Fe^{3+}; see Table 42) and non-normally distributed within sample types (Table 43).

For several soil characteristics, their distribution on the soil surface (0-20 cm) and/ or subsurface (20-40 cm) varied significantly among the eight types of samples considered in this study (Table 43 and Figure 15). Caution is needed in interpreting the results, however, because the non-normally distributed data led to significant differences in the final analysis.

3.3.2 Fertility

Standard assessments of soil fertility refer to quantitative soil properties (see section 2), while 'local fertility classes' refers to assessments based on observable characteristics (see section 3.2.1.2) for each sample.

In preparing our study, we believed that local judgments about fertility might be based on land factors beyond just observable soil characteristics, such as slope, the site's distance from the village or major rivers, and land use history. Consequently, our analysis attempted to investigate such relations.

Sites perceived as having high fertility were largely found in flatter locations marked by relatively high pH and base saturation (Table 44). Conversely, low and very low fertilities were generally found on steeper slopes with lower overall pH and base saturation.

Table 45. Comparison test of soil (0-20 cm) characteristics among local fertility classes using the Kruskal-Wallis method

Characteristics	N	df	p-value
Bulk Density	190	3	0.106
Relascope Avg.	197	3	0.629
H_2O pH	197	3	0.314
C	197	3	*0.035
N	197	3	*0.016
P_2O_5	197	3	0.126
K_2O	197	3	0.293
Ca^{2+}	197	3	0.426
Mg^{2+}	197	3	0.136
K^+	197	3	0.267
Na^+	197	3	0.752
Clay	197	3	0.669
Sand	197	3	0.198
Silt	197	3	0.091
CEC	141	3	0.597
Base Saturation	141	3	0.699
Al^{3+}	197	3	0.207
H^+	197	3	*0.032
Fe^{3+}	141	3	0.309

* difference is significant at 95% interval

In order to determine the relationship between standard and local fertility classes, all the data was tested using comparison and correlation studies. We found C, N, and H content were significantly different among the samples grouped by local people's fertility classes (Table 45).

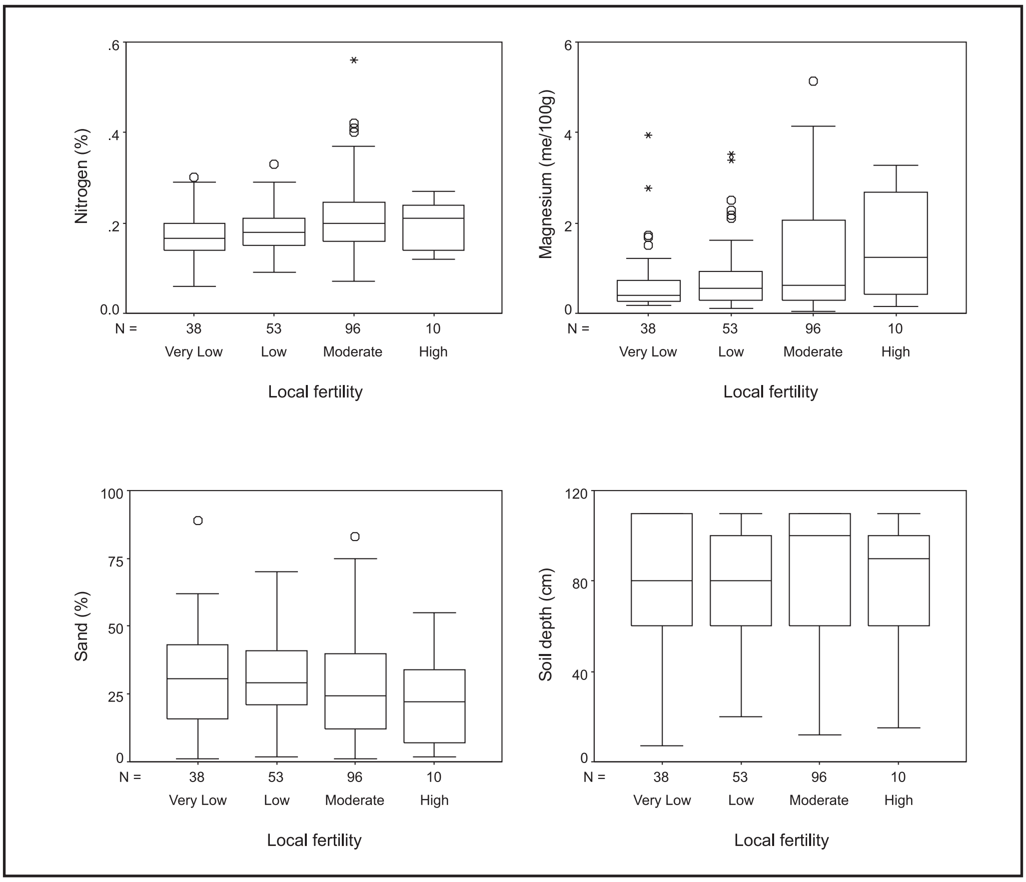
Correlation analyses showed that local fertility classes are significantly correlated with the following measured components: depth, sand percentage, N content (%), Mg^{2+} content (me/100gr), H^+ and the Munsell color components (chrome and value) (Spearman,

Table 46. Significant rank correlation between local fertility assessment (very fertile, fertile, moderately fertile, not fertile) and measured soil characteristics (0-20 cm depth)

	Spearman	N	Mg^{2+}	Sand	Silt	H^+	Munsell Color		Soil Depth
							Value	Chrome	
Local Fertility	**Coefficient**	0.220	0.166	-0.141	0.133	-0.208	-0.183	-0.169	0.142
	p-value	***0.002	**0.02	**0.048	*0.063	***0.003	**0.01	**0.01	**0.047
	N	197	197	197	197	197	197	197	197

Note :
Blank data omitted
* Correlation is significant at the .1 level (2-tailed).
** Correlation is significant at the .05 level (2-tailed).
*** Correlation is significant at the .01 level (2-tailed).

Figure 16. Chemical Characteristics+ with a significant association to local fertility



$p<0.05$; $r=0.2$) (see Table 46 and Figure 16). This suggests that these characteristics reflect criteria available to local farmers. This is clear enough for depth, sand percentage and color but harder to understand for N content (%), Mg^{2+} content (me/100gr), and H^{+}.

N content is associated with organic material, which according to interviews with farmers, is strongly related with fertility perception.

Our exploration of correlation and univariate relationships between visible and invisible variables by graphs show no clear pattern. This suggests that multiple factors are being used.

Associations between standard and local assessments were also studied, with no significant association found between them (chi-square, p-value >.05, eta <. 5, n=197). This result is likely due to differences in the parameter numbers and the scale of measurement used in each assessment.

3.3.2.1 Soil characteristics and local assessment

Soil characteristics were tested to find out whether they have different ranges within each fertility class. The test was applied separately for each ethnic group (Table 47). Using the same code of fertility classes, we found that some standard soil characteristics (i.e. C, N, K^{+}, Ca^{2+}, Mg^{2+}, CEC, and base saturation) present significant differences among Merap's assessment scheme (Figure 17). Including the observations of the other ethnic groups appears to reduce rather than confirm the strength of these relationships.

The Merap assessment system thus appears to have a clearer relationship with our technical measurements than do Punan or Kenyah systems, although the smaller Kenyah sample sizes influence this result. In addition, no characteristics displayed significant differences within Punan and Kenyah assessment systems.

Table 47. Comparison test of soil (0-20 cm)characteristics among local fertility classes using Kruskal-Wallis (df=3)

Characteristics	p-value n=197 (Overall)	p-value n=82 (Punan)	p-value n=78 (Merap)	p-value n=34 (Kenyah)	p-value n=112 (Merap + Kenyah)
Sand	0.198	0.436	0.419	0.846	0.606
Silt	*0.091	0.105	0.259	0.768	0.510
Clay	0.669	0.985	0.081	0.770	0.459
H_2O pH	0.314	0.219	0.291	0.108	*0.066
C	**0.035	0.245	**0.032	0.795	0.364
N	**0.016	0.443	***0.001	0.104	*0.071
P_2O_5	0.126	0.368	0.074	0.430	0.354
K_2O	0.293	0.749	**0.041	0.548	0.132
Ca^{2+}	0.426	0.170	***0.001	0.730	0.086
Mg^{2+}	0.136	0.317	**0.039	0.200	***0.004
K^+	0.267	0.813	0.695	0.353	0.121
Na^+	0.752	0.835	0.318	0.256	0.520

Note:
grouping variable is local fertility assessment (1-4)
Blank data omitted
*** Differences is significant at the 0.01 level (2-tailed)
** Differences is significant at the 0.05 level (2-tailed)
* Differences is significant at the 0.10 level (2-tailed)

Table 48. Correlation between local fertility classes and distance from village and river (using Spearman)

		Travel time (hour)	Distance to the village (m)	Distance to big river (m)
Local	**N**	197	197	197
Fertility	**Coeff.**	-.063	-.132	-.140
	p-value	.382	*.064	**0.050

Note :
Blank data omitted
** Correlation is significant at the .05 level (2-tailed)
* Correlation is significant at the .10 level (2-tailed)

3.3.2.2 Locations of plot and local assessment

This analysis aims to understand if access to sites (distance and relation to river flow) relate to perceived fertility. Such relationships could arise from both the choice of village locations and the selection of suitable areas to cultivate.

A weak correlation (p-value= 0.1) was found between local fertility classes and distance to both village and river (Table 48); that is, the closer the field is to the village or river, the higher the fertility. We found no significant correspondence between plot position (up or down-stream relative to the villages) and local fertility classes (chi-square; p-value=0.132). It is hard to untangle causation in such results because villages are normally located in areas chosen for cultivation and located by rivers. As we have already seen, the best soils are close to rivers.

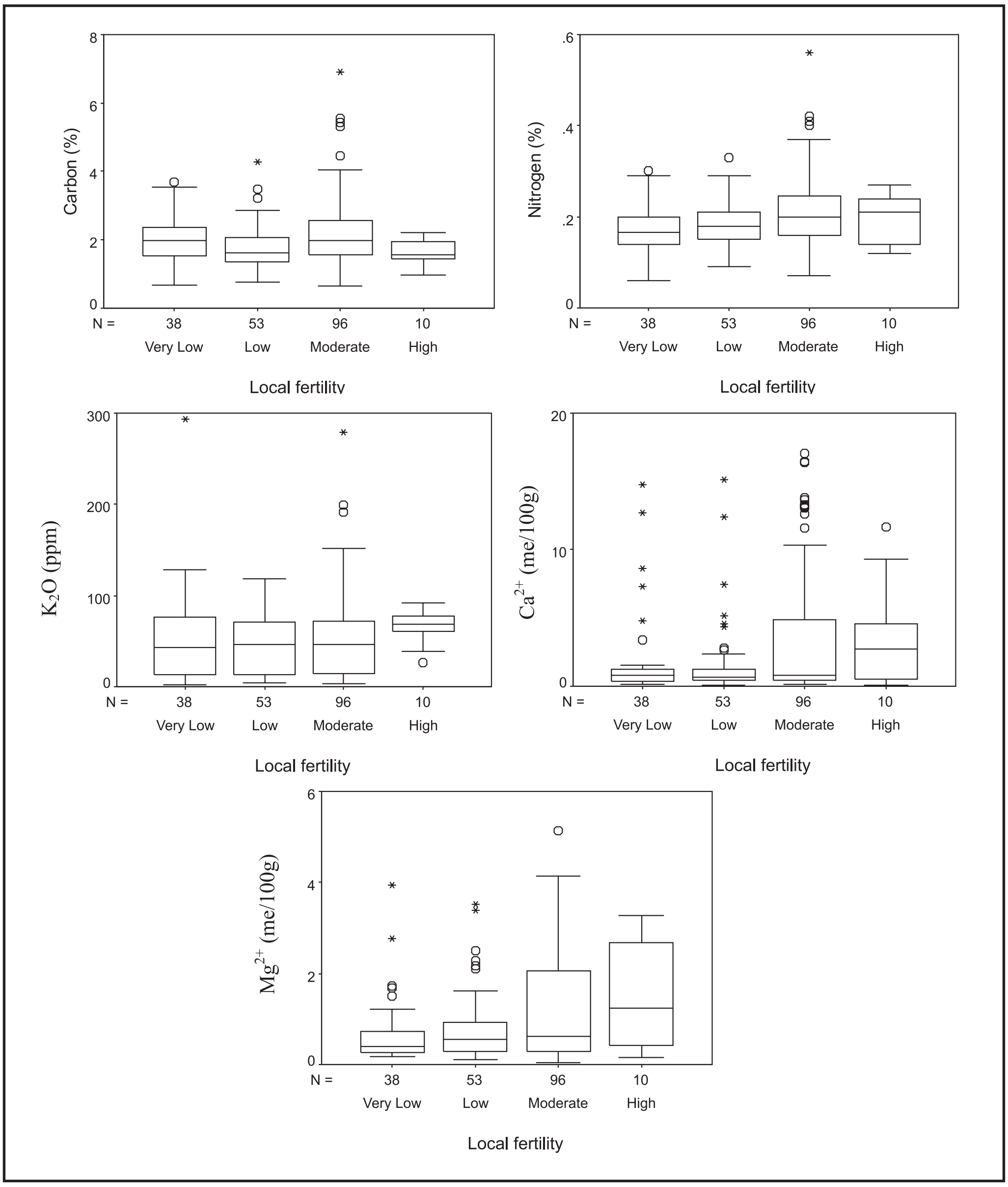
3.3.2.3 Slopes and local assessment

Focus group discussions implied that flat land is generally considered more fertile than sloping land. Slope in the sample data is indeed significantly different among local fertility classes (kruskal-wallis, n=197; df = 3; p-value = 0.023, Figure 18).

3.3.2.4 Sample types and local assessment

We examined associations between our eight general sample types (see previous table 4) and local fertility classes. The results indicate a non-random association (Chi-square; n = 197; p-value = 0.004; coef. = 0.4).

Figure 17. Soil characteristics that differ significantly with Merap's perception of local fertility



As can be seen in Figure 19, primary forest and special-modified land are generally perceived as being the most fertile. Primary forest has about the same number of fertile and unfertile sites, while fertile sites dominate special-modified samples. Agricultural and horticultural samples were usually perceived as having fertile soils.

3.3.2.5 Discriminant analysis

Local fertility classes were assessed using discriminant analyses. However, the application of these techniques faces a large number of obstacles. Among these are the non-normal and non-ratio scale of many of the variables,

Figure 18. Slope distribution by people's perception of fertility (n=197)

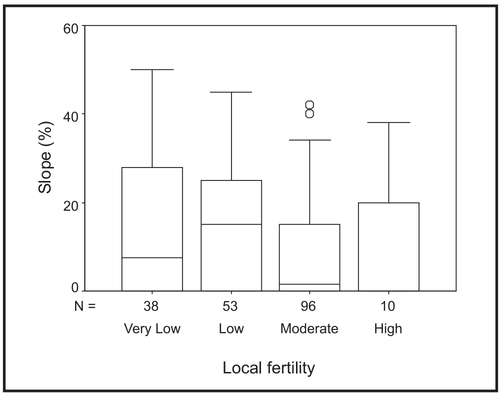


Figure 19. Sample types distribution by local people's perception of fertility

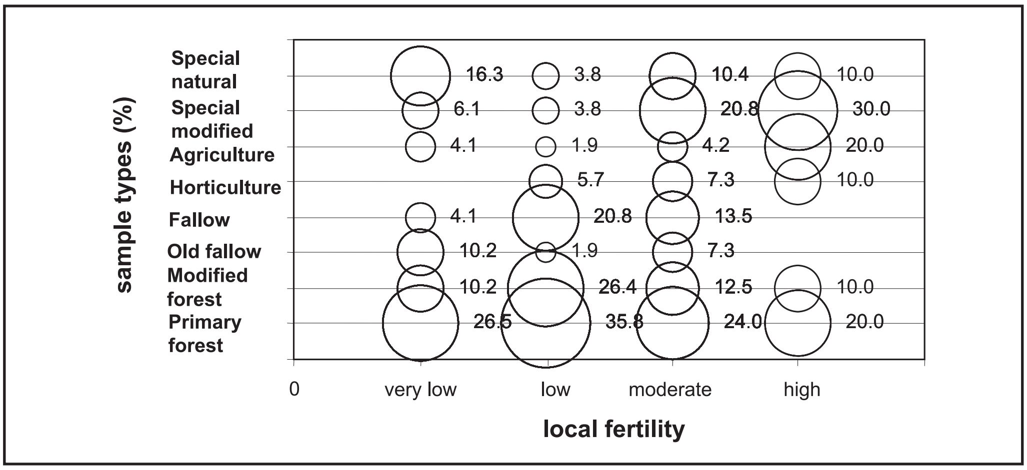


Table 49. Discriminant function classification results

Local Fertility	Predicted Group Membership				Total
Class	Very Low	Low	Moderate	High	
Very Low	0	1	37	0	38
Low	0	4	49	0	53
Moderate	0	8	88	0	96
High	0	0	10	0	10

the likelihood of non-linear relationships, co-linearity, interaction, and non-independence of key variables, and objective representation of color data. We hope in the future to be able to address these, as the data warrant fuller evaluation and the question of how fertile soils relate to accessible location is one of both practical and technical importance. Here we shall report one simple, but promising, result.

Our method follows Everitt (1991), relying on an examination of five analytically suitable variables (slope, N, Mg, sand and H^+). We sought to detect variables that are able to reliably build classification functions for the local people's fertility assessment (4 classes, not fertile to very fertile). Only 197 of the 200 plots were analyzed due to "don't know" answer on the rest.

Only N and sand were selected as significant for the final model (Figure 20). This function was able to correctly classify 46.7% of all samples (Table 49).

N and sand are accessible to direct evaluation by farmer. Exploratory analysis suggests that local people recognize these variables-related fertility through humus and friable soil. This soil usually yield good and easy to work with.

3.3.3 Land Evaluation

Except for field-rice, local suitability classes included in the analyses were derived from informant responses regarding suitable crops (e.g. coconut, soybean, peanut). Such assessments, although highly dependent on individual knowledge, may be helpful in judging if any general patterns exist.

Significant relationships were found between these local assessments and standard methods of the Agricultural Department of Indonesia (Bina Program 1987) for coconut suitability (Chi-square, p- value = 0.005, strength/coef. = 0.4). Interestingly, this relationship does not appear for rice (p-value = 0.735, strength/ coef. = 0.06), which is a local staple crop (see Table 50). This fact may be relevant to the contradiction between the general local view that *tana tiem*, wherever it is (i.e. whether on flat or sloped land), is suitable for planting rice for one or two growing seasons after clearance and burning, and the text-book view that slopes limit rice growing potential. This stands in contrast to coconut, which is more tolerant of slopes, and also reflects the short-term nature of rice swidden versus sustainability. Rice is not locally grown in any sustained cropping system as nutrients and weeds do not allow it.

Figure 20. Sand and N as variables to discriminate classes of farmer's fertility perception (n=197)

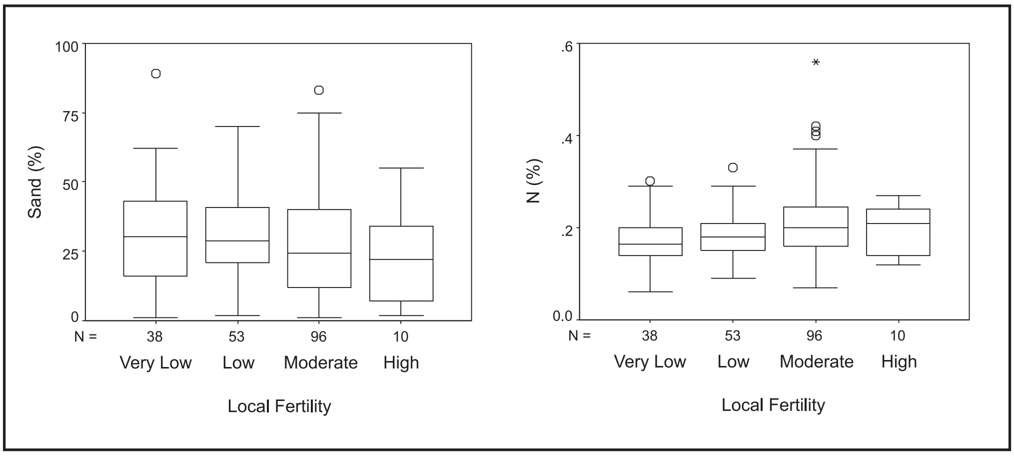


Table 50. Independency test between local and standard land suitability assessment (Suit/Not Suit) using Chi-square

Land Suitability Classes	N	Coef.	p-value
Field Rice	200	0.066	.735
Coconut	200	0.416	***.005

Note :
*** dependency is significant at the .01 level (2-tailed)

Table 51. Independency test between local fertility and suitability classes using Chi-square

Local Suitability for	Local Fertility		
	n	Coef.	p-value
Rice	197	0.479	***.001
Peanut	197	0.235	***.009
Coconut	197	0.235	***.009

Note:
*** dependency is significant at the .01 level (2-tailed)

Table 52. Significant difference between soil characteristics and local suitability classes for rice using Kruskal-Wallis test

	N	P	Clay	Sand	CEC	Al^{3+}	Fe^{3+}	Consistency
n	200	200	200	198	200	198	141	142
df	1	1	1	1	1	1	1	1
p-value	**0.036	**0.032	***0.004	**0.046	**0.032	**0.042	***0.001	**0.026

** Difference is significant at the .05 level (2-tailed)
*** Difference is significant at the .01 level (2-tailed)

There is a significant relation between local judgment of fertility and suitability for certain crops (Table 51). This pattern is in line with local statements about the relationship between fertility and suitability as explored in various interviews and focus group discussion.

3.3.3.1 Soil Characteristics and local assessment

Local perceptions of land suitability (a "yes or no" scale) are determined based to some degree on soil characteristics (e.g. color) rather than on any measured specific landscape trait included here (e.g. slope, basal area). These exploratory evaluations examined every one of these variables (detailed in appendix 1). Many measured soil characteristics significantly relate to local assessments of land suitability, something that cannot be said of any specific site characteristics (Table 52 to Table 54).

3.3.3.2 Distance, slope and local assessment

The distance of each sample site from the river and from the village was investigated against local statements of suitability. No correlation was found (see Table 55).

Table 53. Significant difference between soil characteristics and local suitability classes for coconut using Kruskal-Wallis test

Characteristics	df	n	p-value
C	1	200	*0.054
P	1	200	**0.024
K^+	1	200	***0.001
Ca^{2+}	1	200	***0.003
Mg^{2+}	1	200	**0.017
Na^+	1	200	*0.051
Clay	1	200	*0.059
B-sat	1	200	***0.005
H^+	1	198	***0.001
Hue	1	200	***0.001
Depth	1	200	***0.002

* Difference is significant at the .1 level (2-tailed)
** Difference is significant at the .05 level (2-tailed)
*** Difference is significant at the .01 level (2-tailed)

Table 54. Significant difference within measured soil characteristics by local suitability classes for peanut using Kruskal-Wallis test

Characteristics	df	n	p-value
Bulk Density	1	193	**0.014
P_2O_5	1	200	**0.031
K_2O	1	200	***0.001
Ca^{2+}	1	200	***0.005
Mg^{2+}	1	200	**0.026
Clay	1	200	*0.057
Silt	1	200	*0.062
Base saturation	1	200	***0.007
H^+	1	198	***0.001
Hue	1	200	**0.001
Depth	1	200	***0.001

* Difference is significant at the .1 level (2-tailed)
** Difference is significant at the .05 level (2-tailed)
*** Difference is significant at the .01 level (2-tailed)

Table 55. Comparison test of distance between local suitability classes (suitable and not suitable) for peanut, coconut and field rice using Kruskal-Wallis test (n= 200; df= 1)

		Local Rice Suitability	Local Coconut Suitability	Local Peanut Suitability
Distance to River	**p-value**	.246	.781	.911
Distance to Villages	**p-value**	.958	.807	.505
Travel time	**p-value**	.862	.254	.144

Table 56. Comparison test of slope between local suitability classes (suitable and not suitable) for peanut, coconut and field rice using Mann Whitney test

Local Suitability for	Slope		
	df	n	p-value
Rice	1	200	.524
Coconut	1	200	.232
Peanut	1	200	.185

Table 57. Independency test between local sample type and local land suitability classes using Chi-square

Chi-square	rice	coconut	Peanut
n	200	200	200
df	7	7	7
coef.	.211	.285	.271
p-value	.228	**.013	**.027

Note: ** Dependency is significant at the .05 level (2-tailed)

Despite the fact that the local population feels that land on slopes, with the exception of black soil, has low overall fertility, there is no clear relationship between slope and local determinations of suitability (Table 56). This result is surprising. The contrast with the positive relationship for local fertility assessments is striking, but the explanation may rest in the problems of using a two-level as opposed to a more sensitive four-level scale. However, according to focus group discussions, local people consider a sloping area of *tana tiem* as suitable for cultivation. Thus the general consensus is that the character of the soil is more important than the degree of slope it is found on.

3.3.3.3 Sample types and local assessment

A significant relationship was found between sample types and suitability for coconut and peanut (Table 57).

The sample types that have highest overlap with suitability for rice, peanut and coconut are horticultural, fallow and old fallow lands (Table 58). Such results underline the rational basis for traditional local land use choices and suggest their continuing relevance to new options.

3.3.3.4 Discriminant analysis

Local suitability assessment for rice were assessed using discriminant analyses. Our method, the same for local fertility assessment (see section 3.3.2.5) follows Everitt (1991), only relying on an examination of four most correlated and relatively normal distributed variables (N, clay, sand and Fe^{3+}). We sought to detect variables that are able to reliably build classification functions for the local people's suitability assessment (two classes, suitable and not). Missing values are located both in dependent and independent variables. Only 142 of the 200 plots were analyzed due to insufficient data of Fe^{3+} that was not collected in the first field activity.

Only Fe^{3+} was selected as significant for the final model (Figure 21). This function was able to correctly classify 71.1% of all samples (Table 59).

Though Fe^{3+} may not be accessible to direct evaluation by farmer, but its ability to classify local people suitability assessment suggest an indirect and strong influence. Exploratory analysis suggests that local people recognize iron-related fertility through greyish and hard soil. Further analyses of Fe^{3+} against what we believe to be visible soil characteristics shows a strong correlation with bulk density, texture, nitrogen (humus component) and color (Table 60 and Figure 22).

Table 59. Discriminant function classification results

Local Suitability	Predicted Group Membership		Total
Classes	Not Suit	Suit	
Not Suit	10	38	48
Suit	3	91	94

Table 58. Description of local land suitability classes among sample types using Cross-tab

Sample types	Peanut		Coconut		Rice	
	not suit	suit	Not suit	suit	not suit	suit
Primary Forest	38	19	37	20	18	39
Modified Forest	19	13	19	13	11	21
Old Fallow	5	8	5	8	4	9
Fallow	12	15	12	15	7	20
Horticulture	2	9	1	10	2	9
Agriculture	6	4	6	4	5	5
Special Modified	13	15	14	14	10	18
Special Natural	16	6	16	6	13	9
Total	111	89	110	90	70	130

Figure 21. Fe^{3+} as variable to discriminates classes of farmer's suitability assessment for rice

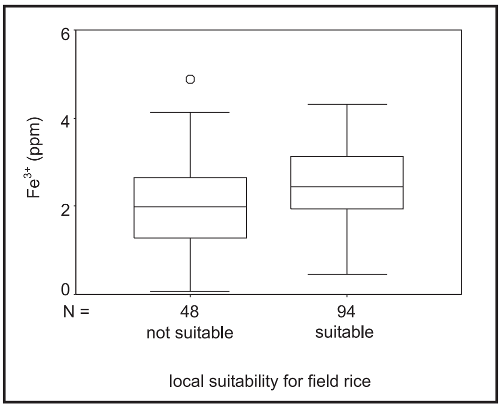
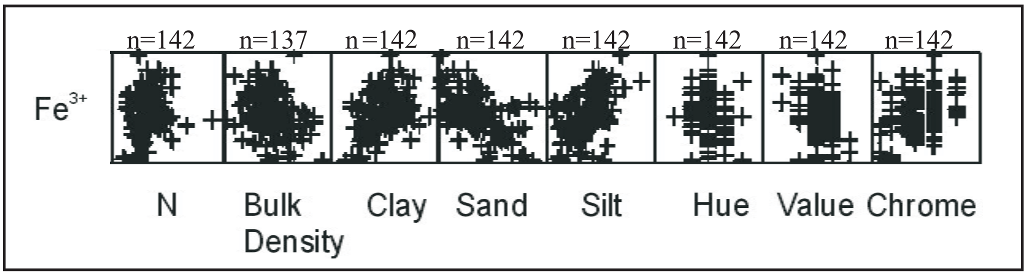


Table 60. Strong rank correlation (p-value < 0.1) between Fe^{3+} and some visible soil characteristics using Kendal's tau

	Correlation	N	Bulk Density	Clay	Sand	Silt	Munsell Chrome
Fe^{3+}	Coef.	0.134	-0.204	0.250	-0.351	0.313	0.113
	p-value	0.021	0.000	0.000	0.000	0.000	0.07
	n	142	137	142	142	142	141

Figure 22. Scatters of measured Fe^{3+} versus visible soil characteristics (Munsell hue, value, chrome) (For units see text)



4. Conclusions

Our various methods have captured a range of valuable information regarding land resources from both a soil and crop science, and a local perspective. This study has been based on the simple proposition that local people's knowledge of land resources can and should be used to guide, facilitate and inform any agriculture or forestry interventions. So what can we conclude?

Five soil orders were identified in the sampled region: Oxisols, Ultisols, Alfisols, Inceptisols, and Entisols, with Oxisols being the most common. The soils studies are mostly acidic (average pH 4.5 to 5). The area is highly infertile by any standard. Most nutrients are very low and aluminum and manganese toxicity may be significant. The cation exchange capacity and the resultant base availability of most soil is "low" to "very low." Impermeable pan underlies about a third of all samples, further reducing the potential for cultivation. Erosion rates appear high even in natural forests. Steep slopes and heavy rain combine to create major erosion potential. Mechanical harvesting has compacted soils in some logged-over areas.

Significant differences in pH, C/N, Ca^{2+}, Mg^{2+}, base saturation, Al^{3+}, erosion and soil compaction were found between cultivated, logged and forested land. We cannot directly assess the effect of land use changes. The most obvious human activities that influence soil include swidden agriculture and mechanized logging. The first reduces soil nutrients, while the second leads to loss of soil structure and increased erosion.

Using land evaluation criteria, it was shown that there was little potential for commercial development of the examined crops. More than half the plots fall in the totally unsuitable class (field rice 26%, oil palm 46.5%, pepper 46%, cocoa 50.5%, candlenut and peanut 100%, coconut 36.5%, coffee and rubber 64%). The limiting factors are: poor drainage, shallow soil depth, coarse texture, steep slopes, and a high occurrence of hardpans and rock debris.

Given widespread poor fertility, application of fertilizers (including organic-matter and lime) would be needed to sustain agricultural productivity. Since the region have high rainfall, application would be required in small amounts quite frequently. High additions would almost certainly lead to impacts from losses in runoff.

Characteristics used by farmers to judge and classify land are: soil color, texture, consistency, stoniness, humus content, vegetation cover, depth, and perceived fertility.

Soil fertility, in particular, was judged by several factors, including color, associated vegetation and the perceptions of other local community members. This perception of fertility has a significant correlation with standard assessments. A significant positive correlation was also found between perceived fertility and proximity to the village, and was associated with more level plain. Cultivated land was generally more fertile than other areas.

Of the ethnic groups studied, the Merap appear to have the richest knowledge of land soil and cultivation. The Merap assessment system also has the clearest correlation to our own laboratory assessments.

The local assessments of suitability for three crops (upland rice, peanut and coconut) are influenced by soil fertility. Neither distance from the village nor sample-site slope seems to relate to suitability. However, a significant relationship was found between land-cover-type and local perceptions of suitability for coconut and peanut. This highlights the practical logic of local people's land use planning systems.

The two main conclusions we draw from our analyses are 1) the limited opportunities for expanding non-forestry land-uses in the upper Malinau and 2) the sophisticated knowledge of local communities that allows them to gain livelihoods in the face of local conditions. To illustrate the first point we refer to the fact that out of 200 diverse sample sites, not a single one appeared to offer potential for major cash crops such as oil palm, pepper, and coffee. We can understand that this is a result of both the low soil fertility and topographic difficulty intrinsic to the region. Local people have been able to live in this region only through a sophisticated ability requiring small scale shifting agricultural practices augmented by food from wild sources – illustrating the second point. Indeed the low population densities in the region seem likely to be a direct result of these conditions and limitations.

The understanding we have gained of both the limited opportunities presented by the soils of the upper Malinau, along with their crucial significance to the local people, provides a fundamental basis for examining any future land use in the region. The sustainability of the cultivation, the future of the forests, and the welfare of the local people depend on good management that heeds this knowledge.

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6. Appendices

Appendix 1. Summary of dependence amongst measured variables

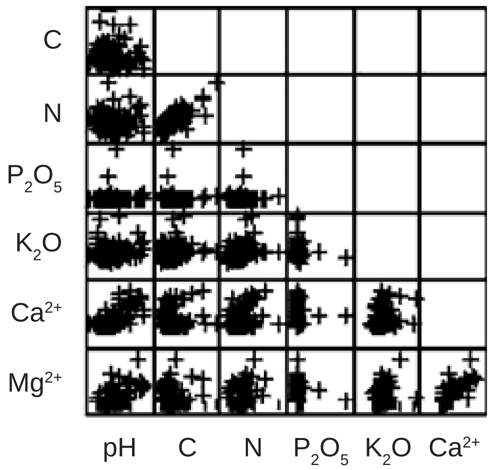
The exploration of relationships among soil characteristics was performed using correlations and scatter graphs.

The graphs give a two dimensional view of relations that exist between characters, for each sample. This clarifies the form of the relation and its strength, e.g. outliers (which can cause misleading results) and evidence of a linear relationship.

The correlations measure the strength (coef.) of the association. We use Kendall's tau-b a nonparametric measure of association for ordinal or ranked variables that take ties into account. The sign of the coefficient indicates the direction of the relationship, and its absolute value indicates the strength, with larger absolute values indicating stronger relationships. Possible values range from -1 to 1.

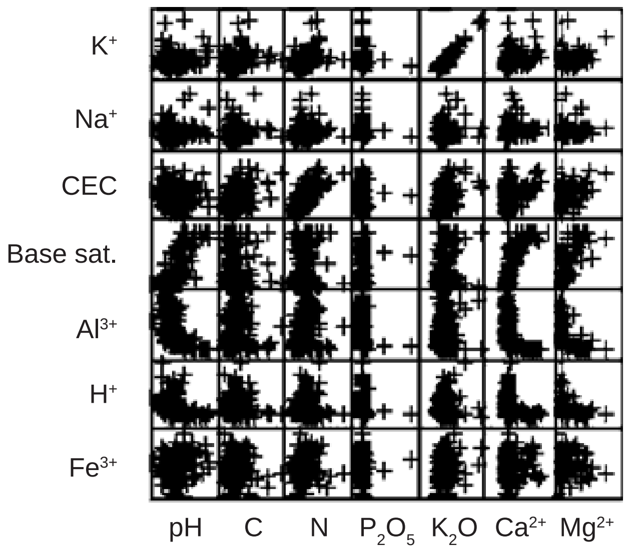
Appendix 1a. Rank correlation between measured variable using Kendall's rank coefficient and their graph

	Correlation	pH	C	N	P_2O_5	K_2O	Ca^{2+}
C	Coef.	-0.044					
	p-value	*0.374*					
	n	200	200				
N	Coef.	0.037	0.562				
	p-value	*0.456*	***0.001*				
	n	200	200	200			
P_2O_5	Coef.	0.118	0.131	-0.015			
	p-value	**0.016*	***0.006*	*0.764*			
	n	200	200	200	200		
K_2O	Coef.	0.138	0.089	0.226	0.165		
	p-value	***0.005*	*0.063*	***0.001*	***0.001*		
	n	200	200	200	200	200	
Ca^{2+}	Coef.	0.532	0.028	0.204	0.039	0.188	
	p-value	***0.001*	*0.562*	***0.001*	*0.413*	***0.001*	
	n	200	200	200	200	200	200
Mg^{2+}	Coef.	0.430	0.071	0.300	-0.057	0.232	0.616
	p-value	***0.001*	*0.139*	***0.001*	*0.237*	***0.001*	***0.001*
	n	200	200	200	200	200	200



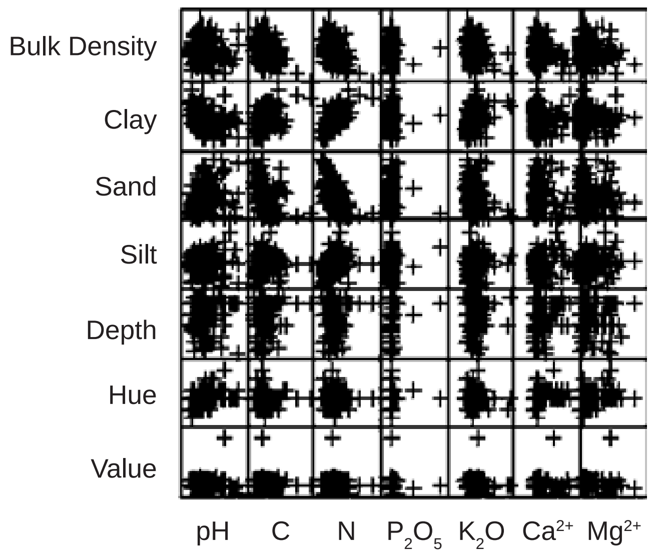
Appendix 1b. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	pH	C	N	P_2O_5	K_2O	Ca^{2+}	Mg^{2+}
K^+	Coef.	0.110	0.235	0.342	-0.059	0.363	0.274	0.362
	p-value	*0.028*	***0.001*	***0.001*	*0.229*	***0.001*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200
Na^+	Coef.	0.080	*0.028	0.058	-0.039	0.117	0.241	0.205
	p-value	*0.114*	*0.575*	*0.246*	*0.431*	*0.018*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200
CEC	Coef.	-0.112	0.294	0.515	-0.068	0.293	0.080	0.191
	p-value	*0.056*	***0.001*	***0.001*	*0.230*	***0.001*	*0.157*	***0.001*
	n	142	142	142	142	142	142	142
Base Sat.	Coef.	0.537	-0.161	-0.085	0.160	0.160	0.670	0.538
	p-value	***0.001*	***0.005*	*0.147*	***0.005*	***0.006*	***0.001*	***0.001*
	n	142	142	142	142	142	142	142
Al^{3+}	Coef.	-0.526	0.105	0.074	-0.111	-0.064	-0.458	-0.366
	p-value	***0.001*	**0.028*	*0.131*	**0.020*	*0.183*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200
H^+	Coef.	-0.448	0.016	-0.027	-0.135	-0.193	-0.343	-0.277
	p-value	***0.001*	*0.730*	*0.577*	***0.005*	***0.001*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200
Fe^{3+}	Coef.	0.044	-0.044	0.134	-0.265	0.129	-0.041	0.145
	p-value	*0.448*	*0.440*	**0.021*	***0.001*	**0.024*	*0.475*	**0.011*
	n	142	142	142	142	142	142	142



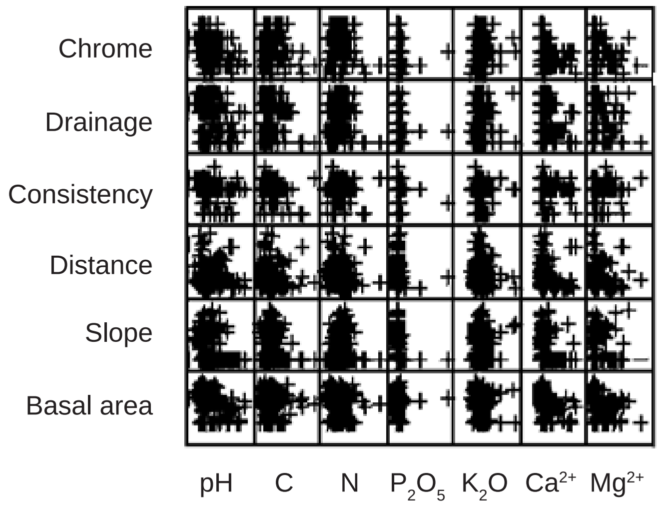
Appendix 1c. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	pH	C	N	P_2O_5	K_2O	Ca^{2+}	Mg^{2+}
Bulk Density	Coef.	-0.017	-0.286	-0.316	0.026	0.019	-0.130	-0.146
	p-value	*0.739*	***0.001*	***0.001*	*0.589*	*0.703*	***0.008*	***0.003*
	n	193	193	193	193	193	193	193
Clay	Coef.	-0.218	0.208	0.420	-0.119	0.252	-0.108	-0.007
	p-value	***0.001*	***0.001*	***0.001*	**0.014*	***0.001*	**0.025*	*0.891*
	n	200	200	200	200	200	200	200
Sand	Coef.	0.045	-0.268	-0.532	0.169	-0.150	-0.066	-0.158
	p-value	*0.360*	***0.001*	***0.001*	***0.001*	***0.002*	*0.171*	***0.001*
	n	200	200	200	200	200	200	200
Silt	Coef.	0.093	0.194	0.391	-0.159	0.027	0.152	0.227
	p-value	*0.062*	***0.001*	***0.001*	***0.001*	*0.579*	***0.002*	***0.001*
	n	200	200	200	200	200	200	200
Depth	Coef.	-0.019	0.108	0.085	0.078	-0.242	0.014	-0.019
	p-value	*0.721*	**0.036*	*0.107*	*0.131*	***0.001*	*0.780*	*0.707*
	n	200	200	200	200	200	200	200
Hue	Coef.	0.107	-0.008	0.008	-0.094	-0.260	0.203	0.184
	p-value	*0.070*	*0.885*	*0.888*	*0.100*	***0.001*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200
Value	Coef.	-0.190	-0.047	-0.086	-0.126	-0.203	-0.165	-0.094
	p-value	***0.001*	*0.377*	*0.108*	**0.017*	***0.001*	***0.002*	*0.074*
	n	200	200	200	200	200	200	200



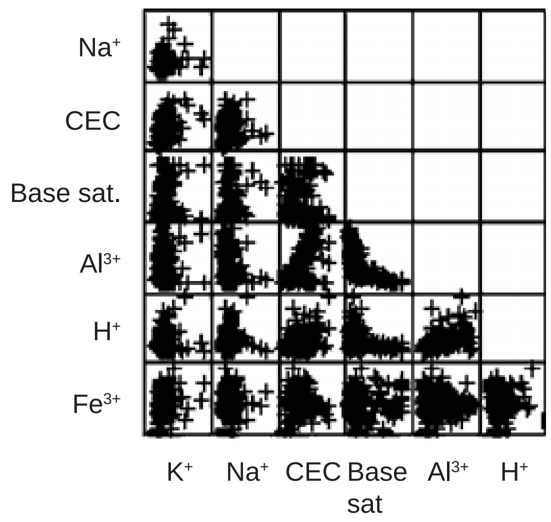
Appendix 1d. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	pH	C	N	P_2O_5	K_2O	Ca^{2+}	Mg^{2+}
Chrome	Coef.	-0.262	-0.018	-0.018	-0.253	-0.256	-0.263	-0.143
	p-value	***0.001*	*0.732*	*0.737*	***0.001*	***0.001*	***0.001*	***0.006*
	n	200	200	200	200	200	200	200
Drainage	Coef.	-0.161	0.025	0.068	-0.080	0.067	-0.206	-0.138
	p-value	***0.003*	*0.628*	*0.199*	*0.128*	*0.205*	***0.001*	***0.009*
	n	200	200	200	200	200	200	200
Consistency	Coef.	-0.133	-0.118	0.058	-0.143	-0.020	-0.047	-0.055
	p-value	*0.052*	*0.075*	*0.392*	**0.031*	*0.766*	*0.475*	*0.406*
	n	142	142	142	142	142	142	142
Distance	Coef.	-0.164	-0.039	-0.101	-0.131	-0.185	-0.182	-0.142
	p-value	***0.001*	*0.422*	**0.039*	***0.006*	***0.001*	***0.001*	***0.003*
	n	200	200	200	200	200	200	200
Slope	Coef.	-0.264	-0.024	0.014	-0.082	-0.005	-0.267	-0.203
	p-value	***0.001*	*0.633*	*0.793*	*0.108*	*0.928*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200
Basal Area	Coef.	-0.218	-0.012	-0.064	0.096	0.054	-0.344	-0.278
	p-value	***0.001*	*0.806*	*0.191*	**0.048*	*0.266*	***0.001*	***0.001*
	n	200	200	200	200	200	200	200



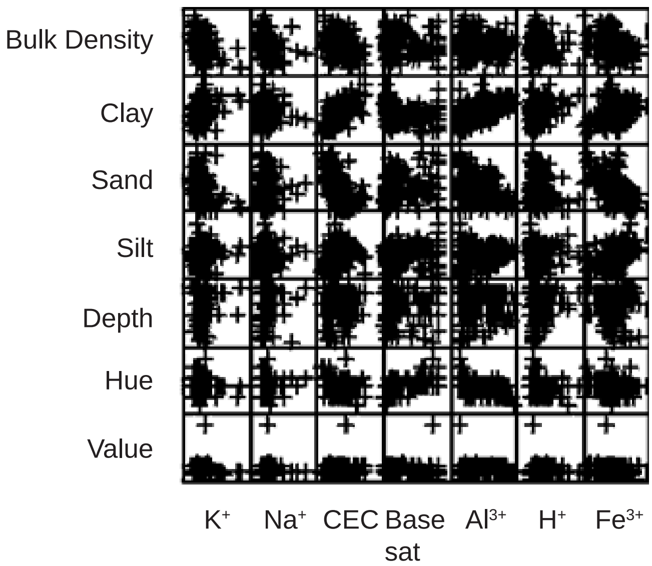
Appendix 1e. Relation between measured variable. I) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	K^+	Na^+	CEC	Base Sat.	Al^{3+}	H^+
Na^+	Coef.	0.172					
	p-value	***0.001*					
	n	200					
CEC	Coef.	0.290	0.030				
	p-value	***0.001*	*0.605*				
	n	142	142				
Base Sat.	Coef.	0.161	0.322	-0.198			
	p-value	***0.006*	***0.001*	***0.001*			
	n	142	142	142			
Al^{3+}	Coef.	-0.039	-0.165	0.361	-0.668		
	p-value	*0.428*	***0.001*	***0.001*	***0.001*		
	n	200	200	142	142		
H^+	Coef.	0.024	0.038	0.149	-0.368	0.527	
	p-value	*0.623*	*0.442*	***0.009*	***0.001*	***0.001*	
	n	200	200	142	142	200	
Fe^{3+}	Coef.	0.173	0.026	0.022	0.033	-0.027	-0.026
	p-value	***0.003*	*0.656*	*0.697*	*0.567*	*0.630*	*0.652*
	n	142	142	142	142	142	142



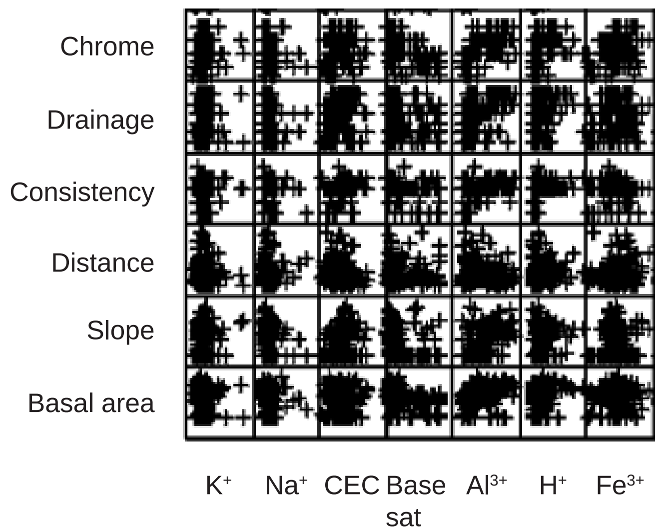
Appendix 1f. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	K^+	Na^+	CEC	Base Sat.	Al^{3+}	H^+	Fe^{3+}
Bulk Density	Coef.	-0.301	-0.163	-0.178	-0.063	-0.005	-0.051	-0.204
	p-value	***0.001*	***0.001*	***0.002*	*0.282*	*0.924*	*0.300*	***0.001*
	n	193	193	137	137	193	193	137
Clay	Coef.	0.127	-0.051	0.471	-0.359	0.332	0.130	0.250
	p-value	**0.010*	*0.308*	***0.001*	***0.001*	***0.001*	***0.007*	***0.001*
	n	200	200	142	142	200	200	142
Sand	Coef.	-0.221	0.006	-0.414	0.195	-0.180	-0.043	-0.351
	p-value	***0.001*	*0.905*	***0.001*	***0.001*	***0.001*	*0.373*	***0.001*
	n	200	200	142	142	200	200	142
Silt	Coef.	0.194	0.039	0.229	0.010	0.020	-0.028	0.313
	p-value	***0.001*	*0.430*	***0.001*	*0.865*	*0.676*	*0.554*	***0.001*
	n	200	200	142	142	200	200	142
Depth	Coef.	0.090	0.012	-0.052	0.021	-0.024	0.076	0.066
	p-value	*0.088*	*0.824*	*0.398*	*0.734*	*0.648*	*0.138*	*0.283*
	n	200	200	142	142	200	200	142
Hue	Coef.	0.216	0.120	-0.079	0.354	-0.211	-0.016	-0.047
	p-value	***0.001*	**0.042*	*0.245*	***0.001*	***0.001*	*0.776*	*0.485*
	n	200	200	142	142	200	200	142
Value	Coef.	0.011	-0.002	0.136	-0.059	0.243	0.336	-0.028
	p-value	*0.834*	*0.977*	**0.036*	*0.372*	***0.001*	***0.001*	*0.662*
	n	200	200	142	142	200	200	142



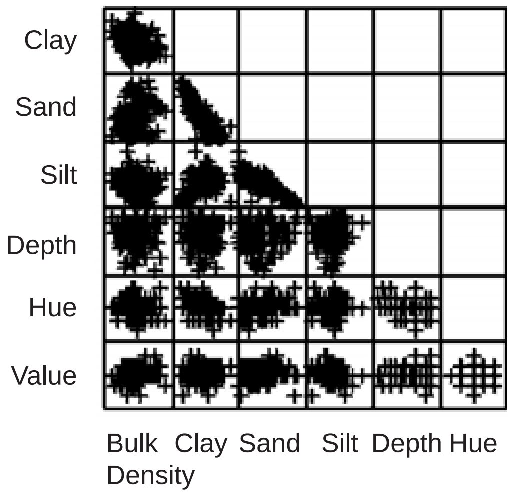
Appendix 1g. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	K^+	Na^+	CEC	Base Sat.	Al^{3+}	H^+	Fe^{3+}
Chrome	Coef.	0.046	-0.163	0.149	-0.307	0.347	0.364	0.113
	p-value	*0.380*	***0.002*	**0.018*	***0.001*	***0.001*	***0.001*	*0.072*
	n	200	200	142	142	200	200	142
Drainage	Coef.	-0.007	-0.117	0.188	-0.344	0.342	0.150	0.008
	p-value	*0.894*	**0.029*	***0.002*	***0.001*	***0.001*	***0.004*	*0.901*
	n	200	200	142	142	200	200	142
Consistency	Coef.	-0.032	-0.026	0.226	-0.162	0.269	0.258	-0.040
	p-value	*0.638*	*0.700*	***0.001*	**0.015*	***0.001*	***0.001*	*0.547*
	n	142	142	142	142	142	142	142
Distance	Coef.	0.022	0.025	-0.092	-0.073	0.179	0.225	0.091
	p-value	*0.658*	*0.615*	*0.107*	*0.209*	***0.001*	***0.001*	*0.113*
	n	200	200	142	142	200	200	142
Slope	Coef.	0.059	-0.094	0.271	-0.286	0.436	0.285	-0.007
	p-value	*0.260*	*0.071*	***0.001*	***0.001*	***0.001*	***0.001*	*0.913*
	n	200	200	142	142	200	200	142
Basal Area	Coef.	-0.202	-0.126	-0.003	-0.360	0.248	0.151	0.020
	p-value	***0.001*	**0.011*	*0.963*	***0.001*	***0.001*	***0.002*	*0.728*
	n	200	200	142	142	200	200	142



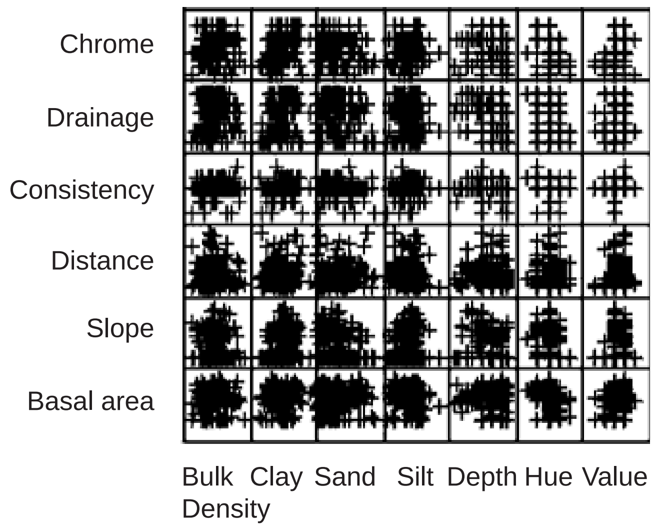
Appendix 1h. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	Bulk Density	Clay	Sand	Silt	Depth	Hue
Clay	Coef.	-0.127					
	p-value	**0.010*					
	n	193					
Sand	Coef.	0.220	-0.617				
	p-value	***0.001*	***0.001*				
	n	193	200				
Silt	Coef.	-0.170	0.248	-0.649			
	p-value	***0.001*	***0.001*	***0.001*			
	n	193	200	200			
Depth	Coef.	-0.167	-0.071	-0.103	0.181		
	p-value	***0.002*	*0.170*	**0.046*	***0.001*		
	n	193	200	200	200		
Hue	Coef.	-0.174	-0.196	0.059	0.048	0.100	
	p-value	***0.003*	***0.001*	*0.302*	*0.403*	*0.105*	
	n	193	200	200	200	200	
Value	Coef.	0.032	0.019	-0.020	0.042	0.038	0.140
	p-value	*0.548*	*0.717*	*0.705*	*0.425*	*0.502*	**0.026*
	n	193	200	200	200	200	200



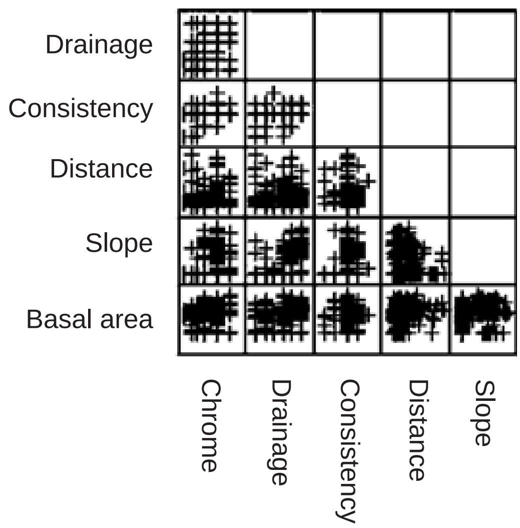
Appendix 1i. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	Bulk Density	Clay	Sand	Silt	Depth	Hue	Value
Chrome	**Coef.**	0.071	0.312	-0.200	0.077	-0.045	0.070	0.673
	p-value	*0.277*	***0.001*	*0.002*	*0.231*	*0.506*	*0.259*	***0.001*
	n	136	141	141	141	141	200	200
Drainage	**Coef.**	0.077	0.252	-0.108	-0.016	-0.164	-0.115	0.054
	p-value	*0.151*	***0.001*	*0.040*	*0.758*	*0.004*	*0.065*	*0.347*
	n	193	200	200	200	200	200	200
Consistency	**Coef.**	0.045	0.241	-0.205	0.119	-0.146	-0.042	0.097
	p-value	*0.510*	***0.001*	*0.002*	*0.075*	*0.041*	*0.595*	*0.200*
	n	137	142	142	142	142	142	142
Distance	**Coef.**	-0.018	-0.028	0.017	-0.024	0.027	0.053	0.228
	p-value	*0.720*	*0.565*	*0.730*	*0.621*	*0.598*	*0.359*	***0.001*
	n	193	200	200	200	200	200	200
Slope	**Coef.**	0.026	0.227	-0.075	-0.046	-0.143	-0.105	0.234
	p-value	*0.613*	***0.001*	*0.143*	*0.371*	*0.009*	*0.084*	***0.001*
	n	193	200	200	200	200	200	200
Basal Area	**Coef.**	0.102	0.112	0.032	-0.147	-0.101	-0.268	0.037
	p-value	*0.039*	*0.022*	*0.508*	*0.003*	*0.052*	***0.001*	*0.491*
	n	193	200	200	200	200	200	200



Appendix 1j. Relation between measured variable. i) Kendall's rank coefficient (tau) and ii) scatter grams

	Correlation	Chrome	Drainage	Consistency	Distance	Slope
Drainage	Coef.	0.155				
	p-value	*0.006*				
	n	200				
Consistency	Coef.	0.238	0.201			
	p-value	*0.001*	*0.005*			
	n	142	142			
Distance	Coef.	0.229	0.025	-0.016		
	p-value	***0.001*	*0.634*	*0.808*		
	n	200	200	142		
Slope	Coef.	0.284	0.457	0.284	0.167	
	p-value	***0.001*	***0.001*	***0.001*	*0.001*	
	n	200	200	142	200	
Basal Area	Coef.	0.067	0.196	0.025	0.139	0.217
	p-value	*0.198*	***0.001*	*0.709*	*0.004*	***0.001*
	n	200	200	142	200	200



Appendix 2. Summary of all plot's data and soil characteristics

Appendix 2a. All plot's data and soil surface characteristics (see main report for definitions; part 1)

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm³)	(%)			(cm)				(%)
1	3.9	1.89	0.17	11	2.2	8	0.39	0.42	0.15	0.2	.	.	6.69	0.96	.	0.84	33	14	53	110	10YR 6/8	impeded	.	2.5
2	3.9	0.9	0.08	11	5.7	3	0.15	0.15	0.06	0.02	.	.	2.06	0.58	.	1.39	13	53	34	80	10YR 4/2	impeded	.	2.6
3	5.2	3.08	0.37	8	4.4	14	5.72	2.83	0.22	0.07	.	.	0.2	0.11	.	0.77	24	2	74	110	2.5Y 3.5/3	moderate	.	1
4	4.8	1	0.12	8	4.1	12	4.54	2.5	0.14	0.07	.	.	1.18	0.19	.	1.09	24	40	36	110	2.5Y 3.5/3	moderate	.	0
5	4.8	1.93	0.24	8	6.1	13	11.55	2.86	0.21	0.13	.	.	0.67	0.17	.	1.05	25	29	46	110	2.5Y 4.5/4	moderate	.	0
6	5.2	2.45	0.3	8	4.2	21	9.4	3.29	0.38	0.09	.	.	0.13	0.09	.	0.77	26	5	69	110	2.5Y 3.5/3	moderate	.	2
7	4.8	2.02	0.16	13	28.9	4	0.15	0.17	0.08	0.02	.	.	4.23	0.72	.	0.92	33	35	32	110	2.5Y 6/3.5	moderate	.	5
8	4.5	4.47	0.28	16	20	8	0.15	0.25	0.16	0.03	.	.	7.15	1.03	.	0.84	27	34	39	110	10YR 4/3	moderate	.	7.5
9	4.3	0.97	0.13	7	2.3	6	0.67	0.54	0.08	0.13	.	.	3.9	0.6	.	1.05	30	36	34	60	2.5Y 6/7	moderate	.	12.5
10	4	1.12	0.11	10	5.7	4	0.2	0.18	0.08	0.03	.	.	3.43	0.53	.	1.18	20	60	20	110	2.5Y 4.5/4	moderate	.	20
11	4.1	1.29	0.13	10	2	4	0.26	0.3	0.08	0.32	.	.	4.7	0.72	.	1.07	25	41	34	110	2.5Y 6/7	moderate	.	5
12	5	2.32	0.21	11	3.5	9	4.4	2.13	0.16	0.07	.	.	0.19	0.1	.	1.27	34	10	56	110	2.5Y 5.5/6	slow	.	3
13	4.8	1.36	0.14	10	4.3	7	1.94	0.84	0.14	0.06	.	.	1.14	0.21	.	1.35	23	44	33	40	10YR 6/7	moderate	.	1.5
14	4	1.88	0.18	10	3	7	0.21	0.24	0.13	0.15	.	.	7.77	0.97	.	1	35	30	35	110	2.5Y 6/6	moderate	.	22.5
15	3.8	2.01	0.2	10	5.4	10	0.16	0.17	0.21	0.07	.	.	9.48	1.03	.	0.92	37	24	39	110	2.5Y 6/7	moderate	.	2.7
16	4.6	2.27	0.19	12	4.1	8	2.3	0.69	0.15	0.05	.	.	3.56	0.61	.	0.97	37	21	42	110	2.5Y 5/5	moderate	.	7.5
17	4.2	2.07	0.2	10	2.1	5	0.58	0.55	0.1	0.13	.	.	4.18	0.65	.	1.01	15	26	59	80	2.5Y 5.5/5	moderate	.	5
18	4.5	1.37	0.15	9	2.6	10	1.38	0.98	0.16	0.06	.	.	2.46	0.51	.	1.17	19	62	19	60	10YR 3.5/4	impeded	.	0
19	4.1	1.37	0.13	11	2.6	6	0.2	0.32	0.12	0.06	.	.	3.88	0.55	.	0.92	18	64	18	60	2.5Y 5/5	impeded	.	2.8
20	4.6	3.18	0.2	16	4.6	20	2.16	0.98	0.41	0.26	.	.	11.65	1.23	.	0.52	38	24	38	20	2.5Y 4.5/4	slow	.	0
21	5.4	3.49	0.41	9	7.4	20	17.06	2.89	0.35	0.17	.	.	0.2	0.11	.	0.51	26	9	65	110	2.5Y 3/2.5	impeded	.	0
22	3.8	2.1	0.15	14	22.2	5	0.26	0.17	0.1	0.07	.	.	9.41	1.36	.	0.72	27	36	37	110	10YR 5.5/6	moderate	.	25
23	4.1	2.19	0.18	12	9.5	7	0.16	0.17	0.13	0.07	.	.	9.61	1.03	.	0.86	36	26	38	110	10YR 5.5/6	moderate	.	6
24	4.1	2.5	0.14	18	24.2	7	0.16	0.17	0.14	0.18	.	.	8.84	0.88	.	1.11	32	26	42	80	10YR 7/5	moderate	.	50
25	4.3	1.56	0.12	13	2.6	6	0.26	0.21	0.12	0.08	.	.	5.84	0.74	.	1.17	26	46	28	40	10YR 6/7	moderate	.	30
26	4.9	2.32	0.27	9	1.5	13	14.79	1.21	0.25	0.13	.	.	4.32	0.61	.	1.02	42	13	45	40	2.5Y 5.5/6	moderate	.	12.5

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
27	4.7	1.54	0.2	8	1.2	8	7.32	0.46	0.17	0.08	.	.	5.23	0.66	.	1.06	29	7	64	110	10YR 4.5/4	moderate	.	2.9
28	4.7	2.79	0.18	16	4.5	8	1.37	0.64	0.16	0.1	.	.	1.43	0.5	.	.	8	75	17	40	10YR 2/2	slow	.	2.1
29	4.2	2.13	0.13	16	20	8	0.15	0.17	0.16	0.07	.	.	9.66	1	.	0.88	25	46	29	110	2.5Y 6/7	moderate	.	50
30	4.2	1.56	0.12	13	9.4	7	0.26	0.2	0.12	0.06	.	.	8.2	0.95	.	1.32	28	43	29	110	2.5Y 6/7	moderate	.	35
31	4.1	2.14	0.22	10	9.2	10	0.7	0.53	0.17	0.07	.	.	5.01	0.67	.	0.81	79	9	12	110	2.5Y 4.5/4	moderate	.	0
32	3.8	2.51	0.24	10	5.9	11	0.37	0.3	0.17	0.07	.	.	9.93	0.98	.	0.85	44	4	52	110	2.5Y 6/7	moderate	.	12.5
33	3.8	1.94	0.2	10	5.5	8	0.42	0.29	0.17	0.07	.	.	11.54	1.15	.	1.05	34	15	51	110	10YR 6/7	moderate	.	7
34	5	2.29	0.2	11	2.9	8	8.66	0.65	0.16	0.08	.	.	0.21	0.08	.	0.98	19	23	58	80	2.5Y 4.5/4	moderate	.	0
35	4.8	1.59	0.16	10	4.3	16	1.14	0.42	0.33	0	.	.	3.1	0.51	.	0.94	29	32	39	110	2.5Y 5/5	moderate	.	2.1
36	5.7	1.67	0.21	8	3.5	9	13.06	3.71	0.17	0.07	.	.	0.13	0.08	.	0.86	26	27	47	110	2.5Y 3/2.5	moderate	.	4
37	5.5	1.98	0.21	9	15.8	24	12.63	3.03	0.5	0.13	.	.	0	0	.	1	34	17	49	110	2.5Y 3.5/3	moderate	.	0
38	4.7	1.88	0.16	12	4.3	11	2.82	0.79	0.22	0.07	.	.	0.92	0.19	.	1.02	23	45	32	60	2.5Y 6/7	moderate	.	5
39	4.4	1.51	0.17	9	5.8	6	0.78	0.68	0.12	0	.	.	5.26	0.65	.	0.9	35	27	38	40	2.5Y 6/6	moderate	.	3.5
40	5.7	2.86	0.36	8	5.1	17	16.37	4.15	0.34	0.07	.	.	0	0	.	0.72	30	4	66	110	2.5Y 5/4	moderate	.	0
41	4.9	2.13	0.29	7	2.7	11	13.17	3.54	0.17	0.07	.	.	0.82	0.18	.	0.88	39	4	57	110	2.5Y 4/4	moderate	.	0
42	5.5	1.88	0.18	10	11.1	13	12.37	3.38	0.17	0.07	.	.	0	0	.	0.75	24	45	31	110	2.5Y 4/4	moderate	.	0
43	4.2	1.6	0.21	8	2.3	11	1.93	1.46	0.19	0.07	.	.	5.39	0.78	.	0.97	28	40	32	110	2.5Y 5/5	moderate	.	2.1
44	4.1	2.13	0.2	11	4.1	10	0.37	0.35	0.21	0	.	.	6.73	0.96	.	1.06	33	35	32	60	2.5Y 5/6	moderate	.	45
45	4.8	1.61	0.22	7	3	17	7.42	3.14	0.3	0.02	.	.	1.91	0.52	.	0.85	33	23	44	110	10YR 5/5	impeded	.	8
46	3.9	1.78	0.22	8	5.7	9	0.54	0.58	0.15	0.07	.	.	7.35	1.16	.	0.87	44	4	52	110	10YR 6/7	moderate	.	30
47	4.3	1.38	0.17	8	23.3	10	0.42	0.6	0.21	0	.	.	6.19	0.83	.	1.13	31	21	48	110	2.5Y 6/7	moderate	.	30
48	4.4	1.6	0.15	11	2.9	13	0.37	0.21	0.15	0.07	.	.	6.33	0.92	.	1.27	42	6	52	110	10YR 6/8	quick	.	5
49	4.2	1.97	0.19	10	3	14	0.38	0.36	0.26	0	.	.	9.07	1	.	0.96	36	24	40	110	2.5Y 6/7	moderate	.	15
50	4.5	2.76	0.26	11	2.3	16	5.56	2.31	0.34	0.1	.	.	11.01	1.64	.	0.55	30	7	63	110	10YR 6/6	moderate	.	17.5
51	4.7	3.29	0.24	14	6.1	10	2.08	1.62	0.21	0.08	.	.	2.49	0.51	.	0.58	27	15	58	110	2.5Y 5/2.5	slow	.	0
52	4.6	2.17	0.26	8	3.8	14	3.46	2.17	0.25	0.07	.	.	3.53	0.62	.	0.82	26	24	50	110	2.5Y 5/4	moderate	.	0
53	4.4	1.69	0.12	14	3.7	8	0.36	0.25	0.16	0.39	.	.	2.78	0.59	.	0.87	14	63	23	40	2.5Y 5/5	moderate	.	25
54	4.1	1.07	0.11	10	10.5	5	0.51	0.17	0.08	0.06	.	.	4.02	0.6	.	1.26	17	58	25	110	2.5Y 5/4	moderate	.	2.1
55	5.1	2.23	0.17	13	15.4	6	2.12	0.66	0.12	0.06	.	.	0.39	0.1	.	1.08	9	83	8	110	10YR 2.5/1.5	quick	.	0

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
56	4.2	1.58	0.12	13	11.5	4	0.36	0.2	0.08	0.02	.	.	4.02	0.62	.	0.92	19	50	31	110	2.5Y 6/7	moderate	.	27.5
57	4.5	1.01	0.12	8	3.4	6	0.41	1.2	0.12	0.06	.	.	1.87	0.46	.	.	22	38	40	110	10YR 6/7	moderate	.	9
58	4.3	2.78	0.17	16	20	8	0.41	0.29	0.16	0.18	.	.	4.01	0.66	.	0.86	22	47	31	40	10YR 6/5	moderate	.	45
59	5.1	2.12	0.2	11	4.5	32	1.62	0.38	0.08	0.18	6.57	34	2.04	0.16	2.77	1.03	30	23	47	80	10YR3/2	slow	friable	2.1
60	5.4	1.46	0.21	7	7.4	77	4.58	2.09	0.17	0.07	8.97	77	0.83	0.15	3.81	0.97	38	20	42	80	10YR4/3	slow	friable	0
61	4.7	1.27	0.13	10	6	23	0.2	0.12	0.08	0.03	3.62	12	2.34	0.24	1.59	1.3	18	64	18	80	10YR4/3	quick	friable	21
62	6.2	0.65	0.08	8	72.4	148	7.14	2.53	0.33	0.03	6.14	100	0	0.1	2.8	1.17	14	69	17	100	10YR5/4	very slow	friable	0
63	5	1.6	0.1	16	21.6	29	1.01	0.28	0.08	0	1.96	70	0.24	0.08	0.26	1.04	10	70	20	80	2.5Y5/2	impeded	strong	0
64	4.7	1.33	0.12	11	23.4	18	0.3	0.08	0.06	0	2.62	17	1.11	0.05	0.46	1.3	14	55	31	60	10YR3/3	slow	friable	0
65	4.8	1.3	0.16	8	8.5	55	0.66	0.45	0.12	0	5.41	23	1.39	0.13	3.14	1.17	34	30	36	80	10YR3/3	slow	friable	0
66	6	3.02	0.34	9	20.5	66	13.19	2.4	0.17	0.07	13.67	100	0	0.02	3.96	0.95	41	6	53	100	10YR3/2	moderate	friable	0
67	4.4	2.61	0.28	9	3	149	0.72	0.87	0.36	0.19	10.39	21	3.25	0.01	2.81	0.85	46	10	44	60	10YR3/2	moderate	very friable	15
68	4.8	1.13	0.09	13	7.8	46	0.41	0.35	0.08	0	4.28	20	1.85	0.08	2.41	1.1	20	46	34	30	10YR3/2	moderate	friable	1.6
69	4.8	1.67	0.11	15	4.3	53	0.36	0.26	0.13	0.03	7.66	10	3.57	0.08	2.14	1.09	23	40	37	40	2.5Y4/4	quick	friable	1.7
70	4.7	1.9	0.21	9	4.3	65	1.55	2.67	0.13	0.08	5.86	76	0.87	0.19	3.74	1.08	34	24	42	15	2.5Y3/2	very slow	friable	0
71	4.8	1.62	0.22	7	3	47	1.26	1.62	0.09	0.05	9.3	32	2.09	0.79	3.73	1.04	40	15	45	80	10YR3/3	slow	friable	0
72	6	1.93	0.26	7	28.2	124	13.77	3.14	0.26	0.08	12.94	100	0	0	3.44	0.97	33	15	52	100	10YR3/3	moderate	friable	0
73	5	1.49	0.18	8	7.8	48	1.24	0.74	0.09	0.05	6.18	34	1.48	0.3	2.75	0.77	37	25	38	80	10YR3/3	very slow	friable	0
74	4.7	1.09	0.13	8	9.4	38	0.41	0.5	0.08	0.02	3.41	30	1.9	0.28	2.74	1.09	22	56	22	80	10YR4/3	quick	friable	15
75	4.5	2.04	0.2	10	25.8	93	1.06	0.44	0.18	0.02	6.37	27	2.06	0.14	2.93	1.04	39	17	44	20	2.5Y5/6	moderate	friable	20
76	4.6	2.86	0.22	13	7.4	101	0.52	0.41	0.19	0.05	11.04	11	7.18	0.65	2.53	0.91	30	40	30	80	10YR5/6	moderate	friable	20
77	4.3	1.23	0.11	11	16.1	43	0.54	0.32	0.09	0.37	5.05	26	3.53	0.39	2.49	1.17	23	54	23	100	10YR6/6	moderate	friable	15
78	4.9	1.36	0.16	9	2.7	71	0.98	1.27	0.15	0.06	7.89	31	3.06	0.2	3.69	1.13	32	24	44	80	10YR5/6	moderate	friable	0
79	5.2	1.84	0.2	9	6.8	52	5.16	1.58	0.11	0.06	6.88	100	0.56	0	3.38	1.22	27	27	46	100	2.5Y5/4	quick	friable	0
80	5	0.69	0.14	5	5.1	128	0.87	0.59	0.26	0.06	6.38	28	2.24	1.56	4.87	1.28	40	1	59	70	10YR5/3	quick	friable	25
81	4.7	1.32	0.14	9	11.7	43	0.52	0.22	0.09	0.09	4.84	19	2.09	0.8	2.53	1.19	19	58	23	100	10YR3/2	quick	friable	25
82	4.9	1.01	0.1	10	6.4	28	0.92	2.16	0.06	0.04	2.92	100	0.63	0.29	2.14	1.47	19	41	40	30	10YR6/8	very slow	friable	0
83	4.7	1.94	0.2	10	4.5	60	0.75	0.62	0.09	0.14	8.73	18	3.58	1.1	3.8	0.87	33	15	52	110	10YR5/4	moderate	friable	0
84	5.1	1.08	0.14	8	16.2	138	3.5	0.65	0.26	0.69	6.98	73	1.07	0.09	2.21	1	30	23	47	90	10YR3/2	very slow	friable	15

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat (%)	Al^{3+}	H^{+}	Fe^{3+} (%)	BD (g/cm^3)	Clay	Sand	Silt	Depth (cm)	Colour	Drainage	Consistency	Slope (%)
	-	(%)		-	(ppm)		(me/100g)						(me/100g)				(%)							
85	5.6	1.59	0.23	7	11	92	11.63	3.28	0.11	0.13	11.31	100	0.2	0	3.44	1.02	38	2	60	100	10YR5/2	slow	friable	0
86	5.6	1.92	0.19	10	13	86	1.08	0.27	0.18	0.08	7.55	21	2.8	0.32	3.14	0.91	30	30	40	100	2.5Y5/4	very slow	friable	0
87	4.7	0.85	0.06	14	43.6	2	0.46	0.17	0	0.06	3.81	18	1.03	0.21	0.33	1.24	22	38	40	110	10YR5/2	very slow	friable	0
88	4.4	1.75	0.14	13	9.3	19	1.22	0.38	0.04	0.06	3.46	49	1.42	0.17	0.16	1.55	19	34	47	110	10YR3/2	impeded	friable	0
89	4.4	3.44	0.19	18	24.6	99	1.32	0.66	0.21	0.19	6.12	39	3.29	0.64	0.54	1.24	30	37	33	110	10YR5/2	very slow	friable	0
90	4.5	3.55	0.13	27	17.1	98	0.66	0.38	0.08	0.1	4.51	27	0.98	0.39	0.34	1.12	20	61	19	60	10YR4/2	moderate	friable	0
91	4.4	2.27	0.17	13	11.5	19	0.52	0.29	0.04	0.28	4.66	24	1.1	0.25	1.04	1.1	33	42	25	100	2.5Y3/2	quick	friable	0
92	4.2	2.55	0.16	16	22.7	76	0.49	0.29	0.16	0.06	5.99	17	2.11	0.29	1.96	0.89	34	30	36	55	10YR5/4	moderate	friable	10
93	4.1	2.58	0.33	8	14	192	1.98	0.45	0.38	0.45	22.83	14	8.43	1.94	1.15	0.8	52	14	34	100	10YR4/2	very slow	strong	25
94	4.3	2.02	0.19	11	7.6	81	0.52	0.53	0.17	0.17	8.11	17	3.09	0.5	2.84	1.02	41	9	50	100	10YR5/4	moderate	friable	0
95	4.1	2.08	0.2	10	3.8	65	0.26	0.29	0.13	0.02	7.45	9	3.11	0.44	3.04	1.07	38	31	31	53	10YR4/4	quick	friable	10
96	4.3	1.46	0.17	9	3.1	48	0.32	0.32	0.1	0.42	6.82	17	2.25	0.44	3.16	0.83	41	28	31	80	7.5YR5/6	impeded	friable	20
97	4.8	3.1	0.26	12	6.8	40	2.45	1.68	0.08	0.08	7.41	58	1.33	0.22	2.35	0.87	26	27	47	100	10YR5/4	moderate	friable	0
98	4.3	3.23	0.33	10	7.4	90	0.28	0.59	0.19	0.13	14.24	8	5.77	1.24	3.44	0.98	51	3	46	100	10YR5/6	very quick	friable	2.2
99	4.3	1.95	0.21	9	11.5	47	0.44	0.87	0.1	0.06	8.98	16	3.24	0.53	3.49	1.11	33	31	36	100	10YR5/4	moderate	friable	25
100	4.4	1.95	0.17	11	5.7	71	0.57	0.53	0.15	0.26	8.19	18	2.77	0.64	3.11	1	34	23	43	100	10YR5/4	very slow	friable	0
101	4.5	2.15	0.22	10	3.8	56	0.47	0.95	0.12	0.21	7.28	24	1.63	0.22	3.7	1.09	32	25	43	100	10YR4/3	moderate	friable	0
102	4.2	2.88	0.21	14	8.8	38	0.27	0.23	0.08	0.17	7.36	10	2	0.41	3.12	0.99	43	29	28	100	10YR3/2	very quick	friable	0
103	4.2	1.56	0.16	10	4.4	38	0.26	0.26	0.08	0.2	6.75	12	3.97	0.65	3.58	1.1	33	28	39	110	10YR5/6	moderate	friable	28
104	4.2	1.11	0.08	14	2.9	58	0.26	0.05	0.12	0	4.71	9	1.56	0.11	3.13	0.92	48	22	30	12	10YR3/2	quick	very friable	0
105	5.1	3.41	0.29	12	8.7	293	12.66	1.72	0.62	0.19	14.37	100	0.15	0	3.95	0.73	47	6	47	110	10YR3/2	impeded	friable	33
106	5.6	5.44	0.42	13	13.5	81	16.44	3.48	0.17	0.2	16.61	100	0.25	0.02	1.81	0.73	58	5	37	100	10YR5/1	impeded	loose	0
107	4.2	5.56	0.24	23	46.7	96	0.91	0.37	0.2	0.13	8.77	18	1.38	0.09	0.13	.	20	55	25	110	10YR3/2	impeded	loose	0
108	5.1	3.16	0.16	20	15.9	110	2.44	0.79	0.23	0.12	4.35	82	0.21	0	0.08	.	21	70	9	100	10YR3/3	quick	loose	0
109	4.1	3.49	0.33	11	11.2	86	0.6	0.45	0.18	0.03	22.94	5	4.67	0.77	2.24	1.09	65	18	17	100	10YR5/6	moderate	friable	0
110	4.4	1.18	0.09	13	4.9	39	0.31	0.24	0.08	0.09	6.45	11	2	0.03	3.25	1.01	40	29	31	100	10YR3/2	very slow	friable	0
111	4.2	1.89	0.16	12	3.9	28	0.31	0.36	0.06	0.06	6.85	12	3.12	0.08	3.27	1.11	32	26	42	30	10YR3/2	very quick	friable	0
112	4.1	2.04	0.25	8	4.2	60	0.22	0.24	0.12	0.03	9.88	6	4.68	0.18	2.39	1.07	49	5	46	80	10YR5/6	quick	friable	13
113	4.1	2	0.24	8	5.4	61	0.11	0.41	0.12	0.06	10.43	7	4.47	0.24	3.13	1.04	51	6	43	100	10YR5/4	quick	friable	20

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	Bsat	Al^{3+}	H^+	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
114	4.1	1.35	0.12	11	12.1	39	0.16	0.16	0.08	0.12	5.46	10	4.09	0.34	1.94	1.21	30	30	40	100	10YR4/3	moderate	friable	14
115	4.5	2.41	0.17	14	8.5	85	0.64	0.87	0.18	0.05	5.47	32	2.81	0.04	3.21	0.89	25	27	48	75	10YR3/2	quick	very friable	0
116	4.1	2.67	0.24	11	4.7	152	0.22	0.65	0.32	0.02	12.77	9	9.96	0.69	3.94	1.04	54	1	45	100	10YR5/8	impeded	friable	19
117	5.3	4.04	0.25	16	3.9	81	2.74	1.31	0.17	0.82	8.05	63	0.65	0	3.27	0.94	25	35	40	110	10YR5/2	moderate	loose	0
118	5.8	2.44	0.24	10	6.8	39	10.1	2.35	0.08	0.06	8.81	100	0	0	3.74	0.96	27	2	71	100	10YR5/4	very slow	friable	0
119	4.6	1.88	0.19	10	27.6	39	0.74	0.89	0.08	0.02	6.55	26	1.89	0.01	3.48	1.08	34	17	49	110	10YR3/2	very slow	very friable	0
120	4.9	2.27	0.23	10	472.1	39	4.58	1.45	0.08	0.02	10.1	61	0.94	0.05	3.05	1.11	37	8	55	100	10YR3/2	very slow	very friable	0
121	4.2	3.17	0.29	11	2.8	71	0.72	0.9	0.15	0.08	17.18	11	8.08	0.31	2.08	1.34	48	5	47	100	10YR5/4	very slow	friable	0
122	4.4	3.07	0.26	12	11.5	86	0.86	0.62	0.18	0.02	15.4	11	7.77	0.19	2.12	1.05	35	17	48	100	10YR5/4	quick	friable	27
123	4.4	1.95	0.2	10	6	43	0.27	0.34	0.09	0.02	14.52	5	9.73	0.84	2.34	1.41	41	12	47	100	7.5YR5/6	quick	friable	20
124	4.4	1.85	0.22	8	4.4	53	0.38	0.4	0.09	0.03	15.07	6	9.06	0.57	2.53	1.2	45	10	45	100	10YR5/6	moderate	friable	0
125	4.8	5.32	0.4	13	12.5	68	5.31	1.97	0.13	0.13	15.37	49	0.5	0.21	0.98	.	23	35	42	40	10YR5/2	impeded	loose	0
126	4.6	2.14	0.14	15	18	38	0.31	0.28	0.08	0.02	10.15	7	4.11	0.25	1.35	1.45	27	41	32	100	10YR5/2	moderate	very friable	0
127	4.2	2.51	0.21	12	7.2	33	0.39	0.22	0.07	0	15.91	4	11.34	0.12	2.28	1.22	45	10	45	100	7.5YR5/6	quick	strong	22
128	4.5	2.36	0.21	11	8.6	43	0.27	0.3	0.09	0.02	12.06	6	6.95	0.69	2.03	1.24	36	22	42	100	10YR5/4	quick	friable	18
129	4.6	2.21	0.26	9	6.9	76	0.5	0.72	0.16	0	14.38	10	8.23	0.2	2.5	1.3	46	7	47	60	10YR5/4	very quick	strong	38
130	4.5	1.72	0.18	10	3.7	47	0.11	0.18	0.09	0.02	14.31	3	9.69	0.67	2.43	1.21	43	16	41	40	10YR5/6	very quick	strong	20
131	4.4	2	0.19	11	10.5	71	0.37	0.66	0.15	0	12.6	9	10.68	0.01	1.97	1.03	36	25	39	60	10YR3/2	quick	very friable	42
132	4.6	3.68	0.25	15	14.5	52	0.42	0.29	0.1	0.02	11.25	7	5.36	0.17	1.6	1.07	27	46	27	100	7.5YR3/2	moderate	very friable	0
133	4.4	2.27	0.22	10	6.8	45	0.38	0.27	0.09	0.02	16.83	5	11.28	0.49	2.38	1.09	52	6	42	50	10YR5/6	quick	friable	32
134	6.2	1.46	0.14	10	5.7	94	4.82	2.76	0.17	0.58	8.84	94	0	0.13	2.4	1.37	29	33	38	7	2.5Y5/2	moderate	friable	0
135	4.5	1.97	0.24	8	8.6	52	0.91	0.87	0.09	0.05	13.89	14	9.16	0.28	2.62	1.17	45	12	43	50	10YR5/6	moderate	strong	10
136	4.4	2.8	0.21	13	8	71	0.36	0.34	0.15	0.05	12.34	7	6.18	0.51	1.65	1.23	32	30	38	30	10YR4/4	very slow	strong	5
137	4.3	3.69	0.3	12	13	80	0.32	0.61	0.17	0.03	17.88	6	8.97	0.86	2.17	0.88	48	8	44	60	10YR5/6	quick	friable	0
138	4.6	6.9	0.56	12	45.8	73	1.64	0.7	0.15	0.06	20.7	12	5.12	0.12	2.02	0.63	55	7	38	100	10YR3/2	impeded	strong	0
139	5.1	1.76	0.19	9	12.9	71	3.55	2.79	0.15	0.05	12.27	53	2.9	0.06	1.75	1.25	31	29	40	30	10YR5/4	very quick	friable	42
140	4.6	2.44	0.24	10	3.1	61	0.36	0.84	0.13	0.06	15.42	9	7.59	0.24	2.45	1.22	45	11	44	40	10YR5/4	very quick	friable	38
141	4.7	1.78	0.24	7	5	80	3.37	3.93	0.15	0.07	13.39	56	1.81	0.26	2.33	1.09	39	20	41	40	10YR5/4	very quick	friable	44
142	4.1	2.01	0.22	9	9	52	0.38	0.27	0.07	0.02	14.12	5	10.06	0.25	1.86	0.85	49	17	34	50	10YR3/2	very quick	friable	14

Sample nr	pH	C	N	C/N	P	K	Ca²⁺	Mg²⁺	K⁺	Na⁺	CEC	Bsat	Al³⁺	H⁺	Fe³⁺	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm³)	(%)			(cm)				(%)
143	4.1	1.99	0.23	9	7.8	60	0.62	0.26	0.11	0	12.11	8	6.86	0.22	1.78	1.02	43	23	34	60	10YR5/4	very quick	friable	29
144	4.2	1.69	0.18	9	10.8	54	0.56	0.22	0.09	0	11.54	8	8.06	0.33	1.73	1.22	41	25	34	60	10YR3/2	quick	strong	40
145	4.4	1.73	0.17	10	5.2	35	0.51	0.22	0.06	0	10.89	7	6.37	0.32	1.51	0.99	39	27	34	60	10YR5/6	very quick	strong	29
146	4.6	1.17	0.12	10	5.4	57	1.28	0.84	0.09	0.03	7.12	31	1.7	0.11	1.4	1.35	25	48	27	60	10YR6/4	very slow	loose	0
147	4.6	2.07	0.22	9	7.4	61	0.49	0.27	0.09	0	12.18	7	6.8	0.25	1.88	1.2	43	24	33	60	10YR5/6	very quick	friable	30
148	4.5	3.21	0.27	12	10.9	110	0.93	1.19	0.22	0.05	15.27	16	5.4	0.34	2.16	0.93	33	35	32	20	10YR5/4	very quick	friable	28
149	4.8	1.14	0.12	10	5.2	40	1.28	1.69	0.06	0.03	9.28	33	2.96	0.18	1.79	1.41	29	40	31	60	10YR5/4	slow	very strong	5
150	4.5	1.9	0.18	11	6.3	53	0.55	0.16	0.07	0	10.67	7	5.58	0.31	1.7	1.14	36	25	39	100	10YR5/6	moderate	friable	10
151	4.4	2.18	0.2	11	5.8	44	0.57	0.09	0.07	0.04	10.46	7	5.79	0.28	2.14	1.08	42	25	33	100	10YR5/4	quick	friable	18
152	4.6	1.46	0.15	10	6.2	57	0.84	0.63	0.07	0.02	7.66	20	3.19	0.24	1.93	1.47	29	39	32	30	10YR5/4	very slow	friable	0
153	4.3	1.54	0.12	13	13.4	27	0.51	0.17	0.04	0.02	9.19	8	4.94	0.29	1.82	1.39	21	42	37	110	10YR5/4	very slow	friable	0
154	4.3	2.26	0.22	10	11.7	62	0.47	0.23	0.1	0	11.29	7	6.65	0.31	1.93	1.16	41	28	31	60	10YR3/2	very quick	friable	34
155	5.4	0.74	0.07	11	18.4	104	5.1	1.59	0.18	0.03	7.31	94	0.11	0.09	2.59	1.26	13	72	15	110	10YR5/3	impeded	loose	0
156	4.2	2.12	0.26	8	4.3	279	0.53	0.25	0.59	0.02	16.42	8	10.53	0.27	2.59	1.04	53	10	37	60	10YR5/4	very quick	friable	30
157	4.6	2.75	0.23	12	7.5	112	0.53	1.48	0.22	0.07	12.55	18	4.77	0.39	2.21	1	38	32	30	60	10YR5/6	moderate	friable	22
158	4.4	1.55	0.19	8	4.4	40	0.52	0.85	0.06	0.02	10.78	13	5.81	0.11	2.46	1.17	42	23	35	60	10YR5/4	quick	strong	30
159	3.9	1.81	0.23	8	5.3	66	0.53	0.26	0.13	0.02	13.63	7	8.89	0.49	2.7	0.99	54	7	39	60	10YR5/6	quick	strong	26
160	4.7	1.63	0.25	7	4.6	81	0.68	0.43	0.17	0.1	9.3	15	4.22	0.16	4.26	1.06	46	10	44	80	10YR4/4	moderate	friable	32
161	4.4	1.38	0.12	12	1.7	38	0.41	0.17	0.08	0	10.38	6	6.19	0.26	3.18	1.06	40	29	31	80	7.5YR3/2	very slow	friable	5
162	4.4	1.43	0.13	11	3.3	48	0.47	0.22	0.1	0	9.23	9	5.63	0.15	3.01	0.87	31	26	43	110	7.5YR3/2	impeded	friable	0
163	4.5	2.02	0.2	10	13	86	0.95	0.79	0.18	0.15	11.26	18	8.05	1.28	1.97	1.12	32	42	26	80	10YR4/2	quick	friable	18
164	5.6	0.97	0.11	9	11.2	78	7.15	2.32	0.09	0.13	8.89	100	0	0.11	1.69	0.98	15	59	26	80	2.5YR4/2	impeded	friable	0
165	4.5	1.65	0.16	10	9.5	33	1.36	0.2	0.07	0.15	6.56	27	2.43	0.56	1.27	1.19	21	47	32	80	10YR3/3	impeded	friable	0
166	4.7	1.34	0.12	11	8.4	33	0.65	0.19	0.07	0.13	6.6	16	3.6	0.3	1.3	1.23	26	48	26	80	10YR5/4	moderate	friable	0
167	4.9	1.84	0.22	8	6.3	80	0.77	1	0.17	0.15	16.63	13	9.14	1.17	2.83	0.8	47	14	39	80	10YR3/3	very quick	friable	28
168	5.4	1.17	0.19	6	4.3	85	4.35	1.43	0.18	0.24	12.17	51	1.94	0.14	4.31	0.95	39	21	40	20	10YR6/6	quick	friable	30
169	5.1	1.19	0.12	10	11.4	43	1.57	0.7	0.09	0.26	4.65	56	0.29	0.15	4.13	.	6	89	5	20	2.5Y5/1	impeded	loose	0
170	4.5	2.04	0.16	13	8.9	38	0.82	0.2	0.08	0.13	7.29	17	2.52	0.51	0.87	1.03	20	31	49	80	10YR5/4	impeded	friable	0
171	4.6	1.98	0.23	9	9.8	57	1.04	0.97	0.12	0.14	14.85	15	7.01	0.48	1.77	1.02	38	27	35	80	10YR5/4	quick	friable	22

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	Bsat	Al^{3+}	H^+	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm³)	(%)			(cm)				(%)
172	5.2	1.48	0.16	9	6.1	34	1.79	0.32	0.07	0.13	6.36	36	1.43	0.18	1.17	1.38	22	47	31	80	10YR4/2	very slow	friable	0
173	4.9	1.33	0.16	8	38.6	46	1.51	0.46	0.09	0.13	5.17	42	1.56	0.18	1.17	1.22	20	51	29	80	10YR4/3	moderate	friable	0
174	5.5	1.98	0.25	8	15.1	48	9.5	2.45	0.1	0.14	14.67	83	0	0.07	1.86	0.99	32	17	51	80	2.5Y5/3	very slow	friable	0
175	4.8	0.94	0.11	9	3.6	48	0.58	0.83	0.09	0.13	11.52	14	5.98	0.48	2	1.21	35	33	32	60	10YR5/6	very quick	strong	15
176	5.9	2.57	0.32	8	18.9	199	13.68	5.13	0.42	0.21	20.59	94	0	0.05	2.08	0.87	36	22	42	100	10YR4/2	impeded	strong	0
177	4.8	1.27	0.18	7	6	66	0.84	0.61	0.14	0.14	13.92	12	8.52	0.88	2.1	0.9	37	13	50	60	10YR6/4	very quick	strong	30
178	5.4	0.98	0.14	7	6.9	61	3.98	0.78	0.13	0.13	6.5	77	0.9	0.22	1.49	1.12	22	55	23	40	2.5Y4/2	very quick	friable	25
179	4.8	0.76	0.1	8	6	34	1.24	0.28	0.07	0.13	9.24	19	7.39	0.64	1.45	1.06	28	46	26	80	10YR7/6	very quick	friable	32
180	4.6	1.7	0.15	11	9.5	46	1.8	0.29	0.08	0.16	9.47	25	6.36	0.2	1.02	0.91	24	55	21	100	10YR3/1	very quick	friable	25
181	4.7	2.09	0.2	10	61.4	62	1.11	0.36	0.13	0.13	18.15	10	9.47	1.01	2.38	0.95	37	16	47	100	10YR3/1	very quick	friable	22
182	4.1	1.35	0.2	7	2.6	118	0.68	1.03	0.25	0.18	12.47	17	6.83	0.62	2.17	1.17	39	11	50	80	2.5Y4/2	very quick	friable	34
183	4.1	1.59	0.17	9	5.1	81	1.19	0.76	0.17	0.17	11.36	20	5.86	0.46	1.76	1.11	38	41	21	60	10YR5/4	very quick	friable	21
184	4	1.33	0.16	8	5.9	71	0.8	1.5	0.15	0.23	11.96	22	7.62	0.66	1.98	1.05	38	32	30	60	10YR5/4	quick	friable	20
185	4.8	1.25	0.14	9	4.7	109	6.81	2.76	0.23	0.18	11.71	85	0.92	0.15	1.45	1.38	26	44	30	60	10YR4/2	quick	strong	28
186	4.4	2.06	0.15	14	12.9	28	1.05	0.35	0.06	0.14	4.95	32	1.18	0.24	0.42	.	14	62	24	70	2.5Y5/2	impeded	loose	0
187	4	1.89	0.2	9	8.2	62	0.56	0.28	0.13	0.18	18.72	6	11.89	1.46	2.17	1.1	45	13	42	80	7.5YR5/4	very quick	strong	18
188	5.5	1.54	0.18	9	10.7	90	9.27	2.83	0.19	0.12	13.3	93	0	0.13	1.86	1.58	25	34	41	100	2.5Y4/2	impeded	friable	0
189	4.6	1.67	0.13	13	20.8	44	2.16	0.57	0.09	0.13	4.56	65	0.52	0.18	0.5	1.02	13	64	23	60	2.5Y5/2	impeded	friable	0
190	5.5	1.21	0.13	9	5.4	72	13.32	3.17	0.15	0.19	15.55	100	0	0.04	2.57	1.06	17	60	23	60	2.5Y5/3	impeded	very friable	0
191	3.6	1.74	0.17	10	3.2	48	0.79	0.29	0.1	0.17	13.39	10	6.16	0.75	2.72	1.12	49	25	26	60	10YR5/3	moderate	friable	16
192	4.2	1.96	0.27	7	3.4	72	3.94	1.68	0.15	0.28	13.42	45	2.92	0.27	2.1	0.9	42	7	51	60	2.5Y4/2	very slow	friable	0
193	4.2	1.7	0.22	8	4.2	85	2.36	2.1	0.18	0.16	18.81	26	7.25	0.74	2.36	0.9	40	16	44	60	10YR4/3	very quick	strong	30
194	5	4.29	0.29	15	14.1	118	15.15	3.51	0.25	0.17	21.62	88	0	0.13	1.48	0.97	31	33	36	60	2.5Y5/3	moderate	friable	15
195	4.8	1.28	0.18	7	6.2	123	4.58	1.74	0.26	0.13	9.9	68	2.05	0.23	2.61	1.06	34	27	39	60	2.5Y4/2	moderate	strong	21
196	4.4	1.51	0.25	6	3.2	61	7.49	2.29	0.13	0.45	14.95	69	1.01	0.28	2.41	1.03	44	2	54	60	2.5Y4/2	very slow	strong	0
197	4.6	1.71	0.21	8	211.7	71	5.24	2.36	0.15	0.15	12.22	65	0.63	0.19	2.2	0.85	28	37	35	80	2.5Y3/2	very slow	friable	0
198	5	1.9	0.24	8	10.5	81	10.34	2.8	0.17	0.12	15.1	89	0	0.08	2.45	1	35	19	46	80	2.5Y5/3	very slow	friable	0
199	4.2	1.3	0.15	9	6.2	88	2.69	0.92	0.18	0.13	8.51	46	1.68	0.28	2.55	1.27	26	42	32	80	10YR4/2	moderate	friable	0
200	3.7	1.33	0.21	6	5.9	62	0.8	0.49	0.13	0.19	11.96	13	6.25	0.5	3.05	1.02	36	14	50	80	10YR5/4	quick	strong	0

Appendix 2a. All plot's data and soil surface characteristics (see main report for definitions; part 2)

Sample nr	Local Fertility (very low - very high)	Standard Fertility (very low - very high)	Standard Suitability for Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	Local Suitability for Rice	Soil Type Classification Standard	Local
1	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tana Tiem (M)
2	Moderate	Very Low	N	N	S3	N	N	N	N	S	Oxisols	-
3	Moderate	Low	S3	S3	S2	S3	N	S3	S3	S	Alfisols	Tana Tiem (M)
4	Low	Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	Tana Mbloa (M)
5	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Tiem (M)
6	Moderate	Low	S3	S3	S2	S3	N	S3	S3	S	Oxisols	Tana Tiem Bao (M)
7	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	-
8	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	-
9	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	-
10	Very Low	Very Low	N	N	N	N	N	N	N	N	Oxisols	-
11	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	-
12	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Salang Bala (K)
13	Low	Very Low	S3	S3	S3	N	N	N	N	N	Oxisols	Tana A'bu (K)
14	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Salang Bala (K)
15	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Salang Bala (K)
16	Low	Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	Tana A'bu (K)
17	Low	Low	S3	S3	S3	S3	N	S3	S3	N	Ultisols	Tana A'bu (K)
18	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tana A'bu (K)
19	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tana A'bu (K)
20	Moderate	Low	N	N	N	N	N	N	N	S	Entisols	Tano Pangka (P)
21	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Punyuh (P)
22	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	Tana Salang (K)
23	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	Tana Salang A'bu(K)
24	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tana A'bu Pulut (K)
25	Moderate	Low	S3	S3	S3	N	N	N	N	S	Ultisols	Tana Salang (K)
26	Very Low	Low	S3	S3	S3	N	N	N	N	N	Inceptisols	Tana Bengaheng (K)
27	Very Low	Low	S3	S3	S3	S3	N	S3	S3	S	Alfisols	Tana Bengaheng (K)
28	Moderate	Very Low	S3	S3	S3	N	N	N	N	N	Oxisols	Tana Bawang (K)
29	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tana Mahing (K)
30	Very Low	Low	N	N	N	N	N	N	N	N	Ultisols	Tana Mahing (K)
31	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Salang (K)
32	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	Tana Bala (K)
33	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	Tana Bala (K)

Sample	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability	Soil Type Classification	
nr	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice	Standard	Local
34	Very Low	Low	S3	S3	S2	S3	N	S3	S3	N	Alfisols	Tana Aib (K)
35	Very Low	Low	S3	S3	S3	S3	N	S3	S3	N	Ultisols	Tana Salang A'bu (K)
36	Moderate	Low	S3	S3	S1	S3	N	S3	S3	S	Oxisols	Tana Leka
37	Moderate	Low	S3	S3	S1	S3	N	S3	S3	S	Oxisols	Tana Leka
38	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Salang A'bu (K)
39	Low	Low	S3	S3	S3	N	N	N	N	S	Entisols	Tana Mbloa (M)
40	Moderate	Low	S3	S3	S1	S3	N	S3	S3	S	Alfisols	Tana Pulut (K)
41	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Pulut (K)
42	Low	Low	S3	S3	S1	S3	N	S3	S3	S	Alfisols	Tana A'bu (K)
43	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Tihgah (K)
44	Low	Low	N	N	N	N	N	N	N	N	Ultisols	-
45	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	-
46	Low	Low	N	N	N	N	N	N	N	N	Oxisols	-
47	Low	Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	-
48	Low	Low	N	N	S3	N	N	N	N	N	Oxisols	Tana Pulut (K)
49	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	-
50	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	-
51	Moderate	Low	S3	S3	S3	S3	N	S3	S3	N	Ultisols	Tano Pangka (P)
52	.	Low	S3	S3	S3	S3	N	S3	S3	N	Ultisols	-
53	.	Very Low	S3	S3	S3	N	N	N	N	N	Oxisols	Tano Mengan (P)
54	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	Tano Punyuh (P)
55	Moderate	Very Low	N	N	N	N	N	N	N	N	Oxisols	Tano Punyuh (P)
56	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tano Mengan (P)
57	Moderate	Very Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Punyuh (P)
58	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tano Mengan (P)
59	.	Low	S3	S3	S2	S3	N	S3	S3	S	Oxisols	Tana Mla (M)
60	High	Low	S3	S3	S2	S3	N	S3	S3	N	Oxisols	Tana Layah, Tana Tiem (M)
61	Low	Very Low	S3	S3	S3	S3	N	N	N	N	Ultisols	Tana Mla. (M)
62	Moderate	Low	S3	S3	S3	S3	N	N	N	N	Entisols	Tana Yie Tiem. (M)
63	Low	Very Low	N	N	S3	N	N	N	N	N	Oxisols	Tana Pangkah, Yie Toi (M)
64	Moderate	Very Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Pangkah, Tana tiem, Yie Toi (M)
65	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Ya , Ngemura Ran, Tana Tiem Mla. (M)
66	Moderate	Moderate	S3	S3	S2	S3	N	S3	S3	S	Oxisols	Tana Lau Ran (Muara Ran), Tana Tiem. (M)
67	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Lepei, Tana Lohoya , Tana Mieg kunyi (M).

Sample nr	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability	Soil Type Classification	
	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice	Standard	Local
68	Moderate	Very Low	S3	S3	S3	N	N	N	N	S	Oxisols	Tana Lepei, Tana Lohoya, Tana Mieg Kunyi. (M)
69	Moderate	Low	N	N	N	N	N	N	N	N	Oxisols	Tana Tiem, Tana Mieg Kunyie (M)
70	High	Low	N	N	N	N	N	N	N	S	Entisols	Tana Mbloa (M)
71	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Mbloa (M)
72	Moderate	Low	S3	S3	S2	S3	N	S3	S3	N	Oxisols	Tana Mbloa, Tana Tiem (M)
73	Very Low	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tana Mbla tuuk (M)
74	Low	Very Low	N	N	S3	N	N	N	N	S	Ultisols	Tana Mbla (M)
75	Low	Low	N	N	N	N	N	N	N	S	Entisols	Tana Mbloa (M)
76	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Mieg Kunyie (M)
77	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Mieg Kunyie (M)
78	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Mbloa (M)
79	Low	Low	S3	S3	S2	S3	N	N	N	S	Oxisols	Tana Mbloa (M)
80	Very Low	Low	N	N	S3	N	N	N	N	N	Oxisols	Tana Mieg kunyie (M)
81	Moderate	Very Low	N	N	S3	N	N	N	N	S	Ultisols	Tana Mieg Kunyie, Tana Mbloa (M)
82	Low	Very Low	S3	S3	S3	N	N	N	N	S	Entisols	Tana Bao-bao, Tana Mbloa (M)
83	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Mieg Kunyie (M)
84	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Mieg Kunyie (M)
85	High	Low	S3	S3	S2	S3	N	S3	S3	S	Oxisols	Tana Tiem Bao-bao (M)
86	Very Low	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tana Mieg Kunyie (M)
87	Very Low	Very Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tana Toi, Tana Toi Pangkah (M)
88	Very Low	Very Low	S3	N	S3	N	N	N	N	N	Oxisols	Tana Bao-Bao (M)
89	Very Low	Moderate	N	S3	S3	S3	N	N	N	N	Oxisols	Tana Bao-Bao (M)
90	Very Low	Very Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	Tana Tiem, Tana Pangkah Lohoya (M)
91	Very Low	Very Low	S3	N	S3	N	N	N	N	N	Oxisols	Tano Jemit (P)
92	Very Low	Low	N	S3	S3	S3	N	S3	S3	N	Oxisols	Tano Mengan (P)
93	Moderate	Low	S3	S3	S3	S3	N	N	N	S	Inceptisols	Tano Mpu (P);
94	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Mengan (P)
95	Low	Low	S3	N	S3	N	N	N	N	S	Oxisols	Tano Mengan (P)
96	Low	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Mengan (P)
97	Moderate	Low	N	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Pangkah (P)
98	Moderate	Low	S3	N	N	N	N	N	N	S	Oxisols	Tano Mengan (P)
99	Low	Low	N	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Mengan (P)
100	Very Low	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tano Mengan; Tano Pakat (P)
101	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Mengan (P)

Sample nr	Local Fertility	Standard Fertility (very low - very high)	Standard Suitability for Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	Local Suitability for Rice	Soil Type Classification Standard	Local
102	Moderate	Low	S3	N	N	N	N	N	N	S	Oxisols	Tano Bulah (P)
103	Moderate	Low	N	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Punyuh; Tano Mengan (P)
104	Moderate	Very Low	S3	N	N	N	N	N	N	S	Oxisols	Tano Pekelet; Tano Punyuh; Tano Jemit (P)
105	Very Low	Low	N	N	N	N	N	N	N	N	Entisols	Tano Mengan (P)
106	Moderate	Low	N	N	S3	N	N	N	N	N	Oxisols	Tano Pangkah (P)
107	Moderate	Low	N	N	S3	N	N	N	N	N	Oxisols	Tano Pangkah (P)
108	Moderate	Very Low	N	N	S2	N	N	N	N	N	Oxisols	Tano Pangkah (P)
109	Low	Low	N	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Mengan (P)
110	Low	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tano Mengan (P)
111	Moderate	Low	S3	N	N	N	N	N	N	S	Oxisols	Tano Punyuh; Tano Jemit (P)
112	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Mengan (P)
113	High	Low	N	S3	S3	S3	N	N	N	S	Oxisols	Tano Mengan (P)
114	High	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Bulah (P)
115	Low	Low	S3	N	N	N	N	N	N	S	Ultisols	Tano Mengan (P)
116	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Mengan (P)
117	Moderate	Low	N	S3	S2	S3	N	S3	S3	N	Oxisols	Tano Pangkah (P)
118	Moderate	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tano Mpu (P)
119	Moderate	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tano Bulah (P)
120	Moderate	Moderate	S3	S3	S3	S3	N	N	N	S	Oxisols	Tano Bulah (P)
121	Moderate	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tano Mengan (P)
122	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Mengan (P)
123	Moderate	Low	N	N	S3	N	N	N	N	N	Oxisols	Tano Mengan (P)
124	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Mengan (P)
125	Moderate	Low	N	N	S3	N	N	N	N	N	Entisols	Tano Pangkah (P)
126	Moderate	Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	Tano Jemit(P);
127	Very Low	Low	N	N	S3	N	N	N	N	N	Oxisols	Tano Mengan(P)
128	Very Low	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tano Jemit(P)
129	High	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Mengan(P); Tano Nyekadit(P)
130	Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tano Mengan(P); Tano Nyekadit(P)
131	Very Low	Low	N	N	N	N	N	N	N	N	Ultisols	Tano Batuh(P); Tano Jiet(P)
132	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Jemit; Tano Praeh; Tano Pakat (P)
133	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tano Mengan(P)
134	Very Low	Low	N	N	N	N	N	N	N	S	Entisols	Tano Batuh
135	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Mengan(P)

Sample	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability	Soil Type Classification	
nr	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice	Standard	Local
136	Low	Low	S3	S3	S3	N	N	N	N	N	Oxisols	Tano Jemit(P)
137	Very Low	Low	S3	S3	S3	S3	N	N	N	N	Inceptisols	Tano Batuh; Tano Bulah(P)
138	Moderate	Moderate	N	N	S3	N	N	N	N	N	Inceptisols	Tano Ancut(P)
139	Moderate	Low	N	N	N	N	N	N	N	N	Entisols	Tano Batuh(P)
140	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tano Batuh; Tano Jemit(P)
141	Very Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tano Batuh(P)
142	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Jemit(P)
143	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Jemit(P)
144	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Bulah(P)
145	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Mengan(P)
146	Very Low	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tano Pekelet; Tano Awa (P);
147	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Bulah(P)
148	Low	Low	N	N	N	N	N	N	N	S	Entisols	Tano Bulah; Tano Batuh(P)
149	Very Low	Low	S3	N	S3	S3	N	S3	S3	S	Oxisols	Tano Jemit(P)
150	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Jemit(P)
151	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Jemit(P)
152	Low	Low	S3	S3	S3	N	N	N	N	S	Oxisols	Tano Bulah(P)
153	High	Low	S3	N	S3	N	N	N	N	S	Oxisols	Tano Bulah(P)
154	Low	Low	N	N	N	N	N	N	N	S	Oxisols	Tano Bulah(P)
155	Moderate	Low	N	N	S3	N	N	N	N	S	Entisols	Tano Pkelet(P)
156	Moderate	Low	N	N	N	N	N	N	N	S	Inceptisols	Tano Jemit(P)
157	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tano Jemit(P)
158	Low	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Bulah(P)
159	Low	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Bulah(P)
160	Low	Low	N	S3	N	S3	N	S3	S3	S	Oxisols	Tano Bulah(P)
161	Low	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tano Bulah(P)
162	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tano Jemit(P)
163	Moderate	Low	N	N	S3	N	N	N	N	S	Oxisols	Tana Mieg(M)
164	Moderate	Low	N	N	S3	N	N	N	N	N	Alfisols	Tano Tiem Blouh(M)
165	Very Low	Low	N	N	S3	N	N	N	N	N	Oxisols	Tana Yie Mieg(M)
166	Low	Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	Tana Yie Mieg(M)
167	Very Low	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Mla(M)
168	Low	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Tau(M)
169	Very Low	Very Low	N	N	N	N	N	N	N	N	Entisols	Tano Pangkah(M)

Sample nr	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability	Soil Type Classification	
	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice	Standard	Local
170	Very Low	Low	N	N	S3	N	N	N	N	N	Ultisols	Tana Plub(M)
171	Low	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tana Mieg Kunyie(M)
172	Moderate	Low	S3	S3	S3	S3	N	N	N	S	Ultisols	Tana Tiem(M)
173	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Mla Tiem(M)
174	Moderate	Low	S3	S3	S3	S3	N	N	N	N	Oxisols	Tana Yie Tiem(M)
175	Low	Low	N	N	N	N	N	N	N	N	Oxisols	Tana Mla(M)
176	Moderate	Low	N	N	S3	N	N	N	N	S	Inceptisols	Tana Tiem(M)
177	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Mieg Bau(M)
178	High	Low	N	N	N	N	N	N	N	S	Alfisols	Tana Tiem(M)
179	Low	Low	N	N	N	N	N	N	N	S	Ultisols	Tana Mieg(M)
180	Low	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Mieg(M)
181	Very Low	Low	N	N	N	N	N	N	N	S	Ultisols	Tana Mla(M)
182	Moderate	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Mieg Bau(M)
183	Low	Low	N	N	N	N	N	N	N	S	Oxisols	Tana Mieg Mbloah(M)
184	Very Low	Low	N	N	S3	N	N	N	N	N	Oxisols	Tana Mla(M)
185	Moderate	Low	N	N	S3	N	N	N	N	S	Alfisols	Tana Tiem(M)
186	Very Low	Very Low	N	N	S3	N	N	N	N	N	Alfisols	Tana Pangkah(M); Tana Toi Bau(M);
187	Moderate	Low	N	N	N	N	N	N	N	S	Inceptisols	Tana Mla Lumpuem(M)
188	High	Low	N	N	S3	N	N	N	N	S	Oxisols	Tana Tiem Bau(M)
189	Moderate	Very Low	N	N	S3	N	N	N	N	S	Alfisols	Tana Pangkah(M); Tana Bau(M)
190	Moderate	Low	N	N	S3	N	N	N	N	N	Oxisols	Tana Yie Tiem(M)
191	Low	Low	S3	S3	S3	S3	N	S3	S3	N	Oxisols	Tana Mieg Kunyie(M)
192	High	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tana Tiem(M); Tana Entat(M)
193	Low	Low	N	N	N	N	N	N	N	S	Inceptisols	Tana Mohoya Talaye(M); Tana To'ou(M)
194	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Matau(M)
195	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S	Oxisols	Tana Tiem Mla; Tana Lenteya Hei (M)
196	Low	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tana Bau Entat(M)
197	Moderate	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tana Tiem(M)
198	Moderate	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tana Tiem Petlat(M)
199	Low	Low	S3	S3	S3	S3	N	S3	S3	S	Ultisols	Tana Mla Mieg(M); Tana Petantaung(M)
200	Low	Low	S3	S3	S3	S3	N	N	N	S	Oxisols	Tana Mieg Mla(M)

Appendix 2a. All plot's data and soil surface characteristics (see main report for definitions; part 3)

Sample nr	Local Fertility (very low - very high)	Standard Fertility (very low - very high)	Standard Suitability for: Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	Local Suitability for Rice
1	Moderate	Low	N	N	S3	N	N	N	N	S
2	Moderate	Very Low	N	N	S3	N	N	N	N	S
3	Moderate	Low	S3	S3	S2	S3	N	S3	S3	S
4	Low	Low	S3	S3	S3	S3	N	S3	S3	N
5	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
6	Moderate	Low	S3	S3	S2	S3	N	S3	S3	S
7	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
8	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
9	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
10	Very Low	Very Low	N	N	N	N	N	N	N	N
11	Low	Low	S3	S3	S3	S3	N	S3	S3	S
12	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
13	Low	Very Low	S3	S3	S3	N	N	N	N	N
14	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
15	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
16	Low	Low	S3	S3	S3	S3	N	S3	S3	N
17	Low	Low	S3	S3	S3	S3	N	S3	S3	N
18	Moderate	Low	N	N	S3	N	N	N	N	S
19	Moderate	Low	N	N	S3	N	N	N	N	S
20	Moderate	Low	N	N	N	N	N	N	N	S
21	Moderate	Low	N	N	S3	N	N	N	N	S
22	Low	Low	S3	S3	S3	S3	N	S3	S3	S
23	Low	Low	S3	S3	S3	S3	N	S3	S3	S
24	Very Low	Low	N	N	N	N	N	N	N	N
25	Moderate	Low	S3	S3	S3	N	N	N	N	S
26	Very Low	Low	S3	S3	S3	N	N	N	N	N
27	Very Low	Low	S3	S3	S3	S3	N	S3	S3	S
28	Moderate	Very Low	S3	S3	S3	N	N	N	N	N
29	Very Low	Low	N	N	N	N	N	N	N	N
30	Very Low	Low	N	N	N	N	N	N	N	N
31	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
32	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
33	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S

Sample	Local Fertility	Standard Fertility			Standard Suitability for					Local Suitability
nr	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice
34	Very Low	Low	S3	S3	S2	S3	N	S3	S3	N
35	Very Low	Low	S3	S3	S3	S3	N	S3	S3	N
36	Moderate	Low	S3	S3	S1	S3	N	S3	S3	S
37	Moderate	Low	S3	S3	S1	S3	N	S3	S3	S
38	Low	Low	S3	S3	S3	S3	N	S3	S3	S
39	Low	Low	S3	S3	S3	N	N	N	N	S
40	Moderate	Low	S3	S3	S1	S3	N	S3	S3	S
41	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
42	Low	Low	S3	S3	S1	S3	N	S3	S3	S
43	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
44	Low	Low	N	N	N	N	N	N	N	N
45	Moderate	Low	N	N	S3	N	N	N	N	S
46	Low	Low	N	N	N	N	N	N	N	N
47	Low	Low	S3	S3	S3	S3	N	S3	S3	N
48	Low	Low	N	N	S3	N	N	N	N	N
49	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
50	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
51	Moderate	Low	S3	S3	S3	S3	N	S3	S3	N
52	.	Low	S3	S3	S3	S3	N	S3	S3	N
53	.	Very Low	S3	S3	S3	N	N	N	N	N
54	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
55	Moderate	Very Low	N	N	N	N	N	N	N	N
56	Very Low	Low	N	N	N	N	N	N	N	N
57	Moderate	Very Low	S3	S3	S3	S3	N	S3	S3	S
58	Very Low	Low	N	N	N	N	N	N	N	N
59	.	Low	S3	S3	S2	S3	N	S3	S3	S
60	High	Low	S3	S3	S2	S3	N	S3	S3	N
61	Low	Very Low	S3	S3	S3	S3	N	N	N	N
62	Moderate	Low	S3	S3	S3	S3	N	N	N	N
63	Low	Very Low	N	N	S3	N	N	N	N	N
64	Moderate	Very Low	S3	S3	S3	S3	N	S3	S3	S
65	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
66	Moderate	Moderate	S3	S3	S2	S3	N	S3	S3	S
67	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
68	Moderate	Very Low	S3	S3	S3	N	N	N	N	S

Sample nr	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability
	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice
69	Moderate	Low	N	N	N	N	N	N	N	N
70	High	Low	N	N	N	N	N	N	N	S
71	Low	Low	S3	S3	S3	S3	N	S3	S3	S
72	Moderate	Low	S3	S3	S2	S3	N	S3	S3	N
73	Very Low	Low	S3	S3	S3	S3	N	N	N	N
74	Low	Very Low	N	N	S3	N	N	N	N	S
75	Low	Low	N	N	N	N	N	N	N	S
76	Low	Low	S3	S3	S3	S3	N	S3	S3	S
77	Low	Low	S3	S3	S3	S3	N	S3	S3	S
78	Low	Low	S3	S3	S3	S3	N	S3	S3	S
79	Low	Low	S3	S3	S2	S3	N	N	N	S
80	Very Low	Low	N	N	S3	N	N	N	N	N
81	Moderate	Very Low	N	N	S3	N	N	N	N	S
82	Low	Very Low	S3	S3	S3	N	N	N	N	S
83	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
84	Moderate	Low	N	N	N	N	N	N	N	S
85	High	Low	S3	S3	S2	S3	N	S3	S3	S
86	Very Low	Low	S3	S3	S3	S3	N	N	N	N
87	Very Low	Very Low	S3	S3	S3	S3	N	N	N	N
88	Very Low	Very Low	S3	N	S3	N	N	N	N	N
89	Very Low	Moderate	N	S3	S3	S3	N	N	N	N
90	Very Low	Very Low	S3	S3	S3	S3	N	S3	S3	N
91	Very Low	Very Low	S3	N	S3	N	N	N	N	N
92	Very Low	Low	N	S3	S3	S3	N	S3	S3	N
93	Moderate	Low	S3	S3	S3	S3	N	N	N	S
94	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
95	Low	Low	S3	N	S3	N	N	N	N	S
96	Low	Low	N	N	N	N	N	N	N	S
97	Moderate	Low	N	S3	S3	S3	N	S3	S3	S
98	Moderate	Low	S3	N	N	N	N	N	N	S
99	Low	Low	N	S3	S3	S3	N	S3	S3	S
100	Very Low	Low	S3	S3	S3	S3	N	N	N	N
101	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
102	Moderate	Low	S3	N	N	N	N	N	N	S
103	Moderate	Low	N	S3	S3	S3	N	S3	S3	S

Sample nr	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability
	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice
104	Moderate	Very Low	S3	N	N	N	N	N	N	S
105	Very Low	Low	N	N	N	N	N	N	N	N
106	Moderate	Low	N	N	S3	N	N	N	N	N
107	Moderate	Low	N	N	S3	N	N	N	N	N
108	Moderate	Very Low	N	N	S2	N	N	N	N	N
109	Low	Low	N	S3	S3	S3	N	S3	S3	S
110	Low	Low	S3	S3	S3	S3	N	N	N	S
111	Moderate	Low	S3	N	N	N	N	N	N	S
112	Moderate	Low	N	N	S3	N	N	N	N	S
113	High	Low	N	S3	S3	S3	N	N	N	S
114	High	Low	S3	S3	S3	S3	N	S3	S3	S
115	Low	Low	S3	N	N	N	N	N	N	S
116	Moderate	Low	N	N	S3	N	N	N	N	S
117	Moderate	Low	N	S3	S2	S3	N	S3	S3	N
118	Moderate	Low	S3	S3	S3	S3	N	N	N	N
119	Moderate	Low	S3	S3	S3	S3	N	N	N	S
120	Moderate	Moderate	S3	S3	S3	S3	N	N	N	S
121	Moderate	Low	S3	S3	S3	S3	N	N	N	S
122	Moderate	Low	N	N	S3	N	N	N	N	S
123	Moderate	Low	N	N	S3	N	N	N	N	N
124	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
125	Moderate	Low	N	N	S3	N	N	N	N	N
126	Moderate	Low	S3	S3	S3	S3	N	S3	S3	N
127	Very Low	Low	N	N	S3	N	N	N	N	N
128	Very Low	Low	S3	S3	S3	S3	N	N	N	N
129	High	Low	N	N	N	N	N	N	N	S
130	Low	Low	N	N	N	N	N	N	N	N
131	Very Low	Low	N	N	N	N	N	N	N	N
132	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
133	Very Low	Low	N	N	N	N	N	N	N	N
134	Very Low	Low	N	N	N	N	N	N	N	S
135	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
136	Low	Low	S3	S3	S3	N	N	N	N	N
137	Very Low	Low	S3	S3	S3	S3	N	N	N	N

Sample	Local Fertility	Standard Fertility			Standard Suitability for				Local Suitability
nr	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice
138	Moderate	Moderate	N	N	S3	N	N	N	N	N
139	Moderate	Low	N	N	N	N	N	N	N	N
140	Very Low	Low	N	N	N	N	N	N	N	N
141	Very Low	Low	N	N	N	N	N	N	N	N
142	Moderate	Low	N	N	N	N	N	N	N	S
143	Moderate	Low	N	N	N	N	N	N	N	S
144	Moderate	Low	N	N	N	N	N	N	N	S
145	Moderate	Low	N	N	N	N	N	N	N	S
146	Very Low	Low	S3	S3	S3	S3	N	N	N	N
147	Moderate	Low	N	N	N	N	N	N	N	S
148	Low	Low	N	N	N	N	N	N	N	S
149	Very Low	Low	S3	N	S3	S3	N	S3	S3	S
150	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
151	Moderate	Low	N	N	S3	N	N	N	N	S
152	Low	Low	S3	S3	S3	N	N	N	N	S
153	High	Low	S3	N	S3	N	N	N	N	S
154	Low	Low	N	N	N	N	N	N	N	S
155	Moderate	Low	N	N	S3	N	N	N	N	S
156	Moderate	Low	N	N	N	N	N	N	N	S
157	Low	Low	S3	S3	S3	S3	N	S3	S3	S
158	Low	Low	N	N	S3	N	N	N	N	S
159	Low	Low	N	N	S3	N	N	N	N	S
160	Low	Low	N	S3	N	S3	N	S3	S3	S
161	Low	Low	S3	S3	S3	S3	N	N	N	S
162	Moderate	Low	N	N	S3	N	N	N	N	S
163	Moderate	Low	N	N	S3	N	N	N	N	S
164	Moderate	Low	N	N	S3	N	N	N	N	N
165	Very Low	Low	N	N	S3	N	N	N	N	N
166	Low	Low	S3	S3	S3	S3	N	S3	S3	N
167	Very Low	Low	N	N	N	N	N	N	N	S
168	Low	Low	N	N	N	N	N	N	N	S
169	Very Low	Very Low	N	N	N	N	N	N	N	N
170	Very Low	Low	N	N	S3	N	N	N	N	N
171	Low	Low	S3	S3	S3	S3	N	N	N	S

Sample	Local Fertility	Standard Fertility	Standard Suitability for							Local Suitability
nr	(very low - very high)		Oilpalm	Pepper	Rice	Cacao	Candlenut	Rubber	Coffee	for Rice
172	Moderate	Low	S3	S3	S3	S3	N	N	N	S
173	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
174	Moderate	Low	S3	S3	S3	S3	N	N	N	N
175	Low	Low	N	N	N	N	N	N	N	N
176	Moderate	Low	N	N	S3	N	N	N	N	S
177	Moderate	Low	N	N	N	N	N	N	N	S
178	High	Low	N	N	N	N	N	N	N	S
179	Low	Low	N	N	N	N	N	N	N	S
180	Low	Low	N	N	N	N	N	N	N	S
181	Very Low	Low	N	N	N	N	N	N	N	S
182	Moderate	Low	N	N	N	N	N	N	N	S
183	Low	Low	N	N	N	N	N	N	N	S
184	Very Low	Low	N	N	S3	N	N	N	N	N
185	Moderate	Low	N	N	S3	N	N	N	N	S
186	Very Low	Very Low	N	N	S3	N	N	N	N	N
187	Moderate	Low	N	N	N	N	N	N	N	S
188	High	Low	N	N	S3	N	N	N	N	S
189	Moderate	Very Low	N	N	S3	N	N	N	N	S
190	Moderate	Low	N	N	S3	N	N	N	N	N
191	Low	Low	S3	S3	S3	S3	N	S3	S3	N
192	High	Low	S3	S3	S3	S3	N	N	N	S
193	Low	Low	N	N	N	N	N	N	N	S
194	Low	Low	S3	S3	S3	S3	N	S3	S3	S
195	Moderate	Low	S3	S3	S3	S3	N	S3	S3	S
196	Low	Low	S3	S3	S3	S3	N	N	N	S
197	Moderate	Low	S3	S3	S3	S3	N	N	N	S
198	Moderate	Low	S3	S3	S3	S3	N	N	N	S
199	Low	Low	S3	S3	S3	S3	N	S3	S3	S
200	Low	Low	S3	S3	S3	S3	N	N	N	S

Appendix 2b. All plot's data and soil sub-surface characteristics (see main report for definitions; part 1)

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
1	442729	341625	Seturan	Fallow	Swamp	none	5.0	quite fine	n.a.	n.a.
2	442726	341373	Seturan	Special, natural	Plain	none	7.3	moderate	n.a.	n.a.
3	442042	341155	Seturan	Fallow	Plain	none	1.7	moderate	n.a.	n.a.
4	440262	340394	Seturan	Horticulture	Aluvial Plain	none	5.3	moderate	n.a.	n.a.
5	440337	340505	Seturan	Special, modified	Aluvial Plain	none	7.3	moderate	n.a.	n.a.
6	442022	340993	Seturan	Agriculture	Plain	none	0.0	moderate	n.a.	n.a.
7	443082	341061	Seturan	Primary forest	Hill	none	11.0	quite fine	n.a.	n.a.
8	443228	341086	Seturan	Primary forest	Hill	none	10.7	quite fine	n.a.	n.a.
9	441878	341883	Seturan	Fallow	Hill	none	0.0	quite fine	n.a.	n.a.
10	442361	341985	Seturan	Primary forest	Hill	sheet	5.0	quite fine	n.a.	n.a.
11	442797	338832	Seturan	Primary forest	Hill	none	10.7	moderate	n.a.	n.a.
12	442704	339311	Seturan	Fallow	Plain	none	4.0	quite fine	n.a.	n.a.
13	442801	339284	Seturan	Fallow	Plain	none	1.3	moderate	n.a.	n.a.
14	442302	337337	Seturan	Primary forest	Hill	none	9.0	quite fine	n.a.	n.a.
15	442415	337388	Seturan	Primary forest	Hill	none	9.3	quite fine	n.a.	n.a.
16	442355	337630	Seturan	Fallow	Hill	none	5.7	quite fine	n.a.	n.a.
17	442450	337671	Seturan	Fallow	Hill	none	4.3	moderate	n.a.	n.a.
18	443312	339434	Seturan	Primary forest	Plain	none	3.0	quite coarse	n.a.	n.a.
19	443507	339233	Seturan	Modified forest	Plain	none	5.0	quite coarse	n.a.	n.a.
20	445498	332304	Seturan	Special, modified	Plain	none	3.0	quite fine	n.a.	n.a.
21	445870	331957	Seturan	Old fallow	Plain	none	11.7	moderate	n.a.	n.a.
22	450244	331496	Seturan	Primary forest	Hill	none	11.7	quite fine	n.a.	n.a.
23	450372	331294	Seturan	Primary forest	Hill	none	10.7	quite fine	n.a.	n.a.
24	445633	333533	Seturan	Special, natural	Hill	none	8.0	quite fine	n.a.	n.a.
25	445556	333386	Seturan	Primary forest	Hill	none	11.7	moderate	n.a.	n.a.
26	446757	331671	Seturan	Special, natural	Hill	none	6.0	fine	n.a.	n.a.

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
27	446818	331677	Seturan	Special, natural	Plain	none	6.7	quite fine	n.a.	n.a.
28	444626	333921	Seturan	Special, modified	Plain	sheet	8.0	quite coarse	n.a.	n.a.
29	448482	332868	Seturan	Primary forest	Hill	none	11.0	moderate	n.a.	n.a.
30	448485	332692	Seturan	Primary forest	Hill	sheet	10.7	quite fine	n.a.	n.a.
31	445483	331749	Seturan	Old fallow	Aluvial Plain	none	7.7	fine	n.a.	n.a.
32	445465	331540	Seturan	Primary forest	Hill	none	5.7	fine	n.a.	n.a.
33	445105	331899	Seturan	Primary forest	Plain	none	8.7	quite fine	n.a.	n.a.
34	448058	330082	Seturan	Special, natural	Plain	none	6.3	moderate	n.a.	n.a.
35	442142	340969	Seturan	Agriculture	Plain	none	0.0	quite fine	n.a.	n.a.
36	442033	340871	Seturan	Special, modified	Aluvial Plain	none	0.0	moderate	n.a.	n.a.
37	441259	340946	Seturan	Horticulture	Plain	none	3.3	quite fine	n.a.	n.a.
38	441630	341853	Seturan	Agriculture	Plain	none	0.3	moderate	n.a.	n.a.
39	441448	341789	Seturan	Fallow	Plain	none	1.7	quite fine	n.a.	n.a.
40	441539		Seturan	Horticulture	Plain	none	4.7	quite fine	n.a.	n.a.
41	441533	341173	Seturan	Horticulture	Plain	none	2.7	quite fine	n.a.	n.a.
42	441153	341021	Seturan	Horticulture	Plain	none	4.3	moderate	n.a.	n.a.
43	445339	339528	Seturan	Old fallow	Aluvial Plain	none	4.3	quite fine	n.a.	n.a.
44	445165	339796	Seturan	Primary forest	Hill	sheet	9.3	quite fine	n.a.	n.a.
45	445488	339111	Seturan	Old fallow	Plain	none	7.3	quite fine	n.a.	n.a.
46	445530	339159	Seturan	Modified forest	Hill	none	5.3	fine	n.a.	n.a.
47	444385	343744	Seturan	Modified forest	Hill	sheet	8.3	quite fine	n.a.	n.a.
48	444504	343903	Seturan	Special, modified	Hill	none	0.0	fine	n.a.	n.a.
49	443480	339104	Seturan	Primary forest	Hill	none	8.7	quite fine	n.a.	n.a.
50	443286	338928	Seturan	Primary forest	Hill	none	8.0	quite fine	n.a.	n.a.
51	443650	339620	Seturan	Special, natural	Swamp	none	5.3	quite fine	n.a.	n.a.
52	443729	339933	Seturan	Agriculture	Plain	none	0.0	moderate	n.a.	n.a.
53	443853	338622	Seturan	Special, natural	Hill	none	7.3	quite coarse	n.a.	n.a.
54	443451	340084	Seturan	Horticulture	Swamp	none	5.7	quite coarse	n.a.	n.a.
55	443501	339972	Seturan	Special, natural	Plain	none	9.3	coarse	n.a.	n.a.

Sample nr	Eastings	Northings	Village	Sample Type	Landform	Erosion	Relascope	Texture	Hardpan	Rooting
	(m)						Average		Depth (cm)	Depth (cm)
56	444716	340913	Seturan	Special, natural	Hill	none	15.3	moderate	n.a.	n.a.
57	444750	340924	Seturan	Special, natural	Hill	none	9.0	moderate	n.a.	n.a.
58	444510	339299	Seturan	Primary forest	Hill	sheet	8.0	moderate	n.a.	n.a.
59	439668	345359	Langap	Fallow	Plain	none	5.3	quite fine	n.a.	0-50
60	441780	345867	Langap	Agriculture	Aluvial Plain	none	0.0	quite fine	n.a.	0-20+
61	441985	346956	Langap	Modified forest	Hill	sheet	13.7	quite coarse	n.a.	0-20+
62	440552	345489	Langap	Horticulture	Aluvial Plain	none	8.7	quite coarse	n.a.	0-85
63	439401	344202	Langap	Fallow	Swamp	none	1.0	quite coarse	n.a.	0-50
64	439283	344056	Langap	Modified forest	Plain	none	9.3	quite coarse	9-30+	0-30+
65	440185	346228	Langap	Fallow	Aluvial Plain	none	0.0	quite fine	n.a.	0-24
66	440109	345787	Langap	Special, modified	Aluvial Plain	none	0.3	fine	n.a.	0-40
67	442618	346459	Langap	Modified forest	Hill	sheet	11.0	fine	18-40	0-40
68	443666	345145	Langap	Modified forest	Hill	gully	11.0	moderate	9-30	0-30/35
69	443755	345393	Langap	Primary forest	Hill	gully	11.7	moderate	0-40	0-40
70	440632	345665	Langap	Special, natural	Swamp	none	7.3	quite fine	n.a.	0-7
71	441666	345847	Langap	Horticulture	Aluvial Plain	none	5.7	quite fine	n.a.	0-12+
72	440177	345820	Langap	Fallow	Aluvial Plain	none	1.0	quite fine	n.a.	0-35+
73	440059	346019	Langap	Old fallow	Aluvial Plain	none	2.7	quite fine	20/24+	0-20/24+
74	441586	348555	Langap	Primary forest	Hill	rill	14.0	quite fine	19-30+	0-30+
75	443388	347454	Langap	Modified forest	Hill	sheet	8.7	quite fine	n.a.	0-30
76	443782	348987	Langap	Primary forest	Hill	gully	10.7	quite fine	n.a.	0-25/33+
77	443041	348562	Langap	Primary forest	Hill	sheet	16.7	quite fine	n.a.	0-35+
78	445308	343990	Langap	Primary forest	Plain	gully	8.3	quite fine	n.a.	0-20+
79	445114	343902	Langap	Modified forest	Plain	rill	7.3	moderate	n.a.	0-24/30+
80	445416	343587	Langap	Primary forest	Hill	gully	11.7	fine	n.a.	0-60/70
81	443973	343703	Langap	Modified forest	Hill	none	15.3	quite coarse	n.a.	0-39+
82	444125	343786	Langap	Modified forest	Aluvial Plain	none	8.7	moderate	0-30	0-30
83	442701	345680	Langap	Old fallow	Aluvial Plain	gully	11.0	quite fine	n.a.	0-10+
84	443321	347470	Langap	Modified forest	Hill	gully	7.3	quite fine	n.a.	0-32

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
85	440393	345282	Langap	Horticulture	Aluvial Plain	none	9.7	quite fine	0-2	0-35
86	440193	345038	Langap	Fallow	Plain	none	4.3	quite fine	n.a.	0-45
87	440282	342633	Langap	Horticulture	Swamp	none	10.3	moderate	n.a.	0-40
88	439799	345495	Langap	Special, modified	Swamp	none	0.0	moderate	7/40+	0-29/40
89	439521	345025	Langap	Special, modified	Swamp	none	7.7	quite fine	6-60+	0-40
90	439366	343924	Langap	Special, natural	Swamp	none	11.7	quite coarse	n.a.	0-40
91	438153	344521	Laban Nyarit	Old fallow	Plain	rill	6.7	quite fine	n.a.	0-25+
92	437340	344717	Laban Nyarit	Primary forest	Hill	rill	8.3	quite fine	n.a.	41+
93	438267	342045	Laban Nyarit	Special, natural	Hill	rill	12.7	fine	n.a.	0--30/40
94	438280	343473	Laban Nyarit	Fallow	Plain	sheet	4.0	fine	17-25+	0-25+
95	436845	340418	Laban Nyarit	Modified forest	Hill	sheet	12.7	quite fine	11-42+	0-42+
96	436698	340278	Laban Nyarit	Primary forest	Hill	rill	12.0	fine	n.a.	0--53
97	437389	340700	Laban Nyarit	Primary forest	Swamp	rill	10.3	moderate	0-30+	0-5
98	437173	340171	Laban Nyarit	Special, natural	Hill	rill	13.0	fine	n.a.	0-40+
99	437177	340752	Laban Nyarit	Modified forest	Hill	gully	13.3	quite fine	n.a.	0-19+
100	437584	344023	Laban Nyarit	Modified forest	Hill	gully	9.7	quite fine	n.a.	0-50+
101	437613	344459	Laban Nyarit	Horticulture	Plain	sheet	7.7	quite fine	n.a.	0-50+
102	437843	344342	Laban Nyarit	Fallow	Plain	sheet	9.7	fine	n.a.	0-6/18+
103	437613	345394	Laban Nyarit	Primary forest	Hill	gully	10.0	quite fine	n.a.	0-29/58+
104	437473	344872	Laban Nyarit	Primary forest	Hill	rill	15.0	fine	n.a.	0-33+
105	437250	344598	Laban Nyarit	Agriculture	Hill	rill	0.0	quite fine	n.a.	0-20+
106	434151	338311	Laban Nyarit	Special, modified	Swamp	none	6.3	fine	n.a.	-
107	438978	343331	Laban Nyarit	Special, modified	Swamp	none	10.0	quite coarse	n.a.	-
108	438459	343814	Laban Nyarit	Agriculture	Swamp	none	0.0	quite fine	n.a.	-
109	438317	343978	Laban Nyarit	Primary forest	Hill	sheet	11.7	fine	n.a.	0-50+
110	432464	338779	Laban Nyarit	Primary forest	Hill	rill	12.7	fine	n.a.	0-25+
111	434246	338723	Laban Nyarit	Special, modified	Plain	none	13.0	quite fine	n.a.	0-40+
112	433196	337010	Laban Nyarit	Primary forest	Hill	rill	13.3	fine	n.a.	0-30
113	433289	337099	Laban Nyarit	Primary forest	Hill	rill	10.3	fine	n.a.	0-20/30
114	437533	345388	Laban Nyarit	Primary forest	Hill	rill	16.3	quite fine	n.a.	0-30+

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
115	437821	345633	Laban Nyarit	Fallow	Hill	gully	5.3	moderate	3-17	0-45
116	436389	339271	Laban Nyarit	Old fallow	Hill	rill	14.0	fine	n.a.	0-40+
117	433743	342423	Laban Nyarit	Special, modified	Swamp	none	3.0	moderate	n.a.	-
118	437786	344622	Laban Nyarit	Horticulture	Aluvial Plain	gully	5.7	moderate	n.a.	0-30/35+
119	437468	341711	Laban Nyarit	Horticulture	Aluvial Plain	none	14.3	quite fine	n.a.	0-38+
120	437848	342499	Laban Nyarit	Horticulture	Aluvial Plain	none	10.0	quite fine	n.a.	0-55
121	406374	313622	Long Jalan	Fallow	Hill	none	1.0	fine	n.a.	0-36+
122	406151	314032	Long Jalan	Agriculture	Hill	sheet	0.0	quite fine	n.a.	0-20+
123	405866	314009	Long Jalan	Modified forest	Hill	sheet	16.3	fine	0-21/36+	0-21/36+
124	405887	313632	Long Jalan	Fallow	Hill	sheet	0.0	fine	32+	0-32+
125	405707	313431	Long Jalan	Primary forest	Swamp	rill	8.7	moderate	n.a.	-
126	403488	313389	Long Jalan	Horticulture	Plain	none	7.3	moderate	n.a.	0-32+
127	405671	313722	Long Jalan	Primary forest	Hill	gully	9.3	fine	n.a.	0-45+
128	403850	313397	Long Jalan	Old fallow	Hill	rill	8.0	quite fine	n.a.	0-45+
129	406485	314012	Long Jalan	Modified forest	Hill	rill	10.0	fine	0-30+	0-30+
130	404333	313353	Long Jalan	Primary forest	Hill	rill	11.3	fine	6-27	0-27+
131	405146	314127	Long Jalan	Primary forest	Hill	rill	13.7	quite fine	6-16+	0-16+
132	405690	313835	Long Jalan	Modified forest	Aluvial Plain	rill	11.0	quite fine	n.a.	0-37
133	403715	312602	Long Jalan	Primary forest	Hill	rill	15.0	fine	7-50+	0-50+
134	404515	314456	Long Jalan	Special, natural	Aluvial Plain	gully	6.3	quite fine	n.a.	0-7
135	403640	312200	Long Jalan	Modified forest	Hill	rill	11.7	fine	0-23+	0-23+
136	403919	312086	Long Jalan	Fallow	Aluvial Plain	sheet	6.3	quite fine	n.a.	0-32+
137	405649	314767	Long Jalan	Primary forest	Hill	rill	16.3	fine	0-40+	0-40+
138	405901	313051	Long Jalan	Primary forest	Swamp	none	7.3	fine	n.a.	0-17+
139	404804	313377	Long Jalan	Modified forest	Hill	rill	8.3	quite fine	n.a.	0-30
140	403546	313038	Long Jalan	Primary forest	Hill	gully	9.3	fine	n.a.	0-30+
141	404014	312109	Long Jalan	Primary forest	Hill	gully	9.0	quite fine	0-40	0-40
142	431324	326220	Liu Mutai	Primary forest	Hill	rill	12.7	fine	23/30+	0-23/30+
143	431263	326159	Liu Mutai	Primary forest	Hill	rill	12.3	fine	8-40+	0-40+
144	431212	326290	Liu Mutai	Fallow	Hill	rill	0.0	fine	10-25+	0-25+

Sample nr	Eastings	Northings	Village	Sample Type	Landform	Erosion	Relascope	Texture	Hardpan	Rooting
	(m)						Average		Depth (cm)	Depth (cm)
145	432105	326298	Liu Mutai	Modified forest	Hill	gully	10.0	quite fine	28+	0-28+
146	432094	326236	Liu Mutai	Primary forest	Swamp	gully	8.0	quite fine	n.a.	0-20
147	432451	326162	Liu Mutai	Primary forest	Hill	rill	11.7	fine	n.a.	0-30+
148	431545	326637	Liu Mutai	Special, natural	Hill	sheet	10.0	quite fine	n.a.	0-5/15+
149	427213	325560	Liu Mutai	Old fallow	Hill	gully	8.3	quite fine	n.a.	0-9+
150	427946	325733	Liu Mutai	Fallow	Hill	rill	5.0	quite fine	n.a.	0-45+
151	430493	327038	Liu Mutai	Special, natural	Hill	rill	15.7	fine	n.a.	0-50+
152	430643	326368	Liu Mutai	Modified forest	Hill	sheet	7.3	quite fine	n.a.	-
153	430561	326513	Liu Mutai	Horticulture	Aluvial Plain	sheet	14.0	moderate	n.a.	35+
154	429035	326128	Liu Mutai	Primary forest	Hill	rill	15.3	fine	32+	32+
155	429574	325836	Liu Mutai	Special, modified	Aluvial Plain	none	0.0	quite coarse	n.a.	27+
156	433019	327949	Liu Mutai	Primary forest	Hill	rill	14.0	fine	13-38+	38+
157	432819	328144	Liu Mutai	Primary forest	Hill	rill	14.0	quite fine	36+	36+
158	428205	325230	Liu Mutai	Primary forest	Hill	rill	14.7	fine	0-40+	40+
159	428154	325451	Liu Mutai	Primary forest	Hill	rill	12.0	fine	n.a.	40+
160	428443	325902	Liu Mutai	Primary forest	Hill	rill	8.0	fine	4-40+	40+
161	432939	327514	Liu Mutai	Old fallow	Hill	rill	12.7	quite fine	n.a.	20+
162	432996	327590	Liu Mutai	Horticulture	Aluvial Plain	rill	10.0	quite fine	n.a.	40+
163	449341	368282	Gong Solok	Special, natural	Hill	rill	13.7	quite fine	n.a.	40+
164	449599	367979	Gong Solok	Horticulture	Aluvial Plain	none	6.3	quite coarse	n.a.	10/12+
165	448502	368214	Gong Solok	Special, natural	Swamp	none	12.3	moderate	n.a.	18+
166	448695	367836	Gong Solok	Modified forest	Plain	rill	10.0	quite fine	32+	32+
167	446912	368093	Gong Solok	Modified forest	Hill	rill	15.0	fine	12-32+	32+
168	447095	367488	Gong Solok	Fallow	Plain	gully	3.0	quite fine	0-23	8-23
169	44914	368972	Gong Solok	Primary forest	Swamp	none	10.7	coarse	n.a.	-
170	448962	369039	Gong Solok	Modified forest	Swamp	none	10.3	moderate	12-37/45+	37/45+
171	448973	368066	Gong Solok	Primary forest	Hill	rill	8.7	quite fine	n.a.	30+
172	449164	367945	Gong Solok	Old fallow	Aluvial Plain	sheet	7.3	moderate	n.a.	40/50+
173	448678	367460	Gong Solok	Horticulture	Plain	rill	8.0	moderate	n.a.	26/28+

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
174	448157	367029	Gong Solok	Horticulture	Aluvial Plain	none	6.0	quite fine	n.a.	33+
175	450512	365566	Gong Solok	Modified forest	Hill	gully	11.3	quite fine	41+	41+
176	450462	366625	Gong Solok	Agriculture	Aluvial Plain	none	0.0	quite fine	n.a.	-
177	452774	368631	Gong Solok	Primary forest	Hill	rill	11.0	quite fine	0-40+	40+
178	452173	367942	Gong Solok	Horticulture	Hill	rill	6.7	quite fine	n.a.	32+
179	452178	367957	Gong Solok	Modified forest	Hill	rill	15.7	quite fine	n.a.	38+
180	452340	368772	Gong Solok	Fallow	Hill	rill	0.0	quite fine	n.a.	-
181	450943	366160	Gong Solok	Fallow	Hill	rill	0.0	quite fine	n.a.	-
182	451440	365333	Gong Solok	Modified forest	Hill	rill	9.0	quite fine	67+	67+
183	450665	366074	Gong Solok	Fallow	Hill	rill	0.0	quite fine	3-40+	40+
184	449697	368682	Gong Solok	Primary forest	Hill	rill	9.7	quite fine	21-40	40+
185	449937	368917	Gong Solok	Modified forest	Hill	rill	8.7	moderate	n.a.	8/16+
186	449020	369295	Gong Solok	Old fallow	Swamp	none	5.7	quite coarse	n.a.	-
187	449173	369145	Gong Solok	Modified forest	Hill	rill	12.7	fine	n.a.	27+
188	449912	368281	Gong Solok	Special, modified	Aluvial Plain	none	20.7	moderate	n.a.	30+
189	448646	358486	Gong Solok	Special, modified	Swamp	none	10.3	quite coarse	n.a.	30+
190	449499	360812	Gong Solok	Special, natural	Aluvial Plain	none	0.0	quite coarse	n.a.	33/40+
191	450759	369722	Gong Solok	Modified forest	Plain	rill	9.7	fine	n.a.	39+
192	450867	369328	Gong Solok	Agriculture	Plain	none	0.0	fine	n.a.	25+
193	449850	367849	Gong Solok	Primary forest	Hill	rill	5.0	fine	4/13-42+	42+
194	449881	367721	Gong Solok	Old fallow	Plain	rill	9.3	quite fine	0-20+	20+
195	449842	367606	Gong Solok	Horticulture	Plain	rill	7.3	quite fine	0-35+	35+
196	449806	367914	Gong Solok	Horticulture	Plain	none	4.7	fine	8-29+	29+
197	449667	367810	Gong Solok	Horticulture	Plain	none	8.7	moderate	n.a.	30+
198	450205	308710	Gong Solok	Fallow	Plain	none	0.7	quite fine	n.a.	19-29/35
199	449147	360628	Gong Solok	Fallow	Plain	rill	5.0	moderate	n.a.	40+
200	449107	360390	Gong Solok	Primary forest	Hill	rill	9.7	quite fine	33+	33+

Appendix 2b. All plot's data and soil sub-surface characteristics (see main report for definitions; part 2)

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
1	4.3	0.64	0.08	8	2.6	6	0.41	0.25	0.08	0	.	.	5.31	0.72	.	0.84	33	20	47	110	10YR 6/8	impeded	.	2.5
2	4.3	0.26	0.03	9	21.5	2	0.4	0.13	0.02	0	.	.	1.85	0.45	.	1.39	15	54	31	80	2.5Y 7/3	impeded	.	2.6
3	5.1	1.15	0.17	7	0.9	11	10.05	2.84	0.11	0.27	.	.	0.4	0.11	.	0.77	38	6	56	110	2.5Y 5/5	moderate	.	1
4	4.5	0.97	0.14	7	2.6	10	3.4	2.63	0.11	0.81	.	.	2.07	0.54	.	1.09	22	44	34	110	2.5Y 4.5/4	moderate	.	0
5	4.4	1.27	0.19	7	4.5	13	3.11	2.46	0.19	1.07	.	.	3.86	0.76	.	1.05	25	38	37	110	2.5Y 4.5/4	moderate	.	0
6	4.9	1.16	0.17	7	1.2	12	7.55	3.07	0.17	0.51	.	.	0.97	0.2	.	0.77	26	23	51	110	2.5Y 4.5/4	moderate	.	2
7	4	0.91	0.09	10	18.7	4	0.61	0.34	0.06	0.97	.	.	3.32	0.68	.	0.92	28	44	28	110	2.5Y 6/3	moderate	.	5
8	4	1.28	0.09	14	6.4	4	0.51	0.17	0.08	0.14	.	.	4.48	0.77	.	0.84	26	38	36	110	2.5Y 6/3.5	moderate	.	7.5
9	4.2	0.7	0.1	7	4.1	6	0.78	0.36	0.08	0.14	.	.	4.91	0.82	.	1.05	29	34	37	60	2.5Y 6/7	moderate	.	12.5
10	4.2	0.6	0.07	9	1.7	4	0.51	0.13	0.08	0	.	.	1.43	0.5	.	1.18	21	56	23	110	2.5Y 6/7	moderate	.	20
11	4.3	0.75	0.1	8	3.2	5	1.99	1.31	0.1	0.12	.	.	4.42	0.8	.	1.07	25	40	35	110	2.5Y 6.5/7	moderate	.	5
12	4.7	1.02	0.07	15	2	8	0.67	0.38	0.08	0.12	.	.	0.95	0.17	.	1.27	25	39	36	110	2.5Y 6/7	slow	.	3
13	4.5	0.84	0.09	9	4.3	7	1.53	0.77	0.1	0.15	.	.	2.2	0.54	.	1.35	23	44	33	40	10YR 6/7	moderate	.	1.5
14	4	0.94	0.11	9	3.2	4	0.52	0.19	0.06	0.14	.	.	7.51	1.12	.	1	37	28	35	110	2.5Y 6/7	moderate	.	22.5
15	4	1.35	0.13	10	5	6	0.37	0.19	0.11	0.44	.	.	8.75	1.27	.	0.92	39	24	37	110	10YR 6/7	moderate	.	2.7
16	4.3	1.1	0.12	9	3.8	4	1.14	0.55	0.08	0.56	.	.	4.48	0.81	.	0.97	40	32	28	110	2.5Y 5.5/6	moderate	.	7.5
17	4.5	0.86	0.1	9	9.5	8	1.32	0.92	0.15	0.39	.	.	5	1.05	.	1.01	41	28	31	80	2.5Y 6/5	moderate	.	5
18	4.3	0.72	0.09	8	4.1	7	0.52	0.21	0.06	0	.	.	2.83	0.6	.	1.17	17	63	20	60	10YR 5/5	impeded	.	0
19	4.1	0.69	0.08	9	3.4	4	0.51	0.39	0.08	0.41	.	.	3.26	0.71	.	0.92	16	67	17	60	2.5Y 5.5/6	impeded	.	2.8
20	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	20	.	slow	.	0
21	5.3	1.69	0.24	7	3.7	12	12.62	2.31	0.18	0.35	.	.	0.13	0.09	.	0.51	31	21	48	110	2.5Y 4.5/4	impeded	.	0
22	4	0.71	0.1	7	2.9	4	0.77	0.24	0.08	0.28	.	.	7.99	0.95	.	0.72	35	32	33	110	10YR 6/7	moderate	.	25
23	4.1	0.85	0.09	9	1.5	4	0.52	0.19	0.08	0.31	.	.	8.5	1.17	.	0.86	44	28	28	110	10YR 6.5/8	moderate	.	6
24	4.2	1.36	0.11	12	6.1	4	0.62	0.27	0.08	0.72	.	.	5.37	0.78	.	1.11	34	29	37	80	10YR 7/5	moderate	.	50
25	4.3	0.67	0.08	8	6.1	4	0.52	0.14	0.08	0.1	.	.	6.13	0.82	.	1.17	38	30	32	40	10YR 6/7	moderate	.	30
26	5.4	1.56	0.21	7	2.3	9	22.57	0.77	0.15	0.13	.	.	0.44	0.09	.	1.02	49	13	38	40	2.5Y 5.5/6	moderate	.	12.5
27	4.7	0.69	0.1	7	1.1	6	5.81	0.23	0.11	0.05	.	.	6.66	0.86	.	1.06	40	7	53	110	10YR 5/5	moderate	.	2.9

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
28	4.5	2.4	0.13	18	5.1	4	0.67	0.48	0.08	0	.	.	2.03	0.55	.	.	7	78	15	40	10YR 2/1.5	slow	.	2.1
29	4.3	1.04	0.08	13	2.7	4	0.26	0.14	0.08	0	.	.	6.55	1.06	.	0.88	25	50	25	110	2.5Y 6.5/7	moderate	.	50
30	4.3	0.66	0.08	8	10.1	6	0.15	0.1	0.08	0	.	.	9.1	1.12	.	1.32	35	33	32	110	2.5Y 6/6	moderate	.	35
31	3.9	1.04	0.12	9	3.7	4	0.16	0.27	0.08	0	.	.	5.3	0.82	.	0.81	38	13	49	110	2.5Y 6/6	moderate	.	0
32	3.9	1.24	0.16	8	2.5	8	0.16	0.35	0.15	0.87	.	.	9.29	1.19	.	0.85	80	9	11	110	2.5Y 6/7	moderate	.	12.5
33	3.8	0.97	0.13	7	1.3	9	0.16	0.39	0.17	0.74	.	.	11.57	1.29	.	1.05	49	13	38	110	10YR 6/7	moderate	.	7
34	5.1	0.82	0.11	7	1.9	6	7.1	0.56	0.08	0	.	.	1.44	0.5	.	0.98	32	14	54	80	2.5Y 5/5	moderate	.	0
35	4.4	1.12	0.11	10	4.5	8	0.67	0.31	0.17	0.07	.	.	4.06	0.81	.	0.94	36	32	32	110	2.5Y 5/5	moderate	.	2.1
36	5.6	0.9	0.13	7	4.6	8	9.79	3	0.11	0.21	.	.	0.04	0.02	.	0.86	23	41	36	110	2.5Y 4.5/4	moderate	.	4
37	5.6	1.17	0.16	7	11.8	19	9.49	2.66	0.34	0.05	.	.	0	0	.	1	24	43	33	110	2.5Y 4/4	moderate	.	0
38	4.3	0.61	0.08	8	5	6	0.66	0.22	0.12	0	.	.	2.61	0.55	.	1.02	27	47	26	60	2.5Y 6/7	moderate	.	5
39	4.6	1.04	0.12	9	6.1	6	1.18	0.47	0.08	0.07	.	.	3.68	0.72	.	0.9	37	32	31	40	2.5Y 6/6	moderate	.	3.5
40	5.3	1.5	0.22	7	3.5	14	12.32	3.08	0.26	0.07	.	.	0.19	0.11	.	0.72	38	6	56	110	2.5Y 5/4	moderate	.	0
41	4.7	1.29	0.18	7	1.1	11	8.1	2.54	0.17	0.09	.	.	2.33	0.52	.	0.88	37	9	54	110	2.5Y 5/4	moderate	.	0
42	5.4	0.93	0.11	8	18.5	10	8.46	2.7	0.17	0.14	.	.	0.06	0.02	.	0.75	31	25	44	110	2.5Y 4.5/3.5	moderate	.	0
43	4.3	0.86	0.13	7	1.6	10	0.52	0.79	0.11	0	.	.	6.61	0.79	.	0.97	28	43	29	110	2.5Y 5.5/6	moderate	.	2.1
44	4.3	1.05	0.14	8	1.9	8	0.05	0.22	0.15	0.07	.	.	7.8	0.92	.	1.06	43	26	31	60	2.5Y 6/6	moderate	.	45
45	4.4	1.09	0.15	7	1.3	13	4.32	2.45	0.17	0.07	.	.	3.83	0.86	.	0.85	33	24	43	110	2.5Y 5.5/6	impeded	.	8
46	4.1	1.02	0.18	6	2.8	6	0.11	0.32	0.11	0	.	.	7.13	0.89	.	0.87	46	5	49	110	7.5YR 6.5/8	moderate	.	30
47	4.3	0.83	0.12	7	1.1	8	0.1	0.42	0.12	0	.	.	6.67	0.86	.	1.13	36	22	42	110	10YR 6.5/8	moderate	.	30
48	4.7	1.56	0.14	11	4.9	10	0.05	0.14	0.08	0	.	.	6.6	0.83	.	1.27	44	6	50	110	7.5YR 6/7	quick	.	5
49	4.3	1.33	0.13	10	2.2	10	0.16	0.28	0.19	0	.	.	9.66	1.28	.	0.96	55	8	37	110	10YR 6.5/8	moderate	.	15
50	4.3	1.76	0.19	9	1.2	14	1.89	1.47	0.28	0	.	.	20.85	1.63	.	0.55	62	9	29	110	8.75YR 6.5/8	moderate	.	17.5
51	4.6	1.75	0.15	12	2.4	9	1.04	2.18	0.17	0.09	.	.	5.8	0.74	.	0.58	45	11	44	110	2.5Y 6/4	slow	.	0
52	4.5	1.13	0.16	7	0.8	10	1.45	1.46	0.13	0	.	.	5.46	0.65	.	0.82	36	24	40	110	1.25Y 5/5	moderate	.	0
53	4.4	0.68	0.06	11	1.3	3	0.05	0.13	0.06	0	.	.	2.23	0.5	.	0.87	16	61	23	40	2.5Y 6.5/8	moderate	.	25
54	4.2	0.51	0.07	7	5.6	4	0.05	0.14	0.08	0	.	.	4.24	0.6	.	1.26	32	34	34	110	2.5Y 6/6	moderate	.	2.1
55	4.9	1.07	0.08	13	10.4	4	0.4	0.3	0.08	0	.	.	0.56	0.12	.	1.08	7	86	7	110	10YR 4/1.5	quick	.	0
56	4.3	0.68	0.06	11	8.1	4	0.1	0.13	0.08	0	.	.	2.27	0.5	.	0.92	18	59	23	110	10YR 6.5/8	moderate	.	27.5

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)			(me/100g)				(%)	(me/100g)		(%)	(g/cm^3)		(%)		(cm)				(%)
57	4.6	0.94	0.11	9	5.9	8	0.05	1.58	0.13	0	.	.	2.97	0.64	.	.	24	40	36	110	2.5Y 6/6	moderate	.	9
58	4.4	1.55	0.1	16	2.9	4	0.05	0.13	0.08	0	.	.	3.06	0.71	.	0.86	25	51	24	40	10YR 6/7	moderate	.	45
59	5	0.48	0.07	7	7	11	0.15	0.12	0.02	0	4.15	7	1.65	0.34	3.32	1.03	32	25	43	80	10YR6/6	slow	friable	2.1
60	5.2	0.83	0.14	6	1.8	73	2.31	1.73	0.08	0.05	7.61	55	2.71	0.17	4.26	0.97	39	15	46	80	10YR5/4	slow	friable	0
61	4.5	0.48	0.06	8	4.6	35	0.1	0.08	0.06	0.15	3	13	2.14	0.16	2.12	1.3	23	60	17	80	10YR6/6	quick	friable	21
62	5.9	0.87	0.14	6	67.5	131	9.96	2.16	0.3	0.23	8.49	100	0	0.18	2.79	1.17	35	15	50	100	10YR3/2	very slow	friable	0
63	4.8	0.68	0.03	23	6	9	0.51	0.17	0.02	0.08	1.3	60	0.24	0.08	0.14	1.04	9	76	15	80	5Y5/2	impeded	strong	0
64	5	0.16	0.03	5	5	11	0.25	0.05	0.02	0.03	1.5	23	0.87	0.08	0.68	1.3	14	52	34	60	2.5Y5/2	slow	friable	0
65	4.6	0.52	0.09	6	3.3	46	0.36	0.13	0.06	0	4.48	12	1.55	0.17	3.7	1.17	34	32	34	80	10YR5/6	slow	friable	0
66	5.8	1.03	0.18	6	11.2	57	7.42	0.21	0.13	0.13	8.65	91	0.13	0.05	3.8	0.95	40	10	50	100	10YR3/3	moderate	friable	0
67	5	1.28	0.13	10	10.5	101	0.52	0.65	0.23	0	8.46	17	3.49	0.14	2.7	0.85	44	13	43	60	10YR5/4	moderate	very friable	15
68	4.9	0.71	0.14	5	5	41	0.36	0.25	0.08	0.05	4.27	17	1.32	0.28	2.58	1.1	9	18	73	30	10YR5/6	moderate	friable	1.6
69	4.8	1.08	0.3	4	7.8	55	0.36	0.25	0.12	0.06	7.16	11	2.97	0.4	2.18	1.09	26	36	38	40	2.5Y6/6	quick	friable	1.7
70	4.8	0.69	0.13	5	1.6	28	0.68	1.03	0.06	0.06	7.87	23	4.28	0.84	3.96	1.08	42	12	46	15	5Y4/1	very slow	friable	0
71	4.8	2.87	0.23	12	8.1	60	2.17	2.3	0.11	0.08	7.81	60	0.91	0.4	3.98	1.04	38	16	46	80	10YR4/4	slow	friable	0
72	5.9	0.8	0.22	4	42.9	62	9.41	3.34	0.13	0.06	9.29	100	0	0.08	2.95	0.97	33	21	46	100	10YR4/4	moderate	friable	0
73	4.9	0.55	0.1	6	2.4	20	0.36	0.25	0.04	0.05	4.47	16	2.14	0.34	4.1	0.77	40	23	37	80	10YR4/4	very slow	friable	0
74	4.8	0.52	0.08	7	19.4	19	0.51	0.56	0.04	0.05	3.77	31	2.01	0.32	3.38	1.09	28	52	20	80	10YR5/6	quick	friable	15
75	4.7	1.11	0.14	8	5.5	86	0.73	0.17	0.17	0.02	5.14	21	1.75	0.05	3.42	1.04	41	13	46	20	2.5Y6/6	moderate	friable	20
76	4.7	0.77	0.09	9	2.2	49	0.42	0.24	0.09	0.02	9.01	9	5.84	0.11	3.48	0.91	35	36	29	80	10YR6/8	moderate	friable	20
77	4.6	0.72	0.05	14	6.2	21	0.36	0.2	0.04	0.05	4.78	14	3.21	0.35	2.67	1.17	24	54	22	100	10YR6/8	moderate	friable	15
78	4.9	0.63	0.1	6	2.4	38	0.72	0.92	0.08	0.2	6.14	31	3.13	0.36	3.31	1.13	36	18	46	80	10YR5/8	moderate	friable	0
79	5.4	1.46	0.15	10	4.6	53	5.17	1.84	0.11	0.06	6.22	100	0.39	0	3.7	1.22	32	23	45	100	10YR5/4	quick	friable	0
80	5	0.5	0.12	4	3.2	63	0.51	0.3	0.13	0.06	7.18	14	4.2	1.11	4.2	1.28	41	2	57	70	10YR5/6	quick	friable	25
81	4.9	0.63	0.07	9	5.1	25	0.52	0.2	0.04	0.06	4.61	18	2.17	0.2	3.1	1.19	27	49	24	100	10YR5/4	quick	friable	25
82	5	0.68	0.08	9	5.6	20	0.61	2.08	0.04	0.05	2.72	100	0.75	0.41	2.16	1.47	21	44	35	30	5Y6/3	very slow	friable	0
83	4.8	0.78	0.11	7	2.7	43	0.62	0.63	0.09	0.26	6.93	23	2.37	0.68	4.27	0.87	34	15	51	110	10YR5/6	moderate	friable	0
84	5.3	0.53	0.07	8	4.4	81	1.8	0.37	0.17	0.08	7.05	34	2.79	0.52	2.14	1	29	26	45	90	10YR5/4	very slow	friable	15
85	5.7	0.86	0.15	6	5.5	43	10.7	2.7	0.09	0.14	11.15	100	0.21	0	3.4	1.02	37	4	59	100	10YR4/3	slow	friable	0

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
86	4.7	0.73	0.09	8	4.1	46	0.62	0.17	0.09	0.11	5.2	19	1.62	0.24	3.6	0.91	30	26	44	100	10YR6/6	very slow	friable	0
87	4	3.38	0.13	26	21.1	20	0.66	0.3	0.04	0.35	5.23	26	1.23	0.41	0.46	1.24	23	40	37	110	10YR6/1	very slow	friable	0
88	4.3	0.88	0.07	13	11.4	20	1.19	0.51	0.04	0.72	2.83	87	1.22	0.18	0.11	1.55	16	36	48	110	7.5YR4/2	impeded	friable	0
89	4.5	2.42	0.11	22	23.7	92	0.51	0.56	0.11	0.17	5.26	26	1.96	0.31	0.35	1.24	35	35	30	110	10YR7/1	very slow	friable	0
90	4.5	4.29	0.19	23	22.5	29	0.74	0.44	0.06	0.37	4.71	34	0.89	0.09	0.27	1.12	15	66	19	60	10YR5/2	moderate	friable	0
91	4.6	0.89	0.09	10	7.6	10	0.52	0.2	0.02	0.17	3.16	29	0.96	0.16	1.16	1.1	32	44	24	100	2.5Y5/4	quick	friable	0
92	4.6	1.05	0.09	12	11.9	38	0.52	0.19	0.08	0.09	3.8	23	1.37	0.16	2.39	0.89	36	30	34	55	10YR6/6	moderate	friable	10
93	4.3	1.75	0.21	8	4	293	1.36	0.23	0.48	0.14	24.85	9	9.59	2.41	1.03	0.8	55	15	30	100	10YR5/4	very slow	strong	25
94	4.5	0.81	0.12	7	11.6	38	0.47	0.34	0.08	0.06	6.74	14	3.18	0.77	3.96	1.02	43	10	47	100	10YR5/6	moderate	friable	0
95	4.5	0.62	0.09	7	11.5	39	0.26	0.22	0.08	0.03	5.43	11	3.51	0.56	1.66	1.07	43	28	29	53	10YR5/6	quick	friable	10
96	4.6	0.79	0.12	7	1.7	57	0.27	0.26	0.08	0.06	6.89	10	3.72	0.64	3.09	0.83	46	22	32	80	7.5YR5/8	impeded	friable	20
97	4.8	2.04	0.16	13	11	48	3.34	1.69	0.1	0.09	7.37	71	1.37	0.2	2.04	0.87	28	26	46	100	10YR6/4	moderate	friable	0
98	4.4	1.44	0.18	8	2.1	91	0.28	0.47	0.19	0.17	11.77	9	7.45	1.54	4.06	0.98	55	3	42	100	7.5YR5/8	very quick	friable	2.2
99	4.4	1.07	0.14	8	2.2	82	0.26	0.74	0.08	0.39	7.88	19	4.26	0.57	3.59	1.11	38	28	34	100	7.5YR5/6	moderate	friable	25
100	4.5	0.63	0.08	8	1.7	40	0.21	0.26	0.06	0.19	6.12	12	3.51	0.56	3.57	1	36	22	42	100	10YR6/6	very slow	friable	0
101	4.7	0.6	0.11	5	1.7	29	0.16	0.57	0.06	0.13	5.88	16	2.45	0.73	3.42	1.09	35	19	46	100	10YR5/4	moderate	friable	0
102	4.7	1.23	0.1	12	4.7	28	0.27	0.21	0.06	0.12	5.66	12	0.97	0.21	3.54	0.99	47	26	27	100	10YR5/6	very quick	friable	0
103	4.5	0.9	0.1	9	4.6	29	0.26	0.22	0.06	0.05	7.05	8	4.14	1.18	2.73	1.1	38	26	36	110	10YR6/6	moderate	friable	28
104	3.9	3.06	0.19	16	23.2	48	0.22	0.2	0.1	0.02	8.52	6	2.63	0.25	3.08	0.92	42	29	29	12	10YR5/6	quick	very friable	0
105	4.5	0.92	0.12	8	6.5	99	1.72	0.43	0.21	0.02	9.64	25	4.89	0.28	4.01	0.73	50	2	48	110	10YR5/4	impeded	friable	33
106	5.4	4.61	0.33	14	7.9	67	13.08	3.32	0.14	0.32	14.15	100	0	0.02	0.88	0.73	45	1	54	100	10YR5/1	impeded	loose	0
107	4.2	6.39	0.18	36	23.3	38	0.36	0.22	0.08	0.02	7.94	9	1.43	0.09	0.08	.	14	58	28	110	10YR3/4	impeded	loose	0
108	5.4	2.24	0.09	25	4.6	34	2.03	1.07	0.07	0.06	3.06	100	0.12	0	0.22	.	20	74	6	100	10YR5/3	quick	loose	0
109	4.4	1.51	0.12	13	19.6	38	0.27	0.19	0.08	0.08	7.79	8	5.89	0.42	3.37	1.09	49	23	28	100	7.5YR6/6	moderate	friable	0
110	4.3	1.99	0.13	15	2.8	38	0.36	0.34	0.08	0.12	7.45	12	2.34	0.2	2.81	1.01	41	29	30	100	7.5YR5/6	very slow	friable	0
111	4.4	0.71	0.08	9	3.7	20	0.21	0.1	0.04	0.02	5.02	7	2.72	0.24	2.88	1.11	32	28	40	30	10YR4/2	very quick	friable	0
112	4.3	0.9	0.17	5	2.9	52	0.21	0.27	0.11	0.02	7.47	8	3.34	0.04	3.39	1.07	50	1	49	80	10YR6/6	quick	friable	13
113	4.2	0.77	0.13	6	1.8	29	0.1	0.51	0.06	0.18	7.87	11	3.59	0.1	3.7	1.04	44	11	45	100	10YR6/6	quick	friable	20
114	4.5	0.9	0.09	10	7.5	44	0.1	0.15	0.08	0	7.07	5	3.96	0.02	2.41	1.21	35	27	38	100	10YR6/4	moderate	friable	14

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
115	4.5	0.62	0.09	7	2.9	61	0.1	0.27	0.13	0.05	3.93	14	3.6	0.02	3.11	0.89	30	22	48	75	10YR5/4	quick	very friable	0
116	4.3	1.34	0.18	7	4.9	38	0.22	0.27	0.08	0.03	11.67	5	5.22	0.45	4.37	1.04	52	1	47	100	7.5YR5/8	impeded	friable	19
117	5.9	1.27	0.1	13	3.3	52	1.13	1.89	0.11	1.54	4.71	99	0.39	0	2.29	0.94	22	46	32	110	2.5Y5/2	moderate	loose	0
118	5.7	1.15	0.18	6	5.4	29	7.33	1.88	0.06	0.05	6.73	100	0	0.15	3.51	0.96	32	4	64	100	10YR5/4	very slow	friable	0
119	4.6	0.6	0.11	5	7.5	19	0.26	0.48	0.04	0	4.76	16	1.57	0.05	3.97	1.08	37	20	43	110	10YR5/4	very slow	very friable	0
120	5.2	2.46	0.18	14	959.2	39	11.25	1.02	0.08	0.05	15.51	80	0.2	0	3	1.11	37	12	51	100	10YR5/4	very slow	very friable	0
121	4.2	1.26	0.14	9	1.3	34	0.37	0.38	0.07	0.02	14.82	6	8.25	0.21	3.18	1.34	51	5	44	100	10YR5/6	very slow	friable	0
122	4.2	0.83	0.13	6	3.4	28	0.36	0.26	0.06	0.02	10.22	7	8.04	0.67	2.57	1.05	40	14	46	100	10YR5/8	quick	friable	27
123	4.2	1.41	0.17	8	2.6	43	0.31	0.29	0.09	0.03	14.61	5	10.18	0.57	2.32	1.41	46	11	43	100	7.5YR5/8	quick	friable	20
124	4.4	0.88	0.14	6	3.4	33	0.26	0.26	0.07	0.03	12.63	5	8.63	0.55	2.59	1.2	42	15	43	100	7.5YR5/8	moderate	friable	0
125	4.6	3.59	0.25	14	6.3	22	3.15	1.42	0.02	0.06	9.99	47	0.69	0.31	2.53	.	19	55	26	40	10YR5/2	impeded	loose	0
126	4.6	0.66	0.07	9	6.3	10	0.31	0.17	0	0	6.77	7	3.9	0.17	0.87	1.45	29	38	33	100	10YR5/4	moderate	very friable	0
127	4.5	0.97	0.12	8	2.7	21	0.22	0.18	0.02	0	13.57	3	10.5	0.51	1.65	1.22	50	9	41	100	7.5YR5/8	quick	strong	22
128	4.4	0.98	0.1	10	3.4	20	0.21	0.21	0.02	0	11.11	4	6.89	0.27	2.5	1.24	37	19	44	100	10YR6/6	quick	friable	18
129	4.5	1.2	0.18	7	3.4	48	0.37	0.73	0.09	0	8.28	14	7.66	0.27	2.15	1.3	40	8	52	60	7.5YR5/6	very quick	strong	38
130	4.5	0.68	0.09	8	2.1	20	0.16	0.14	0.02	0	13.66	2	10.09	0.26	2.73	1.21	45	15	40	40	7.5YR6/6	very quick	strong	20
131	4.5	1.66	0.15	11	5.8	70	0.37	0.78	0.15	0.03	12.71	10	10.12	0.22	2	1.03	50	34	16	60	10YR5/6	quick	very friable	42
132	4.8	1.87	0.15	12	9.3	47	0.37	0.25	0.09	0.03	8.27	9	4.01	0.13	1.89	1.07	31	37	32	100	10YR5/4	moderate	very friable	0
133	4.5	1.32	0.16	8	3.3	34	0.27	0.23	0.07	0.07	14.99	4	11.6	0.89	1.8	1.09	50	6	44	50	7.5YR5/6	quick	friable	32
134	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1.37	.	.	.	7	2.5Y5/2	moderate	friable	0
135	4.6	1.18	0.17	7	6.2	34	0.59	0.48	0.07	0.02	13.82	8	9.54	0.65	2.61	1.17	50	10	40	50	7.5YR5/6	moderate	strong	10
136	4.6	0.76	0.08	10	3.3	15	0.2	0.2	0.02	0.03	7.53	6	5.27	0.03	1.98	1.23	36	26	38	30	10YR6/6	very slow	strong	5
137	4.3	2.04	0.18	11	7.8	60	0.26	0.48	0.11	0	16.08	5	11.09	0.62	1.98	0.88	37	17	46	60	10YR5/8	quick	friable	0
138	4.7	4.61	0.37	12	26.4	75	2.81	1.33	0.16	0.02	17.08	25	3.78	0.17	1.75	0.63	53	6	41	100	10YR5/2	impeded	strong	0
139	5	2.52	0.26	10	13.7	87	3.57	2.71	0.18	0.02	13.42	48	3.25	0.03	1.84	1.25	37	19	44	30	10YR5/4	very quick	friable	42
140	4.5	1.2	0.14	9	3.9	35	0.5	0.54	0.07	0.03	12.66	9	7.57	0.3	2.71	1.22	42	11	47	40	10YR5/8	very quick	friable	38
141	4.6	1.33	0.2	7	5.5	47	1.52	3.36	0.08	0.06	13.08	38	4.45	0.07	2.34	1.09	40	21	39	40	10YR5/6	very quick	friable	44
142	4.3	1.64	0.17	10	6.7	40	0.28	0.25	0.07	0	14.02	4	10.28	0.54	2.4	0.85	52	15	33	50	10YR4/3	very quick	friable	14
143	4.4	0.87	0.12	7	5.1	33	0.79	0.26	0.05	0	10.91	10	7.67	0.63	2.58	1.02	49	19	32	60	10YR6/6	very quick	friable	29

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	CEC	Bsat	Al^{3+}	H^{+}	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
144	4.3	1.14	0.14	8	6.1	34	0.83	0.18	0.07	0	11.06	10	8.13	0.35	1.73	1.22	40	23	37	60	10YR6/6	quick	strong	40
145	4.4	0.73	0.1	7	5.1	31	0.43	0.18	0.04	0.02	10.17	7	7.47	0.04	1.88	0.99	43	22	35	60	7.5YR6/6	very quick	strong	29
146	4.8	0.92	0.1	9	6.5	52	1.41	0.93	0.07	0.04	7.26	34	2.32	0.06	1.59	1.35	26	47	27	60	7.5YR5/1	very slow	loose	0
147	4.6	1.42	0.16	9	5.4	46	0.39	0.26	0.07	0	11.65	6	6.95	0.26	2.22	1.2	45	23	32	60	10YR6/6	very quick	friable	30
148	4.4	1.31	0.18	7	7.8	76	0.64	0.56	0.16	0.07	12.75	11	7.72	0.12	1.69	0.93	46	19	35	20	10YR6/6	very quick	friable	28
149	4.7	0.29	0.06	5	4.1	21	0.71	0.39	0	0.02	6.71	17	3.44	0.04	1.8	1.41	25	45	30	60	7.5YR6/6	slow	very strong	5
150	4.7	0.76	0.1	8	4.5	35	0.56	0.13	0.05	0.05	8.76	9	5.78	0.12	2.14	1.14	39	23	38	100	10YR6/6	moderate	friable	10
151	4.6	1.47	0.17	9	5	34	0.71	0.1	0.02	0	10.14	8	6.36	0.12	2.41	1.08	41	28	31	100	10YR5/6	quick	friable	18
152	4.9	0.94	0.1	9	5.7	44	0.86	0.71	0.07	0.02	6.19	27	2.44	0.14	1.83	1.47	29	37	34	30	10YR6/6	very slow	friable	0
153	4.5	0.81	0.07	12	7.5	10	0.46	0.08	0	0.02	6.97	8	4.59	0.31	2.03	1.39	25	39	36	110	10YR6/6	very slow	friable	0
154	4.5	1.21	0.14	9	6.6	36	0.57	0.19	0.05	0	10.3	8	7	0.24	2.33	1.16	44	26	30	60	10YR5/6	very quick	friable	34
155	4.8	1.01	0.12	8	25.7	246	2.15	0.54	0.52	0.03	8.44	38	2.47	0.1	2.63	1.26	25	46	29	110	10YR5/3	impeded	loose	0
156	4.4	2.13	0.22	10	4.5	64	0.8	0.26	0.13	0.02	17.39	7	9.92	0.39	2.05	1.04	50	12	38	60	7.5YR5/6	very quick	friable	30
157	4.7	1.14	0.11	10	3.9	70	0.52	1.03	0.13	0.02	11.93	14	5.93	0.2	3.15	1	34	33	33	60	10YR6/6	moderate	friable	22
158	4.4	0.97	0.17	6	5.2	42	0.52	0.81	0.06	0	11.46	12	6.66	0.37	2.91	1.17	24	19	57	60	10YR6/6	quick	strong	30
159	4.2	1.09	0.16	7	4.2	152	0.52	0.22	0.32	0	12.1	9	8.16	0.17	1.08	0.99	54	8	38	60	7.5YR6/6	quick	strong	26
160	4.7	0.79	0.14	6	1.5	67	0.52	0.57	0.14	0.05	7.88	16	4.02	0.15	3.69	1.06	43	10	47	80	10YR6/6	moderate	friable	32
161	4.5	1.07	0.1	11	0.5	38	0.52	0.17	0.08	0.02	9.65	8	5.94	0.11	3.97	1.06	38	28	34	80	7.5YR6/8	very slow	friable	5
162	4.7	0.48	0.07	7	3	29	0.26	0.13	0.06	0	7.75	6	5.18	0.19	3.4	0.87	35	22	43	110	10YR5/4	impeded	friable	0
163	4.6	1.08	0.09	12	5.6	71	0.88	0.56	0.11	0.13	8.92	19	4.91	0.53	2.31	1.12	33	40	27	80	2.5Y6/4	quick	friable	18
164	5	1.2	0.19	6	5.8	43	5.9	1.89	0.09	0.16	14.43	56	2.64	0.11	2.09	0.98	39	12	49	80	2.5Y5/3	impeded	friable	0
165	4.8	0.52	0.06	9	4.1	19	0.42	0.1	0.04	0.13	3.54	19	2.28	0.22	1.55	1.19	24	45	31	80	10YR5/4	impeded	friable	0
166	4.6	0.69	0.07	10	4.6	19	0.58	0.17	0.04	0.13	5.28	17	3.55	0.36	1.4	1.23	27	44	29	80	10YR6/6	moderate	friable	0
167	4.8	1.08	0.15	7	3.6	42	0.68	0.85	0.09	0.16	15	12	9.86	0.98	3.04	0.8	48	12	40	80	7.5YR5/4	very quick	friable	28
168	5.2	0.37	0.06	6	3.1	62	1.24	0.36	0.13	0.15	11.06	17	6.48	0.16	4.5	0.95	25	20	55	20	10YR6/6	quick	friable	30
169	5.2	1.2	0.09	13	8	38	2.31	1.15	0.08	0.19	5.61	66	0.35	0.19	0.37	.	10	81	9	20	2.5Y6/2	impeded	loose	0
170	4.8	0.33	0.06	6	5.5	19	0.41	0.14	0.04	0.11	4.34	16	2.94	0.2	1.58	1.03	25	27	48	80	10YR6/6	impeded	friable	0
171	4.7	0.89	0.12	7	3.8	35	1	0.42	0.07	0.12	14.22	11	8.73	0.62	2.07	1.02	42	24	34	80	10YR6/6	quick	friable	22
172	4.9	0.53	0.07	8	3.9	34	0.69	0.17	0.07	0.11	5.34	19	2.51	0.27	1.58	1.38	27	40	33	80	10YR7/6	very slow	friable	0

Sample nr	pH	C	N	C/N	P	K	Ca^{2+}	Mg^{2+}	K^+	Na^+	CEC	Bsat	Al^{3+}	H^+	Fe^{3+}	BD	Clay	Sand	Silt	Depth	Colour	Drainage	Consistency	Slope
	-	(%)		-	(ppm)		(me/100g)					(%)	(me/100g)		(%)	(g/cm^3)	(%)			(cm)				(%)
173	4.8	0.61	0.09	7	11.4	19	1.1	0.22	0.04	0.11	4.56	32	2.19	0.26	1.11	1.22	23	48	29	80	2.5Y6/6	moderate	friable	0
174	5.3	0.7	0.12	6	4.2	49	5.02	1.6	0.09	0.13	10.87	63	1.6	0.05	1.93	0.99	34	16	50	80	10YR4/2	very slow	friable	0
175	4.8	0.52	0.07	7	2.9	24	0.61	0.45	0.05	0.14	9.04	14	7.44	0.86	2.44	1.21	14	30	56	60	10YR6/6	very quick	strong	15
176	5.6	1.13	0.19	6	6.5	110	10.09	2.58	0.23	0.15	17.31	75	0.62	0.03	2.11	0.87	36	24	40	100	10YR4/2	impeded	strong	0
177	4.8	0.67	0.12	6	4	133	0.82	0.54	0.18	0.13	13.59	12	9.5	0.9	2.29	0.9	40	14	46	60	10YR6/6	very quick	strong	30
178	5.2	0.49	0.1	5	4.1	43	3.57	1	0.09	0.13	7.85	61	3.2	0.29	2.08	1.12	31	38	31	40	2.5Y5/2	very quick	friable	25
179	4.8	0.44	0.08	6	3.9	35	0.7	0.28	0.07	0.13	10.7	11	8.82	0.87	2.23	1.06	34	37	29	80	10YR6/4	very quick	friable	32
180	4.7	0.7	0.06	12	8.4	29	0.9	0.19	0.06	0.13	7.61	17	7.91	0.65	1.03	0.91	27	56	17	100	10YR5/4	very quick	friable	25
181	4.8	1.46	0.14	10	5	48	1.09	0.42	0.1	0.15	18.28	10	10.61	0.86	2.67	0.95	53	13	34	100	10YR6/6	very quick	friable	22
182	4.2	0.64	0.1	6	1.5	119	0.46	0.67	0.25	0.18	11.99	13	8.59	0.62	4.72	1.17	41	10	49	80	2.5Y6/4	very quick	friable	34
183	4.3	0.91	0.11	8	2.1	47	0.63	0.57	0.1	0.18	10.1	15	6.57	0.52	2.21	1.11	17	37	46	60	10YR6/6	very quick	friable	21
184	4.1	0.72	0.1	7	2.1	60	0.69	1.53	0.11	0.15	10.94	23	8.93	0.98	2.43	1.05	39	29	32	60	7.5YR6/6	quick	friable	20
185	4.6	0.63	0.1	6	3.2	48	5.23	2.53	0.1	0.18	10.92	74	3.14	0.12	1.58	1.38	32	39	29	60	2.5Y6/4	quick	strong	28
186	4.3	0.59	0.04	15	8.2	19	0.79	0.35	0.04	0.15	3.36	40	1.62	0.32	0.49	.	17	58	25	70	2.5Y7/1	impeded	loose	0
187	4	0.81	0.11	7	2.7	43	0.55	0.23	0.09	0.19	17	6	11.99	2.12	2.67	1.1	45	12	43	80	5YR5/4	very quick	strong	18
188	6	0.87	0.14	6	4.1	48	9.38	2.7	0.1	0.18	11.38	100	0	0.04	2	1.58	27	24	49	100	G16/N	impeded	friable	0
189	4.3	0.68	0.07	10	15.6	28	1.47	0.48	0.06	0.12	4.2	51	1.28	0.28	0.58	1.02	18	54	28	60	2.5Y6/2	impeded	friable	0
190	5.3	1.03	0.12	9	4.8	39	12.85	2.96	0.08	0.17	15.46	100	0	0.02	2.2	1.06	20	56	24	60	2.5Y5/3	impeded	very friable	0
191	3.7	0.87	0.09	10	2.4	39	0.52	0.26	0.08	0.12	10.87	9	5.88	0.45	3.09	1.12	49	25	26	60	10YR6/4	moderate	friable	16
192	4.2	0.81	0.14	6	1.6	39	1.58	0.86	0.08	0.12	11.75	22	5.4	0.47	2.1	0.9	42	7	51	60	2.5Y5/4	very slow	friable	0
193	4.2	0.6	0.1	6	2.7	52	1.47	1.53	0.11	0.13	16.05	20	9.04	1.1	2.57	0.9	34	19	47	60	10YR6/4	very quick	strong	30
194	5.3	1.55	0.17	9	7.5	67	6.25	1.77	0.14	0.13	11.46	72	0.39	0.15	1.65	0.97	29	42	29	60	2.5Y6/4	moderate	friable	15
195	4.4	0.68	0.15	5	2.9	90	2.11	1.7	0.19	0.12	8.45	49	5.52	0.6	2.86	1.06	37	23	40	60	10YR6/6	moderate	strong	21
196	4.3	0.73	0.16	5	2.7	38	5.13	2.09	0.08	0.18	13.21	57	3.34	0.23	2.52	1.03	44	3	53	60	2.5Y5/3	very slow	strong	0
197	4.3	0.64	0.1	6	136.9	38	3.14	2.24	0.08	0.15	10.29	55	2.16	0.26	2.74	0.85	27	37	36	80	2.5Y4/2	very slow	friable	0
198	4.7	0.71	0.14	5	4.7	72	6.94	2.16	0.15	0.15	11.42	82	0.38	0.13	1.99	1	32	29	39	80	2.5Y4/2	very slow	friable	0
199	4.4	0.51	0.08	6	4.7	72	1.09	0.48	0.15	0.16	7.85	24	3.84	0.3	2.44	1.27	33	34	33	80	10YR5/6	moderate	friable	0
200	3.7	0.86	0.15	6	4.5	62	0.63	0.35	0.13	0.12	11.08	11	7.98	0.78	4.34	1.02	43	14	43	80	10YR6/6	quick	strong	0

Appendix 2b. All plot's data and soil sub-surface characteristics (see main report for definitions; part3)

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
1	442729	341625	Seturan	Fallow	Swamp	none	5	quite fine	.	.
2	442726	341373	Seturan	Special, natural	Plain	none	7	moderate	.	.
3	442042	341155	Seturan	Fallow	Plain	none	2	moderate	.	.
4	440262	340394	Seturan	Horticulture	Aluvial Plain	none	5	moderate	.	.
5	440337	340505	Seturan	Special, modified	Aluvial Plain	none	7	moderate	.	.
6	442022	340993	Seturan	Agriculture	Plain	none	0	moderate	.	.
7	443082	341061	Seturan	Primary forest	Hill	none	11	quite fine	.	.
8	443228	341086	Seturan	Primary forest	Hill	none	11	quite fine	.	.
9	441878	341883	Seturan	Fallow	Hill	none	0	quite fine	.	.
10	442361	341985	Seturan	Primary forest	Hill	sheet	5	quite fine	.	.
11	442797	338832	Seturan	Primary forest	Hill	none	11	moderate	.	.
12	442704	339311	Seturan	Fallow	Plain	none	4	quite fine	.	.
13	442801	339284	Seturan	Fallow	Plain	none	1	moderate	.	.
14	442302	337337	Seturan	Primary forest	Hill	none	9	quite fine	.	.
15	442415	337388	Seturan	Primary forest	Hill	none	9	quite fine	.	.
16	442355	337630	Seturan	Fallow	Hill	none	6	quite fine	.	.
17	442450	337671	Seturan	Fallow	Hill	none	4	moderate	.	.
18	443312	339434	Seturan	Primary forest	Plain	none	3	quite coarse	.	.
19	443507	339233	Seturan	Modified forest	Plain	none	5	quite coarse	.	.
20	445498	332304	Seturan	Special, modified	Plain	none	3	quite fine	.	.
21	445870	331957	Seturan	Old fallow	Plain	none	12	moderate	.	.
22	450244	331496	Seturan	Primary forest	Hill	none	12	quite fine	.	.
23	450372	331294	Seturan	Primary forest	Hill	none	11	quite fine	.	.
24	445633	333533	Seturan	Special, natural	Hill	none	8	quite fine	.	.
25	445556	333386	Seturan	Primary forest	Hill	none	12	moderate	.	.
26	446757	331671	Seturan	Special, natural	Hill	none	6	fine	.	.
27	446818	331677	Seturan	Special, natural	Plain	none	7	quite fine	.	.
28	444626	333921	Seturan	Special, modified	Plain	sheet	8	quite coarse	.	.
29	448482	332868	Seturan	Primary forest	Hill	none	11	moderate	.	.
30	448485	332692	Seturan	Primary forest	Hill	sheet	11	quite fine	.	.
31	445483	331749	Seturan	Old fallow	Aluvial Plain	none	8	fine	.	.
32	445465	331540	Seturan	Primary forest	Hill	none	6	fine	.	.

Sample nr	Eastings	Northings	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
	(m)									
33	445105	331899	Seturan	Primary forest	Plain	none	9	quite fine	.	.
34	448058	330082	Seturan	Special, natural	Plain	none	6	moderate	.	.
35	442142	340969	Seturan	Agriculture	Plain	none	0	quite fine	.	.
36	442033	340871	Seturan	Special, modified	Aluvial Plain	none	0	moderate	.	.
37	441259	340946	Seturan	Horticulture	Plain	none	3	quite fine	.	.
38	441630	341853	Seturan	Agriculture	Plain	none	0	moderate	.	.
39	441448	341789	Seturan	Fallow	Plain	none	2	quite fine	.	.
40	441539		Seturan	Horticulture	Plain	none	5	quite fine	.	.
41	441533	341173	Seturan	Horticulture	Plain	none	3	quite fine	.	.
42	441153	341021	Seturan	Horticulture	Plain	none	4	moderate	.	.
43	445339	339528	Seturan	Old fallow	Aluvial Plain	none	4	quite fine	.	.
44	445165	339796	Seturan	Primary forest	Hill	sheet	9	quite fine	.	.
45	445488	339111	Seturan	Old fallow	Plain	none	7	quite fine	.	.
46	445530	339159	Seturan	Modified forest	Hill	none	5	fine	.	.
47	444385	343744	Seturan	Modified forest	Hill	sheet	8	quite fine	.	.
48	444504	343903	Seturan	Special, modified	Hill	none	0	fine	.	.
49	443480	339104	Seturan	Primary forest	Hill	none	9	quite fine	.	.
50	443286	338928	Seturan	Primary forest	Hill	none	8	quite fine	.	.
51	443650	339620	Seturan	Special, natural	Swamp	none	5	quite fine	.	.
52	443729	339933	Seturan	Agriculture	Plain	none	0	moderate	.	.
53	443853	338622	Seturan	Special, natural	Hill	none	7	quite coarse	.	.
54	443451	340084	Seturan	Horticulture	Swamp	none	6	quite coarse	.	.
55	443501	339972	Seturan	Special, natural	Plain	none	9	coarse	.	.
56	444716	340913	Seturan	Special, natural	Hill	none	15	moderate	.	.
57	444750	340924	Seturan	Special, natural	Hill	none	9	moderate	.	.
58	444510	339299	Seturan	Primary forest	Hill	sheet	8	moderate	.	.
59	439668	345359	Langap	Fallow	Plain	none	5	quite fine	.	0-50
60	441780	345867	Langap	Agriculture	Aluvial Plain	none	0	quite fine	.	0-20+
61	441985	346956	Langap	Modified forest	Hill	sheet	14	quite coarse	.	0-20+
62	440552	345489	Langap	Horticulture	Aluvial Plain	none	9	quite coarse	.	0-85
63	439401	344202	Langap	Fallow	Swamp	none	1	quite coarse	.	0-50
64	439283	344056	Langap	Modified forest	Plain	none	9	quite coarse	9-30+	0-30+
65	440185	346228	Langap	Fallow	Aluvial Plain	none	0	quite fine	.	0-24
66	440109	345787	Langap	Special, modified	Aluvial Plain	none	0	fine	.	0-40

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
67	442618	346459	Langap	Modified forest	Hill	sheet	11	fine	18-40	0-40
68	443666	345145	Langap	Modified forest	Hill	gully	11	moderate	9-30	0-30/35
69	443755	345393	Langap	Primary forest	Hill	gully	12	moderate	0-40	0-40
70	440632	345665	Langap	Special, natural	Swamp	none	7	quite fine	.	0-7
71	441666	345847	Langap	Horticulture	Aluvial Plain	none	6	quite fine	.	0-12+
72	440177	345820	Langap	Fallow	Aluvial Plain	none	1	quite fine	.	0-35+
73	440059	346019	Langap	Old fallow	Aluvial Plain	none	3	quite fine	20/24+	0-20/24+
74	441586	348555	Langap	Primary forest	Hill	rill	14	quite fine	19-30+	0-30+
75	443388	347454	Langap	Modified forest	Hill	sheet	9	quite fine	.	0-30
76	443782	348987	Langap	Primary forest	Hill	gully	11	quite fine	.	0-25/33+
77	443041	348562	Langap	Primary forest	Hill	sheet	17	quite fine	.	0-35+
78	445308	343990	Langap	Primary forest	Plain	gully	8	quite fine	.	0-20+
79	445114	343902	Langap	Modified forest	Plain	rill	7	moderate	.	0-24/30+
80	445416	343587	Langap	Primary forest	Hill	gully	12	fine	.	0-60/70
81	443973	343703	Langap	Modified forest	Hill	none	15	quite coarse	.	0-39+
82	444125	343786	Langap	Modified forest	Aluvial Plain	none	9	moderate	0-30	0-30
83	442701	345680	Langap	Old fallow	Aluvial Plain	gully	11	quite fine	.	0-10+
84	443321	347470	Langap	Modified forest	Hill	gully	7	quite fine	.	0-32
85	440393	345282	Langap	Horticulture	Aluvial Plain	none	10	quite fine	0-2	0-35
86	440193	345038	Langap	Fallow	Plain	none	4	quite fine	.	0-45
87	440282	342633	Langap	Horticulture	Swamp	none	10	moderate	.	0-40
88	439799	345495	Langap	Special, modified	Swamp	none	0	moderate	7/40+	0-29/40
89	439521	345025	Langap	Special, modified	Swamp	none	8	quite fine	6-60+	0-40
90	439366	343924	Langap	Special, natural	Swamp	none	12	quite coarse	.	0-40
91	438153	344521	Laban Nyarit	Old fallow	Plain	rill	7	quite fine	.	0-25+
92	437340	344717	Laban Nyarit	Primary forest	Hill	rill	8	quite fine	.	41+
93	438267	342045	Laban Nyarit	Special, natural	Hill	rill	13	fine	.	0--30/40
94	438280	343473	Laban Nyarit	Fallow	Plain	sheet	4	fine	17-25+	0-25+
95	436845	340418	Laban Nyarit	Modified forest	Hill	sheet	13	quite fine	11-42+	0-42+
96	436698	340278	Laban Nyarit	Primary forest	Hill	rill	12	fine	.	0--53
97	437389	340700	Laban Nyarit	Primary forest	Swamp	rill	10	moderate	0-30+	0-5
98	437173	340171	Laban Nyarit	Special, natural	Hill	rill	13	fine	.	0-40+
99	437177	340752	Laban Nyarit	Modified forest	Hill	gully	13	quite fine	.	0-19+
100	437584	344023	Laban Nyarit	Modified forest	Hill	gully	10	quite fine	.	0-50+

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
101	437613	344459	Laban Nyarit	Horticulture	Plain	sheet	8	quite fine	.	0-50+
102	437843	344342	Laban Nyarit	Fallow	Plain	sheet	10	fine	.	0-6/18+
103	437613	345394	Laban Nyarit	Primary forest	Hill	gully	10	quite fine	.	0-29/58+
104	437473	344872	Laban Nyarit	Primary forest	Hill	rill	15	fine	.	0-33+
105	437250	344598	Laban Nyarit	Agriculture	Hill	rill	0	quite fine	.	0-20+
106	434151	338311	Laban Nyarit	Special, modified	Swamp	none	6	fine	.	-
107	438978	343331	Laban Nyarit	Special, modified	Swamp	none	10	quite coarse	.	-
108	438459	343814	Laban Nyarit	Agriculture	Swamp	none	0	quite fine	.	-
109	438317	343978	Laban Nyarit	Primary forest	Hill	sheet	12	fine	.	0-50+
110	432464	338779	Laban Nyarit	Primary forest	Hill	rill	13	fine	.	0-25+
111	434246	338723	Laban Nyarit	Special, modified	Plain	none	13	quite fine	.	0-40+
112	433196	337010	Laban Nyarit	Primary forest	Hill	rill	13	fine	.	0-30
113	433289	337099	Laban Nyarit	Primary forest	Hill	rill	10	fine	.	0-20/30
114	437533	345388	Laban Nyarit	Primary forest	Hill	rill	16	quite fine	.	0-30+
115	437821	345633	Laban Nyarit	Fallow	Hill	gully	5	moderate	3-17	0-45
116	436389	339271	Laban Nyarit	Old fallow	Hill	rill	14	fine	.	0-40+
117	433743	342423	Laban Nyarit	Special, modified	Swamp	none	3	moderate	.	-
118	437786	344622	Laban Nyarit	Horticulture	Aluvial Plain	gully	6	moderate	.	0-30/35+
119	437468	341711	Laban Nyarit	Horticulture	Aluvial Plain	none	14	quite fine	.	0-38+
120	437848	342499	Laban Nyarit	Horticulture	Aluvial Plain	none	10	quite fine	.	0-55
121	406374	313622	Long Jalan	Fallow	Hill	none	1	fine	.	0-36+
122	406151	314032	Long Jalan	Agriculture	Hill	sheet	0	quite fine	.	0-20+
123	405866	314009	Long Jalan	Modified forest	Hill	sheet	16	fine	0-21/36+	0-21/36+
124	405887	313632	Long Jalan	Fallow	Hill	sheet	0	fine	32+	0-32+
125	405707	313431	Long Jalan	Primary forest	Swamp	rill	9	moderate	.	-
126	403488	313389	Long Jalan	Horticulture	Plain	none	7	moderate	.	0-32+
127	405671	313722	Long Jalan	Primary forest	Hill	gully	9	fine	.	0-45+
128	403850	313397	Long Jalan	Old fallow	Hill	rill	8	quite fine	.	0-45+
129	406485	314012	Long Jalan	Modified forest	Hill	rill	10	fine	0-30+	0-30+
130	404333	313353	Long Jalan	Primary forest	Hill	rill	11	fine	6-27	0-27+
131	405146	314127	Long Jalan	Primary forest	Hill	rill	14	quite fine	6-16+	0-16+
132	405690	313835	Long Jalan	Modified forest	Aluvial Plain	rill	11	quite fine	.	0-37
133	403715	312602	Long Jalan	Primary forest	Hill	rill	15	fine	7-50+	0-50+
134	404515	314456	Long Jalan	Special, natural	Aluvial Plain	gully	6	quite fine	.	0-7

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
135	403640	312200	Long Jalan	Modified forest	Hill	rill	12	fine	0-23+	0-23+
136	403919	312086	Long Jalan	Fallow	Aluvial Plain	sheet	6	quite fine	.	0-32+
137	405649	314767	Long Jalan	Primary forest	Hill	rill	16	fine	0-40+	0-40+
138	405901	313051	Long Jalan	Primary forest	Swamp	none	7	fine	.	0-17+
139	404804	313377	Long Jalan	Modified forest	Hill	rill	8	quite fine	.	0-30
140	403546	313038	Long Jalan	Primary forest	Hill	gully	9	fine	.	0-30+
141	404014	312109	Long Jalan	Primary forest	Hill	gully	9	quite fine	0-40	0-40
142	431324	326220	Liu Mutai	Primary forest	Hill	rill	13	fine	23/30+	0-23/30+
143	431263	326159	Liu Mutai	Primary forest	Hill	rill	12	fine	8-40+	0-40+
144	431212	326290	Liu Mutai	Fallow	Hill	rill	0	fine	10-25+	0-25+
145	432105	326298	Liu Mutai	Modified forest	Hill	gully	10	quite fine	28+	0-28+
146	432094	326236	Liu Mutai	Primary forest	Swamp	gully	8	quite fine	.	0-20
147	432451	326162	Liu Mutai	Primary forest	Hill	rill	12	fine	.	0-30+
148	431545	326637	Liu Mutai	Special, natural	Hill	sheet	10	quite fine	.	0-5/15+
149	427213	325560	Liu Mutai	Old fallow	Hill	gully	8	quite fine	.	0-9+
150	427946	325733	Liu Mutai	Fallow	Hill	rill	5	quite fine	.	0-45+
151	430493	327038	Liu Mutai	Special, natural	Hill	rill	16	fine	.	0-50+
152	430643	326368	Liu Mutai	Modified forest	Hill	sheet	7	quite fine	.	-
153	430561	326513	Liu Mutai	Horticulture	Aluvial Plain	sheet	14	moderate	.	35+
154	429035	326128	Liu Mutai	Primary forest	Hill	rill	15	fine	32+	32+
155	429574	325836	Liu Mutai	Special, modified	Aluvial Plain	none	0	quite coarse	.	27+
156	433019	327949	Liu Mutai	Primary forest	Hill	rill	14	fine	13-38+	38+
157	432819	328144	Liu Mutai	Primary forest	Hill	rill	14	quite fine	36+	36+
158	428205	325230	Liu Mutai	Primary forest	Hill	rill	15	fine	0-40+	40+
159	428154	325451	Liu Mutai	Primary forest	Hill	rill	12	fine	.	40+
160	428443	325902	Liu Mutai	Primary forest	Hill	rill	8	fine	4-40+	40+
161	432939	327514	Liu Mutai	Old fallow	Hill	rill	13	quite fine	.	20+
162	432996	327590	Liu Mutai	Horticulture	Aluvial Plain	rill	10	quite fine	.	40+
163	449341	368282	Gong Solok	Special, natural	Hill	rill	14	quite fine	.	40+
164	449599	367979	Gong Solok	Horticulture	Aluvial Plain	none	6	quite coarse	.	10/12+
165	448502	368214	Gong Solok	Special, natural	Swamp	none	12	moderate	.	18+
166	448695	367836	Gong Solok	Modified forest	Plain	rill	10	quite fine	32+	32+
167	446912	368093	Gong Solok	Modified forest	Hill	rill	15	fine	12-32+	32+
168	447095	367488	Gong Solok	Fallow	Plain	gully	3	quite fine	0-23	8-23

Sample nr	Eastings (m)	Northings (m)	Village	Sample Type	Landform	Erosion	Relascope Average	Texture	Hardpan Depth (cm)	Rooting Depth (cm)
169	44914	368972	Gong Solok	Primary forest	Swamp	none	11	coarse	.	-
170	448962	369039	Gong Solok	Modified forest	Swamp	none	10	moderate	12-37/45+	37/45+
171	448973	368066	Gong Solok	Primary forest	Hill	rill	9	quite fine	.	30+
172	449164	367945	Gong Solok	Old fallow	Aluvial Plain	sheet	7	moderate	.	40/50+
173	448678	367460	Gong Solok	Horticulture	Plain	rill	8	moderate	.	26/28+
174	448157	367029	Gong Solok	Horticulture	Aluvial Plain	none	6	quite fine	.	33+
175	450512	365566	Gong Solok	Modified forest	Hill	gully	11	quite fine	41+	41+
176	450462	366625	Gong Solok	Agriculture	Aluvial Plain	none	0	quite fine	.	-
177	452774	368631	Gong Solok	Primary forest	Hill	rill	11	quite fine	0-40+	40+
178	452173	367942	Gong Solok	Horticulture	Hill	rill	7	quite fine	.	32+
179	452178	367957	Gong Solok	Modified forest	Hill	rill	16	quite fine	.	38+
180	452340	368772	Gong Solok	Fallow	Hill	rill	0	quite fine	.	-
181	450943	366160	Gong Solok	Fallow	Hill	rill	0	quite fine	.	-
182	451440	365333	Gong Solok	Modified forest	Hill	rill	9	quite fine	67+	67+
183	450665	366074	Gong Solok	Fallow	Hill	rill	0	quite fine	3-40+	40+
184	449697	368682	Gong Solok	Primary forest	Hill	rill	10	quite fine	21-40	40+
185	449937	368917	Gong Solok	Modified forest	Hill	rill	9	moderate	.	8/16+
186	449020	369295	Gong Solok	Old fallow	Swamp	none	6	quite coarse	.	-
187	449173	369145	Gong Solok	Modified forest	Hill	rill	13	fine	.	27+
188	449912	368281	Gong Solok	Special, modified	Aluvial Plain	none	21	moderate	.	30+
189	448646	358486	Gong Solok	Special, modified	Swamp	none	10	quite coarse	.	30+
190	449499	360812	Gong Solok	Special, natural	Aluvial Plain	none	0	quite coarse	.	33/40+
191	450759	369722	Gong Solok	Modified forest	Plain	rill	10	fine	.	39+
192	450867	369328	Gong Solok	Agriculture	Plain	none	0	fine	.	25+
193	449850	367849	Gong Solok	Primary forest	Hill	rill	5	fine	4/13-42+	42+
194	449881	367721	Gong Solok	Old fallow	Plain	rill	9	quite fine	0-20+	20+
195	449842	367606	Gong Solok	Horticulture	Plain	rill	7	quite fine	0-35+	35+
196	449806	367914	Gong Solok	Horticulture	Plain	none	5	fine	8-29+	29+
197	449667	367810	Gong Solok	Horticulture	Plain	none	9	moderate	.	30+
198	450205	308710	Gong Solok	Fallow	Plain	none	1	quite fine	.	19-29/35
199	449147	360628	Gong Solok	Fallow	Plain	rill	5	moderate	.	40+
200	449107	360390	Gong Solok	Primary forest	Hill	rill	10	quite fine	33+	33+

Appendix 3. Rice Suitability Model for the Upper Malinau

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In the main report it is clear that most land in the upper Malinau has little if any potential for intensive land-uses, such as sustainable rice or plantation crops. Given this limitation, a map showing where land is most likely to be suitable for more intensive rice production could be useful. It can guide local communities and local government in identifying those few areas where agriculture might be intensified. This is the main reason for our work on developing a rice suitability map for Upper Malinau, which is discussed here.

As the initial step, each of the 200 plots were classified into one of the four rice suitability classes as defined using a set of standard criteria (Bina Program, 1997: see main text). These criteria are based on large-scale permanent cropping without continuous fertilization, not on local swidden-fallow cultivation. Since plots in the most suitable classes, S1 and S2, are few (4 and 11 respectively), we combined these classes as 'suitable', and compare them against the unsuitable (S3 and N) classed sites.

Using these data we developed a spatial model to predict suitability. We assumed that the probability of a plot being suitable for rice depends on its *distance to nearest river (m)* and its *altitude (m asl.)*. The distance and altitude data were generated using "near" and "overlay" analysis in ArcGIS (version 8.3, 2002). One hundred and ninety eight plots were used in this analysis. The two plots excluded from our analysis are two plots located far away from the river (> 2 km) – exploratory analysis had revealed that the suitability of these plots is anomalous.

To assess model accuracy we split the data into two subsets. One hundred and fifty plots are randomly chosen and the following model,

$$P(Y_i = suitable) = \frac{\exp(\beta_0 + \beta_1 D_i + \beta_2 A_i + \beta_3 D_i^2 + \beta_4 A_i^2)}{1 + \exp(\beta_0 + \beta_1 D_i + \beta_2 A_i + \beta_3 D_i^2 + \beta_4 A_i^2)}$$

where:
Y_i = rice suitability class of plot i
D_i = distance to the river from plot i
A_i = altitude of plot i
was selected. This choice was based on minimising its AIC (Akaike, 1974). Estimation of coefficients was carried out using the R package (www.r-project.org) within the Generalized Linear Models (GLM) framework (McCullagh and Nelder, 1989).

Using a data re-sampling approach we took 100 random samples of 150 plots (without replacement) giving us 100 different realisations. For each realisation the model's coefficients are estimated. Then, using these estimates, the remaining 48 plots are classified. This approach uses all the data but reduces the sensitivity of the estimates to specific plot distributions and values, and therefore increases the robustness of the estimates. The average of estimates from the 100 realisations is given in Table Ap3. I below.

Table Ap3. I. Average parameter estimates of the suitability model

Parameter	Average
Intercept	-3.835
Altitude (m a.s.l.)	0.0338
Distance (m)	0.0151
Squared Altitude	-0.0002
Squared Distance	-0.00003

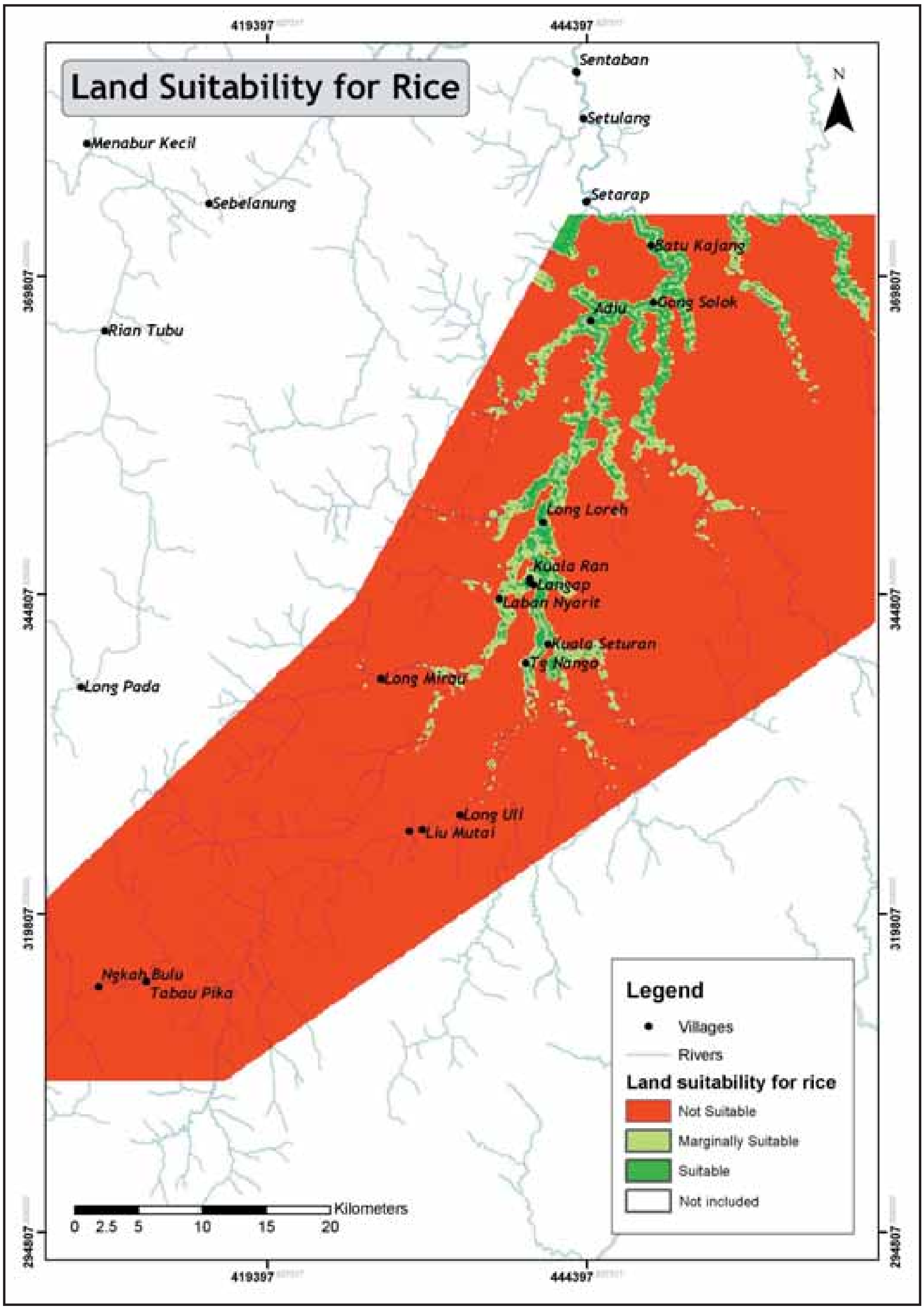
We assess model accuracy by looking at the percentage of correctly-classified plots. A plot of is classified as 'suitable' if it has at least 50% probability of being 'suitable'. For each of the 100 realisations, a classification table is computed to measure the accuracy of the model. The tables are then averaged to yield an 'average' classification table. The classification table below shows that an average model is good in predicting 'non-suitable' plots (accuracy 90.5%) but is less good in predicting 'suitable' plots (accuracy 28.1%).

Table Ap3. II. Average classification accuracy based on 100 realisations of the suitability model

Actual Predicte	'Non-suitable'	'Suitable'
'Non-suitable'	0.905	0.729
'Suitable'	0.095	0.281

Based on the average parameter estimates in Table Ap3. II, we predicted rice suitability over an area in the vicinity of our sample

Figure Ap3. I. Predicted rice suitability map for Upper Malinau



plots based on altitude and distance from river. These predictions were performed on a grid of points of approximaetly 120m x 120m. To cover the area between these points the Inverse Distance Weight (IDW) method (Cressie, 1993) was used. The suitability at a point is given by a weighted average of suitability probability of neigbouring points. Instead of allowing the data values to contribute equally to the average, they are weighted inversly by distance.

The resulting map is shown as Figure Ap3. I. The red-shaded area is unsuitable. 'Suitable' areas have at least 40% chance of being suitable and are seen predominantly along the riverbanks. The 'marginally suitable' areas are those with 20-40% chance of being suitable.

Model limitation

The classification (table Ap3. II) gives a measure of model accuracy. However, such statistics should be treated cautiously. The clustered nature of the plots means that systemmatic error associated with the classification is reduced near some villages (i.e, where plots are abundant) but will likely be larger, and thus less accurate, for areas where there are fewer plots.

Although we are able to produce a map of predicted suitability (Figure Ap3. I) the model itself is not perfect. Field observation indicates most suitable plots are located in flood plains. Our model does not incorporate this knowledge and hence cannot predict or distinguish these areas directly. We had previously tried to model the probability of suitability not only as a function of altitude and distance to river but also as a function of altitudinal difference between a plot and the nearest river. The idea was we would be able to predict suitable plots located in flood plains (i.e., plots far away from river but with very slight altitudinal difference to the river). However, this attempt was abandoned because our Digital Elevation Model (DEM), proved inadequate to resolve the necessary altitudinal differences.

Even altitude and data on distance from the river contain errors associated with the DEM. Certainly the rugged landscape of Malinau includes many areas that are too steep or rocky to be cultivated – though we do not have direct access to such local information on the larger spatial scale. The river layer itself includes only larger water bodies, and we have no basis for assessing the validity of this cut-off choice with respect to cultivation. A proper statistical treatment of these data will be to use methods for data with measurement errors (for example see Ruppert, *et al.*, 1995). A more accurate DEM and other spatial data could be used in the future to improve the model and reduce uncertainties. There may also be more sophisticated techniques that could be used to address uncertainties.

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All too often communities and their natural environments are the victims of poorly informed decisions. Those coming from outside often have little understanding of how local people perceive and prioritize the natural resources they depend on. The enormous harm poorly informed decisions can inflict on both people and the environment can and must be avoided.

Our research evaluates the relationship between the people of the forest rich Malinau River Valley of East Kalimantan and the condition of local land resources. Its central aim is to clarify local peoples' views and knowledge about their land resources and to suggest promising land-use choices.

We worked with seven communities in implementing a variety of natural resource research activities. This report focuses on results from the land and soils aspects of these surveys.

We consider a range of important questions and issues, including:
- The nature of land and soil conditions in the upper Malinau Watershed
- How local people perceive and use this landscape
- How local views regarding cultivation choices differ from technical evaluations
- Best land-use options




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