Royal Government of Bhutan

Bhutan Soil Survey Project
National Soil Services Centre, Simtokha
Research, Extension, and Irrigation Division
Ministry of Agriculture

TECHNICAL REPORT OF SEMI-DETAILED SOIL SURVEY OF LINGMUTEY CHHU WATERSHED

Report No SS. 5(a)

April, 1999

CONTENTS

SUMMARY

The Bhutan Soil Survey Project carried out the fieldwork for a semi-detailed soil survey of the Lingmutey Chhu watershed in February - March 1998. The watershed is the focus of multidisciplinary research and extension effort, with an emphasis on inter-disciplinary integration.

The watershed covers about 33 km^2, and stretches from about 1200 m altitude, along the main Tsang Chhu river, to over 3000 m. The geology is varied and the underlying rock types include gneiss, schist, limestone, amphibolite, skarn and quartzite. The surface deposits include alluvial terraces along Tsang Chhu, an old lake or marsh above Limbukha village, and hillwash and landslip deposits on many hill slopes.

There are still large areas of forest, including chir pine, broadleaf and some blue pine woodlands. The river terraces the Limbukha basin, and many of the gentler lower hill slopes have been terraced for irrigated cultivation of rice in summer and wheat, mustard and potatoes in winter.

The soils of the low terrace along Tsang Chhu have silty, hard topsoils over loose white sand and beds of rounded river boulders at depth. The upper horizons in the profiles of soils on the middle and upper terrace are similar to those of the low terrace. However the soils are deeper, and there are no boulder beds or sand layers in the top two metres.

The alluvial soils of the Limbukha basin are quite distinct, and consist of alternating layers of sand, silt and clay, and include some black organic layers at depth.

The main soils of the hill slopes are grey and brown sandy loams developed from gneiss. These vary in depth according to the slope and local variations in the erosion and deposition of hillwash. The red clays formed from skarn or amphibolite is another extensive hill soils. Unlike the gneiss soils, these are readily erodible and have large areas of bare red surfaces and extensive systems of deep gullies. Another distinctive hill soil is the deep, bright orange-looking light sandy loam on the quartzite ridge between Limukha and Shengana.

This survey is only of semi-detailed intensity, and gives a general picture of the soil pattern. It shows that the soils of the watershed are representative of large areas of West Central Bhutan, and that extrapolation of research results will not be invalidated by atypical soils. It is anticipated that selected areas will be studied in greater detail, as and when required by researchers in other subsectors and disciplines.

ACKNOWLEDGEMENTS

The fieldwork for this survey was done by Kado Tshering, H B Tamang and Ian Baillie of the Bhutan Soil Survey Project. They were assisted in the field by villagers from Bajothanka, Wonjokha, Matamlumchhu, Omtekha, Dompola, Nabche and Limbukha. The report was prepared by Pema Wangmo. The analyses of the soil samples were done by the Soil and Plant Analytical Laboratory (SPAL) at Simtokha. The 1:25 000 soil map was prepared by Deki Wangmo of the GIS unit of Land Use and Statistics Section of the Planning and Policy Division of the Ministry of Agriculture. The interim 1:10 000 map of the lower catchment was prepared by BSSP.

We are grateful to the Programme Coordinator, Research Officers and other staff of the Bajo Renewable Natural Resources Research Centre for their guidance and assistance in setting up the logistic arrangements for the fieldwork.

The multidisciplinary contributions from the participants at the Interdisciplinary Meeting for the Natural Resources Management in Lingmutey Chhu watershed, held at Bajo RNR-RC on 28 November 1997, provided useful insights and contributed to a better understanding of the landscape and soil pattern.

We are grateful to the Ministry of Trade and Industry for geological and meteorological data.

We are grateful to colleagues at Bajo RNR-RC, SSFPNMP, Simtokha and the Bhutan –German RNR Project, Lobesa for their detailed and helpful comments on the draft text and map.

PLACE NAMES

The Romanised spellings of place names in this report are those designated by the Lingmutey Chhu study coordinator. They do not all agree with spellings in the Survey of India topo sheet #78E/14 (1964), the Survey of Bhutan 1:25 000 topo sheet #78E/14 SE (1998), geological survey reports and maps, the PCI (1996) maps for the Wangdi Groundwater Study, and other sources. As the interim soil 1:10 000 map of the lower end of the watershed is based on the PCI 1996 topo sheets, its spellings do not all accord with those in the report.

Standardisation of Romanised place names in Bhutan is becoming a matter of general and growing urgency as data are increasingly stored in digital forms.

1. INTRODUCTION

1.1 Bhutan Soil Survey Project

The Bhutan Soil Survey Project (BSSP) was set up by an Agreement signed in September 1996 by the Royal Government of Bhutan (RGOB) and Danish International Development Assistance (Danida). It was initiated because of a perceived need for systematic information about the nature and distribution of the soils of Bhutan. The Project is part of the National Soils Services Centre of the Research, Extension and Irrigation Division in the Ministry of Agriculture.

The emphasis in the initial stages of the Project is on the training of Bhutanese nationals as soil surveyors, and the establishment of a functioning Soil Survey unit. The main method of training is by on-the-job instruction and close supervision of actual soil surveys, carried through from initial planning to final presentation. In the early stages detailed surveys were best for instruction purposes (i.e. BSSP reports 1, 2, SS3, and SS4 - see Appendix D for details). They enabled soil patterns to be worked out by direct observation with the minimum of extrapolation and assumptions.

This is the first semi-detailed soil survey undertaken by Project. It training objective is to acquaint the soil surveyors with the factor – based pedogenic approach to the planning, fieldwork, mapping, reporting, and interpretation for soil surveys in which only limited field data are collected.

1.2 Lingmutey Chhu integrated study area.

Bajo RNR-RC has initiated the Lingmutey Chhu study area so as to focus practical research and research–based extension efforts by different groups of subsector professionals on a restricted area. The idea is that this concentration will enable integration of investigations on crop and, animal production, and the management of forest, land and water resources. The results can be evaluated in the context of the demographic, cadastral, the availability and gender partitioning of labour, trading relations, and other socio-economic-cultural aspects of the area. The spatial concentration of research should highlight interactions between the subsectors. This is particularly important in Bhutan where present agricultural practices and future developments depend on the judicious and synergistic partitioning of human skills and labour, and the natural resources of water, biomass-energy, nutrients, livestock draught-power, and land between subsectors.

BSSP hopes that this soil survey will contribute to the integrated research by establishing the range and distribution of soil conditions and resources within the study area. This should help subsector specialists with the assessment of the nutrient and water resources. In addition, fuller appreciation of the soil pattern may clarify some inter-subsector interactions. The survey should also contribute to putting Lingmutey Chhu in its environmental context, and indicate where and to what extent research findings in Lingmutey Chhu can be extrapolated. This survey is only the first approximation, and BSSP anticipates doing further soil surveys in the watershed, as required by other subsectors and disciplines.

1.3 Aims of the Lingmutey Chhu semi-detailed soil survey

This semi-detailed soil survey was undertaken with objectives of:

- Further training of BSSP staff in soil survey field techniques and an introduction to the techniques of semi-detailed soil surveys.
- Adjusting standard semi-detailed soil survey practices to suit Bhutan conditions.

- Providing Bajo RNR-RC and other participants in the Lingmutey Chhu integrated study with information on the soils of the area, and their relevance elsewhere.
- Adding to the BSSP data for the development of a national soil classification and national and regional soil maps.

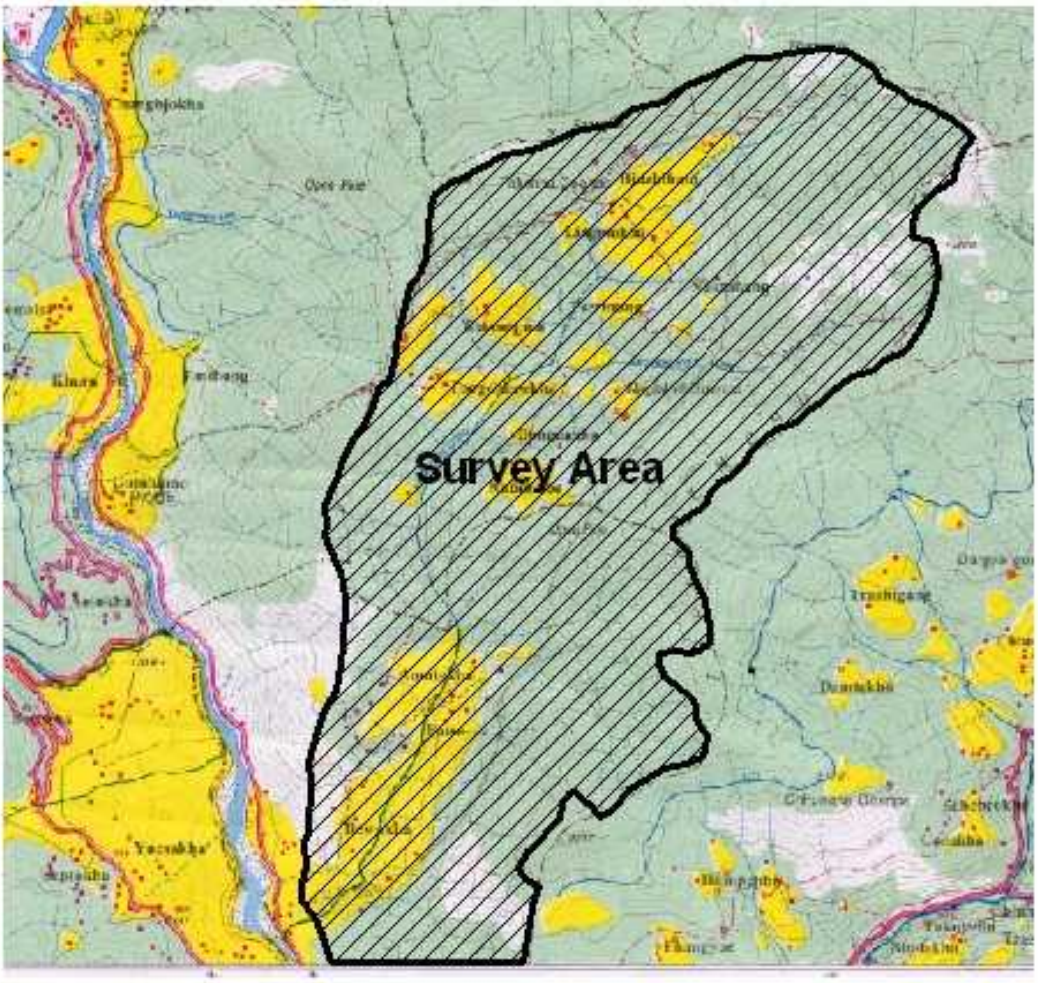
2. SURVEY AREA

2.1 Location and extent

The survey area covers the whole watershed of Lingmutey Chhu. This is a true left (i.e. east) bank tributary of Tsang Chhu, which is the main river draining much of West Central Bhutan. The survey area stretches in latitude from 27^0 30.1' to 27^0 34.9' N and in longitude from 89^0 53.3' to 89^0 57.7' E. It covers about 3340 ha (33.4 km^2).

The Lingmutey watershed is roughly lens-shaped, with the long axis oriented NNE-SSW. The axis stretches about 10.5 km, and the watershed is about 4 km across at its widest point, more or less through Dompola. The survey also includes an area along Tsang Chhu, which is not strictly part of the Lingmutey watershed. Its natural drainage is by the small stream just north of the Lingmutey, hereafter referred to as Bajothangkha Chhu. This area, of about 120 ha, is managed as part of the watershed and is partly irrigated with water from Lingmutey Chhu. Figure 2.1 gives the exact location of the survey area.

Figure 2.1 Location map of the Survey area



Nearly all of the arable land in the survey area has been titled by Survey of Bhutan (SoB) to individual households. However most of the area is still under forest, and remains as state land, administered by the Forest Services Division of the Ministry of Agriculture. Some blocks of forest are dedicated to the collection of oak leaf litter for livestock bedding and organic fertilizers (sokshing), and are regarded as the property or exclusive usufruct holdings of individual households. Sokshing blocks are usually small (< 3 ha).

2.2 Climate

The watershed ranges in altitude from about 1200 to about 3000 m a.s.l. It encompasses four major altitudinal-ecological zones (subtropical, chir pine, temperate broadleaf and blue pine forests). The climate varies considerably, even over short distances.

There are no meteorological stations in the survey area. There is a station at Bajo RNR-RC, about 2.5 km down Tsang Chhu from the Lingmutey confluence. Its data are summarised in Table 2.1, and are thought to be valid for the lower part of the watershed, which is at about the same altitude.

The Bajo data indicate that the lower part of the watershed has a subtropical - warm temperate climate, with winter mean minima of about 5^0C and winter mean maximum temperatures of about 18-19^0C. In summer the mean minima are about 20^0C. and the mean maxima rise to almost 30^0C. Maxima for individual days can reach the high 30's. The mean annual rainfall is about 700 mm, of which about 75% fall in the summer (monsoon) months of June – September. There may be showers in any other month of the year. Vegetation is liable to prolonged moisture stress at any time of the year, even in the monsoon. The climate has been characterised as so dry as to be only marginal for forest (Ohsawa 1991, Eguchi 1991 & 1997). The tendency to droughtiness is strengthened by the strong winds ('Troll winds') that blow up the Tsang Chhu valley on many afternoons (Eguchi 1997).

Table 2.1 Climatic summary for Bajo RNR-RC, 1985-1995

Period	J	F	M	A	M	J	J	A	S	O	N	D	Year mean/total
Mean minimum temperature ^{0}C	5	8	11	13	17	20	20	20	19	15	9	5	13
Mean maximum temperature ^{0}C	18	18	22	25	28	29	28	28	28	26	22	19	24
Mean rainfall (mm)	12	16	20	44	35	139	154	126	91	36	11	10	693

Source: PCI (1996)

The only data from an area equivalent to the higher parts of the catchment are for Shengana School, located at an altitude of 1680 m a.s.l. in the next main valley to the north. Although it is only 4 km from Limbukha village to Shengana, there are distinct differences in topography. The valley of Shelgna Rong Chhu is generally lower and is aligned almost due E-W, compared to the NNE-SSW orientation of Lingmutey Chhu. Nonetheless the Shengana data should give a general picture of the climate in the mid-altitude sections of the survey area.

The rainfalls reported for Shengana in the Wangdi Groundwater Study (PCI, 1996), are very high, with an annual mean of over 3000 mm and mean monthly totals of over 500 mm/month for the four monsoon months of June-September. The consultants felt that these represented an ''unbelievably large amount'' (PCI, 1996, p.E-8) but had no explanation for the apparent anomaly

There are fuller data for the same station, which is known as Shelgana, in the MTI records. These are summarised in Table 2.2, and they show a more credible picture, with a mean annual rainfall of about 1300 mm. The rainfall has the normal monsoonal seasonal distribution, as at Bajo. The rainfall is mostly gentle, with few daily falls exceeding 50 mm. Temperatures are slightly cooler than at Bajo, conforming to Eguchi's (1997) estimated lapse rate of about 0.5-0.6 ^{0}C per 100 m rise in altitude. Although absolute minimum temperatures of 0^{0} C have been recorded at Shelgana on rare days in December and January, these occurred in only two out of the 13 years of data.

The vegetation indicates that the upper Lingmutey is substantially wetter than the lower watershed, and rainfalls similar to those in Table 2.2 appear feasible. Until data from the upper Lingmutey are available, annual rainfalls in the range of 800 -1500 mm appear to be reasonable estimates, with the higher totals on the summits at the top end of the valley.

Moisture stress on the vegetation is therefore less in the upper watershed than in the warmer and drier lower section. There are also distinct and highly localised aspect effects on the forest vegetation in the upper catchment. Tall broadleaf forest occurs on north-facing slopes, and much scrubbier broadleaf and some chir pine forest on south-facing slopes at similar altitudes. This is attributed to the lower insolation, temperatures, and evapotranspiration rates on sites of northerly aspect.

Table 2.2 Climatic summary for Shelgana 1985-1997

	J	F	M	A	M	J	J	A	S	O	N	D	Year mean or total
Temperature ^{0}C													
n (number of complete records)	13	13	13	13	12	12	12	12	12	12	12	12	12
Mean	11.6	12.7	14.9	17.0	18.8	20.3	21.3	20.9	20.6	18.3	15.7	13.4	17.1
Mean minimum	5.5	6.5	8.3	9.9	12.1	14.5	16.2	15.4	15.1	12.3	9.0	6.6	11.0
Absolute minimum	0	1	1	3	3	4	4	6	6	4	3	0	0
Mean maximum	17.7	18.9	21.5	24.2	25.4	26.2	26.4	26.4	26.1	24.4	22.5	20.2	23.3
Absolute maximum	28	27	29	31	33	34	34	33	31	30	32	33	34
Rainfall (mm)													
n (number of complete records)	13	13	13	13	12	11	12	12	12	12	12	12	11
Mean	16	36	42	88	129	203	305	247	167	58	29	18	1360
Monthly maximum	36	68	119	134	218	284	400	352	416	202	62	46	1633
Monthly minimum	5	5	18	56	47	145	211	133	105	12	0	0	1109
Highest daily rainfall	19	28	29	33	34	74	60	60	88	62	16	20	88

Source: Data from MTI

2.3 Geology and soil parent materials

There are two main groups of soil parent materials in watershed:

- Long distance alluvium deposited by Tsang Chhu. These deposits are derived from rocks located well outside the watershed. They are restricted to the alluvial landforms at the lower end of the watershed.

- Short distance alluvial, colluvial and residual parent materials, derived from the local bedrock types. These cover the rest of the watershed.

The long distance alluvia come from the upstream catchment of the Tsang Chhu system (Laskar, 1995). The lithology is very varied, and includes a wide range of igneous and metamorphic rocks. Schists, gneisses and granite form the most extensive outcrops, and there are also limestones, veins of quartz, and mafic/ultramafic intrusions. The harder rocks are more resistant to abrasion during long distance transportation, and the quartzites and leucogranites are disproportionately represented in the large stones and boulders in the alluvium. The interstitial fines are predominantly fine white sand in the deposits of the modern river and on the most recent lower terrace. In the lower terraces the boulders occur as thick densely packed, beds, with the fine sand as the main component of the interstitial matrix. These coarse textured lower terrace deposits are often capped by more or less stone-free silty alluvium, which is over a metre thick in places.

The alluvia of middle and upper groups of terraces also contain boulder beds, but these are thinner and patchier than in the younger alluvium. They also occur at greater depths, and are seen only in the lower sections of deep gullies and road cuttings. The boulders therefore do not significantly affect the formation of the modern agricultural soils. These are formed in the upper layers, which consist of layered silts and sands, with variable contents of clay and some scattered rounded pebbles. In both of the middle and upper groups of river terraces the sand fractions are mainly fine and very fine grained in the surface layers. Below about 2-3 m, the alluvium is lighter textured and the sand fraction is coarser grained.

The C^{14} dating of a charcoal layer in the subsoil of the 15-40 m middle terrace in the Bajo area (the exact location is not specified), of about 350 years BP (Takada 1991) suggests that the Tsang Chhu alluvia are very young. The implications of such young deposits for landscape dynamics and soil formation need detailed consideration.

In the upper parts of the catchment there appear to be three groups of residual parent materials, each derived from in situ weathering of distinct types of bedrock. The most extensive are those derived from the gneisses and schists of the Thimphu group. The predominant rock types are garnetiferous muscovite and biotite gneisses. There are also some better laminated and less metamorphosed mica schists, which weather to similar saprolites and soil parent materials. In the latest Geological Survey of India account of Bhutan, the gneisses and schists rocks have been mapped together as the Sure Formation of the Thimphu group (Bhargava 1995). Gansser (1983) separated the schists as the Paro Formation, leaving the gneisses in the Thimphu Formation. Both the gneisses and the schists are inter-layered with substantial beds of quartzites. In the survey areas these appear to be particularly thick on the interfluve ridge between Limbukha and Shengana, and in the Nabche area. They may also occur on the lower slopes in the gorge-like section in the middle catchment.

Gansser and Bhargava agree that the other rock types in the Thimphu Group are:

- Carbonate and marble beds, and their skarn metamorphic derivatives (formed by siliceous hydrothermal suffusion of the carbonates)
- Anatectic migmatitic granite bodies, with aureoles of metamorphism and scheelite mineralisation
- Amphibolite and other mafic/ultramafic intrusive sills and dykes.
- Intrusive quartz veins which postdate the country rock quartzites

The limestones and their skarn derivatives and also the amphibolites are particularly concentrated across river on the TRB (west) bank of Tsang Chhu in the Rinchengang Lobeysa - Talo – Punakha area (Bhargava 1995). They also occur in the survey area, and further north in the valley of Shelgna Rong Chhu. These rock types both weather easily to give deep, highly ferruginous, strikingly bright red saprolites with moderate or high clay contents, which the geologists refer to as 'residual clays'.

The distributions of the amphibolites, skarn, carbonates and granites (and especially the latter's economic possibilities of associated scheelite mineralisation) are discussed in more detail in the original geological survey reports for the area (Ravindra & Chattopadhyay 1982; Singh 1965; Sarvotnaman & Jadhia 1988).

Many of the soils on the slopes in middle and upper parts of the catchment are formed in local hillwash (= colluvium) which is moved by a combination of slow gravity creep and jerky mass movements, such as landslips. Where colluvium is derived from one rock type, the material is similar in colour and texture to the residual saprolite. However the colluvia tend to be deeper, contain randomly distributed and oriented angular fragments of less weathered rock, and may show signs of layering, including buried topsoils. There are also colluvia that appear to derive from two different groups of rocks. The commonest examples in the survey area are brown sandy gneissic materials overlying redder, finer textured skarn and amphibolite colluvium and saprolites.

There are narrow and discontinuous stretches of alluvium along the more gently graded sections of the upper Lingmutey Chhu. They differ from the alluvia deposited by the main Tsang Chhu, in that they are less clearly sorted or layered, the stones are mainly subrounded or subangular, and they occur at only limited heights above the river (< 30 m). These deposits are characteristic of the alluvia of short, low order, steep, high energy, mountain streams.

A quite different alluvial deposit is found in the basin upstream of Limbukha village. This appears to be quasi-lacustrine or marshy in origin. It consists of strongly contrasting sand, clay and humic silt layers to depths of at least 3 m. It is thought that deposition occurred in a swamp or shallow lake that was dammed up behind the Limbukha rock bar, before it was broken fairly recently by down-cutting of Lingmutey Chhu.

High contents of fine sand and silt occur in a high proportion of the surface layers of many soils in the area. This may be due to aeolian deposition. Windblown material has been noted in the surface layers of hill and old terrace soils in East Central Bhutan (Gratzer et al. 1997; BSSP Report 2(a) 1998). A late Holocene date (ca 3000-5000 years before the present) has been suggested as a possible period of climatic desiccation and high winds.

The Wangdi Groundwater Study mapped the geology of the lower part of the watershed at scale 1:10 000 (PCI 1996). They were primarily concerned with potential aquifers and some of their units are defined by hard rock lithology, and others as types of clastic regolith, e.g. colluvium. Their schist – phyllite metasediment hard rock unit appears to be more or less equivalent to amphibolite/skarn/carbonate lithology, as used in this report.

A unit they mapped extensively is 'slided blocks'. The areas designated appear to have subjected to many mass movements, mostly shallow translational slides. The slopes affected have a jumbled mixture of wide-floored, straight-edged shallow declivities of varying sizes, running up and down slope, usually with curved, steep, and low back walls. These areas appear to have been affected by several phases of landslipping, so that the local meso-topography is complex, with shallow trenches within shallow trenches. The role of natural throughflow, especially in texture contrast soils with loam topsoils over clay loam subsoils (like some of the BR soils - see Chapter 5) in initiating these slides is not known. However it is likely to be significant, and could be exacerbated by irrigation, particularly where poor puddling and/or overflowing or leaking channels increase the local supply of subsoil moisture. Certainly there are some signs of piping, another form of throughflow-initiated erosion, in the wetlands on the slopes below Omtekha village

2.4 Topography and drainage

As with soil parent materials, the main division in topography is between the alluvial landforms in the lower end of the catchment, and the hilly topography of the rest.

The Tsang Chhu alluvia form a series of river terraces, in which old alluvia have been dissected and left as valley-side benches, by tectonic uplifts and depression of the river bed and erosion base levels. The terraces are grouped as lower, middle and upper (PCI 1996). Each group includes sub-terraces. In places the natural differences in elevation between these are small, and are obscured by the multiple steps formed by the construction of terraces for irrigated agriculture.

The lower terraces (as named by PCI (1996), Drukpa (1996) and in this report) occur at elevations of 2-10 m above the current level of Tsang Chhu. This group includes the relict low beach of white sand along the Bajothangka section of the Wangdi - Shengana road. Because of the low relief within this group, it is difficult to distinguish the sub-terraces, as agricultural terracing and bunds obscure minor height differences.

There is no marked riser bluff between the lower and middle groups of river terraces in the survey area, unlike at Bajo RNR-RC 3 km downstream. The middle group of river terraces occurs at elevations of 10-40 m above the current river level. The sub-terraces within this group are not easily distinguished because some areas have naturally concave slopes, and also because the steps between agricultural terraces are up to 1.5 m high.

There is an area of the upper river terrace downslope of Bajo Lakhang along the southeastern boundary of the survey area. The area is badly eroded, with vertically-walled gullies up to 10 m deep. These are sufficiently dense in places to give patches of badland topography. The upper river terraces also form the crest of the divide between the lower courses of the true Lingmutey Chhu and the Bajothangka Chhu. This interfluve has a knoll-and-col profile with flat-topped remnants of river terrace separated by low dips. The cols have been artificially terraced for irrigated agriculture. The separate knolls have been used for house sites, and the tops have been artificially flattened.

Takada (1991) examined the river terraces in the Wangdi area. He differs in his nomenclature from later workers such as PCI (1996) and Drukpa (1996). Takada refers to their (and our) high terrace as his M3 and M4, and their middle terrace as his L2. Clearly these names need to be sorted out, but the Takada and PCI studies are clearly mapped and it is possible to identify the levels and deposits that are meant. A valuable part of Takada's study is that he includes a C^{14} dating for the charcoal layer that lies about 1.5 m below the surface of our main middle terrace level (his L2). The material is estimated to be about 350 years old. If this was originally deposited at the surface, it means a further 1.5 m of alluvium and/or aeolian material has been deposited, the erosional base level has dropped by about 20-25 m, and a suite of lower terrace deposits have been emplaced - all within one third of a millenium. Even by the standards of the Himalayas, this is an extremely rapid rate of uplift and/or downcutting and topogenesis. Some confirmation of the dating is required, and its mode of emplacement and the full implications need to be examined and discussed in detail.

The boundary between the Tsang Chhu alluvial and the upstream hilly topographies is clear in places, such as the break of slope up to the steep hill behind Bajothangka village. Elsewhere it is not so obvious. For instance the highest (the fourth inland from Tsang Chhu) of the isolated knolls on the Lingmutey-Bajothangka interfluve appears to be colluvial, with weathered rock at depth, whereas the three lower knolls are remnants of alluvial high terraces.

Within the general hilly terrain of the upper catchment, there is one important alluvial landform. This is the relatively flat area that floors the valley upstream of the cross-valley ridge at Limbukha village. The ridge seems to be rock-cored, and is not an old moraine or some other kind of glacial or fluvio-glacial remnant. It appears to have acted as a natural dam and impounded a lake or marsh behind it. The stream has since cut

deep into the ridge along the base of the northern hills, rather than through the low point in the centre of the bar. The incision of the stream has removed some of the former alluvium, and the Limbukha 'flats' now have longitudinal and transverse gradients of about 5-10%.

Apart from the Limbukha basin, the only other alluvial landforms are river terraces along the mainstream of Lingmutey Chhu. These are discontinuous, narrow and low, with none of them more than about 30 m above the current stream level. They are minor features compared with the Tsang Chhu terraces in the lower catchment.

Most of the upper catchment is steep and hilly. The middle section of the valley, between Omtekha and Dompola, is all steep land, with long slopes running down to a narrow-floored, V-shaped, gorge-like valley The upper slopes are convex and the mid- and lower slopes are steep and rectilinear.

Further downstream, in the Omtekha-Matamlumchhu section, and further upstream, from Dompola/Nabche up to Limbukha, the lower slopes are irregularly concave and tend to be mantled with deeper accumulations of colluvium. The shapes of the gentler lower slopes have been modified by agricultural terracing.

There is a prominent red spur that forms the interfluve between the TRB (i.e. North West bank) of the middle section of the Lingmutey valley, from Dompola down to Matamlumchhu, and the main valley of Tsang Chhu in the Bajothangka area. Much of the eastern flank of this spur is formed of skarn, amphibolites and related rock types. The deeply weathered saprolite and red clays formed from these are highly erodible and the spur has a high proportion of reddish bare ground. These saprolites are also susceptible to gullying. The upper and middle slopes have extensive areas of dendritic steep–walled gullies up to 10 m deep (see Profile PH025 in Appendix B). The erodibility of the red clay shows up clearly after rain when both Lingmutey Chhu and Bajothangka Chhu carry heavy suspended loads, and have bright red colours. At the Lingmutey – Tsang Chhu confluence the contrast between the grey-green glacial water of the main river and the blood red water of Lingmutey Chhu is very striking. The suspended clay is also carried in the irrigation channels, and results in many fields having temporary bright red surface coatings a few millimetres thick after irrigation.

The hillslopes on the other main rock types, gneiss and quartzite, appear to be fairly stable. There are only localised pockets of accelerated erosion, mainly along paths and trails running up-and downslope, especially where these have been used for skidding logs. The areas of intensive fuelwood collection on the lower and middle slopes of the quartzite ridge of the Limbukha-Shengana interfluve have quite severe surface erosion in places. However none of the eroded areas on gneiss and quartzite have the deep-seated instability of the weathered skarn and amphibolites, and do not develop into large, deep and steep-walled gully systems.

2.5 Land use and vegetation

These have been described, and their dynamics will be studied by other specialists in the multidisciplinary team focussing on the watershed. Those needing details should contact the Study Coordinator at Bajo RNR-RC for inventories and other studies.

The survey area has a relief of over 1800 m, from about 1200 on Tsang Chhu to over 3000 m a.s.l. at Nosudzong, the high point of the divde with the Tang Chhu valley to the east. The area spans four ecological-climatic zones – subtropical, chir pine, temperate broadleaf and blue pine forests.

There is no undisturbed natural subtropical vegetation left on the Tsang Chhu terraces, as this land has been intensively developed for irrigated arable cultivation. There are some patches of low broadleaf and cactus scrub in the gullies of the badlands incised into the high terrace remnant downslope of Bajo Lakhang.

The main vegetation of the lower hill slopes is chir pine (Pinus roxburghii) woodland. This is fairly open, and has a predominantly grass ground cover. At about 2000 m the chir pine gives way to temperate broadleaf forest. This is floristically diverse and includes several species of oaks and rhododendrons. The altitudinal

divide between the chir and broadleaf forests varies with aspect. Chir stretches higher up south-facing, drought-prone slopes. Broadleaf forest stretches further down moist north-facing slopes. Aspect also affects variations within the broadleaf forest, with higher stature on the north-facing slopes, and scrubbier stands on south-facing slopes. The differences are clear on the 1:15 000 aerial photograph that covers the Limbukha area. Chir pine woodland stretches unusually high up the north-facing slope in the gorge section of the valley, to the west of Nabche. This may be due to the occurrence of shallow, stony and droughty quartzitic soils, but this need field investigation.

The comparison between the slopes around Limbukha is complicated by soil differences. The soils of the south-facing slope with the scrubby forest are derived from quartzite and are predominantly sandy. The vulnerability of their forest to moisture stress is exacerbated by the coarse soil textures. The soils on the north-facing slope with the high stature forest are deep clay loams with high organic matter contents and open porous structures and deep rooting. Such soils have good supplies of available moisture and are able to buffer vegetation against stress.

The aerial photograph shows a few areas of open meadows, possibly anthropogenic, above the broadleaf forest, at altitudes above 2700 m. a.s.l. These were not visited during this survey. There may also be some stands of blue pine (Pinus wallichiana) on the higher slopes of the watershed, above about 2800 m a.s.l, but these were also not visited during our fieldwork.

The natural vegetation has been removed for arable agriculture on many of the gentler slopes. Even where forest remains, it has been modified in many areas by management practices. Some areas of oak close to settlements have been preserved as sokshing stands, which are dedicated to leaf litter production and harvesting. They are carefully excluded from any felling or lopping. The collection of leaves is thorough and can take place at any time between November and March. The litter is taken to the homesteads, and is used as bedding for cattle and horses that are stalled at night. The farmyard manure thus produced is spread on arable land in the spring and summer. The sokshing areas appear to be communally owned, i.e. they are not titled. However harvesting rights for different blocks appear to be allocated to individual households. The sokshing areas around Limbukha are quite distinct on the ground, and also on the aerial photograph, aligned as a series of blocks along the forest/farmland boundary. The ecology and management of sokshing is a topic that needs systematic research. The forest floor of some sokshing areas around Limbukha are kept clean, and there does not appear to be any regeneration. It is not clear if this absence of regeneration under sokshing is widespread or permanent. The ways that sokshing areas are replenished – by regeneration of existing areas, or by conversion of a new stand from general forest to dedicated sokshing is also not clear.

Cattle are night-stalled at homesteads, even when this is not necessitated by low temperatures. There may be a security element in this practice. However it would be interesting to know the extent to which this is also regarded as an essential step in the conversion of sokshing leaf litter to a more useful form of organic fertilizer. The practice also has the effect of concentrating some of the nutrients harvested by daytime grazing in the non-sokshing forests into usable organic fertilizers.

There is a less distinct and apparently less well maintained area of planted walnut trees on a north – facing lower slope about 1 km NE of Limbukha village.

The broadleaf forest upslope of the sokshing blocks has been intensively exploited and disturbed. It is used for fuelwood and construction timber cutting, and is also grazed by cattle that are herded out each day. Especially on the south - facing lower slope of the Limbukha – Shengana ridge and along the Limbukha access road, the broadleaf forest has been heavily degraded. Further upslope, and at greater carrying distances from the villages, the forest is less used for fuelwood, but timbers for construction and prayer flagpoles are collected and skidded down. These areas are also used for daytime grazing and browse by cattle

The chir pine woodlands at lower altitudes are also used for litter collection and FYM production, but pine needles are less esteemed than oak leaves. Chir is also used for construction timber, and prayer flagpoles. However it is not popular for fuel, as it has lower heat value and gives more smoke than broadleaf timber.

For details of the arable cropping systems in the watershed, see Sangay Duba (1997).

All of the arable land on the alluvium of Tsang Chhu is served by irrigation systems and is used for wet rice in summer, and mustard or wheat in winter (Van den Brand, 1997). The lower slopes of the hilly terrain around Omtekha and Matamlumchhu and across on the opposite bank are terraced and have water supplies for irrigation. Some of them are double-cropped, with winter mustard or wheat following summer rice. Others, especially around Omtekha are farmed more traditionally, with fallow rather than cropping during winter. This is partly due to the shortage of suitable grazing, and the need to supplement the forage from the chir pine woodlands.

In the upper part of the catchment, the farmers of Nabche have very limited water rights, and practice dryland farming. They mostly grow maize in the summer, and much of the arable land is fallowed in winter. However some Nabche farmers appear to be able to grow a winter mustard crop using residual soil moisture on slopes of northerly aspect. Dompola has some restrictions on water availability in winter and early in the rice transplanting season. However some Dompola farmers are able to grow summer rice and an irrigated winter crop of wheat or mustard. Limbukha has the most plentiful water supplies. It also has the largest areas of broadleaf forest grazing, and therefore the least need of winter fallow for livestock forage. The arable lands there, especially those of the alluvial basin upstream of the village, are extensively used for winter cropping as well as summer rice. The winter crops include mustard, wheat and significant areas of potatoes (Van den Brand 1997).

3. PREVIOUS SOIL INFORMATION

The lower part of the survey area is covered by two studies that are not conventional soil surveys but contain useful soils data.

Drukpa (1996) is a multidisciplinary land evaluation study of the Baap and Thedtsho geogs (both in Thimphu Dzongkhag), making use of GIS for mapping and analysis. As part of the ground truthing and base data collection, 22 soil profiles were described and sampled for laboratory analysis. Five of these are located in the lower part of survey area, with four on Tsang Chhu river terraces around Wonjokha and Bajothangka villages, and one on a gullied hillslope above Omtekha village. There are two further profiles (numbers DF-10 and DT-12) on the river terraces near Bajo High school about 1 km the south of the survey area. The profiles are summarised in Table 3.1 and further details can be found in Drukpa, (1996).

The data in Table 3.1 show the textural layering in the alluvial soils, and a general pattern of slightly alkaline subsoils beneath acid and slightly acid topsoils. The reddish topsoil colours at Wonjokha may be due to the red clay that comes in suspension in the irrigation water that drains from the skarn hills. The single hill profile is more homogeneous with respect to pH, being slightly acid throughout. It is somewhat layered texturally, possibly due to irregular colluviation.

The second useful survey is the Wangdi Groundwater study by Pacific Consultants International for MoA and JICA (PCI 1996). Their mapping covers a similar section of our survey area as does that of Drukpa (1996), i.e. from Tsang Chhu up to just above Omtekha. PCI did not map soils but their output included helpful contour, landform, and geological maps. The geological maps are actually of surface materials, with bedrock indicated only for the shallower soils on hills. The other hillslopes are mapped as drift materials, such as landslides, colluvium or slided blocks. The text does not define or describe these materials.

They map the slopes around Omtekha as a mixture of slided blocks and quartzite. Further downstream, still on the TRB (northwest) of Lingmutey Chhu, they map the red spur between Matamlumchhu and Bajothangka as schist and phyllitic metasediments. The lower slope of the TLB (SE bank) from opposite Omtekha almost down to Bajo Lakhang is mapped as colluvium. The upper slopes are mapped as gneiss. The lower end of the survey area is mapped as Tsang Chhu alluvial river terraces.

Although not quite adjoining this survey area, the detailed soil survey of Bajo RNR-RC (BSSP Report 3 (a) 1998) 2.5 km to the south is relevant. It includes details on the morphological variation and analytical characteristics of the soils of the middle and lower Tsang Chhu river terraces. The middle river terrace soils have hard silty upper layers overlying more reddish, friable and sandy lower subsoils. The depth of hard upper section is greatest at the lower, front end of the terrace and thins out back upslope. The lower river terrace soils also have silty upper sections, which are even harder then those of the middle river terrace, overlying loose, pale, fine sandy alluvium. The analytical data indicate that all of the river terrace soils are slightly alkaline and fully base-saturated.

Table 3.1 Summary of Drukpa (1996) soils data from Lingmutey Chhu survey area.

Dungkar (1996) Profile No.	Location	Topography	Morphological summary (Depths in cm)	Analytical summary				
				pH (H_2O)	Organic C (%)	AvP (ppm)	CEC (me%)	Clay (%)
DT-6	Below Wangjokha	Middle river terrace	0-19 Reddish FSCL 19-74 Brown ZiC 74+ Pale brown CsSL	5.9 7.7 7.8	1.6 0.5 0.2	10 6 2	13 12 6	22 25 10
DT-7	Bajothangka	Low river terrace	0-2 Reddish FSCL 20-85 Brown CsSCL 85+ Dark brown ZiL	5.0 8.2 8.2	1.3 0.3 0.3	1 1 1	5 8 6	26 20 13
DT-8	Above Wangjokha	Upper river terrace	0-20 Very dark brown ZiCL 20-100+ Greyish brown SCL	6.2 7.7	1.5 0.2	7 4	10 8	25 22
DT-11	Above Wangjokha	Mid-slope	0-20 Dark greyish brown ZiCL 20-78 Dark yellow brown FSC 78-97+ Dark brown SCL	6.3 7.6 8.0	1.4 0.3 0.5	1 1 6	7 6 6	20 27 15
DT-14	Umtekha	Gullied hillslope	0-7 Dark reddish brown SL 7-28 Reddish grey SCL 28-50+ Dark brown SCL	6.3 6.2 6.5	1.4 1.6 0.7	1 1 1	8 12 10	13 22 3

S= sand, Zi = silt C = clay, L = loam F = fine, Cs = coarse

Source: Drukpa, (1996).

Another soils study of a nearby area is that of Kashi geog by LUPP (1997). This geog is located immediately to the east of Limbukha, so that their and our survey areas are adjoining. Tethyan rocks of the Chekha and Wachi La groups underlie much of Kashi (Bhargava 1997). These give different soil parent materials from those Lingmutey Chhu. However the western part of Kashi, i.e. the Komathang area, is underlain by gneisses and associated high-grade metamorphics of the Thimphu group. These are an eastward extension of the outcrop that underlies most of the hilly land in Lingmutey Chhu. The LUPP study includes six detailed profile descriptions and about 20 augerings from the Komathang area. The profiles show the soils to be similar to those in our survey area. Some are grey - brown and of medium texture (similar to our GS and GD soil classes – see Section 5.2). There are also some redder and finer textured soils, which are similar to our RC and BR classes. One of their profiles (KP4) is similar to the dark brown, highly porous soil that we found under forest near Limbukha (see class RM in Section 5.2 and Profile PK 039 in Appendix B).

4. METHODS

4.1 Field

This was the first semi-detailed soil survey done by the Project. In such surveys soil boundaries are delineated by a combination of direct observation and inference using changes in landform, vegetation and other surface features as indicators. In this they differ from the previous surveys by BSSP. These were at detailed scales and intensities, and soil mapping was based mostly on field observations (see BSSP Reports 1, 2, SS3 (all 1998), and SS4 (1999)). In semi-detailed surveys soil observations are sited so as to sample different elements of the landscape the landscape, rather than to give uniform spatial coverage.

In this survey the routine soil observations were located along traverse lines. In the alluvial areas downstream and in open cultivated areas on some of the lower hill slopes, these were straight line compass traverses, and the observations were located at regular intervals (50 or 100 m), measured on the ground. In steeper terrain and thicker vegetation, the traverses ran along paths or tracks. Observations were sited at fixed altitude intervals (10, 20 or 50 m) as measured with a hand-held Thommen altimeter. Many of the paths followed are visible on the high quality aerial photograph that covers the upper catchment. This type of traversing requires careful map interpretation and use of the global positioning system (GPS) to give reasonably accurate location of the observation sites. As can be seen from the soil map, the observations were concentrated in the cultivated areas and along the accessible western side of the valley. This was intentional, and more detailed work on the mostly forested eastern slopes can be done if and when required.

The soils were examined on a routine basis at 164 sites, mainly with a 1.2 m Edelman auger, fitted with a 7 cm combination head where possible, but switching to a 7cm stony soil head where necessary. Duplicate augerings were done at about 50 of the sites where the first attempt was stopped by stones at less than 50 cm. About 20 of the routine examinations were done in road and track cuttings, cut back at least 15 cm to expose fresh soil.

At each routine soil observation the following site data were collected:

Location, GPS; general topography, site position; the angle (in %), aspect, length and form of the slope; solid and drift parent material; general land use and crops/vegetation; presence and type of irrigation; presence type and size of artificial land shaping features; fertiliser use, if known; surface stones; and site drainage.

The soils were described by layers (= horizons), as shown on the auger, with the following data collected for each horizon:

Munsell colour of matrix (in field moisture condition); number, size, contrast and colour of mottles; field texture; number, size and type of stones; moisture condition; and consistence on the auger.

The soils were described in more detail at 29 sites. Eight of the detailed descriptions were done in freshly cut back gully walls or road/track cuttings, and the rest in purpose-dug profile pits. The site data were the same as for the routine sites, with addition of a detailed description of surface features, including:

Microrelief, rock outcrops; litter, faunal activity, cracks, and capping.

The profiles were described by horizons according to international conventions (FAO 1990). The data collected for each horizon were as in the routine descriptions, with the addition of:

Strength, size and type of soil structure; number and size of pores, presence strength and continuity of cutans (coatings on surfaces of soil structural units); consistence in situ and in hand; number size and type of roots; reaction to HCl (to test for presence of free carbonate minerals); concretions of iron, manganese or other secondary formations; presence and effects of animals (wormcasts etc.); any other features (e.g. charcoal); clarity and shape of lower boundary.

Samples were collected for laboratory analysis from 124 of the main horizons in 27 of the described profiles.

4.2 Mapping

The area is covered by the Survey of Bhutan/ Survey of India topographic sheet # 78 E/14 (1964), at scale 1:50 000. This is based on aerial photography taken in the late 1950's and ground control in the early 1960's. Despite its age, the map is of high quality, but inevitably its data on infrastructure and land use are now dated. This is the topo base currently in the LUSS GIS, and has been used for the 1:25 000 soil map of the whole survey area

The survey area is one of the first covered by the recently started re-mapping programme at scale 1:25 000 by the Survey of Bhutan (SoB). The relevant sheet (#78 E/14 SE) was published in 1998 and is based on 1:30 000 aerial photography taken in the late 1980's. The ground-truthing of the infrastructural detail in the survey area appears to have been updated to about the mid-1990's. The improved topographic data has not yet been entered into the LUSS GIS. Our 1:25 000 soil map will be upgraded when the new topo base has been entered into the GIS.

A high quality aerial photograph, frame # 059 of flight run # 12-61, taken in December 1988 at a scale of 1:15 000, was useful in delineating soil boundaries in the upper part of the catchment. Unfortunately the adjacent frame, covering the lower watershed, is of lower quality so that stereo-viewing is difficult. However the steep and well-defined topography in the upper catchment means that lack of stereoscopic cover is not a major problem for interpretation. The poor quality of the aerial photograph of the lower catchment detracts from its value for delineating of soil boundaries there. Fortunately this part of the catchment is covered by the 1:10 000 topographic mapping, with contour intervals of 10 m, that was prepared for the Wangdi Groundwater study (PCI 1996). This was a considerable aid in delineating soil boundaries and the different groups of Tsang Chhu river terraces.

As well as improving the quality of the the1:25 000 map, the PCI topo map has been used as the base for a more detailed 1:10 000 interim soil map of the lower end of the watershed, from just above Omtekha down to the main Tsang Chhu.

4.3 Laboratory

The 124 soil samples collected from 27 of the detailed profiles were analysed by the Soil and Plant Analytical Laboratory (SPAL) at the National Soils Service Centre, Simtokha of the Research, Extension and Irrigation Division of the Ministry of Agriculture. The methods of analysis used by SPAL are summarised in Appendix A.

The only chemical methodological points that need to be mentioned here concern the measurement of cation exchange capacity (CEC) and calculation of base saturation (BS%). CEC can be measured by saturating the soil with ammonium cations, and then displacing and measuring the amount adsorbed. This is referred to as CEC (NH_4OAc). An alternative is to estimate CEC by summing the total exchangeable bases (Ca + Mg + K + Na = TEB), and the extractable aluminium. This is known as the 'effective cation exchange capacity' (ECEC). SPAL does not measure extractable Al in soils with pH (water) greater than 4.5. As none of samples from this survey are sufficiently acid, there are no determinations for extractable Al. In such cases the ECEC is identical with the TEB, and therefore adds no useful information, and it has not been given in this report.

Base saturation is the quotient TEB/CEC. If the TEB and the ECEC are identical (as is the case where there is no extractable aluminium), the 'effective base saturation' (EBS %) is automatically 100 %. Such values are also not informative, and have also been omitted from this report. The base saturations in the soil class descriptions in Section 5.2, Table 5.2 and in the profile data in Appendix B therefore refer to TEB/CEC (NH_4OAc).

5. SOIL CLASSIFICATION, CHARACTERISTICS AND CORRELATION

5.1 Soil formation and classification

The watershed is the most varied area yet surveyed by BSSP. As well as covering a wide range of altitude and eco-climatic zones, the soil parent materials are also very mixed. The natural soils therefore vary considerably in colour, texture, contents of stone, exchangeable bases, and organic matter. Some of them are made even more heterogeneous by the effects of irrigation and other forms of land management

They are divided into 12 locally formulated classes, which are defined on field characteristics, especially soil profile features such as colour, texture, depth and stones. The definitions also include topographic position, and parent material, as these aid field differentiation and affect important soil properties that are not always apparent in the soil profile, e.g. soil water movement and organic matter dynamics.

The classes are summarized in Table 5.1. The main classification problem for this survey area was the subdivision of the very extensive greyish brown – yellowish brown, medium textured hill soils derived from gneiss and schist parent rocks. In the end they were subdivided into two main groups on the basis of depth to weathered rock, as classes GS (shallow) and GD (deep). Class QG contains greyer, stonier, and slightly sandier soils, also derived mainly from gneiss/schist rocks, but with locally high proportions of quartzite.

For a semi-detailed survey, it is not necessary to separate the riser slopes from the tops of the river terraces, as was done for detailed surveys at Bajo RNR-RC and the Bathpalathang site for Jakar RNR-RC (BSSP reports 2 (a) and 3 (a), 1998).

5.2 Characteristics of soil classes in Lingmutey Chhu survey area

5.2.1 River sand (RS).

This is not an extensive group of soils and there are no described or analysed profiles. These soils are restricted to the banks and floodplain of Tsang Chhu. There is no profile development, and the soil consists of loose white fine sand. This is very similar to the material exposed in the current riverbed at low water levels. In places the surface of this soil is bound together by sward of low grasses. Where overgrazing or vehicles break through, the loose fine sand underneath is easily disturbed and transported by wind. This gives rise to the local dust clouds that occur on the many windy afternoons along the Bajothangka stretch of the Wangdi – Shengana road.

5.2.2 Lower terrace soils (TL)

These soils occupy the low river terraces along Tsang Chhu, upstream of Wonjokha village and between Bajothangkha village and the road. The land is about 2 – 10 m above current river levels. The land is used almost entirely for irrigated production of rice in summer and wheat or mustard in winter. The winter crops receive one or two irrigations, mainly in the early stages. Only one profile in these soils was described and analyzed during this survey (see PH020 in Appendix B). However four additional profiles in similar soils were described and analysed at Bajo RNR-RC, 2.5 km to the south (see Profiles PK022, PK024, PK027 and PK031 in BSSP Report SS3 (a) 1998). Profile DT-7 in Drukpa (1996) also qualifies for this class (see Table 3.1).

Table 5.1 Summary of soil classes in Lingmutey Chhu watershed

SOIL CLASS		Brief description	Profiles and analyses (see Appendix B)
Code	Name		
RS	River sand	Loose, white, fine sand of Tsang Chhu river bed & floodplain.	-
TL	Lower terrace soil	Hard, grey & brown, silty clay silty loam; over pale, loose, loamy sand; over dense boulder bed; on Tsang Chhu lower river terrace	PH020
TM	Middle terrace soil	Hard grey & brown layered silty & fine sandy loam & sandy clay loam; on middle river terrace of Tsang Chhu	PH017 PH027
TU	Upper terrace soil	Grey & brown layered silty clay, silty loam, sandy loam and sand; on upper river terrace of Tsang Chhu	PH026
LB	Limbukha basin soil	Layered sand, silt, clay, loam & muck; in alluvial basin upstream of Limbukha village	PH030 PK040 PK035
RC	Red clay	Reddish loam & clay often deep; over weathered skarn & amphibolite; on gullied red Matamlumchhu - Dompola spur	PH019 PK042 PH025 PK044 PH032
RM	Dark brown clay	Dark brown, friable crumb, clay loam; over friable, brown clay & clay loam, more than 1 m deep; hill slopes.	PK039
GS	Shallow brown sandy loam	Grey & brown sandy loam & sandy clay loam; over weathered gneiss within 1m; hill slopes.	PH021 PK038 PH022 PK041 PK034
GD	Deep brown sandy loam	Grey & brown sandy loam over yellowish brown sandy clay loam; more than 1 m deep to weathered gneiss; hill slopes	PH016 PH031 PH018 PK033 PH024 PK037
BR	Brown over red	Grey & brown loam & clay loam (often like GS & GD); over red clay & loam (like RC); lower hill slope.	PH015 PH028 PH023 PK043
QO	Orange sandy loam	Deep bright orange & reddish yellow loamy sand - sandy loam; over weathered quartzite; Shengana ridge	PH029
QG	Grey stony sandy loam	Greyish brown sandy loam over grey stony sandy loam; over quartzitic gneiss; Nabche hill slopes	-

Some of these soils had a thin (< 5mm) surface veneer of red silty clay at the time of our fieldwork. This is caused by the deposition of suspended material from the irrigation water. The sediment is derived from the erosion of the red loams and clays of the skarn/amphibolite spur between Bajothangkha and Matamlumchhu.

The red surface skin is a temporary feature and the reddish colour disappears when cultivation or cattle poaching incorporate the sediment into the soil. No significant reddening of the topsoils was seen in our profile descriptions, but Drukpa (1996) notes reddish colours in the upper horizons of some of his terrace soils.

The normal low terrace soil profile has two or three distinct sections. The upper part of the profile has a hard grey or greyish brown topsoil of silty clay, silty loam, fine sandy clay or fine sandy loam. This grades into a hard, pale brown – light grey upper subsoil of similar textural range. The depth of this upper section varies between 30 and 100 cm. In some soils it abruptly overlies a densely packed bed of highly rounded granitic or quartzitic river boulders. In other soils the silty upper section and the boulder bed are separated by a layer of more or less stone-free sand or loamy sand. This is very pale coloured, often almost white, loose, and fine or medium grained. It is of similar appearance to the river sand of the RS soil class. Profile PH020 is an example of a three section profile, with grey and brown silty and fine sandy clay and loam clay to 98 cm, light grey, loose, loamy medium sand to 152 cm, and a densely packed boulder bed (with diameters up to 25 cm) down to at least 180 cm.

Profile PH020 has a very acid topsoil but this grades through slightly acid and is slightly alkaline by 50 cm depth, and continues thus to the base. Topsoil organic carbon content and total nitrogen levels are low, and become very low at depth. This is probably an effect of the prolonged cultivation for wetland rice. Cation exchange capacities are moderate in the silty and loamy horizons, but are very low in the underlying sands. The soil is fully base saturated except for the acid topsoil. Available P levels are low throughout. These chemical characteristics are confirmed by the analyses of the lower terrace soils at Bajo RNR-RC, except that none of them had pH values below 6.5, and some topsoils there had high available P levels, presumably due to recent fertilizer applications.

5.2.3 Middle terrace soils (TM).

These soils occupy the river terraces of Tsang Chhu at elevations of 10 – 40 m above the current river level. They form a continuous strip parallel to the river from Wonjokha village to the survey area boundary north of Bajothankha. The land is almost entirely terraced for basin irrigation, and is used for rice in the summer and wheat or mustard in the winter. Land shaping for irrigation obscures the natural surface form of the river terraces.

Two profiles in these soils were described and sampled in this survey (see PH017 and PH027 in Appendix B). A further four profiles have been described in similar soils on this terrace at Bajo RNR-RC (see profiles, PK023, PK026, PK028 and PK029 in BSSP Report SS3 (a), 1998). Profile DT-6 in Drukpa (1996) also qualifies for this class (see Table 3.1).

Like those on the low terrace, some of these soils have thin reddish veneers of bright red loam and clay, deposited from irrigation water. This is a temporary feature that is soon lost. The normal topsoil is light grey – pale brown in colour, and shows little organic darkening. This is an effect of prolonged use of the land for wetland rice. Textures vary from sandy loam to silty clay. The topsoil is structured as coarse blocks – cultivation clods. The dry consistence is hard, almost irrespective of texture. The subsoil consists of layers of grey and pale brown mottled layers of variable texture, ranging from sandy loam to silty clay. Their layering relates to alluvial deposition rather then pedogenesis. Structures are predominantly medium and coarse subangular blocky. The subsoils are hard when dry but the moist consistence varies from friable to very firm. Consistence tends to be firmer with with high silt contents. There are a few rounded pebbles and cobbles (diameters up to 10 cm) in these soils but they are not concentrated as beds. The alternation of loam and fine loamy horizons continues to the base of the described profiles, at depths of 1.5+ m, and no lenses of loose sand or beds of boulders were seen. However, cuttings along the Wangdi-Shengana road to the south of the survey area show beds of sand and boulders in these deposits, at depths below 3 m.

The two profiles in these soils have similar chemical characteristics. Both are slightly acid-neutral in the topsoil but slightly alkaline in all horizons below. Organic carbon and total nitrogen levels are low in the topsoils and very low in the subsoil horizons. Cation exchange capacities are low - very low, as there is little contribution from organic matter and clay contents are low - moderate. However, the CEC's are fully saturated, as is expected from the pH. These characteristics are confirmed by the analyses of the similar soils at Bajo RNR-RC.

5.2.4 Upper terrace soils (TU)

These soils are not extensive in the survey area, and occur around Bajo Lakhang and on the higher knolls along interfluve between Lingmutey and Bajothangka Chhu. In places that are accessible from irrigation channels, these soils are used for wetland rice in summer. Water supply appears to be a problem in the dry season, and many of the terraced soils are fallowed rather than cropped during winter. Some of the knoll summits have previously been flattened for house sites, although all of the houses are now in ruins. These old dwelling sites now mostly carry short grass or dense Opuntia surub.

The area around Bajo Lakhang is under short grass. Downslope from the lakhang, the lower end of this deposit has been intensely gullied, to give a small area of badlands. The gully walls and some gully floors have Opuntia scrub vegetation, but some of the wider gully floors have been cleared and are irrigated. This cultivation is opportunistic, and the erodibility of this area suggests that these small plots are at risk from further erosion, sedimentation, or both.

These soils have been described and sampled in one profile during this survey (see profile PH026 in Appendix B). Profile DT-8 in Drukpa (1996) appears to qualify for this class (see Table 3.1), but none of these soils were seen at Bajo RNR-RC.

The profile morphology of these soils has some similarities to that of the middle terrace soils. The topsoil is pale coloured and of hard consistence when dry. The surface structure in some of the cultivated soils is blocky-cloddy, but it is platy in Profile PH026. The subsoils are greyish – brown to light grey. A feature of these soils is the intensely developed red, brown and black ferric manganese mottling in the subsoils. In places the black mottling is sufficiently concentrated to constitute on incipient manganese pan. Similar mottling occurs in the middle and lower terrace soils, but is not as marked or as concentrated. Increasing segregation of manganese with increasing height and age of alluvial deposits has also been noted in the Chamkar Chhu river terraces at Bumthang (BSSP Report 2 (a) (1998)).

The textures vary according to alluvial deposition, ranging from sandy loam to silt clay in the upper metre or so, with high contents of silt and fine sand. Loose loamy fine and medium sand may occur in the lower subsoil. There are occasional rounded pebbles scattered through the profile, but there are no stone layers or boulder beds.

The chemical characteristics of this soil are similar to those on the medium and low terraces. The topsoil is slightly acid but the lower horizons are neutral or slightly alkaline. Base saturations are high throughout. Organic carbon is low – very low. Total nitrogen is very low in the topsoil, and none was detected in any subsoil horizon in Profile PH026. Available P varies erratically with depth, from very low to high, with the maximum value recorded in a very sandy horizon at below 1m.

5.2.5 Limbukha basin soils (LB)

These are the alluvial soils that occur in the dissected quasi-lacustrine basin upstream of Limbukha village. Most of the middle and lower sections of the basin are terraced and used for wetland agriculture. Because its upstream location and historical precedence, the water supplies are better than elsewhere in the watershed, and the terraced land is intensively cultivated for wetland rice in the summer and for irrigated

potatoes, wheat and mustard in winter. The narrow upper end of the basin is partly cultivated but there are areas of low broadleaf scrub. Within this woody vegetation there are patches of open marshy meadow, with high proportions of sedges and Primula dendriculata.

Three profiles were described and sampled in these soils (see Profiles PH030, PK035 and PK040 in Appendix B) during this survey.

These soils have some morphological similarities with the alluvial soils of the Tsang Chhu river terraces i.e.:
- Textures vary erratically, according to alluvial deposition.
- The textural range is wide, from loamy sandy to clay.
- There are scattered stones and some gravel layers

However they also differ from the Tsang Chhu terrace soils in that:
- The topsoils are darker, and have moderate high organic C and total N in well drained sites, and high levels in marshy sites (see Profile PK040 in Appendix B).
- The buried deposits in the subsoils include muck layers with high contents of organic matter. These are black and tend to be wet. Some of them smell of H_2S, but others are odourless.
- Consistence tends to friable throughout, although some of the silty clay horizons are slightly - moderately firm.
- As well as irrigation water, these soils are kept wet or very moist from natural sources. Throughflow/seepage zones are found in some subsoils, even in winter.
- The stones are mostly subangular, due to their local origin and short travel distance.

Chemically these are also distinct from the Tsang Chhu river terrace soils. In addition to the moderate levels of C and N in the topsoils, the buried humic soils can also have moderate – high organic matter contents. Available P varies erratically, with high levels possible at any depth in the profile, often in buried humic layers. The soils are slightly acid and neutral, with virtually no horizons qualifying as alkaline. Nonetheless exchangeable base status in moderate - high, with high exchangeable Ca^{++} contents in some horizons, possibly because the alluvium is partly derived from limestone, marble or skarn. Base saturations vary from moderate to high, tending to be lower in muck horizons, due to their high CEC's (up to 30 me%).

5.2.6 Red clay (RC)

This class name is not strictly accurate, as some of these soils are not clays. However they are finer textured than the other hill soils, and the red colours are very distinctive.

These soils cover large areas on the crest, upper and middle slopes of the spur that separates Matamlumchhu from Bajothangkha. They also occur as lesser patches elsewhere in the gneissic hill soils, presumably due to intrusive amphibolite dykes or small bodies of skarn. Such patches occur on several spurs on the southeastern side of the main valley. Narrow strips of shallow variants of these soils occur in shallow declivities that run upslope on the ridge behind Bajothangkha village, suggesting that the skarn/amphibolite veins are more erodible than the gneissic country rock. Five profiles in these soils were described and sampled during this survey (see PH019, PH025, PH032, PK042 and PK044 in Appendix B).

This soil class is quite heterogeneous, and includes a range of subtypes, varying mainly in texture and depth. The common features are bright red or yellowish red subsoil colours, and textures of at least sandy clay and usually finer. Depth to weathered rock ranges from a few decimeters (82 cm in PH019, 68 cm in PH032) to several metres (2.8 m in PH025). The underlying material is usually saprolite that is weathered to many metres, but there are some of these soils over fairly hard rock.

The topsoils are mostly brown to dark reddish grey, and range in texture from sandy clay loam to clay. They have crumb or medium – fine subangular blocky structures. The topsoil consistence is fairly hard when dry, but friable when moist. The subsoil is usually red but yellowish red, dark red, reddish brown, and dark

reddish brown matrix colours also occur. Many of the subsoil horizons have faint grey and brown mottles. Some also have distinct black ferrimanganiferous mottles. Subsoil structures are mostly moderate subangular or angular blocky. There is often a subsoil horizon with distinct cutans on the block faces. These are usually brown, and appear to consist mainly of organic matter washed down from horizons above, and are not clayskins or pressure faces. In deep profiles the structure becomes weak blocky, grading towards apedal - micro-aggregated. The underlying saprolite varies from white powdery weathered skarn to orange, yellow and black colours, which are thought to come from weathered amphibolite.

A feature of these soils is their erodibility. There are large dendritic gully systems that have developed almost into badlands in places. The gully walls have only minor earth pillars (< 3 cm high), suggesting that rainsplash erosion is not important. Many overhangs, where soil structures have been undercut, have thick 'melted wax' coatings and small pseudo – stalactite features, where suspended clay has been deposited by evaporating water. This indicates that the clay is easily dispersed, and that the main agent initiating the erosion is surface runoff. The easy dispersion of the red clay is corroborated by the high suspended red clay load of Lingmutey Chhu where it enters Tsang Chhu, and in the red clay that is deposited by water on the wetland plots that are irrigated from channels originating in these soils. The apparently high dispersibility of the red clays needs to be reconciled with the apparently good structures in these soils. The erodibility of these soils is a potentially serious practical problem in this part of Bhutan and urgently needs systematic research.

These soils are chemically district from the other hill soils. They are of almost neutral reaction, with pH values mostly in the range 6.2 – 7.0. They are relatively well supplied with exchangeable bases, with TEB values in the range 6-10 me/100 g. The cation balance is quite variable. In some of these profiles Ca^{++} is the dominant exchangeable cation, with Ca: Mg ratios > 2.5 in all horizons (e.g. profile PH019). Such soils are probably derived from skarn. In other profiles Mg^{++} is the dominant exchangeable cation, with Ca:Mg ratios < 1, and as low as 0.3 in some horizons (see profile PH025). This may indicate a predominantly amphibolitic provenance. The cation exchange capacities of some of these soils are low, indicating mainly 1:1 aluminosilicate and sesquioxide clay minerals (e.g. Profile PH025). These low CEC's lead to high or total base saturations. Other profiles have moderate CEC's and therefore moderate base saturations, in the range 40-60% (e.g. profile PH042). Nearly all of these soils have low contents of organic carbon, total nitrogen and available P. The exception is the upper part of Profile PK044, which has moderate – high available P, possibly because of previous fertilizer applications, as this profile is sited in a terraced dryland field. The mechanical analyses of these soils are variable. The very high silt content (> 80%) in the second horizon of profile PH025 is attributed to strong aggregation by the sesquioxidic clays. This soil hand textured in the field, after vigorous kneading, as silty clay.

5.2.7 Dark reddish brown clay (RM)

This soil is somewhat similar to the red clays but it has darker colours, higher organic matter contents, and occurs under broadleaf forest. The soil was described in detail and sampled in one profile (see profile PK039 in Appendix B). This is located on the steep, lower, north – facing slope of a spur, under high stature oak forest with no Rhododendrons but many ground and tree mosses. The forest gives an impression of being well watered. This profile is dark brown or strong brown down to 106cm, below which there is a dark greyish brown buried topsoil down to 120cm. From there down to 185cm, the matrix colour is brown – strong brown. Field textures are medium, grading from fine sandy loam at the surface to sandy clay loam and clay loam at depth. A striking feature soil is the loose packing, high porosity and friability, right down to 1.8m. This is matched by the persistence to depth of weak subangular blocky compound structures that break to moderate fine crumb. As is to be expected, this consistency and structural profile enables roots to penetrate freely and deeply, and they were seen down to 1.6 m. The soil has virtually no stones, except for a few grit-sized quartz fragments below 1.6 m.

The warm dark brown colours are due to the high contents and good mixing of the organic matter. Organic C and total nitrogen contents are high throughout, but available P is low. The high contents of organic

matter give high contents of exchangeable cations, especially Ca^{++}, in the upper horizons. However, the contents of exchangeable cations drop to low levels in the lower subsoil, and base saturations are below 10%. These soils are more acid than the red clays, with pH (water) values mostly in the range 5.5 - 6.

The loose packing and high contents of deeply mixed organic matter indicate that these soils are similar to the non-volcanic Andosols that have been noted under moist, temperate broadleaf forests in Eastern Nepal (Baumler & Zech 1994) and other parts of the world (e.g. Blaser et al. 1997). However analyses of non-exchangeable Al are necessary to confirm this.

5.2.8 Shallow brown sandy loam (GS)

These are the most extensive soils in the survey area. They occur on the hillslopes and derived from gneiss – schist metamorphic rocks. Some of them are residual, and others are derived from shallow hillwash (= colluvial) deposits. These soils were described in detail and sampled for analysis in five profiles (see PH021, PH022, PK034, PK038 and PK041 in Appendix B).

These soils have relatively light coloured topsoils, mostly greyish brown or brown. Textures are mostly sandy loam, and structures are crumb - subangular blocky. They grade into brown, yellowish brown, strong brown, or reddish yellow subsoils. These are of sandy loam to sandy clay texture, mostly sandy clay loam or heavy sandy loam. The subsoil has a moderate strong subangular or angular blocky structure. It is moderately firm when moist. It usually contains quartz, gneiss and schist stones, and fragments of weathered rock. The softer pieces have weathered to red, yellow, orange and grey colours, which give the soil a mottled appearance, although drainage is good. At depths of less than 1m, the subsoil grades into weathered rock. This is usually soft enough to be hand textured, coming out mainly as sandy loam or sandy clay loam. In places there are minor skarn or amphibolite components in the parent materials of these soils. These make the colours redder (e.g. Profile PH021), but do not affect textures.

Large areas of these soils are under forest. However, some of them, e.g. on the steep slope below the breached rock barrier across the valley at Limbukha village have been terraced for wetland agriculture. The main morphological effect is to make the topsoil colours still lighter and greyer. It also tends to make the structures coarser and cloddier (and occasionally platy), and the dry consistence harder. These changes relate to the decrease in organic matter and the mechanical disruption of natural structures that occur in soils under wetland rice cultivation.

These soils are slightly acid to neutral with pH (water) values in the range 5.7 – 7.1. They have moderate – low cation exchange capacities, in the range of 3-10 me%. The lower CEC's are more or less fully base saturated, but the base saturation of the soils with higher CEC's are below 50%. In most soils Ca^{++} is the dominant cation, but Mg^{++} is at about parity in some horizons in Profile PK034. Organic carbon and total nitrogen contents are low – very low. Available P levels are very low, except in the topsoil of the one wetland rice profile (Profile PK041).

5.2.9 Deep brown sandy loam (GD)

These soils are extensive on the hills of the upper part of the catchment and are the most extensive arable soil in the area. They are the dominant soils on many lower slopes, and have been terraced both for wetland and rainfed cultivation. Six profiles in these soils were described in detail and five were sampled for analysis during this survey (see PH016, PH018, PH024, PH031, PK033 and PK037 in Appendix B).

These soils are somewhat similar to the shallow brown sandy loams (GS). However they are developed in thick colluvium so that, as well as being deeper, they tend to have more complex horizonation, often because of polyphasic deposition.

Five of the six profiles in these soils are, or have been, under wetland cultivation. They have the brownish grey, hard, cloddy topsoils that are typical of prolonged irrigation for rice production. The hard cloddy structures are less apparent in the soil that has not been cultivated for some time and is now under Artemisia and oak seedling scrub (i.e. Profile PK033), and in the profile under old growth forest (PK037). Topsoil textures vary in the range sandy loam – sandy clay, with heavy sandy loam and sandy clay loam predominant.

The subsoils have variable brownish colours, commonly with orange, red and dark mottles. Greyish brown and reddish yellow subsoil horizons also occur. Subsoil textures tend to be slightly finer than in the topsoil, but vary rather erratically, ranging from gritty loam to silty clay loam, according to the colluvial layering. Subsoil structures are moderate subangular blocky, often with weak and patchy cutans.

The soils under wetland rice cultivation are neutral or slightly alkaline (with from pH (water) values ranging from 6.5 to 8). Cation exchange capacities are moderate – low. They are nearly fully base-saturated, with Ca^{++} as the main exchangeable cation. Organic carbon, total N and available P are very low throughout. The single profile under old growth forest (PK037) has pH levels about one unit lower and is slightly acid (pH 6.0-6.5). Topsoil organic carbon and total nitrogen contents are moderate in this profile and higher than in the wetland soils, but available P is still very low. The higher organic matter contents in this profile give higher CEC levels, so that base saturations are low, at about 20%, throughout the subsoil.

5.2.10 Brown loam over red clay (BR)

This soil has been seen mainly on midslopes around Omtekha – Matamlumchhu. It is locally significant there, and is cultivated intensely for wetland summer rice and winter mustard. These soils also occur around Bajo Lakhang, where they used for grazing.

The dominant feature of these soils is the distinct colour boundary, with brown upper layers over redder deep subsoils. Initially this sequence was interpreted as due to polyphasic colluvial deposition, with the upper layer assumed to come from gneissic source rocks and the redder subsoil deriving from skarn or amphibolite. Where the change in colour is accompanied by an increase in clay content, this reading may be correct. However the opposite sequence of red over brown is less common than expected if all of these soils result from the vagaries of colluviation, although it does also occur (see Profile PK043). There are some profiles in which the red and brown materials are similar in texture and apparently also in lithological provenance. Also these soils are particularly associated with wetland cropping. Taken together, these features suggest that some of these soils are anthropogenic, and the brown upper layers may result from changes to the red clays brought about by prolonged irrigation for rice.

Four profiles in these soils have been described in detail and three of them were sampled for analysis (see PH015, PH023, PH028 and PK043 in Appendix B). Three of the profiles are in wetland cultivated areas, and the fourth (PK043) is in chir pine woodland. The topsoil is pale brown-light grey, hard, cloddy, sandy loam-sandy clay loam. At the base of the puddled layer there is often a diffuse layer of black manganiferous mottles and very soft concretions. Below that the colours in the upper subsoils are predominately brown, but greyish and strong browns also occur. Textures are similar to the topsoil, in the sandy loam-sandy clay loam range. Structures are moderate angular - subangular blocky, sometimes with weak discontinuous cutans.

At depths varying between 40 and 100 cm, there is a distinct change. The lower subsoil is yellowish red or red, and sometimes has higher clay contents. The structure is similarly blocky to the brown horizon above, but is sometimes slightly more angular. Textures vary from sandy clay loam to clay. In none of the profile seen in these soils was weathered rock encountered, up to depths of 1.5 m+. There are a few stones, but these are more common in the upper brown layers than in the red lower subsoil. They are mostly fragments of quartz or gneiss.

Most of these soils are of about neutral pH. In one of them (PH028) the pH (water) increases by over one unit to the red subsoil, which is slightly alkaline. In two of the analysed soils, the moderate CEC's are wholly base-saturated, with Ca^{++} as the main cation. In another (PK043), the base saturation levels are low (< 35%) and Mg^{++} is the dominant cation. It is assumed that amphibolite is an important component in the parent material of this profile. Organic carbon and total N contents are very low in all horizons of the forested profile (PK043), but this profile has erratically high available P contents in two subsoil horizons. Organic carbon, total nitrogen and available P are low throughout in the cultivated profiles.

5.2.11 Orange sandy loam (QO)

This soil was seen only in one area, on the side slopes and summit of the quartzite ridge between Limbukha and Shengana. The ridge is mostly under broadleaf forest, but the vegetation is somewhat scrubby and has been disturbed for fuelwood and timber cutting, grazing, and sokshing. Only one profile in these soils has been described in detail and sampled for analysis during this survey (see PH029 in Appendix B). This is located in a sokshing area on the lower slope of the ridge.

The topsoil is a fairly pale coloured, loose, open, porous crumb-structured light sandy loam. It overlies a very friable, strong brown, weakly blocky structured light sandy loam. In the lower subsoil, the colour brightens to yellowish red, and the texture becomes slightly finer to heavy sandy loam. Consistence remains friable all the way down to 160 cm+. Augering up the ridge confirmed the depth, friability, bright orange-yellow colours, and coarse textures of these soils.

The sampled profile has a moderate organic C content in the topsoil, together with moderate total N and high available P. The organic matter content gives the topsoil a moderate cation exchange capacity, but the CEC's are low in the subsoil. These soils have low base saturations, in the range 15-25%. Ca^{++} and Mg^{++} are coequal components of the low total exchangeable bases. The low base saturation is paralleled by slight acidity, with pH (water) values just under 6 in all horizons.

5.2.12 Grey stony sandy loam (QG)

These soils were seen in the Nabche area on the lower and middle sections of the southeastern slopes of the valley. They may also occur on the slopes of the gorge section in the middle catchment, but this area was not examined in the field. These soils appear to be derived from quartzite or highly quartzitic gneiss. The slopes at Nabche are used for rainfed cultivation of maize, mustard and chili. So far there are no detailed descriptions or analysed samples from profiles in these soils.

The profile is relatively simple, with greyish brown stony sandy loam - loamy sand over grey or pale brown stony sandy loam. The interstitial fine earth is friable and porous but stones dominate the overall structure and consistence. The stones are mostly angular and subangular quartz, and made augering difficult.

Although there are no detailed profiles in these soils, some topsoils have been analysed as part of the SSF&PNMP nutrient studies. The analyses show that the soils are distinctly sandier (65% sand against 50%) than the brown sandy loams (GS and GD) of Dompola. However the nutrient status is very similar, with organic carbon at about 1.5% (cf 1.6% at Dompola), total nitrogen at 0.14% (0.15%), available P at 12 ppm (5 ppm), pH (water) 6.7 (6.4), and base saturation 75% (60%). The higher means for available P at Nabche is due to some high-very high readings.

Some of these soils are cultivated for winter crops of mustard without supplementary irrigation, apparently using residual soil moisture. As the high sand and stone contents of these soils indicate low available moisture capacities, the ability to sustain rainfed winter cropping may be due to local micro - and meso-climatic conditions or to subsoil wetting by throughflow from upslope. This is worth investigation.

5.2.13 Soil analytical characteristics

Table 5.2 summarizes the chemical data of the soil classes from the analyses of the 124 profile samples collected during the survey. The chemical features of the individual classes have been mentioned above. In general it can be seen that the soils are slightly acid and moderately base-depleted. Organic carbon, total nitrogen and available P vary considerably, largely because of differences in management.

Table 5.2 Summary of chemical analyses, by soil classes, Lingmutey Chhu

SOIL CLASS (number of profiles)	TOPSOIL ONLY				TOPSOIL AND SUBSOIL (T/S)				
	Org. C (%)	Total N (%)	C:N	AvP (ppm)	pH	TEB me %	BS (%)	Exch K (me %)	AvK (ppm)
TL (1)	1.8	0.21	8	3	6.4/8.3	3/6	43/76	1.1/0.5	213/99
TM (2)	0.1-1.6	0.06- 0.21	2-8	5-35	5.9-6.9/ 7.7-7.8	2-8/3-6	47-100/ 72-100	0.3-0.7/ 0.5-0.8	1-42/ 32-35
TU (1)	1.3	0.20	6	16	5.9/7.8	7/4	92/99	0.3/0.3	2/ 16
LB(3)	3.0-11.8	0.10-0.51	8-33	3-33	5.4-6.5/ 6.9-7.1	3-11/1-7	32-82/ 28-60	0.1-0.4/ 0.2-1.0	25-129/ 14-150
RC (5)	0.1-2.9	0.03-0.25	3-13	1-23	5.1-7.3/ 5.5-6.7	4-16/3-7	66-100/ 40-100	0.4-2.2/ 0.4-1.1	101-386/ 3-150
RM (1)	13.1	0.50	26	4	5.8/6.3	43/4	63/26	0.7/0.2	112/20
GS (5)	0.8-3.2	0.09-0.27	8-12	2-14	5.7-6.7/ 5.7-6.7	2-6/1-6	32-100/ 41-58	0-14/ 0-0.6	62-224/ 10-88
GD (5)	0.9-2.1	0.08-0.19	6-12	1-6	5.4-6.2/ 6.4-8.3	1-6/2-8	16-100/ 20-93	0.2-0.8/ 0.1-0.4	16-122/ 9-63
BR (3)	0.1-1.7	0.13-0.25	1-11	1	6.3-7.1/ 5.8-6.8	5-10/ 1-6	56-100/ 17-100	0.4-1.3/ 0.4-0.6	66-124/ 22-87
QO (1)	3.6	0.25	14	40	5.8/5.9	2/1	21/23	0/0.6	201/103

See Table A.1 in Appendix A for interpretation of these values.

5.3 Soil correlation.

5.3.1 Correlation with other Bhutan soils

As BSSP have now done fieldwork for nine soil survey areas in Bhutan, it is becoming possible to indicate which of the Lingmutey soils are similar to other that have been seen elsewhere in the country. The Tsang Chhu river terrace soils (our classes TL and TM) are clearly similar to those with the same class names only a few kilometers downstream at Bajo RNR-RC (BSSP Report SS3 (a), 1998). They are quite different from the terrace soils along Chamkhar Chhu at Bumthang in East Central Bhutan (BSSP Report 2(a), 1998). The grey

and brown sandy loam hill soils derived from gneissic parent materials (GS and GD) are similar to the main hill soils at Yusipang RNR-RC (Hs, Hm and Hd) and the shallow hill soils at Bathpalathang (Hs) (BSSP Reports 1(a) and 2(a), 1998). All of these soils are derived from high – grade metamorphic rocks of felsic composition. The orange light loamy sand (QO), the Limbukha basin alluvial soils (LB), the reddish brown clay loam (RM) have not been seen elsewhere. One profile (Pd003) in the red clays (RC) has been described, but not sampled, at Lobeysa. Extensive areas of these and of the red-over–brown (BR) soils have been seen in the on-going fieldwork for the semi-detailed survey of Talo geog on the opposite bank of Tsang Chhu.

5.3.2 Correlation with international soil classifications.

The local classification used in Table 5.1 and in Section 5.2 aims to be simple and to clearly indicate the main soil features to those interested specifically in the soils of Bhutan and Lingmutey Chhu. The classes are too generally defined to convey much to people outside Bhutan. The classes are therefore correlated with the two main international systems of soil classification in Table 5.3. The versions of the international systems used are those that were available at the time of our fieldwork. Correlations with more recent versions will follow in BSSP Working Papers on soil classification. The correlations are discussed in Appendix C. The most difficult correlation problems are for the red and dark brown clays (RC and RM).

Table 5.3 International correlation of soils of Lingmutey Chhu

Soil Class		Subunit in FAO Soil Map of the World Legend of (FAO1974 & 1988)	Great group in USDA Soil Taxonomy (Soil Survey Staff 1975 & 1992) [Family in italics]
Code	Name		
RS	River sand	Eutric Fluvisol, Eutric Regosol	Typic Ustipsamment [thermic, sandy, mixed]
TL	Lower terrace soil	Eutric Fluvisol	Typic or anthraquic Ustifluvent [thermic, loamy skeletal, mixed]
TM	Middle terrace soil	Eutric Cambisol (Eutric Fluvisol)	Typic or anthraquic Ustochrept, (Typic or anthraquic Ustifluvent) [thermic, loamy, mixed]
TU	Upper terrace soil	Eutric Cambisol (Haplic Luvisol)	Typic or anthraquic Ustochrept [thermic, fine loamy, mixed]
LB	Limukha basin soil	Eutric Fluvisol	Typic or anthraquic Udifluvent [mesic, loamy, mixed]
RC	Red clay	Ferralic & chromic Cambisol; Haplic Luvisol & Lixisol, Rhodic Ferralsol	Dystric & typic Ustochrept; Typic Rhodustalf, Rhodustox or Rhodustult [mesic, fine loamy, mixed].
RM	Dark brown clay	Humic Cambisol, Humic Ferralsol; (Pachic Andosol)	Pachic or typic Haplumbrept; Humic Rhodic Eutrustox (Pachic Haplustand) [mesic, fine loamy, mixed].
GS	Shallow brown sandy loam	Dystric & eutric Cambisol	Dystric, anthraquic or typic Ustochrept [mesic, loamy-skeletal, mixed].
GD	Deep brown sandy loam	Dystric & eutric Regosol, Dystric & eutric Cambisol	Dystric, anthraquic or typic Ustochrept & Ustorthent [mesic, loamy, mixed].
BR	Brown loam over red clay	Eutric Cambisol	Typic & anthraquic Ustochrept [mesic, loamy, mixed]
QO	Orange sandy loam	Haplic Acrisol; Ferralic Arenosol	Arenic & typic Haplustult; Typic Ustipsamment [mesic, sandy & coarse loamy, mixed]
QG	Grey stony sandy loam	Dystric Cambisol	Dystric & typic Ustochrept [mesic, loamy skeletal, mixed]

5.3.3 Correlation with geotechnical classification of soils.

Stability of soil terraces and water conveyance systems are important for irrigated agriculture in Bhutan in general, and also in the survey area. Table 5.4 correlates the soils of Lingmutey Chhu with the geotechnical classification of the Irrigation Section of REID of MoA. The classification of the red clays needs further discussion, to take account of their erodibility.

Table 5.4 Geotechnical correlation of soils of Lingmutey Chhu

Lingmutey Chhu soil class	REID Irrigation Section geotechnical soil classification	
	Land unit	Soil class
RS	5C	SW (well graded sands)
TL	5A	CL & MH (inorganic clay and silts)
TM		
TU		
LB		
RC	3 A/B, 5C	CL (inorganic lean clays)
RM	3A/B	
GS		SC (clayey sand)
GD		
BR		
QO		SM (poorly graded sand & silt)
QG		SP & SC (poorly graded sand and silt, & gravelly)

Source for class criteria: CIP (1993)

6. SOIL DISTRIBUTION AND MAPPING

6.1 Soil distribution

The soil classification is partly geomorphological, and the distributions of the alluvial soil classes are closely related to topography. Thus the river sand, river terrace soils and the Limbukha basin soils are located on the landforms indicated by their names. The soils on the hilly upper part of the catchment are partly determined by variations in the lithology of the parent materials and their distributions are not so neatly tied in with particular landforms. The red clays are mainly associated with the skam/amphibolite spur between Matamlumchhu and Bajothangkha. The orange sandy loams were seen only on the interfluve ridge between Limbukha and Shengana. The distribution of the extensive gneiss brown sandy loams is less easily related to specific features.

6.2 Soil mapping units.

6.2.1 1:25 000 map of whole catchment

For this it is possible to map some of the area as simple units (consociations), in which one class of soil is predominant. The consociations are not pure, and contain minor inclusions of other soil classes. However, at this scale, much of the watershed is mapped as complex units, in which two or more classes are about coequal. Most of the gneissic loams of the hill land in the upper catchment are mapped as the gneiss hill complex GX. The middle and upper Tsang Chhu terrace soils are mapped as terrace complex TX.

The compositions of the units for the 1:25 000 map are summarised in Table 6.1

Table 6.1 Composition of units for 1:25 000 soil map of Lingmutey Chhu

Mapping unit	Type	Main soil classes	Minor soil classes
TL	Consociation	TL	RS, TM
TX	Complex	TM, TU	-
LB	Consociation	LB	-
RC	Consociation	RC	BR
RM	Consociation	RM	RC
GD	Consociation	GD	GS, RC, BR
GX	Complex	GS, GD	RC, BR, QG
BX	Complex	BR, RC, GD	-
QO	Consociation	QO	GS, GD.

The areas and proportions of the units for this map are summarised in Table 6.2.

Table 6.2 Areas of soil mapping units on 1:25 000 soil map of Lingmutey Chhu

Soil mapping unit	Area		
	ha	acres	% of survey area.
TL	33	82	1.0
TX	70	173	2.1
LB	42	103	1.3
RC	219	541	6.3
RM	84	207	2.5
GD	253	625	7.6
GX	2272	5613	68.2
BX	111	274	3.3
QO	258	637	7.7
TOTAL	3342	8255	100.0

6.2.2 1:10 000 soil map of lower catchment

As noted in Section 4.2, a more detailed soil map has been prepared for the area covered by more detailed topo 1:10 000 base. Because of the greater detail, some of the complexes on the 1:25 000 map are mapped as consociations. The compositions of the mapping units for the 1:10 000 map are summarised in Table 6.3. No area measurements have been done because of the arbitrary boundary of the area covered.

Table 6.3 Composition of units for 1:10 000 soil map of lower Lingmutey Chhu

Mapping unit	Type	Main soil classes	Minor soil classes
RS	Consociation	RS	TL
TL	Consociation	TL	RS, TM
TX	Complex	TM, TU	-
RC	Consociation	RC	BR
GD	Consociation	GD	GS, RC, BR
GS	Consociation	GS	GD, QG
BR	Consociation	BR	RC, GD

7. CONCLUSIONS

7.1 Future soil surveys

This survey is seen as only the beginning of the BSSP involvement in the Lingmutey Chhu watershed studies and activities. It is intended to provide a general soils picture for other disciplines. It should also indicate areas where more detailed soil mapping and characterization may be useful. BSSP welcomes requests and suggestions from co-workers in the watershed for more detailed soil work in sites of specific interest. BSSP anticipates participating in discussions, planning, and other cross- and multidisciplinary activities relating to the watershed.

7.2 Soils of Lingmutey Chhu in regional context

Lingmutey Chhu has been chosen for integrated watershed studies and activities for a complex of reasons, including social attitudes, physical access, and pre-existing work. It is of interest to know if the soils of the watershed are representative of large areas or are unique.

As BSSP is in its early stages, its field experience of Bhutan's soils is still limited. It is not therefore able to pronounce authoritatively on the typicality of Lingmutey Chhu's soils. However enough has been seen for it to be clear that soils similar to the brown sandy loam (GS and GD) are widespread on the extensive gneiss and schist parent materials in mid-altitude Bhutan. The grey stony sandy loams are also thought to be common in areas with abundant quartzite. It is not known if soils like the deep orange light sandy loams on the Shengana-Limukha quartzite ridge are common elsewhere. The terrace soils in the lower catchment are similar to others in the middle section of the Tsang Chhu valley.

There are extensive areas of soils like the red clays (RC) and the related brown-over-red soils in the Lobeysa-Walakha region, on the opposite (west) bank of Tsang Chhu. Similar soils extend far upslope from Walakha through Talo geog, and also up the valley of Tabe Rong Chhu towards Thinleygang. Small patches of similar soils are thought to be common throughout the very extensive Thimphu gneiss outcrop, and are largely determined by the occurrence of amphibolite dykes, carbonate beds or skarn bodies. They are particularly extensive and concentrated in this section of the middle Tsang Chhu valley. The dark brown clays (RM) may occur elsewhere on mafic, ultramafic and carbonate rock types under broadleaf forest, especially on slopes of northerly aspect.

Lingmutey Chhu therefore contains a variety of soils that are significant elsewhere, and the findings in the watershed will not be of restricted spatial relevance because of atypical soils. However other, non-soil, aspects may complicate extrapolation of Lingmutey Chhu results.

7.3 Possible further work

A number of topics for possible future investigation were prompted by our field observations in this survey and elsewhere and also came from colleagues in their feedback on the draft of this report, e.g.

- The nature and mechanisms of the erosion of the reddish clays (RC), particularly the relative roles of clay dispersion, rainsplash, and surface run-off. Because substantial areas of soils like these are being developed for the resettlement and the expansion of arable cropping in Talo geog, this is an urgent problem.

- Possible landslip and erosion hazards that might arise from terracing the grey stony sandy loan (QG) in the Nabche area

- Possible effects of Chir pine plantations on soil properties.

- The mode of formation, rooting and water relationships of the brown-over-red clay soils (BR), especially for those that have a textural discontinuity and are formed in biphasic colluvium.

- The relative importance of aspect and soil effects on the floristics and physiognomy of the broadleaf forest.

- The effect of sokshing on different soil types. There appear to be sokshing areas on different soils near Limbukha village. The analytical data from the single profile PH029 on the deep but coarse textured QO soils gives no indication that soil nutrient status is degraded by sokshing. This is in contrast with findings on the effects of much more intense forest floor sweeping in a tropical forest in Meghalaya (Melkania & Ramnarayan, 1998). They found the topsoils in areas of prolonged and intense harvesting of forest litter to be greatly depleted of organic C, total N and available P. However sokshing in Bhutan may increase vulnerability to sheet erosion. There appears to be some accelerated erosion in sokshing on the lower slopes of the Shengana interfluve ridge.

ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometery
ACB	Austrian Co-operation Bureau
AHT	Agrar - und HydrotechniK, GmbH, (Germany).
AIT	Asian Institute of Technology, Bangkok
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
Av	Available
AvP	Available Phosphate
AWC	Available water capacity
asl	Above sea level
BP	Before present
BS%	Base saturation percentage
BSSP	Bhutan Soil Survey Project
C	Clay
ca	Approximately
CEC	Cation exchange capacity
Chhu	Stream or river
Chhuzing	Irrigated agricultural land
CL	Clay loam
Colluvium	Local hillwash, moved by surface erosion and slow, non-glacial creep processes.
Complex	Soil mapping unit with several co-equal soil classes.
Consociation	Soil mapping unit with one soil class dominant but others as minor constituents.
Creep	Slow gravitational mass movement of colluvium downslope.
Danida	Danish International Development Assistance.
Dzongkhag	Administrative district
EC	Electrical conductivity
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FAO	Food and Agriculture Organisation of United Nations
fe	fine earth (particle size < 2mm)
FSD	Forestry Services Division
FYM	Farmyard manure
Geog	Block or subdistrict, administrative subdivision of Dzongkhag.
GIS	Geographical information system
Gley	Soil that is permanently wet, poorly aerated and has predominantly greyish colours, due to reduction of free iron to ferrous valency state. May have local oxidising conditions giving rust - coloured mottles, especially around root channels.
GLO	Glacial lake outburst
GSI	Geological Survey of India
GPS	Global positioning system
GTZ	Gesellschaft fur Technische Zusammenarbeit (German development cooperation agency)
Gully wash	Rapid movement of coarse, commonly bouldery, unlayered materials down steep streams.
ha	Hectare
HCl	Hydrochloric acid
JICA	Japanese International Cooperation Agency
Krotovina	Old faunal burrow filled with dark soil from topsoil
L	Loam

LUPP	Land Use Planning Project, in PPD
LUSS	Land Use and Statistics Section, in PPD
me%	milliequivalents per 100 g fine earth
MoA	Ministry of Agriculture
MoF	Ministry of Finance
mS/cm	milliSiemens per centimetre (unit of electrical conductivity)
MTI	Ministry of Trade and Industry.
ND	No data
NH_4OAC	Ammonium acetate
NS	Not sampled
NSSC	National Soils Services Centre, REID, Simtokha
OC	Organic carbon
OM	Organic matter
P	Precipitation, rainfall
P	Phosphate
PCI	Pacific Consultants International (Japan)
PDOP	Position dilution of precision (measure of GPS performance)
pH	Measure of acidity - alkalinity
PM	Parent material
PPD	Planning and Policy Division, MoA
ppm	Parts per million
PSC	Particle size class (Soil Taxonomy)
REID	Research, Extension and Irrigation Division, of MoA
RGOB	Royal Government of Bhutan
RNR	Renewable natural resources (includes agriculture, animal husbandry and forestry in RGOB sense)
RNR-RC	RNR Research Centre.
S	Sand
Saprolite	Soft weathered rock beneath solum, often reddish.
Sokshing	Forest from which needles or leaves are collected for livestock bedding and FYM.
Si	Silt
Sk	Skeletal (high stone content)
SMR	Soil moisture regime
SMU	Soil mapping unit
SoB	Survey of Bhutan
SoI	Survey of India
Solum	True soil, in which soil processes have removed many traces of parent materials structure.
sp, spp	Species (singular & plural)
SPAL	Soils and Plant Analysis Laboratory, NSSC, REID, Simtokha.
SSF&PNMP	Sustainable Soil Fertility & Plant Nutrition Management Project, NSSC, REID.
SSS	Soil Survey Staff (of USDA)
ST	Soil Taxonomy (US system of soil classification)
STR	Soil temperature regime
Surface wash	Movement of individual soil particles by running surface water.
Tr	Trace
TE	Trace elements
TEB	Total exchangeable bases (= exchangeable Ca + Mg + Na + K)
TLB	True left bank (facing downstream)
TRB	True right bank (facing downstream)
UNESCO	United Nations Educational, Scientific and Cultural Organsiation
USDA	United States Department of Agriculture
v/v	% by volume
WGS	World Geodetic System

WR	Weathered rock
w/w	% by weight
X	Exchangeable (for cation)
Z,Zi	Silt

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APPENDIX A: METHODS OF SOIL ANALYSIS USED AT SPAL

The full details of the methods used at SPAL are given in 'Soil Analysis' (SPAL 1993).

The SPAL methods vary according to soil pH. The methods summarized below are those for soils of pH (water) both > 7 and < 7, as samples of both types occur in the Lingmutey Chhu survey area.

Sample preparation.

Samples are air - dried, aggregates are hand crushed, and the soil is sieved to 2 mm.

pH.

Soil pH is measured in suspensions of the soil in distilled water and 1 M KCl (1:2.5) using a PHM 83 automatic pH meter.

Soil extracts.

The fine earth fraction is subject to a number of extraction procedures:

- Total N is extracted and converted into ammonium form by micro-Kjeldahl digestion with H_2SO_4 and a Se-based catalyst.
- Ammonium – N and nitrate – N are extracted by shaking with 0.01 M $CaCl_2$ for two hours.
- For soils with pH (water) < 7, available P is extracted by shaking 5 g of fine earth with 35 ml of the Bray and Kurtz extractant of 0.5 M HCl and 1 M NH_4F for 1 minute. For soils with pH > 7, available P is extracted by shaking 5 g of fine earth with 35 ml of the Olsen extractant of 0.5 M Na HCO_3 and 1 M NaOH for 1 minute.
- Available K is extracted by shaking 5 g of fine earth with 50 ml of 0.01 M $CaCl_2$ for 2 hours.
- Exchangeable Ca, Mg, K and Na are extracted by leaching 5 g of fine earth with 100 ml of 1 M ammonium acetate (NH_4OAc).
- For the soils with pH (water) < 7.5, the ammonium is extracted by leaching the soil with excess 1 M KCl, and measured to give the Cation Exchange Capacity. For the soil with pH (water) > 7.5, the ammonium is extracted by leaching with excess 1 M sodium acetate.

Assays of extracts.

The NH_4 in the extract from the Total N digestion, the KCl leaching for CEC determination, and from NH_4 – N; NO_3 – N; available P; available K; and exchangeable K and Na in the various extracts are measured with the Skalar Segmented Flow Analyser system, which includes colorimeters for NH_4, NO_3 and P, and a flame spectrophotometer for K and Na.

Exchangeable Ca and Mg in the NH_4OAc leachate are measured with a Unicom Atomic Adsorption Spectrophotometer.

Organic carbon

OC is measured by the Walkley – Black method of low temperature oxidation with acidified $K_2Cr_2O_7$ and titration of the excess dichromate.

Particle size analysis

Particle size fractions are measured by the pipette method after pre-treatment of the fine earth with H_2O_2 to remove organic binding effects, and with HCl to remove aggregation effects of carbonates, Fe and Al oxides, and other mineral cementing agents, and then dispersion with sodium hexametaphosphate.

TEB, ECEC, BS and C:N.

Total exchangeable bases, Base saturation, and C:N ratios are derived by computation, i.e.;

- TEB = Exchangeable Ca + Mg + K + Na.
- BS% (NH_4OAc) = TEB / CEC (NH_4OAc) x 100.
- C:N = Organic C / Total N.

The analytical results from SPAL are interpreted according to the criteria summarised in Table AppA.1.

Table A.1 Summary of current interpretation of SPAL soil analyses.

	V. High	High	Moderate	Low	V. Low
pH	> 7.6 (alkaline)	6.6 - 7.5 (neutral)	5.6 - 6.5 (s. acid)	4.6 - 5.5 (v. acid)	< 4.5 (ext. acid)
EC mS/cm	> 2.00	0.8 - 1.99	0.4 - 0.79	0.15 - 0.39	< 0.15
CEC (NH_4OAc) me%	> 40	25 - 39.9	15 - 24.9	5 - 14.9	< 5
XCa me%	> 20	10 - 19.9	5 - 9.9	2 - 4.9	< 2
XMg me%	> 8	3 - 7.9	1.5 - 2.9	0.5 - 1.4	< 0.5
XK me%	> 1.2	0.6 - 1.19	0.3 - 0.59	0.1 - 0.29	< 0.1
XNa me%	> 2	0.7 - 1.99	0.3 - 0.69	0.1 - 0.29	< 0.1
TEB me%	> 30	15 - 29.9	7.5 - 14.9	3 - 7.4	< 3
XAl me%	> 10	5 - 9.9	2 - 4.9	0.5 - 1.9	< 0.5
ECEC me%	> 30	20 - 29.9	12 - 19.9	4 - 11.9	< 4
BS % (NH_4OAc)	> 80	65 - 79	50 - 64	35 - 49	< 35
EBS %	> 80	50 - 79	35 - 49	20 - 34	< 20
AvK ppm	> 300	200 - 299	100 - 199	40 - 99	< 40
AvP ppm	> 30		15 - 29	5 - 14	< 5
Org. C %	> 5 > 1	3.1 - 4.9	1.2 - 3	0.6 - 1.1	< 0.6
Total N %	> 1	0.5 - 0.99	0.2 - 0.49	0.1 - 0.19	< 0.1
C:N	> 50	20 - 49	15 - 19	10 - 14	< 10

Source: AHT 1995.

APPENDIX B: SOIL PROFILE DESCRIPTIONS AND ANALYSES

This appendix includes the detailed descriptions and analyses of all the soil profiles. The profiles appear in the order summarised in Table AppB.1.

Table B.1 Summary of Lingmutey Chhu profiles.

Profile	Lingmutey Chhu soil class	Number of horizons analysed
PH017	TM	5
PH019	RC	3
PH021	GS	3
PH022	GS	3
PH023	BR	4
PH024	GD	5
PH025	RC	4
PH026	TU	6
PH028	BR	4
PH029	QO	4
PH031	GD	3
PH032	RC	3
PK033	GD	5
PK034	GS	4
PK037	GD	4
PK038	GS	4
PK040	LB	2
PK041	GS	3
PK043	BR	4
PK044	RC	4
PH018	GD	6
PH020	TL	7
PH027	TM	7
PH030	LB	7
PK035	LB	6
PK039	RM	7
PK042	RC	7
PH015	BR	Ns*
PH016	GD	Ns*
TOTAL	29	124

* Ns = Not sampled.

Profile:	PH017	
Map unit:	TX	
Soil classification:	Lingmutey soil class:	TM (middle terrace soil)
	Soil Taxonomy:	Anthraquic Ustifluvent (themic, fine over loamy, mixed)
	FAO:	Eutric Fluvisol
Survey area:	Lingmutey Chhu watershed.	
Location:	Middle of Wonjokha cultivation area, ca 300m above Shengana road	
GPS:	Not available	
Altitude:	1250 m a. s. l	
Described & sampled:	9.2.1998, H B Tamang	
Climate:	General:	Warm temperate - subtropical, P = ca 700 mm p.a
	Recent weather:	Sunny
Regional topography:	Main Tsang Chhu valley	
Site position:	Midslope of spur of middle terrace	
Slope:	12%, terraced concave, ca 500 m long, aspect W	
Site drainage:	Good	
Parent material:	Solid:	Gneiss & skarn
	Drift:	Old alluvium
Land use:	Wetland	
Vegetation:	Rice stubble	
Surface:	Litter:	Scattered rice straw
	Outcrops:	None
	Stones:	Few angular pebbles
	Cracks:	Thin cracking of thin red clay surface coating
	Roots:	None
	Microrelief:	Poaching of cattle 0-05cm depth
	Faunal activity:	None
	Other features:	Thin platy skin of reddish brown clay loam.

Profile description: (Colours are moist unless indicated)

cm	
< 0.5	Thin platy structured coating of reddish silty clay
0 - 15	2.5Y 5/1 (grey) with few fine faint yellowish brown mottles; silty clay; strong medium subangular blocky; many fine pores; dry & firm; many fine roots no stones; flakes of muscovites; HCl negative; clear regular boundary to: [Sample PH017/1 @ 0-10]
15 – 46	2.5Y 5/1 (grey) with many medium distinct yellowish brown mottles; very fine sandy clay loam; strong medium subangular blocky; many fine pores; moist & very firm; many fine roots no stones; HCl negative; flakes of muscovite; clear regular boundary to: [Sample PH017/2 @ 25-35]
46-73	10YR 4/1 (dark grey) with common medium distinct reddish brown mottles; very fine sandy clay loam; moderate medium subangular blocky breaking to fine crumb in hand; weak discontinuous clayskins; few fine pores; moist & very firm no stones; HCl negative; few flakes of muscovite; gradual slightly wavy boundary to: [Sample PH017/3 @ 50-60]
73-46	10YR 4/1 (dark grey) with many fine distinct reddish & yellowish brown mottles; medium sandy clay loam+; moderate medium subangular blocky breaking to fine crumb in hand; moist & slightly friable; HCl negative; diffuse boundary to: [Sample PH017/4 @ 85-95]
120-155+	2.5Y 4/1 (dark grey) with common fine brightness yellowish brown mottles; coarse sandy clay loam+; weak medium & fine subangular blocky; moist & very friable; many pebbles of quartz; HCl negative: [Sample PH017/5 @ 130-140]

Comment: The land is cultivated for rice in summer & wheat in winter. This is good example of a middle terrace soil that has been cultivated for irrigated rice for many years. The texture profile shows the usual trend from high silt contents to more sandy subsoils. Consistence is firmer in the cultivated topsoil than in the subsoil.

SPAL analytical results for BSS Profile PH017 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH017 /1	0-10	4762	5.9	4.3	1.6	0.01	5	1.6	0.2	7.6
2	25-35	4763	7.3	5.7	1.6	0.01	6	0.4	0.1	5.7
/3	50-60	4764	7.6	5.6	2.0	0.01	4	0.6	0.1	15.0
/4	85-95	4765	7.7	5.8	1.9	0.01	4	0.3	Tr	10.0
/5	130-140	4766	6.9	5.4	1.5	0.02	4	0.2	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH017 /1	5.9	1.2	0.7	0.2	8.0		7.2		100	
/2	4.3	1.8	0.9	0.3	7.3		6.8		100	
/3	4.0	1.2	0.8	0.3	6.3		5.8		100	
/4	3.2	1.0	0.7	0.3	5.2		4.7		100	
/5	3.4	1.1	0.6	0.3	5.6		4.9		100	

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total Sand	20-50 micron	2-20	Total silt		
PH017 /1						35.7	11.9	25.4	37.3	27.0	CL
/2						40.1	9.8	22.0	31.8	28.1	CL
/3						52.8	9.6	17.3	26.9	20.3	SCL
/4						58.6	9.0	16.1	25.1	16.2	SL
/5						68.0	8.4	12.4	20.8	11.1	SL

Profile:	PH019	
Map unit:	RC	
Soil Classification:	Lingmutey soil class:	Red clay (RC)
	Soil Taxonomy:	Typic Ustrochrept (mesic, fine loamy, mixed).
	FAO:	Chromic Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	Omtekha Chorten, ca 400 m SW of village	
GPS:	Not available	
Altitude:	ca 1600 m	
Described & sampled:	4.2.1998, I.C Baillie	
Climate:	General:	Warm temperate, P = ca 750 mm p.a
	Recent weather:	Dry, cool, & windy
Regional topography:	Low Mountains	
Site position:	Old mass movement area on midslope	
Slope:	ca 40%, 1km length, irregular, W facing (270^0)	
Site drainage:	Good	
Parent material:	Solid:	Gneiss & amphibolite
	Drift:	Mass movement
Land use:	Rough grazing	
Vegetation:	Scrub of Artemisia, legume shrub, & grass	
Surface:	Litter:	Thin discontinuous grass litter
	Outcrops:	None
	Stones:	None
	Crack:	None
	Roots:	None
	Microrelief:	Old landslip backstep ca 1m high
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 11	7.5YR 5/2 (brown) with no mottles; very fine sandy - silty loam; moderate medium crumb; slightly dry & friable; many fine & medium roots; few quartz stones; common fine black manganese stains; HCl negative; clear regular boundary to: [Sample PH019/1 @ 0-10 cm]
11 –25	7.5YR 5/4 (brown) with common fine faint white flecks of soft quartz feldspars; fine sandy loam; moderate fine subangular blocky; common fine pores; common medium & fine roots; slightly moist & firm; few fine soft weathering quartz; few fine black manganese stains; HCl negative; clear regular boundary to: [Sample PH019/2 @ 15-25 cm]
25 –52	2.5YR 4/6 (red) with many fine faint black manganese stains & dark reddish brown weathered rock patches; clay – clay loam; strong medium subangular blocky structure; many fine & medium pores; common medium & fine roots; dry & slightly hard; discontinuous moderate dark (organic) & reddish brown clayskins; common fine & medium patches of red, white & orange weathering rock; HCl negative; gradual slightly wavy boundary to; [Sample PH019/3 @ 35 - 45 cm]
52 –82	White, red & orange weathered gneiss; gritty loamy hand texture; weak coarse subangular blocky; many fine & medium pores; rare fine roots; dry & slightly hard; common white soft feldspars & slightly hard quartz; HCl negative; diffuse boundary to: [Not sampled]
82-140+	White, grey & pale yellow, with some orange streaks; weathered rock (hand textures as loamy coarse sand); massive structure with some cracks; slightly dry & slightly friable; no roots; HCl negative: [Not sampled]
Comment:	This is shallow example of red clay from weathered calc – silicate (skarn) rock. The whitish weathered rock is erodible and the profile is undercut at the base.

SPAL analytical results for BSS Profile PH019 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH019 /1	0-10	4740	6.8	5.7	1.1	0.01	1	2.9	0.3	11.6
/2	15-25	4741	6.7	5.7	1.0	0.01	2	0.6	0.1	7.5
/3	35-45	4742	6.6	5.5	1.1	0.01	1	0.9	0.1	8.1

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH019 /1	4.2	0.8	0.4	0.2	5.5		5.8		95	
/2	2.4	0.8	0.3	0.1	3.6		3.9		91	
/3	2.0	0.8	0.5	0.2	3.4		4.0		85	

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH019 /1						53.2	8.4	16.5	24.9	21.8	SCL
/2						39.8	10.4	24.8	35.2	25.0	L
/3						53.6	9.9	16.0	25.9	20.5	SCL

Profile:	PH021	
Map unit:	GS	
Soil Classification:	Lingmutey soil class:	Shallow brown sandy loam (GS)
	Soil Taxonomy:	Dystric Ustochrept (thermic, coarse loamy, mixed)
	FAO:	Dystric Cambisol
Survey area:	Lingmutey watershed	
Location:	Above Bajothangkha village, up steep hillside	
GPS:	Not available	
Altitude:	1375 m a.s.l	
Described & sampled:	10.2.1998, IC Baillie	
Climate:	General:	Subtropical warm temperate, P = ca 700 mm p.a
	Recent weather:	Few showers, cool, & dry windy
Regional topography:	Lower Mountains	
Site position:	Middle of spur running to down Tsang Chhu	
Slope:	Ca 70%, 500m long, irregular, aspect SW (235^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Colluvium
Land use:	Perennial grazing	
Vegetation:	Scattered chir pine regrowth & bushes	
Surface:	Litter:	Discontinuous chir pine needles
	Outcrops:	Few gneiss & schist up to 4 m across
	Stones:	Many gneiss & quartz
	Crack:	None
	Roots:	None
	Microrelief:	Cattle trails eroded to 0.5-1m depth
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 10	7.5YR 3/3 (dark brown) moist & 10YR 5/4 (yellowish brown) dry with no mottles; coarse sandy loam-; weak medium crumb; many medium pores; common fine roots; dry & soft, & moist & friable; many medium coarse quartz & flat gneiss stones; HCl not tested; many fine slightly hard faecal pellets; diffuse boundary to: [Sample PH021/1@ 0-10]
10 –42	7.5YR 3/3 (dark brown) moist & 9YR 6/4 (light yellowish brown) dry with no mottles; coarse sandy loam; weak fine & medium angular blocky; many medium pores; few fine & medium roots; dry & soft, & moist & very friable; few medium & fine gneiss gravels; HCl not tested; clear regular boundary to: [Sample PH021/2 @20-30]
42-64	Stone line of many rounded & flat bedded schist and gneiss plates up to 30 cm across and 5 cm thick parallel to ground surface; interstitial soil as above, except roots increasing to common; HCl not tested: [Not sampled]
64-110	7.5YR4/3 (brown) moist & 10YR 5/6 (yellowish brown) dry, with no mottles; loamy coarse sand; single grain; many fine pores; few fine roots; dry & loose; common soft weathering gneiss; HCl not tested; clear regular boundary to: [Sample PH021/3 @ 80-90]
110- 130+	Yellow, orange & brown in situ soft weathered gneiss with laminations; HCl not tested: [Not sampled]

Comment: This soil is on a spur and seems to be derived from gneiss. It is less red and coarser textured than the skarn-derived soil in the adjacent shallow declivity - see profile PH022. The subsoil has lower levels of exchangeable Ca than the skarn soil, but pH and XMg levels are about the same

SPAL analytical results for BSS Profile PH021 Surveyarea: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH021 /1	0-10	4774	6.5	5.6	0.9	0.01	2	1.1	0.1	7.8
/2	20-30	4775	6.6	4.6	2.0	0.01	1	0.8	0.1	6.6
/3	80-90	4775	7.1	6.1	1.0	0.01	1	0.2	Tr	6.6

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH021 /1	0.2	0.7	0.6	0.1	1.7		1.3		100	
/2	0.2	0.8	0.1	Tr	1.1		2.2		50	
/3	0.2	0.9	0.2	0.1	1.4		3.4		41	

Fine earth granulometric.

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH021 /1						73.8	9.2	9.7	18.9	7.3	LS
/2						74.4	11.7	6.1	17.9	7.9	LS
/3						70.2	8.7	10.3	19.0	10.2	SL

Profile:	PH022	
Map unit:	GS	
Soil Classification:	Lingmutey soil class:	Shallow brown sandy loam (GS)
	Soil Taxonomy:	Typic Ustochrept [theric, coarse loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey watershed	
Location:	In slight declivity on steep slope above Bajothangkha village	
GPS:	Not available	
Altitude:	Ca 1400m a.s.l	
Described & sampled:	10.2.1998, IC Baillie	
Climate:	General : warm Temperate, P = ca 700 mm p.a	
	Recent weather: Few showers & cool dry wind	
Regional topography:	Lower Mountains	
Site position:	Middle of slope on spur	
Slope:	Ca 70%, 500m long rectilinear & aspect SSW (210^0)	
Site drainage:	Good	
Parent material:	Solid: Skarn & gneiss	
	Drift: Colluvium	
Land use:	Parenial grazing	
Vegetation:	Chirepine, Artemesia & few grasses	
Surface:	Litter:	Rare pine & grass litters
	Outcrops:	Common boulders up to 3m across
	Stones:	Many skarn & gneiss cobbles
	Cracks;	None
	Roots:	None
	Micro relief:	Cattle tracks ca 1m depth
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 13	5YR 4/3 (reddish brown) & 7.5YR 6/4(light brown) dry with no mottle; coarse sandy loam; weak medium platy soft subangular blocky structure; many medium & fine pores; common fine roots; dry slightly hard & moist brittle; common slightly hard gneiss & skarn; common fecal pellets; many medium muscovite; HCl not tested; diffuse boundary to: [Sample PH022/1@ 0-10 cm]
13 – 48	5YR 3/3 (dark reddish brown) & 7.5YR 5/4 (brown) dry with no mottle; coarse sandy loam; weak medium subangular blocky structure; many medium pores; many fine & few medium roots; dry slightly hard & moist brittle; Weathering rock of slightly yellow orange & brown colours; common fine flakes of muscovite; HCl not tested; clear regular boundary to: [Sample PH022/2 @25-35]
48 - 105	Boulders of weathered grey, yellow, orange & brown gneiss & skarn with coarse interstitial patches of 10YR 5/6 (yellowish brown); loamy coarse sand; single grain structure; moist & loose; very fine flakes of muscovite; HCl not tested; clear regular boundary to: [Sample PH022/3 @ 80-90]
105+	Foliated in-situ green weathered gneiss: [Not Sampled]

Comments: Compared with profile PH021, the skarn contribution to this profile show up in the slightly higher clay content, the colours and the high exchangeable Ca status. However this is still a GS soil and does not qualify as a shallow version of the red loam – clay (RC)

Profile: PH023

Map unit:	BR	
Soil Classification:	Lingmutey soil class:	Brown loam over red clay (BR)
	Soil Taxonomy:	Typic Ustochrept [mesic, loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	Road cutting ca 500 m W of Omtekha village	
GPS:	Not available	
Altitude:	ca 1600 m	
Described & sampled:	11.2.1998, H B Tamang	
Climate:	General:	Warm temperate, P = ca 750 mm p.a
	Recent weather:	Sunny
Regional topography:	Low Mountains	
Site position:	Middle slope	
Slope:	26%, 500m long, terraced rectilinear, aspect SW	
Site drainage:	Good	
Parent material:	Solid:	Gneiss & skarn
	Drift:	Colluvium
Land use:	Fallow after rice	
Vegetation:	Artemisia scrub	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Small seasonal rills
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 17	7.5YR 4/2 (brown) with common fine faint dark reddish brown mottles; medium sandy loam+; moderate medium subangular blocky; many medium pores; common medium roots; dry & friable; few fine hard quartz gravel; HCl negative; clear regular boundary to: [Sample PH023/1@ 0-10]
17 –51	7.5YR 4/3 (brown) with many medium distinct yellow & dark red mottles; coarse sandy loam+; moderate medium subangular blocky; common fine pores; common fine roots; dry & friable; common black manganese stains; HCl negative; clear regular boundary to: [Sample PH023/2 @30-40]
51-98	5YR 4/4 (reddish brown) with common medium distinct yellowish brown & grey mottles; medium sandy clay loam+; strong medium subangular blocky; dry & hard in face & friable in hand; few fine hard quartz gravel; HCl negative; diffuse boundary to: [Not sampled]
98-108	10YR 4/6 (dark yellowish brown) with many medium distinct red & brown mottles; medium sandy loam+; weak medium subangular blocky; dry & firm; few fine hard quartz; HCl negative; clear regular boundary to: [Sample PH023/3 @ 98-108]
108-140+	5YR 3/4 (dark reddish brown) with common fine faint dark brown mottles; very fine sandy clay; strong medium subangular blocky; no pores seen; dry & very firm; no roots; common black manganese stains; HCl negative: [Sample PH023/4 @125-135]
Comments:	This does seem to be an example of these soils than has formed by polyphasic colluviation and not by anthropogenic modification of a red clay The layering of brownish sandy loam and reddish sandy clay – sandy clay is quite complex, with up to three depositional phases apparent.

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH023 /1	0-10	4780	7.1	5.9	1.2	0.03	1	1.7	0.3	6.8
/2	30-40	4781	6.8	4.8	2.0	0.01	2	0.3	0.1	4.2
/3	98-108	4782	6.8	4.5	2.3	0.01	1	0.3	0.1	6.0
/4	125-135	4783	7.1	5.7	1.4	0.01	2	0.2	0.1	5.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH023 /1	5.9	2.7	1.3	0.1	10.0		8.7		100	
/2	3.4	1.8	0.5	0.1	5.8		5.0		100	
/3	2.6	1.9	0.4	0.1	5.0		4.9		100	
/4	3.8	2.6	0.6	0.2	7.2		6.8		100	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH023 /1						50.7	10.7	16.3	27.0	22.3	SCL
/2						60.7	8.6	13.6	22.2	17.9	SL
/3						49.7	12.5	18.9	31.4	19.2	L
/4						33.3	9.0	14.3	23.3	43.4	C

Profile:	PH024	
Map unit:	GD	
Soil Classification:	Lingmutey soil class:	Deep brown sandy loam (GD)
	Soil Taxonomy:	Typic or Anthraquic Ustorthent [mesic – thermic, fine loamy, mixed]
	FAO:	Eutric Regosol
Survey area:	Lingmutey watershed	
Location:	100m above Omtekha village	
GPS:	Not available	
Altitude:	ca 1600 m a.s.l	
Described & sampled:	11.2.1998, H B Tamang	
Climate:	General:	Warm temperate, P = ca 750 mm p.a.
	Recent weather:	Sunny
Regional topography:	Low Mountains	
Site position:	Midslope	
Slope:	Ca 30%, terraced rectilinear, 400m long, aspect SW	
Site drainage:	Good	
Parent material:	Solid: Gneiss	
	Drift: Colluvium	
Land use:	Wetland	
Vegetation:	Rice stubble	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Crack:	Thin clay surface
	Roots:	None
	Microrelief:	Cattle poaching 0-5cm depth
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 12	10YR 5/2 (greyish brown) with many medium distinct yellow & orange mottles; silty clay; strong medium subangular blocky; many medium pores; many medium roots; dry & firm; few fine hard quartz; HCl negative; clear regular boundary to: [Sample PH024/1@ 0-10]
12 –39	7.5YR 3/2 (dark brown) with common fine faint red & reddish brown mottles; fine sandy clay loam; strong medium angular blocky; few fine pores; few fine roots; moist & very firm; few medium black manganese stains; HCl negative; clear regular boundary to: [SamplePH024/2 @20-30]
39-80	7.5YR 3/2 (dark brown) with abundant medium distinct reddish brown & black mottles; fine sandy clay loam; weak medium subangular blocky; weak discontinuous clayskins; few fine pores; few fine roots; moist & slightly friable; many black medium manganese stains; HCl negative; diffuse boundary to: [Sample PH024/3 @ 50-60]
80-112	10YR 4/3 (brown) with common fine faint reddish brown & black mottles; medium sandy clay loam; moderate medium subangular blocky; dry & slightly friable; many black manganese stains; HCl negative; diffuse boundary to: [Sample PH024/4 @ 90-100]
112-150+	5YR 4/3 (reddish brown) with few fine faint grey & black mottles; coarse sandy loam+; weak fine subangular blocky; moist & friable; many fine black manganese stains; HCl negative: [Sample PH024/5 @120-130]

Comment: No winter crop is cultivated after rice in summer on this land because the winter fallow is needed for grazing. This field requires much water, as reported by the farmer. The underlying in situ rock is just beginning to weather. The second horizon (12 – 39 cm) is compacted.

SPAL analytical results for BSS Profile PH024 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH024 /1	0-10	4784	5.5	4.7	0.8	0.02	1	0.9	0.4	6.4
/2	20-30	4785	7.1	5.7	1.4	0.03	2	0.3	0.1	3.7
/3	50-60	4786	7.6	5.8	1.8	0.01	1	0.2	0.1	4.0
/4	90-100	4787	7.8	5.8	2.0	0.01	1	0.1	0.1	2.5
/5	120-130	4788	7.6	5.3	2.3	0.02	5	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH024 /1	3.0	0.7	0.5	0.1	4.3		4.9		87	
/2	3.4	1.5	0.4	0.1	5.4		5.9		91	
/3	2.4	1.0	0.3	0.1	3.8		4.4		85	
/4	3.4	1.4	0.4	0.1	5.3		5.7		93	
/5	2.0	1.4	0.4	0.1	3.9		5.8		67	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PH024 /1						38.6	11.8	20.9	32.7	28.7	CL
/2						40.7	11.0	19.2	30.2	29.0	CL
/3						44.6	0.9	25.6	26.5	28.0	CL
/4						49.5	2.7	13.2	15.9	34.6	SCL
/5						56.0	9.1	11.1	20.2	23.8	SCL

Profile:	PH025	
Map unit:	RC	
Soil Classification:	Lingmutey soil class:	Red clay (RC)
	Soil Taxonomy:	Typic Rhodustalf [mesic – thermic, clay, mixed]
	FAO:	Haplic Luvisol or Luvic Cambisol.
Survey area:	Lingmutey watershed	
Location:	Gullied area at the head of Bajothangkha Chhu	
GPS:	Not available	
Altitude:	ca 1400m a.s.l	
Described & sampled:	12.2.1998, I.C.Baillie	
Climate:	General:	Warm temperate, P = ca 750 mm p.
Recent weather:	Dry, sunny & slight cool	
Regional topography:	Low Mountains	
Site position:	Very gullied midslope (almost badlands)	
Slope:	Ca 35%, ca 1km long, ' V' shaped gully, rectilinear, aspect E	
Site drainage:	Good	
Parent material:	Solid: Skarn	
	Drift: Colluvium	
Land use:	Waste land	
Vegetation:	Bare with only dark lichen caps on rounded tops of exposed skarn saprolite	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Common angular quartz & gneiss
	Cracks:	None
	Roots:	None
	Microrelief:	Gullies up to 10m deep
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 22	2.5YR 4/4 (reddish brown) moist, 7.5YR 5/6 (strong brown) dry, with no mottles; light clay; moderate medium subangular blocky; common very fine pores; dry & slightly firm; few fine hard white quartz; HCl not tested; common fine & medium charcoal; diffuse boundary to: [Sample PH025/1@ 0-10]
22 –120	2.5YR 4/4 (reddish brown) moist, 5YR 7/8 (reddish yellow) dry, with common medium distinct black mottles; light clay – silty clay; moderate medium subangular blocky; many fine pores; dry & slightly friable; few dark white quartz; few patches dark weathered rock; common fine black manganese stains; HCl not tested; few fine & medium charcoal; diffuse boundary to: [Sample PH025/2 @ 60-70]
120- 200	2.5YR 5/4 (reddish brown) with many medium faint orange, yellow, brown & black mottles; fine sandy clay; moderate coarse subangular blocky; weak discontinuous dark red clayskins; medium fine pores; dry & slightly friable; common hard white quartz; few patches dark weathered rock; common fine soft black manganese stains; HCl not tested; diffuse boundary to: [Sample PH025/3 @ 150-160]
200- 280	2.5YR 5/6 (red) with many medium faint orange, yellow, brown & black mottles; fine sandy clay loam; weak medium subangular blocky; dry & soft; weak discontinuous dark red clayskins; few black manganese stains; few patches of dark weathered rock; HCl not tested; diffuse boundary to: [Sample PH025/4 @ 240-250]
280-400+	Soft powdery; weathering rock; grey matrix with white poryphyritic grains & dark grey, yellow & orange streaks; common hard quartz crystals: [Not sampled]
Comments:	Very deep example of red clay. Shows high dispersion of clay in 'melted wax' clayskins and pseudo-stalactites on gully wall. Very high silt in lab results for 2nd horizon is probably due to incomplete dispersion of aggregated clay

SPAL analytical results for BSS Profile PH025 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH025 /1	0-10	4789	5.1	4.4	0.7	0.01	2	0.1	Tr	3.3
/2	60-70	4790	6.2	5.0	1.2	0.02	1	0.2	Tr	5.0
/3	150-160	4791	6.8	5.7	1.1	0.01	1	0.1	Tr	5.0
/4	240-250	4792	6.6	5.7	0.9	0.01	15	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH025 /1	0.8	1.9	0.7	0.1	3.5		4.1		84	
/2	0.8	3.0	0.5	0.1	4.4		3.9		100	
/3	1.6	2.7	0.4	0.1	4.8		4.8		99	
/4	2.1	2.2	0.4	0.1	4.8		4.0		100	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PH025 /1						32.4	11.4	14.7	26.1	41.5	C
/2						7.8	81.2	2.7	84.1	8.2	Z
/3						52.3	8.9	12.8	22.7	24.9	SCL
/4						57.4	10.8	13.7	24.5	18.1	SL

Profile:	PH026	
Map unit:	TX	
Soil Classification:	Lingmutey soil class:	Upper terrace soil (TU)
	Soil Taxonomy:	Typic Ustorthent [thermic, fine loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey watershed	
Location:	On spur above Wonjokha village	
GPS:	Not available	
Altitude:	Ca 1350 m a.s.l.	
Described & sampled:	12.2.98, IC Baillie	
Climate:	General:	Subtropical, P = ca 700 mm p.a
	Recent weather:	Dry sunny, cool & windy
Regional topography:	Low mountains	
Site position:	On upper slope of spur	
Slope:	Ca 20%, 500m long, convex, aspect W (280^0)	
Site drainage:	Imperfect-good	
Parent material:	Solid: Gneiss	
	Drift: Colluvium & old alluvium	
Land use:	Wet land	
Vegetation:	Rice stubble	
Surface:	Litter:	Discontinuous rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	1cm skin of red clay with cracks and curls
	Roots:	None
	Microrelief:	Cattle poaching 0-2cm depth
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 1	10YR 5/2 (greyish brown) & 10YR 7/2 (light grey) dry with many medium distinct orange & yellow mottles; silty loam; moderate medium & fine subangular blocky; many fine pores; many fine rice roots; dry & soft; HCl not tested; few faecal pellets; clear regular boundary to: [Sample PH026/1@ 0-1]
1 –19	5YR 6/6 (reddish yellow) & 10YR 5/4 (yellowish brown) dry with no mottles; silty clay – clay; moderate fine platy structure; dry & flaky; HCl not tested; clear regular boundary to: [Sample PH026/2 @1-11]
19- 33	10YR 5/1 (grey) with many medium & fine distinct coarse dark brown, reddish brown & orange mottles; medium sandy loam+; moderate medium angular & subangular blocky structure; common fine pores; few fine roots; patches of dry & very hard, & moist & very friable; HCl not tested; gradual regular boundary to: [Not sampled]
33- 62	10YR 5/2 (greyish brown) with abundant medium distinct reddish brown, dark brown, orange & black mottles; fine sandy loam; moderate medium & coarse angular blocky; weak dark discontinuous clay skin; many fine pores; few fine roots; moist & firm; HCl not tested; rare fine pebbles; common fine black soft manganese stains; clear regular boundary to: [Sample PH026/3 @ 40- 50]
62-90	7.5YR 4/2 (brown) with many fine faint dark brown mottles; medium sandy loam-; weak medium breaking to single grain angular blocky structure; many fine pores; moist & very friable; rare round pebbles; many black soft manganese stains in top 5 cm; common fine charcoal; HCl not tested; diffuse boundary to: [Sample PH026/4 @ 70-80]
90 –140	10YR 5/3 (brown) with many medium faint reddish brown & yellow brown mottles; medium sandy loam – loamy sand; weak medium breaking to single grain; many fine pores; moist & very friable; rare rounded pebbles; few fine

soft black manganese stains; HCl not tested; common fine charcoal; diffuse boundary to:
[Sample PH026/5 @ 110-120]

140-165+ 7.5YR 5/3 (brown) with many medium faint red brown & yellow brown mottles; loamy medium sand; single grain structure; many fine pores; moist & loose; HCl not tested; common fine charcoal:
[Sample PH026/6 @ 150-160]

Comment: Mostly alluvial but probably some colluvial additions. Sample of the clay veneer washed in with irrigation water (#1 @ 0-1) is distinctly more acid, but has higher contents of exchangeable C and Mg than the underlying alluvium. The lab results indicate that it is also finer textured, but the field texture is dominated by the higher silt. It is probably derived from suspended clay off the skarn ridge.

SPAL analytical results for BSS Profile PH026 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	OrganicC%	Total N %	C:N
			H2O	KCl	Diff					
PH026 /1	0-1	4793	5.9	4.4	1.5	0.01	16	1.3	0.2	6.5
/2	1-11	4794	7.3	5.7	1.6	0.03	9	0.8	0.1	7.2
/3	40-50	4795	7.6	5.8	1.8	0.02	25	0.2	Tr	6.6
/4	70-80	4796	7.8	5.9	1.9	0.01	51	0.1	Tr	5.0
/5	110-120	4797	7.8	5.8	2.0	0.01	35	0.1	Tr	5.0
/6	15-160	4798	6.8	4.9	1.9	0.01	1	0.8	Tr	80.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH026 /1	5.1	1.2	0.3	0.2	6.7		7.3		92	
/2	2.0	0.6	0.2	0.1	2.9		4.1		71	
/3	1.8	1.0	0.5	0.1	3.3		3.7		90	
/4	3.2	0.8	0.3	0.1	4.4		4.4		99	
/5	2.9	0.7	0.3	0.2	4.1		4.6		90	
/6	2.0	0.6	0.3	0.1	3.0		3.0		99	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH026 /1						30.3	9.9	27.8	37.3	32.0	CL
/2						49.3	14.3	16.5	30.6	20.1	L
/3						62.3	7.8	12.1	19.9	17.9	SL
/4						64.9	8.3	8.3	16.6	18.5	SL
/5						60.6	8.4	12.4	20.8	18.6	SL
/6						79.5	6.0	6.3	12.3	8.2	LS

Profile:	PH028	
Map unit:	BX	
Soil Classification:	Lingmutey soil class:	Brown loam over red clay (BR)
	Soil Taxonomy:	Type Ustochrept [thermic, loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	Ca 100m NNE at 20^0 from Bajo Lhakhang	
GPS:	Not available	
Altitude:	Ca 1400m a.s.l	
Described & sampled:	13.2.1998, IC Baillie	
Climate:	General:	Subtropical, P = ca 700 mm p.a.
	Recent weather:	Dry, cool & windy
Regional topography:	Main Tsang Chhu valley	
Site position:	Crest of broad gully spur	
Slope:	10%, 500m long, convex, aspect W (270^0)	
Site drainage:	Good	
Parent material:	Solid:	Skarn
	Drift:	Alluvium over deep colluvium
Land use:	Abandoned arable	
Vegetation:	Artemisia & low grasses	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Gullying to depth 5m + nearby
	Faunal activity:	None
	Other features:	Dark lichen on cutting face

Profile description: (Colours are moist unless indicated)

cm	
0 – 15	10YR 4/3 (brown) moist, 10YR 6/3 (pale brown) dry, with no mottles; fine sandy loam; moderate medium & fine subangular blocky; many fine pores; common fine roots; dry & hard, friable when moist; slow to wet; rare angular quartz; HCl not tested; fecal pellets; clear regular boundary to: [Sample PH028/1 @ 0-10]
15 –30	10YR 5/4 (yellowish brown) moist, 10YR 6/4 (light yellowish) dry, with abundant fine distinct orange, yellow & red mottles; medium sandy clay loam; moderate medium angular blocky; common fine pores; few fine roots; dry & hard, friable when moist, slow to wet; many flakes of muscovite; HCl not tested; gradual regular boundary to: [Not sampled]
30- 90	9YR 4/4 (dark yellowish brown) with common fine distinct red & reddish brown mottles; medium sandy loam; moderate medium prismatic; weak discontinuous clayskins; few coarse pores; rare fine roots; dry & hard, friable when moist; few medium slightly platy weathering rock; HCl not tested; clear regular boundary to: [Sample PH028/2 @ 50-60]
90- 105	5YR 4/4 (reddish brown) moist, 5YR 6/6 (reddish yellow) dry with many medium distinct dark brown mottles; fine sandy clay; moderate medium subangular blocky; many fine pores; rare fine roots; moist & firm, slightly plastic; few grey platy weathering rock; many black manganese stains; gradual regular boundary to: [Sample PH028/3 @ 95-100]
105-160+	5YR 4/4 (reddish brown) moist, 5YR 6/6 (reddish yellow) dry with many medium faint dark reddish brown, dark brown & black mottles; clay; moderate fine angular blocky; common fine pores; rare fine roots; slightly moist & very firm; common fine manganese stains; HCl not tested: [Sample PH028/4 @ 130-140]
Comment:	Increasing redness and clay content maybe due to biphasic colluviation, but soil pH and exchangeable base status does not change much.

SPAL analytical results for BSS Profile PH028 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	OrganicC%	Total N %	C:N
			H2O	KCl	Diff					
PH028 /1	0-10	4806	6.4	5.4	1.0	0.01	1	1.4	0.1	10.7
/2	50-60	4807	6.7	4.5	2.0	0.13	1	0.3	0.1	6.0
/3	95-100	4808	6.8	4.2	2.6	0.23	1	0.2	0.1	5.0
/4	130-140	4809	6.9	5.8	1.1	0.03	1	0.1	Tr	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH028 /1	3.2	0.7	0.7	0.1	4.8		6.0		79	
/2	3.8	1.0	0.6	0.3	5.7		4.9		100	
/3	4.0	1.0	0.7	0.5	6.2		6.0		100	
/4	3.8	0.9	0.7	0.3	5.7		5.5		100	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PH028 /1						48.6	13.1	19.5	32.6	18.8	L
/2						19.1	9.5	15.8	25.3	19.1	ZL
/3						43.3	12.4	12.2	24.6	32.0	CL
/4						47.5	6.5	9.2	15.7	36.9	CL

Profile:	PH029	
Map unit:	QO	
Soil Classification:	Lingmutey soil class:	Orange sandy loam (QO)
	Soil Taxonomy:	Typic Hapustult [mesic, coarse loamy, mixed]
	FAO:	Haplic Acrisol
Survey area:	Lingmutey Chhu watershed	
Location:	Limukha sokshing area	
GPS:	27^0 34.03' N, 89^0 55. 05' E	
Altitude:	2240 m a.s.l	
Described & sampled:	24.2.1998, IC Baillie	
Climate:	General:	Warm temperate, P = ca 800 mm p.a.
	Recent weather:	Cool & dry
Regional topography:	Middle mountains	
Site position:	Moderately eroded lower midslope	
Slope:	46%, 1km long, rectilinear, aspect NE (45^0)	
Site drainage:	Good	
Parent material:	Solid:	Quartz & schist
	Drift:	Colluvium
Land use:	Sokshing	
Vegetation:	Woodland of almost pure Quercus sp. Very little ground cover & no oak regeneration	
Surface:	Litter:	5-10 cm partially decomposed oak leaves
	Outcrops:	None
	Stones:	Occasional gneiss & schist
	Cracks:	None
	Roots:	None
	Microrelief:	Gullying up to 1.5m depth, with rounded sides
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 8	10YR 3/3 (dark brown) moist, 10YR 5/5 (yellowish brown) dry with no mottles; medium sandy loam-; weak fine crumb; many fine pores; few coarse roots; dry & soft friable; common quartz & gneiss; HCl not tested ant; holes; common fine flakes of muscovite; clear regular boundary to: [Sample PH029/1 @ 0-8]
8 –13	10YR 5/4 (yellowish brown) & 10YR 7/4 (very pale yellowish) dry with few medium faint red & yellow mottles; medium sandy loam-; weak – moderate fine crumb; many fine pores; many fine & few coarse roots; moist – dry & slightly firm; common quartz & gneiss gravel; few flakes of muscovite; HCl not tested; gradual regular boundary to: [Not sampled]
13- 45	7.5YR 5/6 (strong brown) with no mottles; medium sandy loam-; weak - moderate subangular blocky breaking to fine crumb; many fine pores; common coarse roots; moist & slightly friable; few fine quartz & gneiss; HCl not tested; diffuse boundary to: [SamplePH029/2 @25-35]
45- 85	6YR 6/6 (strong brown) with no mottles; medium sandy loam+; weak medium subangular blocky; moist & friable; many fine pores; common medium roots; HCl not tested; common flakes of muscovite; diffuse boundary to: [SamplePH029/3 @ 60-70]
85-160+	7.5YR 4/6 (strong brown) with no mottles but few pebbles of yellow weathered rock; medium sandy loam-; weak medium subangular blocky; many fine pores; common medium roots; moist & friable; few soft yellow weathered gneiss & quartz; HCl not tested; ant nest; common flakes of muscovite: [Sample PH029/4 @ 120-130]

Comment: Deep and friable. Lab textures finer than hand textures in field. pH and base saturation values are low.

SPAL analytical results for BSS Profile PH029 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH029 /1	0-8	4834	5.8	4.2	1.6	0.02	40	3.6	0.3	14.4
/2	25-35	4835	5.9	4.2	1.7	0.01	2	0.7	0.1	10.0
/3	60-70	4836	5.9	4.1	1.8	0.01	1	0.9	0.1	15.0
/4	120-130	4837	5.9	4.2	1.7	0.01	1	0.2	0.1	2.8

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH029 /1	1.0	0.9	Tr	0.1	2.0		9.7		21	
/2	0.2	0.2	0.6	0.2	1.2		5.1		23	
/3	0.2	0.4	0.6	0.1	1.3		5.4		23	
/4	0.2	0.1	0.4	0.1	0.8		5.1		15	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total Sand	20-50 micron	2-20	Total Silt		
PH029 /1						68.7	9.3	13.5	22.8	8.6	SL
/2						63.3	8.8	13.7	22.5	14.2	SL
/3						54.6	9.0	15.7	24.7	20.6	SCL
/4						64.5	6.8	7.0	13.8	21.7	SCL

Profile:	PH031	
Map unit:	GD	
Soil Classification:	Lingmutey soil class:	Deep brown sandy loam (GD)
	Soil Taxonomy:	Typic Ustochrept [mesic, loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	On Nabche path, downhill from Dompola	
GPS:	27^0 33. 20' N, 89^0 54.40' E	
Altitude:	1980 m a.s.l	
Described & sampled:	26.2.1998, H B Tamang	
Climate:	General:	Warm temperate, P = 800 + mm p.a.
Recent weather: Sunny		
Regional topography:	Low Mountains	
Site position:	Terraced midslope	
Slope:	25%, 400m long, terraced convex, aspect SE (150^0)	
Site drainage:	Good	
Parent material:	Solid: Quartz & gneiss	
	Drift: Colluvium	
Land use:	Wetland	
Vegetation:	Rice stubble	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 16	10YR 5/2 (greyish brown) with common medium distinct yellowish brown mottles; fine sandy clay loam+; medium subangular blocky breaking to fine crumb; common fine pores; common fine roots; moist & slightly friable; few medium stones; HCl negative; clear regular boundary to: [Sample PH031/1 @ 0-10]
16-70	10YR 3/1 (very dark grey) with many fine faint reddish brown & yellow mottles; coarse sandy loam; strong medium subangular blocky; weak discontinuous clayskins; common fine pores; common fine roots; moist & slightly firm; few medium & fine stones; HCl negative; clear regular boundary to: [Sample PH031/2 @ 40-50]
70-130+	7.5YR 5/2 (brown) with common medium distinct red, yellow & brown mottles; coarse sandy loam+; weak medium & fine subangular blocky; few fine pores; moist & slightly firm; common fine hard quartz; HCl negative: [Sample PH031/3 @ 80-90]

SPAL analytical results for BSS Profile PH031 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH031 /1	0-10	4845	5.4	4.4	1.0	0.01	2	0.9	0.1	11.2
/2	40-50	4846	7.8	6.9	0.9	0.02	2	0.1	0.1	2.5
/3	80-90	4847	7.8	6.9	0.9	0.01	1	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH031 /1	2.2	0.6	0.3	0.3	3.4		6.1		56	
/2	5.6	1.4	0.4	0.4	7.5		8.1		93	
/3	5.6	1.7	0.4	0.2	7.9		8.2		97	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH031 /1						56.4	8.6	16.3	24.9	18.7	SL
/2						52.7	9.0	17.8	26.8	20.5	SCL
/3						43.9	8.1	23.6	31.7	24.5	L

Profile:	PH031	
Map unit:	GD	
Soil Classification:	Lingmutey soil class:	Deep brown sandy loam (GD)
	Soil Taxonomy:	Typic Ustochrept [mesic, loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	On Nabche path, downhill from Dompola	
GPS:	27^0 33. 20' N, 89^0 54.40' E	
Altitude:	1980 m a.s.l	
Described & sampled:	26.2.1998, H B Tamang	
Climate:	General:	Warm temperate, P = 800 + mm p.a.
	Recent weather:	Sunny
Regional topography:	Low Mountains	
Site position:	Terraced midslope	
Slope:	25%, 400m long, terraced convex, aspect SE (150^0)	
Site drainage:	Good	
Parent material:	Solid:	Quartz & gneiss
	Drift:	Colluvium
Land use:	Wetland	
Vegetation:	Rice stubble	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 16	10YR 5/2 (greyish brown) with common medium distinct yellowish brown mottles; fine sandy clay loam+; medium subangular blocky breaking to fine crumb; common fine pores; common fine roots; moist & slightly friable; few medium stones; HCl negative; clear regular boundary to: [Sample PH031/1 @ 0-10]
16-70	10YR 3/1 (very dark grey) with many fine faint reddish brown & yellow mottles; coarse sandy loam; strong medium subangular blocky; weak discontinuous clayskins; common fine pores; common fine roots; moist & slightly firm; few medium & fine stones; HCl negative; clear regular boundary to: [Sample PH031/2 @ 40-50]
70-130+	7.5YR 5/2 (brown) with common medium distinct red, yellow & brown mottles; coarse sandy loam+; weak medium & fine subangular blocky; few fine pores; moist & slightly firm; common fine hard quartz; HCl negative: [Sample PH031/3 @ 80-90]

SPAL analytical results for BSS Profile PH031 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH031 /1	0-10	4845	5.4	4.4	1.0	0.01	2	0.9	0.1	11.2
/2	40-50	4846	7.8	6.9	0.9	0.02	2	0.1	0.1	2.5
/3	80-90	4847	7.8	6.9	0.9	0.01	1	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH031 /1	2.2	0.6	0.3	0.3	3.4		6.1		56	
/2	5.6	1.4	0.4	0.4	7.5		8.1		93	
/3	5.6	1.7	0.4	0.2	7.9		8.2		97	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH031 /1						56.4	8.6	16.3	24.9	18.7	SL
/2						52.7	9.0	17.8	26.8	20.5	SCL
/3						43.9	8.1	23.6	31.7	24.5	L

Profile:	PH032	
Map unit:	RC	
Soil Classification:	Lingmutey soil class:	Red clay (RC)
	Soil Taxonomy:	Typic Ustochrept [mesic, fine loamy, mixed]
	FAO:	Chromic Cambisol
Survey area:	Lingmutey watershed	
Location:	Cutting ca 400 m down from Dompola Gompa on Omtekha road	
GPS:	Not available	
Altitude:	1995 m a.s.l.	
Described & sampled:	26.2.1998, I C Baillie	
Climate:	General:	Warm temperate, P = 800 + mm p.a.
	Recent weather:	Light cool showers
Regional topography:	Low Mountains	
Site position:	Upper slope of major spur	
Slope:	45%, ca 1 km long, convex, aspect WNW (290^0)	
Site drainage:	Good	
Parent material:	Solid: Skarn	
	Drift: Colluvium	
Land use:	Chir pine grazing & fuelwood woodland	
Vegetation:	Rhododendron, chir pine & grasses	
Surface:	Litter:	Discontinuous chir pine twigs
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Cattle trails eroded to ca 20 cm depth.
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 12	7.5YR 4/2 (brown) with common medium faint reddish yellow mottles; fine sandy loam+; moderate breaking to fine crumb; many fine pores; many fine & medium roots; moist & slightly friable; few fine hard quartz & gneiss; common fecal pellets & wormcasts; HCl negative; common fine charcoal; clear regular boundary to: [Sample PH032/1 @ 0-10]
12-31	5YR 4/4 (reddish brown) with common medium faint brown mottles; medium sandy clay loam; moderate medium subangular blocky; many medium pores; many fine & common medium roots; moist & firm; few fine hard quartz & gneiss; HCl negative; grub seen; rare charcoal; gradual regular boundary to: [Not sampled]
31-68	5YR 4/4(reddish brown) with common medium brown mottles; fine sandy clay loam; moderate medium angular blocky structure; moderate discontinuous clayskins & organic matter cutans; many medium pores; common fine roots; moist & firm; few fine hard quartz & muscovite; HCl negative; diffuse boundary to: [Sample PH032/2 @ 45-55]
68-110	Mixed colours but dominant are 7.5YR 4/4 (brown) & 5YR 4/4 (reddish brown); weathered rock (medium sandy clay loam); weak medium subangular blocky; moderate discontinuous clayskins; common medium & coarse pores; rare fine roots; moist & firm; many white angular quartz & gneiss stones; common soft black manganese stains; HCl not tested; diffuse boundary to: [Sample PH031/3 @ 80-90]
110-140+	Mixed colours but dominant is 7.5 YR 4/4 (brown) with reddish brown mottles; weather rock (medium sandy clay loam); weak medium subangular blocky structure; moderate discontinuous clayskins; common medium pores; rare fine roots; moist & very firm; few soft white subangular quartz & gneiss stones; HCl not tested; common soft manganese stains: [Not sampled]

Comment: Solum is not as red or fine textured as first appeared. Clayskins and clay bulge in granulometric analyses suggest that this soil is tending towards an Ultisol/ Acrisol.

SPAL analytical results for BSS Profile PH032 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH032 /1	0-10	4848	6.3	5.3	1.0	0.02	1	1.7	0.1	13.0
/2	45-55	4849	5.5	4.3	1.2	0.01	1	0.1	0.1	2.5
/3	80-90	4850	6.3	5.4	0.9	0.01	1	0.1	Tr	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH032 /1	4.2	1.6	0.6	0.1	6.4		9.8		65	
/2	1.6	1.4	0.6	0.1	3.7		9.2		40	
/3	2.6	1.5	0.5	0.1	4.6		8.8		52	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH032 /1						47.5	10.7	17.5	28.2	24.3	L
/2						38.4	9.8	16.9	26.7	34.9	CL
/3						49.0	8.4	14.6	23.0	27.9	SCL

Profile:	PK033	
Map unit:	GD	
Soil classification:	Provisional Bhutan soil series:	Deep brown sandy loam (GD)
	Soil Taxonomy:	Typic Ustochrept [mesic, fine loamy, mixed]
	FAO:	Dystric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	100m E of Sangay Dema's house, Nabche	
GPS:	$27^0$33.10' N, 29^0.55. 06' E	
Altitude:	1920m a. s. l	
Described & sampled:	3.3.98, Kado Tshering	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Cloudy
Regional topography:	Low Mountains	
Site slope:	Midslope	
Slope:	15%, convex, ca km 2 long, W facing (285^0)	
Site drainage:	Good	
Parent material:	Solid: Mixed	
Drift: Alluvium		
Land use:	Abandoned rice land.	
Vegetation:	Artemisia, oak regeneration	
Surface:	Litter:	5-6 cm rice stubble
	Outcrops:	None
	Stones:	Few muscovite flakes
	Cracks:	2-3 mm
	Microrelief:	None
	Roots:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-10	10YR 6/1 (grey) with abundant coarse red & orange mottles; fine sandy loam; weak subangular blocky breaking to fine crumb; many medium & fine pores; slightly dry & slightly friable; abundant medium & fine roots; HCl negative; diffuse boundary to: [Sample PK033/1 @ 0-10]
10-36	2.5Y 5/2 (greyish brown) with abundant coarse red & reddish brown, medium sandy clay; moderate medium angular blocky; many fine pores, moist & firm; common fine roots; few fine hard quartz & gneiss stones; HCl negative; gradual regular to: [Sample PK033/2 @ 20-30]
36-56	2.5Y 5/1 (grey) with abundant reddish brown & orange mottles; medium sandy clay loam; moderate medium angular blocky; weak discontinuous clayskins cutans; many fine pores; moist & very hard/very firm; few fine roots; fine medium hard angular gneiss stones; HCl negative; few muscovite flakes; clear regular boundary to: [Sample PK033/3 @ 40-50]
56-76	2.5Y 5/1 (grey) with common fine distinct reddish brown & yellowish orange mottles; medium sandy clay loam; moderate medium subangular blocky; weak discontinuous clayskins; common fine pores; moist & firm, few fine roots; few fine hard quartz & gneiss stones; HCl negative; fine flakes of muscovite; clear gradual boundary to: [Sample PK033/4 @ 60-70]
76-148+	5YR 5/6 (yellowish red) with few fine faint yellowish & orange mottles; coarse sandy clay loam; weak fine subangular blocky; moist & slightly friable; weathered gneiss; HCl negative; few flakes of muscovite: [Sample PK033/5 @ 90-100]

SPAL analytical results for BSS Profile PK033 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
Pk0033 /1	0-10	4825	5.4	4.4	1.0	0.01	6	1.8	0.1	12.0
/2	20-30	4826	5.7	4.2	1.5	0.01	4	1.5	0.2	7.1
/3	40-50	4827	6.7	4.1	2.6	0.01	1	0.6	0.1	5.0
/4	60-70	4828	7.2	4.0	3.2	0.01	1	0.4	0.1	5.7
/5	90-100	4829	7.5	4.8	2.7	0.02	1	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pk0033 /1	0.2	0.5	0.2	0.1	1.0		6.0		16	
/2	2.2	0.8	0.1	0.1	3.2		5.9		54	
/3	3.6	1.1	0.1	0.1	4.9		7.1		69	
/4	3.2	1.5	0.2	0.1	5.0		7.9		63	
/5	2.0	1.2	0.2	0.1	3.5		13.1		26	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
Pk0033 /1						46.0	11.7	18.1	29.8	24.2	L
/2						46.1	9.8	20.2	30.0	23.9	L
/3						44.8	9.0	20.8	29.8	25.5	L
/4						43.3	8.4	1.6	27.0	29.6	CL
/5						52.7	7.1	18.1	25.2	22.1	SCL

Profile:	PK034	
Map unit:	GS	
Soil classification:	Provisional Bhutan soil class:	Shallow brown sandy loam (GS)
	Soil Taxonomy:	Dystric Ustochrept [Mesic, coarse loamy, mixed]
	FAO:	Dystric Cambisol
Survey area:	Lingmutey watershed	
Location:	On path of south bank of Seche Rong Chhu, Nabche	
GPS:	Not available	
Altitude:	1940m a s l	
Described & sampled:	25.2.1998, Ian Baillie	
Climate:	General:	Warm temperate, P = ca 800 mm pa
	Recent weather:	Cool, showers last night
Regional topography:	Middle mountains	
Site position:	Spur on midslope	
Slope:	50%, rectilinear; ca 1km long, aspect W (280^0)	
Site drainage:	Good	
Parent material:	Solid:	Quartz & gneiss
	Drift:	Colluvium
Land use:	Community forest for firewood collection.	
Vegetation:	Broadleaf, with oaks, Rhododendron, Artemisia, bracken, grasses & few chir pine.	
Surface:	Litter:	Discontinuous thin cover of oak leaves
	Outcrops:	None
	Stones:	Few angular quartzite boulders in gullies on path
	Cracks:	None
	Microrelief:	Gullied up to 1.5 m on path; some stepping behind trees
	Roots:	Common few medium & coarse tree root
	Faunal activity:	Abundant ant nest debris
	Other features:	Few charcoal

Profile description: (Colours are moist unless indicated)

cm	
0-9	7.5YR 4/2 brown (moist) & 10YR 5/3 brown (dry) with no mottles; fine sandy loam; moderate & weak very fine crumb; abundant fine & medium pores; moist - dry & soft & very friable; rare quartz & gneiss gravel; HCl negative; abundant ant nests burrows; clear regular boundary to: [Sample PK034/1 @ 0-9]
9-33	Mixed 10YR 3/2 (very dark greyish brown) & 10 YR 5/3 (brown) with few medium yellow mottles; fine sandy loam; moderate medium subangular blocky; abundant fine, medium & coarse pores; slightly moist & friable, many medium & few coarse hard quartzite gravels; HCl negative; ant nests; grubs, few charcoal; gradual regular boundary to: [Sample PK034/2 @ 15-25]
33-59	Mixed colour of 10YR 5/4 (yellowish brown) & 10YR 6/4 (light yellowish brown) with common medium & few fine dark brown mottles; medium sandy loam; weak medium subangular blocky; medium & coarse pores; moist - dry & hard; few fine coarse roots; few hard medium quartz gravel, especially at base; HCl negative; clear regular boundary to: [Sample PK034/3 @ 40-50]
59-110+	10YR 5/6 (yellowish brown) with abundant very coarse orange & dark brown mottles; weathered rock (very fine sandy loam +); weak medium angular blocky; few medium & coarse pores; moist & firm; few medium & fine roots; few quartz gravel; HCl negative: [Sample PK034/4 @ 80-90]

Comment: Very mixed base status.

SPAL analytical results for BSS Profile PK034 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK034 /1	0-9	4838	5.9	4.2	1.7	0.01	2	3.2	0.3	11.8
/2	15-25	4831	5.6	4.3	1.3	0.01	1	1.2	0.1	15.0
/3	40-50	4832	5.8	4.4	1.4	0.01	1	1.0	Tr	33.3
/4	80-90	4833	6.2	4.5	1.7	0.01	1	0.2	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK034 /1	3.4	2.2	0.3	0.1	5.9		10.5		57	
/2	0.2	1.2	Tr	0.1	1.5		7.2		21	
/3	1.2	1.2	Tr	0.1	2.5		6.1		41	
/4	4.0	1.2	Tr	0.1	5.3		6.1		86	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK034 /1						63	4.3	20.7	25.0	11.9	SL
/2						61	6.0	16.6	22.6	16.4	SL
/3						56.9	12.2	17.3	29.5	13.5	SL
/4						64.1	12.1	11.4	23.5	12.4	SL

Profile:	PK037	
Map unit:	GX	
Soil classification:	Provisional Bhutan soil class:	Deep brown sandy loam (GD)
	Soil Taxonomy:	Dystric Ustochrept [Mesic, loamy, mixed]
	FAO:	Dystric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	30 m above Samdruk Gong house, Nabche	
GPS:	Not available	
Altitude:	1910 m a. s. l.	
Described & sampled:	4/3/98, Kado Tshering	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Sunny
Regional topography:	Middle mountains	
Site position:	Lower spur	
Slope:	40%, rectilinear; ca 1km long; aspect NW (305^0):	
Site drainage:	Good	
Parent material:	Solid:	Thimphu formation
	Drift:	Colluvium
Land use:	Broadleaf Forest	
Vegetation:	Oak with chir pine and some Artemisia,	
Surface:	Litter:	Few dry leaves of oak and Artemisia
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	Common coarse medium & fine grass and chir
	Microrelief:	Few steps up to1-2 cm high
	Faunal activity:	Few insect holes
	Other features:	Few charcoal

Profile description: (Colours are moist unless indicated)

cm	
0-14	10YR 3/2 (very dark greyish brown) with few medium dark brown & black mottles; fine loamy sand; medium subangular blocky breaking to fine crumb; many medium & fine pores; moist & slightly firm; common coarse medium fine grass & chir pine roots; very fine hard quartz gravel; HCl negative; few Insect holes; clear regular boundary to: [Sample PK037/1 @ 0-10]
14-40	10YR 4/2 (dark greyish brown) with few coarse greyish brown and orange yellow mottles medium sandy loam +; weak medium subangular blocky breaking to fine crumb; common few coarse, medium & fine pores; moist & friable; abundant fine roots; few coarse & many medium hard quartz gneiss stones; HCl negative; many insect holes; few charcoal; gradual diffuse boundary to: [Sample PK037/2 @ 20-30]
40-80	10YR 5/3 (brown) with many medium faint reddish brown & yellow orange mottles; medium sandy clay; weak medium subangular blocky breaking to fine crumb; moist & slightly friable; many medium & fine roots; common medium-fine angular quartz stores; HCl negative; few insect holes; few charcoal; clear regular boundary to: [Sample PK037/3 @ 55-65]
80-130 +	10YR 5/3 (brown) with few coarse dark brown mottles; coarse sandy clay; moderate coarse breaking to medium subangular blocky; abundant coarse & many medium & fine pores; moist & slightly firm; few coarse & common fine roots; very hard quartz stones; HCl negative: [Sampled PK037/4 @ 100-110]

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK037 /1	0-10	4865	6.2	4.6	1.6	0.01	2	2.1	0.2	11.0
/2	20-30	4866	6.1	5.0	1.1	0.01	1	0.3	0.1	5.0
/3	55-65	4867	6.4	4.2	2.2	0.02	1	0.1	0.0	3.3
/4	100-110	4868	6.3	5.1	1.2	0.02	1	0.1	0.0	5.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK037 /1	4.2	1.3	0.8	0.1	6.4	-	11.0	-	58	-
/2	0.2	0.8	0.3	0.1	1.4	-	6.8	-	21	-
/3	0.2	1.1	0.3	0.1	1.7	-	8.3	-	20	-
/4	0.4	1.2	0.4	0.1	2.1	-	13.0	-	16	-

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK037 /1						57.7	9.9	15.8	25.4	17.0	SL
/2						59.2	8.2	18.4	26.6	14.1	SL
/3						57.0	8.0	12.9	20.9	22.1	SCL
/4						54.7	6.9	17.1	24.0	21.3	SCL

Profile:	PK038	
Map unit:	GX	
Soil classification:	Provisional Bhutan soil class	Shallow brown sandy loam (GS)
	Soil Taxonomy:	Dystric Ustochrept (mesic, coarse loamy, mixed)
	FAO:	Dystric Cambisol
Survey area:	Lingmutey Chhu	
Location:	50 m below (W) the house of Samdruk Gaong, Nabche	
GPS:	Not available	
Altitude:	1890 m a. s. l.	
Described & sampled:	4.3.98, Kado Tshering	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Partly cloudy
Regional topography:	Middle mountains	
Site position:	Lower slope of spur	
Slope:	25%, convex, ca 1km long; aspect WNW (285^0):	
Site drainage:	Good	
Parent material:	Solid: Mixed	
Drift: Colluvium		
Land use:	Dry land for maize cultivation	
Vegetation:	Some weeds and dried maize stoves	
Surface:	Litter:	Some dried maize stoves & leaves
	Outcrops:	None
	Stones:	Rare coarse rounded boulder
	Cracks:	None
	Roots:	Few medium & many fine maize & legume roots
	Microrelief:	None
	Faunal activity	Few insect and rodent holes
	Other features:	Rare charcoal

Profile description: (Colours are moist unless indicated)

cm	
0-25	10YR 6/3 (pale brown) with common medium fine & yellowish orange mottles, medium sandy clay loam, coarse moderate subangular blocky; abundant coarse & many medium & fine pores; slight dry & very hard; few medium & many fine roots; few medium subangular hard quartz stones; HCl negative; clear regular boundary to: [Sample PK038/1 @ 0-10]
25-55	10YR 4/3 (brown) with many medium & coarse dark reddish brown mottles; gravelly clay loamy; moderate medium subangular blocky; abundant weak clayskins; few fine pores; moist & very firm; plastic & sticky when wetted; many fine roots; many medium angular quartz stones; HCl negative; piece of charcoal; gradual wavy boundary to: [Sample PK038/2 @ 35-45]
55-90	5YR 4/4 (reddish brown) with abundant coarse faint very dark reddish brown mottles; fine sandy clay loam – silty loam (weathered rock); moderate weak angular blocky breaking into to fine crumb; discontinuous weak clay skins; few fine pores; moist - slight wet & slightly firm & plastic; few fine roots; weathered skins on hard quartz & gneiss stones; HCl negative; some insect holes; gradual regular boundary to: [Sample PK038/3 @ 70-80]
90-100+	7.5YR 5/4 (brown) with abundant coarse very dark reddish brown weathering patches; weathered quartzite (silty clay loam & patches of coarse sandy loam); moderate - weak fine crumb; few weak clayskins; few fine pores; wet & soft - very friable; HCl negative; coarse burrows: [Sample PK038/4 @ 90-100]

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK038/ 1	0 – 10	4861	6.4	4.1	2.3	0.01	3	0.8	0.1	8.8
/2	35 – 45	4862	5.8	4.0	1.4	0.01	1	0.2	0.1	5.0
/3	70-80	4863	5.7	4.4	1.3	0.02	1	0.1	0.0	5.0
/4	90-100	4864	5.8	4.3	1.5	0.01	1	0.1	0.0	5.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK038 /1	3.2	1.5	1.4	0.1	6.2		8.9		69	
/2	1.6	2.0	0.6	0.2	4.4		10.3		42	
/3	0.8	1.5	0.6	0.2	3.1		8.1		38	
/4	2.0	2.0	0.8	0.1	4.9		9.8		50	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK038 /1						43.9	17.6	16.1	33.7	22.4	L
/2						38.8	10.2	17.8	28.0	33.2	CL
/3						53.2	12.6	14.2	26.8	20.0	SL
/4						52.2	14.7	17.3	32.0	15.8	SL

Profile:	PK040	
Map unit:	LB	
Soil classification:	Provisional Bhutan soil class:	Limbukha basin soil (LB)
	Soil Taxonomy:	Fluventic Endoaquept [mesic, sandy skeletal mixed]
	FAO:	Gleyic Fluvisol
Survey area	Lingmutey Chhu	
Location:	Alluvial fan at top end of Limbukha flats	
GPS:	Not available	
Altitude:	ca 2250 m a. s. l.	
Described & sampled	5.3.98, Ian Baillie	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Overcast
Regional topography	Mid mountain	
Site position	Mid-lower alluvial fan at top end of Limbukha basin	
Slope:	14%, rectilinear, ca 500 m long, aspect W (275^0):	
Site drainage	Poor	
Parent material	Solid	Metamorphic
	Drift:	Alluvium over colluvium
Land use:	Rough grazing	
Vegetation:	Small meadow of flowering Primula dendriculata & sedges	
Surface:	Litter:	Cattle dung and deep sedge litter.
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	Common fine
	Microrelief:	Cattle poaching in wet organic top up to 8 cm
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-16	7.5YR 3/2 (very dark brown) with no mottles; mucky very fine sandy loam; very weak fine crumb; moist-wet & very sticky & plastic; common fine roots; HCl negative clear regular boundary to: [Sample PK040/1 @ 0-10]
16-42	2.5Y 3/1 (very dark grey) with no mottles; gritty fine sandy loam; massive; common medium & fine pores; moist-wet & very sticky & plastic; few fine roots; common fine quartzite grit & abundant muscovite flakes; HCl negative; clear regular boundary to: [Not sampled]
42-48	2.5Y 3/1 (very dark grey) with no mottles; slight gritty silty clay; massive; common fine pores; very wet & very sticky & plastic; few fine roots; few fine hard quartz gravel; HCl negative; clear regular boundary to: [Sample PK040/2 @ 42-48]
48-65	2.5Y 5/2 (greyish brown) with common moderate pale brown, pale yellow & orange mottles; weathered rock stony & gravelly coarse sandy loam +; massive; no pores; moist-wet & very sticky & plastic; many fine angular quartz gravel; no roots; HCl negative; clear regular boundary to: [Not sampled]
65-95+	10YR 4/2 (dark greyish brown) with common moderate pale brown & pale yellow weathered gravel & stones; coarse sandy loam +; massive; no pores: moist-wet & very sticky & plastic; no roots; many fine quartz gravel: HCl negative: [Not sampled]

Comment: Analyses confirm visual indications of moderate organic matter in dark coloured subsoil horizon at 42-48 cm.

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	PH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK040 /1	0-10	4876	5.4	4.5	0.9	0.05	3	11.8	0.5	23.1
/2	42-48	4877	6.9	4.5	1.4	0.01	3	2.4	0.2	16.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pk040 /1	7.9	1.2	0.2	0.1	9.3		29.2		32.1	
/2	6.1	0.7	0.2	0.3	7.3		16.1		46.0	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PK040 /1						55.3	5.4	14.7	20.1	24.6	SCL
/2						66.7	10.9	12.8	23.7	9.7	SL

Profile:	PK041	
Map unit:	GX	
Soil classification:	Provisional Bhutan soil class:	Shallow brown sandy loam (GS)
	Soil Taxonomy:	Dystric Ustochrept [mesic, loamy, mixed]
	FAO:	Dystric Cambisol
Survey area	Lingmutey Chhu	
Location:	Wetland directly below Limbukha village	
GPS:	Not available	
Altitude:	2190 m a. s. l.	
Described & sampled	5.3.1998, Ian Baillie	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Showers
Regional topography	Middle mountains	
Site position:	Down side of ridge across bottom of Limbukha basin	
Slope:	35%, terraced rectilinear, ca 500 m long, SSW facing (195^0)	
Site drainage	Poor	
Parent material:	Solid:	Gneiss and quartzite
	Drift:	Colluvium
Land use	Fallow after rice	
Vegetation:	Grasses and Artemisia	
Surface:	Litter:	Discontinuous Artemisia twigs
	Outcrops:	None
	Stones:	Few boulders to 1.5 m diameter
	Cracks:	None
	Roots:	None
	Microrelief	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-16	10YR 5/3 (brown) moist, few fine faint & orange mottles; very fine sandy clay loam - silty clay loam; strong coarse - medium crumb; common coarse & many fine pores; moist-dry & slight hard; common fine & few medium roots; few fine – medium quartz gravel; HCl negative; abundant casts & common faecal pellets; clear regular boundary to: [Sample PK041/1 @ 0-10]
16-42	10YR 5/3 (brown) with abundant fine orange & reddish yellow orange mottles; fine sandy clay loam +, moderate medium platy breaking to strong fine angular blocky; moderate continuous clayskins; common medium & fine vertical pores; dry - moist & hard & firm; few fine roots; HCl negative; clear regular boundary to: [Sample PK041/2 @ 25-35]
42-48	7.5YR 5/4 (yellowish brown) with abundant medium prominent brown & reddish brown, yellow & black mottles; stony very fine sandy clay; stony - moderate medium subangular blocky; discontinuous clayskins; common medium & fine pores; slightly moist & firm & sticky; few fine roots; many black Mn & reddish brown Fe-stained quartz and granite soft weathered stones; HCl negative; clear regular boundary to: [Not sampled]
48-95	10YR 6/4 (light yellowish brown)with many coarse distinct reddish brown, black, brown & orange mottles; weathered gneiss (very fine sandy to silty loam in hand); weak medium subangular blocky; moist & firm; rare fine roots; HCl negative; gradual regular boundary to: [Sample PK041/3 @ 65-75]
95-140+	Mixed grey & pale brown weathered rock, slightly, too hard to texture; moist & hard to hard & firm; rare roots; HCl negative: [Not sampled]

SPAL analytical results for BSS Profile PK041 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK041 /1	0-10	4878	5.7	4.6	1.1	0.62	19	1.9	0.2	8.6
/2	25-35	4879	6.7	4.5	2.2	0.01	4	0.3	0.1	3.3
/3	65-75	4880	6.9	4.5	2.4	0.01	2	0.1	0.0	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK041 /1	2.4	1.1	0.0	0.2	3.7		11.4		32	
/2	4.3	0.8	0.6	0.1	5.7		9.8		59	
/3	3.2	0.7	0.3	0.1	4.3		9.9		43	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PK041 /1						37.3	11.2	22.7	38.4	24.4	L
/2						39.8	10.6	24.9	24.7	34.7	L
/3						57.7	10.7	11.8	22.5	19.8	SL

Profile:	PK043	
Map unit:	RC	
Soil classification:	Provisi0onal Bhutan soil class:	Brown loam over red clay (BR)
	Soil Taxonomy:	Dystric Ustochrept [mesic, loamy, mixed]
	FAO:	Dystric Cambisol
Survey area:	Lingmutey Chhu watershed	
Location:	Omtekha – Dompala road, below Umtegang microwave station	
GPS:	$27^0$31.99' N; 89^0. 53.92' E	
Altitude:	1910 m a. s. l	
Described & sampled	6.3.1998, Kado Tshering	
Climate:	General:	Warm temperate, P = 800 + mm p.a.
	Recent weather:	Cloudy
Regional topography:	Middle mountains	
Site position:	Midslope of major spur	
Slope:	35%, convex, ca 1 km long, NE facing (60^0)	
Site drainage:	Good	
Parent material:	Solid:	Gneiss
	Drift:	Colluvium, possibly biphasic
Land use	Forest grazing & fuel wood	
Vegetation:	Chir pine woodland also with some oak & rhododendrons	
Surface:	Litter:	Discontinuous, up to 5 cm deep
	Outcrops:	None
	Stones:	Few fine hard quartz & gneiss
	Cracks:	0. 5 – 1 cm wide
	Roots:	None
	Microrelief:	Steps up to 20 cm high
	Faunal activity:	Many earthworm casts
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-15	5YR 4/2 (dark reddish grey) with common medium light orange & greyish brown mottles; fine sandy clay loam; fine subangular blocky; many coarse moderate medium & fine pores; slightly dry & very hard; common medium & fine grass & chir roots; HCl negative; earthworm seen & many wormcasts; clear regular boundary to: [Sample PK043/1 @ 0-10]
15-56	5YR 4/4 (reddish brown) with no mottles; fine sandy clay loam, moderate medium angular blocky; many medium & abundant fine pores; moist - slightly dry, many coarse & medium roots; few medium hard quartz & gneiss gravel & stones; HCl negative; black manganese stains; clear regular boundary to: [Sample PK043/2 @ 30-40]
56-76	5YR 6/4 (light reddish brown) with no mottles; fine sandy clay loam; moderate fine subangular blocky; common coarse, fine & medium pores; slightly dry & slight firm; few coarse grass roots; common medium hard quartz & gneiss angular stones; HCl negative; diffuse boundary to: [Sample PK043/3 @ 60-70]
76-120+	7.5YR (brown) with no mottles; medium sandy clay loam; few coarse & many fine crumb; common coarse & many medium & fine pores; moist - slightly dry & friable; common coarse &few fine roots; many coarse subangular hard quartz & gneiss stones; HCl negative; black manganese stains: [Sample PK043/4 @ 90-100]
Comment:	High silt content in topsoil granulometric analysis may be due to incomplete dispersion. This soil has inversion of the normal colour sequence with redder colours in topsoil than in subsoil.

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK043 /1	0-10	4888	6.3	4.9	1.4	0.01	1	0.1	0.1	0.7
/2	30-40	4889	5.8	4.8	1.0	0.02	31	0.1	0.1	2.0
/3	60-70	4890	5.8	4.8	1.0	0.02	6	0.1	0.1	2.5
/4	90-100	4891	6.1	4.9	1.2	0.01	35	0.1	0.0	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK043 /1	2.4	2.9	0.4	0.1	5.8		10.4		56	
/2	0.2	0.7	0.6	0.1	1.6		8.3		19	
/3	0.2	0.6	0.4	0.1	1.3		7.4		17	
/4	0.2	0.7	0.3	0.1	1.3		4.0		32	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PK043 /1						39.4	11.3	40.0	51.7	8.9	ZL
/2						32.9	14.3	26.4	40.7	26.6	L
/3						41.1	13.7	26.2	39.9	19.0	L
/4						54.0	10.2	21.1	31.3	14.7	SL

Profile:	PK044	
Map unit:	RC	
Soil classification:	Provisional Bhutan soil class:	Red clay (RC)
	Soil Taxonomy:	Typic Rhodustalf [mesic, clay mixed]
	FAO:	Haplic Luvisol
Survey area	Lingmutey Chhu watershed	
Location:	Ca 200 m NW of Dompala Gompa	
GPS:	Not available	
Altitude:	2140 m asl	
Described & sampled	6.3.1998, Ian Baillie	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Light shower
Regional topography	Middle mountains	
Site position:	Upper slope of spur	
Slope:	25%, rectilinear; ca 0.5 km long; aspect ENE (80^0)	
Site drainage:	Good	
Parent material:	Solid:	Gneiss & skarn
	Drift:	Colluvium
Land use:	Fallow after dryland	
Vegetation:	Chilli stalks and weeds	
Surface:	Litter	None
	Outcrops:	None
	Stones:	None
	Cracks:	Few discontinuous, less than 5mm
	Roots:	None
	Microrelief:	Small, irregular < 3 cm
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0–7	7.5YR 5/4 - 5YR 7/4 (brown-pink) with no mottles; silty clay; moderate medium crumb; common medium & few coarse pores; slightly dry & slightly hard; few medium & fine roots; HCl slightly positive, clear regular boundary to: [Sample PK044/1 @ 0-7 cm]
7-23	5YR 5/4 (reddish brown) with common medium pale brown mottles; clay, moderate to strong medium crumb; abundant medium & fine & few coarse pores, slightly dry & very hard; few medium & fine roots; few fine hard quartz & gneiss stones; HCl very slightly positive; gradual regular boundary to: [Sample PK044/2 @ 10-20 cm]
23-54	Mixed 5YR 4/4 (reddish brown) &; 7.5YR 5/4 (brown) with no mottles, clay, massive breaking to moderate medium angular blocky; weak discontinuous clayskins; many medium & fine & few coarse pores; moist & slight firm; rare fine roots; few hard quartz & gneiss stones, HCl negative; diffuse boundary to: Sample PK044/3@ 30-40 cm]
54-100+	Mixed colours of 5YR 5/4 (reddish brown) & 7.5YR 5/4 (brown); clay; massive breaking to weak – moderate subangular blocky; moderate discontinuous clayskins; many medium & few coarse pores; moist & firm; rare roots; few fine hard quartz & gneiss stones; HCl negative. [Sample PK044/4 @ 75-85 cm]
Comment:	Positive HCl reaction in topsoil is matched by high exchangeable Ca.

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK044 /1	0-7	4892	7.3	4.9	2.4	0.01	23	0.8	0.2	5.3
/2	10-20	4893	6.9	5.0	1.9	0.01	31	0.7	0.1	6.3
/3	30-40	4894	6.7	5.1	1.6	0.01	6	0.1	0.1	1.6
/4	75-85	4895	6.3	5.9	0.4	0.02	1	0.1	0.1	1.6

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK044 /1	10.3	3.0	1.2	0.1	15.6		15.0		100	
/2	3.6	2.5	1.5	0.1	7.7		12.3		63	
/3	3.9	1.8	1.1	0.2	7.1		11.1		64	
/4	3.7	2.5	1.0	0.2	7.4		12.1		61	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PK044 /1						27.2	11.0	29.5	40.5	32.4	CL
/2						28.3	10.8	28.0	38.8	32.9	CL
/3						15.6	13.4	33.1	46.5	37.9	ZiCL
/4						22.2	10.3	26.2	36.5	41.3	C

Profile:	PH018	
Map unit:	GX	
Soil Classification:	Lingmutey soil class:	Deep brown sandy loam (GD)
	Soil Taxonomy:	Typic Ustochrept (mesic, coarse loamy, mixed)
	FAO:	Eutric Regosol
Survey area:	Lingmutey Chhu watershed	
Location:	Below Omtekha village	
GPS:	Not available	
Altitude:	ca 1600 m a.s.l	
Described & sampled:	4.2.1998 , I.C. Baillie	
Climate:	General:	Warm temperate, P = ca 800 mm p.a.
	Recent weather:	Dry, cool, & windy
Regional topography:	Low mountain	
Site position:	Terraced lower midslope	
Slope:	ca 20%, terraced concave, 1km long, SSE facing (155 ^{0})	
Site drainage:	Imperfect	
Parent material:	Solid: Gneiss	
	Drift: Colluvium	
Land use:	Wetland	
Vegetation:	Fallow with rice stubble	
Surface:	Litter:	Discontinuous rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Cultivation clods
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 8	2.5Y 7/2 (light grey) dry & 2.5Y 5/1 (grey) moist, with few medium faint orange mottles; very fine sandy loam – silty loam; moderate medium & coarse subangular blocky clods breaking to moderate medium crumb; common coarse vertical pores; common fine roots; slightly dry & friable; few fine flakes of muscovite; HCl negative; clear slightly wavy boundary to: [Sample PH018/1 @ 0 –8]
8 –20	2.5Y 5/2 (greyish brown) with common fine distinct orange mottles; medium sandy loam+; moderate medium breaking to fine subangular blocky; common medium pores; moist & slightly firm; common medium & fine roots; few fine flakes of muscovite; gradual regular boundary to: [Not sampled]
20 –33	2.5YR 5/2 (weak red) with many medium prominent red mottles; medium sandy clay loam; moderate medium subangular blocky; few medium & fine pores; common fine roots; moist & slightly firm; HCl negative; gradual regular boundary to: [Sample PH018/2 @ 20-30]
33 –68	10YR 5/1 (grey) with many fine distinct reddish brown & dark brown mottles; coarse & medium sandy loam+; moderate – weak medium & coarse subangular blocky; continuous but very weak cutans; common fine pores; few fine roots; moist & firm; few fine soft fragments of weathering gneiss; common fine black manganese stains; common very fine muscovite flakes; HCl negative; diffuse boundary to: [Sample PH018/3 @ 40-50]
68-106	2.5Y 5/1 (grey) with common medium distinct reddish brown & orange mottles; medium & coarse sandy clay loam; weak medium subangular blocky; continuous weak cutans; common fine pores; rare fine roots; moist – wet & firm; few angular quartz grit; common fine black manganese stains; rare worm borrows; common very fine muscovite flakes; HCl negative; clear regular boundary to: [Sample PH018/4 @ 80-90]
106-135	5Y 2.5/1 (black) with rare medium brownish yellow weathered colours; gritty coarse sandy loam; weak medium subangular blocky; common fine & medium pores; few medium & fine roots; wet & slightly sticky & plastic; common

very fine flakes of muscovite; common weathering quartz & gneiss; HCl negative; diffuse boundary to:
[Sample PH018/5 @ 110-120]

!35-160+ 5Y 2.5/1 (black) with no mottles; gritty coarse sandy clay loam+; massive structure; common medium & fine pores; wet & plastic; common weathering quartz grits common very fine muscovite; HCl negative;:
[Sample PH018/6 @145-155]

Comment: The reddish and slightly finer textured horizon at 20-33 cm is probably a layer of colluvium derived from skarn as amphibolite upslope. The subsoil wetness is due to throughflow, with seepage at about 120 cm. The deeper horizons (106+) appear to be highly weathered quartzite.

SPAL analytical results for BSS Profile PH018 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	OrganicC%	Total N %	C:N
			H2O	KCl	Diff					
PH018 /1	0-8	4734	5.6	4.0	1.6	0.01	1	1.2	0.2	6.6
/2	20-30	4735	7.4	6.1	1.3	0.01	1	0.6	0.1	6.0
/3	40-50	4736	8.3	6.1	2.2	0.01	1	0.2	Tr	5.0
/4	80-90	4737	8.3	6.1	2.2	0.01	1	0.2	Tr	6.6
/5	110-120	4738	6.9	5.4	1.5	0.01	3	0.3	Tr	10.0
/6	145-155	4739	6.7	5.4	1.3	0.02	3	0.5	Tr	12.5

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH018 /1	2.4	0.6	0.4	0.3	3.7		3.3		100	
/2	4.1	0.6	0.1	0.2	5.1		4.3		100	
/3	3.1	0.5	0.1	0.1	3.9		5.1		75	
/4	2.8	1.2	0.3	0.2	4.5		4.9		92	
/5	1.4	0.4	0.1	0.1	2.1		2.3		90	
/6	2.0	0.8	0.2	0.1	3.1		8.7		36	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH018 /1						56.5	8.6	15.6	24.2	19.3	SL
/2						58.4	8.4	14.5	22.9	18.7	SL
/3						65.0	6.9	11.4	18.3	16.7	SL
/4						64.0	7.2	10.8	18.0	18.0	SL
/5						70.4	2.0	11.4	13.4	16.2	SL
/6						68.1	6.4	11.9	18.3	13.5	SL

Profile: PH020

Map unit: TL

Soil Classification:	Lingmutey soil class:	Lower terrace soil (TL)
	Soil Taxonomy:	Typic or Anthraquic Ustifluvent [thermic, fine loamy over sandy, mixed]
	FAO:	Eutric Fluvisol
Survey area:	Lingmutey Chhu watershed	
Location:	Ca 200 m at bearing 210^0 SSW of Bajothangkha village	
GPS:	27^0 30.57' N, 89^0 53.41' E	
Altitude:	1275 m a.s.l.	
Described & sampled:	10.2.1998, I C Baillie	
Climate:	General:	Warm temperate - subtropical, P = ca 700 mm p.a
	Recent weather:	Dry cool windy
Regional topography:	Main Tsang Chhu valley	
Site position:	Middle of lower terrace	
Slope:	1%, 300 m long, rectilinear, aspect WSW (240^0)	
Site drainage:	Good	
Parent material:	Solid: Mixed	
	Drift: Alluvium	
Land use:	Fallow wetland	
Vegetation:	Rice stubble	
Surface:	Litter:	Discontinuous rice straw
	Outcrops:	None
	Stones:	Few boulders in the bunds
	Cracks:	Continuous network, ca 2-3 mm wide
	Roots:	None
	Microrelief:	Cattle poaching (0-3 cm depth)
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 12	10YR 6/1 (grey) dry, with few medium distinct yellow & orange mottles; silty clay; strong medium clod - subangular blocky; common fine pores; slightly moist & very firm; common fine roots; HCl negative; clear regular boundary to: [Sample PH020/1@ 0-10]
12 –30	10YR 5/1 (grey) with common fine distinct reddish yellow & orange mottles; silty clay; strong moderate clod - subangular blocky; common fine pores; common fine roots; slightly moist & very firm; HCl negative; clear regular boundary to: [Sample PH020/2 @15-25]
30-62	2.5Y 5/1 (grey) with common fine distinct reddish yellow & orange mottles; very fine sandy clay; moderate medium subangular blocky; moderate continuous cutans on vertical & horizontal faces; few fine pores; few fine roots; moist & slightly firm; HCl negative; few flakes of muscovite; clear regular boundary to: [Sample PH020/3 @ 40-50]
62-77	2.5Y 6/2 (light brownish grey) with many fine faint yellow, dark brown, yellowish brown & reddish brown mottles; fine sandy clay loam+; weak medium subangular blocky; moist & slightly friable; common soft black manganese stains; HCl negative; clear regular boundary to: [Sample PH020/4 @ 65-75]
77- 98	10YR 3/2 (very dark greyish brown) with abundant medium distinct reddish brown, yellow & black mottles; medium sandy loam+; weak medium subangular blocky; moist & friable; few fine quartz gravel; common soft black manganese stains; HCl negative; clear regular boundary to: [Sample PH020/5 @ 80-90]
98-123	2.5Y 6/3 (light yellowish brown) with common coarse faint brown & yellow mottles; loamy medium sand; weak medium subangular blocky structure; moist & very friable; HCl negative; clear regular boundary to: [Sample PH020/6 @ 105-115]
123-152	2.5Y 6/2 (light brownish grey) with many medium very faint yellow, brown & grey mottles; loamy medium sand; very weak medium subangular breaking to single grain; moist & very friable; diffuse boundary to: [Sample PH020/7 @ 130-150]
152-180+	As 123-152, but with many rounded boulders. [Not sampled]

Comment: This is an example of a lower terrace soil with a layer of non-bouldery loose sand between the silty upper horizons and the subsoil boulder bed.

SPAL analytical results for BSS Profile PH020 Surveyarea: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH020 /1	0-10	4767	3.4	2.4		0.39	3	1.8	0.2	8.5
/2	15-25	4768	6.3	4.6		0.03	1	1.1	0.2	6.8
/3	40-50	4769	7.9	5.6		0.02	2	0.3	0.1	6.0
/4	65-75	4770	8.3	6.8		0.02	1	0.2	Tr	6.6
/5	80-90	4771	8.2	7.1		0.02	1	0.1	Tr	3.3
/6	105-115	4772	8.2	7.1		0.01	3	0.4	Tr	20.0
/7	130-140	4773	8.1	5.6			3	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH020 /1	0.8	1.7	1.1	0.3	3.4		7.9		43	
/2	5.1	1.7	1.0	0.2	8.0		7.3		100	
/3	5.5	1.8	0.9	0.3	8.6		8.5		100	
/4	4.0	1.3	0.5	0.2	6.0		7.9		76	
/5	2.0	0.9	0.3	0.1	3.3		3.9		84	
/6	0.2	0.3	0.4	0.2	1.0		1.0		100	
/7	0.2	0.2	0.5	0.2	1.1		1.4		75	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PH020 /1						29.9	12.6	26.2	38.8	31.3	CL
/2						31.2	10.8	26.0	36.8	32.0	CL
/3						37.0	7.3	20.8	28.1	34.9	CL
/4						31.9	10.6	30.5	44.1	27.1	ZCL
/5						56.7	11.7	13.6	25.3	18.0	SL
/6						73.2	17.2	7.3	24.5	2.3	LS
/7						87.6	7.6	4.2	11.4	0.9	S

Profile: PH027

Map unit: TX

Soil Classification:	Lingmutey soil class:	Middle terrace soil (TM)
	Soil Taxonomy:	Typic Ustorthent [thermic, coarse loamy, mixed]
	FAO:	Eutric Cambisol
Survey area:	Lingmutey watershed	
Location:	Ca 300m SSE at 150^0 from Bajothangkha village	
GPS:	27^0 30. 58' N, $89^0$53.52' E	
Altitude:	1310m a.s.l	
Described & sampled:	13.2.1998, I C Baillie	
Climate:	General:	Subtropical, P = ca 700 mm p.a.
	Recent weather:	Dry & cool
Regional topography:	Main Tsang Chhu valley	
Site position:	Middle terrace	
Slope:	10%, 400m long, terraced convex, aspect W (270^0)	
Site drainage:	Imperfect	
Parent material:	Solid: Gneiss	
	Drift: Alluvium	
Land use:	Wet land	
Vegetation:	Rice stubble	
Surface:	Litter:	Few rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	Top few cm beginning to crack
	Roots:	None
	Microrelief:	Cattle poaching up to 6cm depth
	Faunal activity:	None
	Other features:	1cm clay cap from irrigation water

Profile description: (Colours are moist unless indicated)

Cm	
0 – 14	2.5Y 5/2 (grey) with many medium distinct dark reddish brown & dark brown mottles; medium sandy loam; weak fine platy at top grading to weak fine subangular blocky beneath; many fine pores; common fine roots; moist & friable; HCl negative; common fine muscovite; gradual regular boundary to: [Sample PH027/1@ 0-10]
14 –33	10YR 4/2 (dark greyish brown) with many medium fine faint brown & dark brown mottles; coarse sandy loam; weak fine subangular blocky; common fine pores; few fine roots; moist & friable; rare rounded pebbles; HCl negative; common flakes of muscovite; clear regular boundary to: [Sample PH027/2 @18-28]
33- 56	2.5Y 5/1 (grey) with many fine distinct reddish brown & dark brown mottles; medium sandy loam+; weak coarse angular & subangular blocky breaking to crumb; common medium pores; rare fine roots; moist & friable; few pieces subangular weathering rock; HCl not tested; common flakes of muscovite; clear regular boundary to: [Sample PH027/3 @ 40-50]
56- 74	2.5Y 5/2 (greyish brown) with abundant medium distinct orange in top few cm, & common fine distinct reddish brown & black mottles throoughou; fine sandy clay loam; weak medium subangular blocky; common medium pores; rare fine roots; moist & friable; rare rounded quartz gravels & subangular weathering rock; HCl negative; common flakes of muscovite; clear regular boundary to: [Sample PH027/4 @ 58-68]
74-81	10YR 5/3 (brown) with abundant medium distinct orange, yellow & dark brown mottles; fine sandy clay loam; weak fine angular blocky; few fine pores; moist & slightly firm; few fine slightly hard weathering rock; few fine faint black manganese stains; HCl negative; few flakes of muscovite; clear regular boundary to: [Not sampled]
81 –104	10YR 6/2 (light brown grey) with many medium faint reddish brown, dark brown & black mottles; silty clay loam; weak medium angular blocky; common medium pores; rare fine roots; moist & friable; few subangular blocky weathering rock; few soft black manganese stains; HCl negative; clear regular boundary to: [Sample PH027/5 @ 91-101]
104 -133	10YR 6/2 (light brownish grey) with many medium & fine distinct orange & red brown mottles; medium sandy clay loam; weak medium angular blocky; common medium pores; rare fine roots; moist & friable; rare rounded quartz gravels; common soft black manganese stains; HCl negative; diffuse boundary to: [Sample PH027/6 @ 115-125]

133-165+ 10YR 4/1 (dark grey) with no mottles; medium sandy loam+; weak fine subangular blocky; common medium pores; moist & friable; rare rounded quartz; HCl negative: [Sample PH027/7 @ 150-160]

Comment: Thin platy surface skin of reddish clay from irrigation water quite apparent on undisturbed surface but does not show in vertical profile.

SPAL analytical results for BSS Profile PH027 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH027 /1	0-10	4799	6.9	5.1	1.8	0.01	35	0.1	0.1	1.6
/2	18-28	4800	7.2	5.3	1.9	0.01	1	0.2	Tr	6.6
/3	40-50	4808	7.8	5.7	2.1	0.01	1	0.1	Tr	2.5
/4	58-68	4802	7.8	5.7	2.1	0.01	1	0.2	Tr	6.6
/5	91-101	4803	7.9	5.8	2.1	0.01	1	0.2	Tr	10.0
/6	115-125	4804	7.9	5.7	2.1	0.01	1	0.1	Tr	6.6
/7	150-160	4805	7.9	5.4	2.1	0.01	1	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH027 /1	0.8	0.3	0.3	0.1	1.5		3.3		47	
/2	2.2	0.3	0.3	0.1	2.9		3.5		85	
/3	3.2	0.6	0.4	0.1	4.3		4.4		97	
/4	2.0	0.5	0.5	0.2	3.1		4.3		72	
/5	2.0	0.6	0.5	0.2	3.3		4.6		71	
/6	1.8	0.6	0.5	0.2	3.1		5.0		62	
/7	3.6	0.7	0.6	0.2	5.1		4.9		100	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PH027 /1						70.0	10.6	10.9	21.5	8.5	SL
/2						80.5	3.1	9.4	12.5	7.1	LS
/3						64.9	10.6	14.3	24.9	10.3	SL
/4						62.1	10.2	15.4	25.6	12.3	SL
/5						55.6	17.6	15.4	33.0	11.5	SL
/6						59.0	12.0	13.9	25.9	15.1	SL
/7						56.0	11.8	27.9	39.7	4.1	SL

Profile: PH030

Map unit: LB

Soil Classification:	Lingmutey soil class:	Limbukha basin soil (LB)
	Soil Taxonomy:	Dystric Udifluvent [mesic, fine loamy over clay, mixed]
	FAO:	Dystric Fluvisol
Survey area:	Lingmutey Chhu watershed	
Location:	Centre of Limbukha basin cultivated area.	
GPS:	27^0 34.03' N, 89^0 55.05' E	
Altitude:	2180 m a.s.l	
Described & sampled:	24.2.1998, H B Tamang	
Climate:	General:	Warm temperate, P = ca 800 mm p.a
Recent weather: Cloudy		
Regional topography:	Middle mountains	
Site position:	Centre of lower end of intermontane basin	
Slope:	5%, 200m long, terraced, aspect W (250^0)	
Site drainage:	Poor	
Parent material:	Solid: Quartz	
	Drift: Colluvium over alluvium	
Land use:	Wetland	
Vegetation:	Rice stubble	
Surface:	Litter:	None
	Outcrops:	Few quartz boulders
	Stones:	Many rounded quartz stones
	Cracks:	None
	Roots:	None
	Microrelief:	Cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm	
0 – 10	7.5YR 4/1 (dark grey) with no mottles; fine sandy loam+; weak medium & fine subangular blocky; common fine pores; many fine roots; moist & slightly friable; few subrounded hard quartz stones; HCl negative; gradual regular boundary to: [Sample PH030/1 @ 0-10]
10 –29	7.5YR 5/4 (dark grey) with few fine faint yellow & orange mottles; fine sandy clay loam; moderate medium subangular blocky; many fine pores; many fine roots; moist & slightly firm; few subrounded hard quartz stones; HCl negative; clear regular boundary to: [Sample PH030/2 @ 15-25]
29- 48	2.5Y 6/1 (grey) with common fine faint dark yellow & red brown mottles; very fine sandy clay loam+; moderate medium angular blocky; few fine pores; few fine roots; moist & firm; few fine hard quartz stones; HCl negative; few flakes of muscovite; clear regular boundary to: [Sample PH030/3 @ 35-45]
48- 77	10YR 5/2 (greyish brown) with few medium distinct reddish brown mottles; fine sandy loam+; weak fine subangular blocky; few fine pores; few fine roots; moist & very friable; HCl negative; few flakes of muscovite; clear regular boundary to: [Sample PH030/4 @ 60-70]
77-103	5Y 2.5/1 (black) with many medium distinct reddish brown, orange & yellow mottles; silty clay; moderate medium subangular blocky; moist & very firm & plastic; HCl negative; few flakes of muscovite; clear regular boundary to: [Sample PH030/5 @ 80-90]
103-123	Mixed colours (yellow & white dominant); coarse sand; single grain; moist - wet & friable; common fine quartz stones; HCl negative; few flakes of muscovite; clear regular boundary to: [Not sampled]
123-144	5Y 2.5/1 (black) with no mottles; very fine clay; massive; moist - wet & firm; HCl negative; few flakes of muscovite; clear regular boundary to: [Sample PH030/6 @ 130-140]

144-163 Munsell 6/N (grey) with no mottles; medium sand; single grain; moist - wet & very friable; HCl negative; few flakes of muscovite; clear regular boundary to: [Not sampled]

163-180+ 5Y 4/1 (dark grey) with no mottles; loamy very fine sand; massive; wet & very friable; many flakes of muscovite; HCl negative; [Sample PH030/7 @ 170-180]

Comment: This profile indicates that the soil is developed in alluvium deposited by Lingmutey Chhu Chhu, not in sedentary parent material. The black horizons (77 – 103 and 123-144 cm) both seem to be buried topsoils. Moisture increases with depth due to throughflow beginning from about 1 m. Base saturations very considerably, possibly because of different parent rock types. The basal fine sand is particularly base deficient.

SPAL analytical results for BSS Profile PH030 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH030 /1	0-10	4838	6.2	4.4	1.8	0.02	33	3.0	0.4	7.8
/2	15-25	4839	6.3	4.3	2.0	0.02	29	2.8	0.3	8.7
/3	35-45	4840	7.2	4.4	2.8	0.01	17	0.4	0.1	10.0
/4	60-70	4841	6.9	4.3	2.6	0.01	35	0.1	1.0	0.1
/5	80-90	4842	6.8	4.3	2.5	0.01	11	0.4	Tr	13.3
/6	130-140	4843	5.3	4.2	1.1	0.01	1	2.4	0.2	16.0
/7	170-180	4844	5.8	4.2	1.6	0.01	15	0.1	Tr	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH030 /1	9.9	0.7	0.1	0.1	10.8		13.1		82	
/2	10.9	0.7	0.1	0.2	11.9		12.2		97	
/3	4.2	0.4	0.3	0.2	5.1		9.3		55	
/4	0.8	0.2	0.3	0.1	1.4		5.1		28	
/5	3.9	0.9	0.5	0.2	5.5		11.8		46	
/6	5.2	1.0	0.4	0.4	7.0		13.2		53	
/7	0.2	0.3	0.1	0.2	0.8		5.2		15	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture Class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PH030 /1						52.1	9.8	19.6	29.4	18.6	L
/2						48.5	10.7	18.2	28.9	22.6	L
/3						51.8	15.0	20.0	35.0	13.2	L
/4						75.4	11.2	3.6	14.8	9.8	SL
/5						50.9	9.4	25.1	34.5	14.6	L
/6						17.5	12.0	31.7	43.7	38.8	ZCL
/7						68.2	17.6	5.5	23.1	8.6	SL

Profile:	PK035	
Map unit:	LB	
Soil classification:	Provisional Bhutan soil class:	Limbukha basin soil (LB)
	Soil Taxonomy:	Typic Udifluvent [Mesic, loamy over sandy, mixed]
	FAO:	Eutric Fluvisol
Survey area:	Lingmutey watershed	
Location:	Upper end of Limbukha basin	
GPS:	Not available	
Altitude:	2220 m a. s. l.	
Described & sampled:	3.3.1998, Ian Baillie	
Climate:	General:	Warm temperate, P = 800 + mm pa
	Recent weather:	Cool, dry
Regional topography:	Mid mountain	
Site position:	Nick point in alluvial flat, near upper end	
Slope :	10%, terraced, ca 1km long, aspect SW (210 ^{o})	
Site drainage:	Imperfect	
Parent material:	Solid; Mixed metamorphic	
Drift: Alluvium		
Land use:	Wet land	
Vegetation:	Dry rice stubble & grass weeds	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Some boulders in terrace risers
	Cracks:	None
	Microrelief:	3 cm poaching by cattle
	Roots:	None
	Faunal activity:	None
	Other features:	Many soft muscovite flakes

Profile description: (Colours are moist unless indicated)

Cm	
0-12	10YR 4/1 (dark grey) with few fine distinct dark reddish brown mottles; slightly gritty fine sandy loam; weak fine subangular blocky; many fine pores; moist & friable; common medium & many fine roots; few fine quartzite stones; HCl negative; many fine muscovite flakes; clear regular boundary to: [Sample PK035/1 @ 0-10]
12-31	10YR 4/1 (dark grey) with common medium & few dark reddish brown mottles; gritty fine sandy loam; weak moderate subangular blocky; few medium pores; moist & slightly friable; common medium roots; common fine hard quartz gravel; HCl negative: abrupt regular boundary to: [Not sampled]
31-41	2.5Y 4/1 (dark reddish grey) with many moderate reddish yellow & orange, mottles; loamy medium sand; weak medium subangular blocky; common medium pores; moist & friable, few fine roots; HCl negative; abrupt regular boundary to: [Sampled PK035/2 @ 35-40]
41-47	10YR 2/1 (black) with no mottles; humic fine silty loam +; moderate fine - medium angular blocky; pressure faces; common fine pores; moist & friable; HCl negative; many fine muscovite flakes; abrupt regular boundary to: [Sample PK035/3 @ 41-47]
47-55	10YR 6/2 (light brownish grey) with many medium faint yellow & orange mottles; gravelly sand; many medium fine pores; moist & very friable, rare roots; few fine hard quartz & granite gravel; HCl negative; many fine muscovite flakes; clear regular boundary to: [Not sampled]

55-63	10YR 5/2 (greyish brown) with few fine faint yellowish orange mottles; loamy very fine sand; weak fine subangular blocky; common medium & fine pores; moist & very friable; many fine muscovite flakes; clear regular boundary to: [Not sampled]
63-80	10YR 5/3 (brown) with common medium faint yellow & orange mottles; stony coarse sandy loam; common medium and fine pores; moist & stony & interstitial friable; rare roots; common hard quartz gravel; HCl negative; clear slight wavy boundary to: [Sample PK035/4 @ 65-70]
80-95	10YR 6/2 (lightly brownish grey) with common medium yellowish orange mottles; gravelly coarse sandy loam; common medium & fine pores; wet & stony, interstitial friable; rare roots; common hard quartz & gravel; HCl negative; common fine muscovite flakes; clear slight wavy boundary to: [Not sampled]
95-106	10YR 6/2 (light brownish grey) with many medium distinct orange mottles; gravelly coarse sandy loam single grain; many pores; wet & loose, rare roots; many quartz & granite gravels; HCl negative; common fine muscovite flakes; clear slight wavy boundary to: [Not sampled]
106-119	2.5Y 4/1 (dark grey) with no mottles; coarse sandy loam; single grain; many pores; wet & loose; few hard quartz & gneiss gravel; HCl negative; common fine muscovite flakes; abrupt slightly wavy boundary to: [Sample PK035/5 @ 110-115]
119-147	2.5Y 2/1 (very dark grey) with no mottles; Humic silty loam; weak angular blocky; moist – wet; sticky & plastic; rare roots; HCl negative; H_2S smell; abrupt regular boundary to: [Sample PK035/6 @ 125-135]
147-160+	5Y 5/1 (grey) with no mottles; slight stony medium sandy clay loam; massive breaking to weak subangular blocky; few medium pores; moist-wet & slightly sticky & plastic; rare fine roots; common hard stones & few large quartz & granite boulders; HCl negative: [Not sampled]
Comment:	Very varied alluvial layering. Dark subsoil horizons appear to be of marshy origin. Lower dark horizon (at 119-147) smells distinctly sulphidic. Horizons vary considerable in base status.

SPAL analytical results for BSS Profile PK035 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK035 /1	0-10	4855	6.5	4.9	1.6	0.01	11	3.3	0.1	33.0
/2	35-40	4856	6.9	5.1	1.8	0.02	6	1.0	Tr	50.0
/3	41-47	4857	6.5	4.3	2.2	0.01	3	5.2	0.4	12.6
/4	65-70	4858	7.1	6.0	1.1	0.01	8	0.1	0.1	5.0
/5	110-115	4859	6.4	4.9	1.5	0.02	8	0.4	Tr	40.0
/6	125-135	4860	6.2	5.2	1.0	0.01	24	2.5	0.3	10.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK035 /1	2.2	0.4	0.1	0.2	2.9		7.9		36	
/2	2.0	0.4	0.3	0.2	2.9		6.9		41	
/3	24.4	0.4	0.5	0.3	25.6		33.9		76	
/4	2.0	1.7	0.2	0.2	4.11		6.8		60	
/5	4.2	0.5	0.2	0.2	4.11		7.0		73	
/6	7.1	0.6	0.3	0.3	8.27		15.9		52	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
PK035 /1						65.2	10.0	14.3	24.3	10.5	SL
/2						66.2	12.2	15.0	27.2	6.7	SL
/3						25.4	16.0	29.8	45.8	28.8	CL
/4						76.7	8.0	10.5	18.5	4.8	LS
/5						72.8	11.7	11.0	22.7	4.5	LS
/6						59.4	9.1	17.0	26.1	14.5	SL

Profile:	PK039	
Map unit:	RM	
Soil classification:	Provisional Bhutan soil class:	Dark brown clay (RM)
	Soil Taxonomy:	Pachic Haplumbrept [mesic fine loamy, mixed]
	FAO:	Humic Cambisol
Survey area:	Lingmutey watershed	
Location:	Top end of Limbukha valley	
GPS:	Not available	
Altitude:	2370 m a. s. l.	
Described & sampled:	5.3.98, Ian Baillie	
Climate:	General:	Warm temperate, P = 800 + mm p.a.
	Recent weather:	Dry & warm
Regional topography:	Middle mountains	
Site position:	Lower slope of spur	
Slope:	65%, rectilinear; ca 300 m long; aspect NE (60^0)	
Site drainage:	Good	
Parent material:	Solid:	Gneiss
	Drift:	Deep, polycylic colluvium
Land use:	Broadleaf forest, exploited for construction timber	
Vegetation:	Large tall oaks with much ground & tree moss	
Surface:	Litter:	3-5 cm continuous leaf
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	Abundant fine & common medium
	Microrelief:	Many root steps & free face scars up to 50 cm high
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-7/15	7.5YR 3/2 (dark brown) with no mottles; humic very fine sandy loam; medium - very fine root bound crumb; many fine pores; slight moist & very friable; abundant fine & medium & common coarse roots; HCl negative; clear wavy boundary to: [Sample PK039/1 @ 0-10]
7/15-17/30	7.5YR 4/2 (brown) with common fine faint dark brown mottles; very fine sandy loam; moderate medium crumb; many fine pores; moist & very friable; many fine & medium & common coarse roots; HCl negative; clear wavy boundary to: [Sample PK039/2 @ 20-30]
30-63	9YR 4/4 (brown) with no mottles; fine sandy loam +, moderate medium subangular blocky breaking moderate medium crumb; common coarse & many fine & medium pores; moist & friable; common coarse & many fine roots; HCl negative; gradual regular boundary to: [Sample PK039/3 @ 40-50]
63-106	9YR 4/6 (strong brown) with no mottles; medium sandy loam +, weak medium subangular blocky breaking to moderate medium crumb; moist & slightly friable; few coarse, medium & fine roots; HCl negative; clear regular boundary to: [Sample PK039/4 @ 80-90]
106-130	7.5YR 4/2 (brown) with common medium faint brown dark brown & yellow brown mottles; medium sandy clay loam +; moderate medium breaking to fine subangular blocky; abundant coarse & medium voids; moist & friable; few coarse, medium & fine roots; HCl negative; clear regular boundary to: [Sample PK039/5 @ 110-120]
130-163	7.5YR 5/3 (brown) with no mottles; clay loam; moderate medium subangular blocky breaking to moderate fine crumb; weak discontinuous clayskins; common fine pores; moist & friable; rare coarse, medium & fine roots; HCl negative; diffuse boundary to: [Sample PK039/6 @ 140-150]

163-180+ 7.5YR 5/4 (brown) with no mottles; gravelly sandy clay loam; moderate medium subangular blocky breaking to moderate fine crumb; weak discontinuous clayskins, common fine pores; moist & friable; rare coarse & many fine roots; few fine hard quartz grit; HCl negative: [Sample PK039/7 @ 170-180]

Comment: Warm brown colours, crumb structures, high porosity and friable consistence accord with high contents of Organic C and Total N to considerable depth. Signs of high natural fertility not confirmed by low AvP throughout, and low subsoil base status. However topsoil has good base status.

SPAL analytical results for BSS Profile PK039 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	PH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK039 /1	0-10	4869	5.8	4.4	1.4	0.04	4	13.1	0.5	26.2
/2	20-30	4870	5.8	4.2	1.6	0.03	3	13.0	0.5	26.0
/3	40-50	4871	6.3	4.8	1.5	0.01	1	1.5	0.2	6.8
/4	80-90	4872	5.8	4.8	1.0	0.01	1	1.1	0.1	7.8
/5	110-120	4873	5.6	4.7	0.9	0.09	1	0.9	0.1	8.1
/6	140-150	4874	5.3	4.8	0.5	0.07	1	1.1	0.1	11.0
/7	170-180	4875	5.7	4.6	1.1	0.01	1	0.6	0.1	6.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK039 /1	35.7	6.2	0.7	0.1	42.7	-	67.5	-	63	
/2	19.4	1.9	0.1	0.1	21.5	-	27.9	-	77	
/3	2.6	0.8	0.2	0.1	3.7	-	14.1	-	26	
/4	0.2	0.5	0.2	0.1	0.9	-	13.0	-	80	
/5	0.2	0.1	0.2	0.1	0.5	-	11.2	-	5	
/6	0.2	0.2	0.2	0.2	0.9	-	10.7	-	8	
/7	0.2	0.1	0.3	0.1	0.7	-	10.1	-	7	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PK039 /1						32.8	13.1	34.5	47.6	19.8	L
/2						25.4	12.1	35.6	47.7	26.9	L
/3						35.1	11.0	23.8	34.8	30.1	CL
/4						32.7	7.8	27.5	35.3	32.0	CL
/5						21.1	12.2	38.3	50.5	28.4	CL
/6						22.5	9.5	28.3	37.8	39.6	CL
/7						35.2	10.6	25.9	36.5	28.3	CL

Profile:	PK042	
Map unit:	Rc	
Soil classification:	Provisional Bhutan soil class:	Norbugang series: RC
	Soil Taxonomy:	Typic Rhodusult (Messie, Clay, Mixed)
	FAO:	Cambic Acrisol
Survey area:	Limbukha (Belogaong)	
Location:	Ca 2km down hill from micro wave station on hill top	
GPS:	$27^0$31 95 E; 89^0 54 04 N,	
Altitude:	1939 m a. s. l	
Described & sampled:	6.3.1998, Kado Tshering	
Climate:	General:	Warm temperate, P = ca--600 mm pa
	Recent weather:	Cloudy
Regional topography:	Mid Mountain	
Site position:	On right side slope of micro wave station	
Slope:	40% rectilinear ca 3km long moderate slope E facing (90^0)	
Site drainage:	Good	
Parent material:	Gneiss	
Drift:	Colluvium	
Land use:	Grazing land for livestock	
Vegetation:	Chir pine and native grasses.	
Surface:	Litter:	Continuos dried Chir pine needles/grass leaves to 2-3 cm
	Outcrops:	None
	Stones:	Few fine hard qtz +gneiss
	Cracks:	1-2 cm between grass swad
	Roots:	Many fine to coarse and medium grass
	Microrelief:	Discontinuous step up to 5 cm
	Faunal activity:	Many earth worm casts and ants borrowed
	Other features:	Clay skin & some manganese stains

Profile description: (Colours are moist unless indicated)

Cm	
0-20	5YR 4/2 5YR 4/2 (dark reddish grey) common medium fine light orange & grey brown mottles; fine sandy clay loam; many moderate medium subangular blocky crumb; moderate coarse & medium fine; slightly dry & slight firm and very hard; many medium & few coarse roots; HCl negative; many earth warm casts & ants holes; clear gradual boundary to: [Sample PK042/1 @ 10-15 cm]
20-55	5YR 4/2 (dark reddish grey) 5YR 4/3 (reddish brown) common medium fine light orange & greyish brown mottles; fine sandy clay, many moderate medium subangular blocky; moderate medium coarse & fine tubular pores; moist slight firm & slight hard, many fine & coarse medium grass roots; HCl negative; many earth worm casts & ants holes; clear gradual boundary to: [Sample PK042/2 @ 30-50 cm]
55-90	5YR 4/3 (reddish brown) 5YR 3/4 (dark reddish brown) common weak few light orange & greyish brown mottles; fine sandy clay loam; moderate medium breaking in fine crumb, medium coarse moderate fine tubular pores; moist slightly hard & firm; medium coarse & fine moderate; HCl negative; common ants holes; diffuse boundary to: [Sampled PK042/3 @ 60-70 cm]
90-120	5YR 3/4 (dark reddish brown) 5YR 4/3 (reddish brown) moderate medium dark black mottles; fine sandy clay loam; moderate medium subangular blocky breaking to fine subangular blocky; medium coarse slightly weak clay cutan; many coarse & medium fine, moist; slight firm & hard; common fine roots; HCl negative; few coarse ants holes, clay skin; lower diffuse boundary to: [Sample PK042/4 @ 100-115 cm]
120-145	5YR 3/4 (dark reddish brown and reddish) 5YR 4/3 brown, few fine dark black mottles; fine sandy clay loam, moderate medium angular blocky breaking in fine subangular blocky; many coarse & slight weak clay cutans; many coarse & moderate fine; slight wet firm and hard; few coarse to fine; few fine hard quartz & gneiss; HCl negative; dark manganese stains boundary to: [Sample PK042/5 @ 120 140 cm]

145-185 2.5Y 3/6 (light yellow brown) 2.5Y 4/4 (Olive brown) few fine dark black mottles; medium sandy clay loam; moderate medium subangular blocky breaking in medium crumbs of subangular blocky , many coarse slightly weak clay skin; moderate coarse medium fine pores; slight wet; firm & hard, rare coarse & few fine roots; abundant medium to fine hard quartz & gneiss; HCl negative; black manganese stains; diffuse boundary to:

[Sample PK042/6 @ 150-160 cm]

185-250 2.5Y 3/6 2.5Y 4/4 (light yellowish brown & light olive brown) abundant coarse - many medium dark black mottles; medium sandy clay loam, moderate medium angular blocky breaking to medium angular blocky crumbs; abundant coarse all over the horizons; few medium to moderate firm pores; slight wet firm and plastic; rare fine roots; moderate medium & fine hard quartz and gneiss; black manganese stains; HCl negative:

[Sample PK042/8 @ 170-240 cm]

SPAL analytical results for BSS Profile PK042 Survey area: Lingmutey watershed

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
Pk042 /1	0-20	4881	6.8	4.6	2.2	0.02	2	0.8	0.1	7.2
/2	30-50	4882	6.8	4.9	1.9	0.01	2	0.4	0.1	5.0
/3	60-70	4883	6.4	4.8	1.6	0.01	1	0.1	0.1	1.6
/4	102- 115	4884	6.4	4.9	1.5	-	2	0.2	0.1	3.3
/5	120-140	4885	6.5	5.2	1.1	0.01	2	0.1	0.0	2.5
/6	150-160	4886	6.4	5.1	1.3	-	2	0.1	0.0	3.3
/7	170-240	4887	6.5	5.2	1.3	0.01	1	0.1	0.0	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pk042 /1	4.1	2.2	0.8	0.2	7.3		10.2		71	
/2	2.8	3.0	0.5	0.1	6.4		10.2		63	
/3	1.6	2.6	0.6	0.1	4.9		10.9		45	
/4	1.4	3.0	0.4	0.1	4.8		11.2		43	
/5	0.8	3.1	0.4	0.1	4.4		11.0		40	
/6	2.4	2.9	0.3	0.1	5.7		10.0		57	
/7	2.6	2.7	0.3	0.1	5.7		11.2		51	

Fine earth granulometric

BSS No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total Silt		
Pk042 /1						36.3	9.5	19.1	28.6	35.1	Cl
/2						25.6	10.6	58.3	68.9	5.5	Zl
/3						22.1	8.5	17.2	25.7	52.1	C
/4						20.3	8.7	15.8	24.5	55.2	C
/5						23.1	0.8	19.9	20.7	56.1	C
/6						30.3	1.6	13.3	12.3	57.4	C
/7						23.9	5.3	14.4	19.7	56.3	C

Profile:	PH015
Map unit:	BX
Soil classification:	Lingmutey soil class name: BR Soil Taxonomy: FAO:
Survey area:	Lingmutey Chhu, Wangdi
Location:	ca 400 m above Lingmutey Chhu, Matalungchu
GPS:	27deg 31.33N.89 degree 54.05 E
Altitude:	1520 m.
Described & sampled:	5.2.98, HB Tamang.
Climate:	General: Temperate, P = 800 mm pa Recent weather: Cloudy
Regional topography:	Lower Mountain
Site position:	Midslope.
Slope:	Ca 22%, terrace rectilinear, ca 1km long, facing SE.
Site drainage:	Good
Parent material:	Solid: Gneiss + Amphibolite Drift: Colluvium
Land use:	Harvested wetland rice.
Vegetation:	Rice stubble, Artemisia & Soucham.
Surface:	Litter: None Outcrops: None Stones: None Cracks: Slightly cracking of clay surface. Roots: None Microrelief: Poaching to 5 cm depth Faunal activity: None Other features: None

Profile description: (Colours are moist unless indicated)

cm	
0 – 16	10YR 6/2 (light brownish grey) with few fine distinct reddish brown & orange mottles; fine sandy loam; moderate medium subangular blocky; few fine pores; slightly dry & slightly firm; many fine roots of paddy; HCl negative; slightly wavy boundary to: [Not sampled]
16 - 50	10YR 5/2 (grayish brown) with few fine distinct reddish brown & dark mottles; medium sandy loam; strong medium subangular blocky structure; weak discontinuous clayskins; few fine pores; slightly moist & very firm; few fine roots; HCl negative; clearly regular boundary: [Not sampled]
50 - 80	5YR 4/4 (reddish brown) with few fine faint dark & reddish brown mottles; coarse sandy loam; weak medium breaking into fine crumb subangular blocky; weak discontinuous clayskins; moist & slightly friable few fine soft gneiss stones; HCl negative; clear regular boundary to: [Not sampled]
80 - 107	10YR 4/2 (dark greyish brown) with many medium distinct dark, orange & yellow brown mottles; medium sandy loam; moderate medium subangular blocky; weak discontinuous clayskins; moist & slightly friable; few fine hard quartz & gneiss stones; HCl negative; few black stain of manganese; slightly wavy boundary to: [Not sampled]
107 - 140 +	5YR 3/3 (dark reddish brown) with many medium distinct block & grey mottles; fine sandy loam; moderate medium subangular blocky structure; moist & slightly friable and sticky when wet; few fine soft + hard quartz stones; HCl negative; few black stain of manganese: [Not sampled]

Comment: The owner of the field, Mrs Kinley Om, of Umtekla village, cultivates rice and adds FYM fertilizer every year. The owner feels that the soil in poor, as it does not give good yield

Profile:	PH016
Map unit:	BR
Soil classification:	Lingmutey soil class: GD Soil Taxonomy: FAO:
Survey area:	Limutey Chhu, Wangdi
Location:	250 m downslope from Nibo Lhakhang, Matalongchu
GPS:	27^0 30.92 N '89.54.02.E
Altitude:	1400 m
Described & sampled:	6.2.98, HB Tamang.
Climate:	General: Temperate, P = ca 800 mm pa Recent weather: Dry cool windy
Regional topography:	Lower Mountain
Site position:	Toe slope.
Slope:	26% convex, 500 m long, aspect 160^0.
Site drainage:	Imperfect.
Parent material:	Solid: Gneiss & amphibolite Drift: Colluvium
Land use:	Wetland.
Vegetation:	Rice stubble.
Surface:	Litter: Rice stubble Outcrops: None Stones: Few boulders on bunds Cracks: Common, 2 - 5 mm wide Roots: None Microrelief: Moderate poaching. Faunal activity: None Other features: None

Profile description: (Colours are moist unless indicated)

cm	
0 – 12	10YR 5/1 (grey) moist, 10YR 7/1 (light grey) dry, with common fine faint yellow & orange mottles: silty loam +; moderate medium - coarse subangular blocky: many medium pores; dry & hard, friable when moistened; common fine roots; HCl negative; clear regular boundary to: [Not sampled]
12 - 18	2.5Y 5/1 (grey) with many medium distinct red brown, red & dark brown mottles; medium sandy clay loam; strong coarse subangular blocky; few medium pores; moist & firm; common fine roots; HCl negative; gradual regular boundary to: [Not sampled]
18 - 33	2.5Y 4/1 (dark grey) with many fine distinct dark brown & red brown; medium sandy clay loam +; moderate medium angular & subangular blocky structure; common fine pores; moist & firm; few fine roots; HCl negative; slow to wet when moistened; gradual regular boundary to: [Not sampled]
33 - 72	2.5Y 3/1 (very dark grey) with common coarse distinct red brown & dark yellow mottles; medium sandy clay; moderate coarse angular blocky - prismatic; moderate discontinuous clayskins; common medium pores; moist & firm; rare fine roots; HCl negative; easily wetted; slightly wavy boundary to: [Not sampled]
72 - 99	2.5Y 4/1 (dark grey) with many fine distinct yellow, reddish & dark brown mottles; medium sandy clay loam +; weak medium angular blocky breaking to fine crumb; moist & slightly firm; rare fine roots; HCl negative; easily wetted; diffuse boundary to: [Not sampled]
99 - 142	10YR 4/2 (dark greyish brown) with many fine faint brown & dark brown mottles; medium sandy weak medium subangular and angular blocky; many very fine muscovite; HCl negative; diffuse boundary to: [Not sampled]

142 - 170	10YR 4/1 (dark grey) with many fine common medium distinct black mottles; silty loam; very weak medium subangular blocky; common medium pores; moist & friable; rare fine roots; abundant very fine muscovite flakes; common medium soft black manganese stains; HCl negative; clear wavy boundary to: [Not sampled]
170 - 180 +	10YR 5/2 (greyish brown) with abundant medium distinct orange & reddish yellow mottles; very fine sandy loam; very weak medium angular subangular blocky; common medium pores; moist & friable; many very fine muscovite flakes; HCl negative: [Not sampled]

APPENDIX C: CORRELATION OF LINGMUTEY CHHU SOILS

AppC I Soil classification and correlation in Bhutan.

Table 5.3 in the main report summarises the correlations of the Lingmutey Chhu soil classes with the two main international systems of soil classification. This appendix discusses further the correlations assigned.

The Soil Taxonomy (ST) was originally developed to meet the needs of soil survey in the continental United States (Soil Survey Staff 1975 & 1992). It has been extended since then, but it is still stronger on temperate than on tropical soils. It is detailed and comprehensive. The FAO (1974 & 1988) system is more globally oriented, and is less detailed, but still comprehensive. One of its advantages is that it uses more traditional and comprehensible soil names. For this survey we use the versions of the FAO system and Soil Taxonomy that were available at the time of our fieldwork. We shall revise the correlations in line with more recent revisions (FAO & ISRIC 1998; Soil Survey Staff 1998) when we draft a national soil classification system for Bhutan (BSSP Working Paper WP3, in progress).

Nepal has adopted the Soil Taxonomy, but previous consultants in Bhutan have preferred the FAO system. At this stage it is not necessary for Bhutan to choose between them. It is intended that, for the present, BSSP will continue to use ad hoc local soil classes and names, and will correlate these against both of the international systems. For the future, BSSP is exploring the possibility of adapting the multi–horizon approach of the FitzPatrick and the French Referentiel Pedologique systems to Bhutan conditions (BSSP Working Paper WP2, 1998).

AppC 2 General criteria

Before assigning soils to classes in Soil Taxonomy, there are some general environmental features of the area that need to be defined.

AppC 2.1 Soil moisture regime

This is necessary for the definition of suborders or great groups in ST. In the absence of soil moisture data, soil moisture regimes (SMR) are approximated from the volume and seasonal distribution of the rainfall.

As noted in Section 2 of the main report, the survey area has a considerable range of atmospheric climates. The lower part of the watershed has distinctly xeric natural vegetation. The soils there have ustic SMR, which are defined as having more than 90 consecutive dry days per year and a summer rainfall distribution. There are no meteorological data from upper end of the survey area. Even though considerably moister, it probably also has an ustic SMR. This has been assumed in the correlations in Table 5.3. However the SMR may be udic, which also has summer rainfall but the soils are dry for less than 90 consecutive days. Some LB soils in the Limbukha basin (e.g. profile PK040 in Appendix B) may have an aquic SMR, as they are kept more or less permanently wet by the replenishment of their subsoil moisture from throughflow. However the wet horizon is below the ST 'control section', the lower limit of which is 125 cm below the ground surface, in some LB profiles. The SMR of such soils qualify as udic.

AppC 2.2 Soil temperature regime

This is a criterion for classification at family level in ST. In the absence of soil temperature data, atmospheric temperatures are used. The survey area spans several soil temperature regimes (STR). The lower part of the watershed has a thermic STR. This is defined as having an annual mean greater between 15^0 C and 22^0 C and a summer – winter difference between monthly means greater than 5^0 C. The upper part of the area

has a mesic STR, which has an annual mean between 8^0 C and 15^0 C and also has a summer – winter difference of more than 5^0 C.

Judging from the Shelgana data (see Table 2.2 in the main report) and Eguchi's (1997) estimated lapse rate, the boundary between the two STR's is probably between 1600 and 1900 m a.s.l., depending on aspect. This keeps Omtekha and below in the thermic STR, but puts Dompola and above in the mesic STR. This seems sensible in the field, and ties in with the presence/absence of orange trees in the house gardens. In Table 5.3 the Tsang Chhu terrace soils have been assigned to thermic families and all of the hill soils to mesic.

AppC 2.3 Mineralogy class

This is another family criterion in Soil Taxonomy. Although muscovite is a visible component in many soils in the watershed, mica contents are less than 40 % of the combined sand and gravel fractions. The soils therefore do not qualify for the micaceous class, and are classified as being of mixed mineralogy.

AppC 2.4 Particle size class

This varies with stone content and fine earth texture, and is therefore different for the different soil classes in the watershed (see Table 5.3 in the main report, and individual profiles in Appendix B).

AppC 3 Correlations of Lingmutey Chhu soils

AppC 3.1 Tsang Chhu alluvial soils (RS, TL, TM and TH).

The soils formed in the alluvium deposited by Tsang Chhu vary considerably in age and degree of profile horizonation. The white river sands (RS) are very young and show no signs of pedogenic horizonation. They therefore qualify clearly as Entisols in Soil Taxonomy and Fluvisols in the FAO system. In ST they may not qualify as Fluvents because their subsoil Organic Carbon contents are too low, even though these soils are of clearly fluvial origin. By default they should strictly be classified as Orthents. This problem does not arise in the FAO system, where fluvial origin is the main criterion for the Fluvisols.

At the other end of the scale, the soils of the high terrace (TH) are relatively old. Although they still have inherited alluvial layering, some of the alluvial stones show post-deposition weathering. These soils also have distinct horizons on manganese accumulation (e.g. profile PH026 in Appendix B). They therefore qualify as soils in which weathering and incipient horizonation are more important than their youth and alluvial origin, i.e. Ustochrepts in Soil Taxonomy or Cambisols in the FAO system

The low and middle terrace soils are intermediate. As can be seen in Table 5.3, it is assumed that the middle terrace soils are sufficiently weathered and have enough pedogenic horizonation to be Ustochrepts or Cambisols (like TH). The lower terrace soils still show too many inherited alluvial characteristics and are therefore better correlated with the Fluvents or Fluvisols

In the latest developments of the FAO system, allowance is made for soils with topsoils that have been drastically modified by prolonged cultivation for irrigated rice (FAO, 1998). The topsoils have probably been artificially gleyed to a sufficient degree to qualify as anthraquic horizons, and the subsoils with black manganese mottling may qualify as hydragric horizons. This qualifies some wetland soils in Lingmutey Chhu, many of the terrace soils, as Anthrosols. However the full implications of the FAO (1998) modifications and the 1998 revision of Soil Taxonomy (Soil Survey Staff 1998) have not yet been fully incorporated into BSSP practice.

AppC 3.2 Limbukha basin soil (LB)

This is another alluvial soil that retains much of its inherited depositional layering. However the soil material is mostly moderately weathered. In Table 5.3 it has been correlated with the Fluvisols and Fluvents. It is arguable that it should be assigned to the Cambisols or Udochrepts. The wetter of these soils qualify as gleyic subclasses in FAO and as Aquents on Aquepts in ST.

AppC 3.3 Red clay and brown loam over red clay (RC and BR)

These classes are difficult to correlate for two main reasons:

- Their chemical heterogeneity, with different profiles qualifying a dystric (<50% base saturation) or eutric (>50%).
- Their erodibilty, which is not a feature normally associated with red soils with high contents of free ferric sesquioxides.

As can be seen in Table 5.3, the more dystric profiles have been assigned to the leached red soils of the tropics and subtropics, i.e. Ferralsols, Oxisols and Ultisols. The less leached soils have been assigned to the Luvisols, Lixisols and Alfisols. These correlations are tentative, because there is little evidence of true argillic horizons in these soils. Also these classes are normally reckoned to be stable rather than erodible, especially if fine or medium textured. The shallow soils are correlated with Cambisols or Ochrepts.

AppC 3.4 Dark brown clay (RM)

This is another problem soil. One alternative is to correlate this class with the soils of limited weathering and high contents of well-mixed organic matter, i.e. Humic Cambisol or Umbrept. Another is to assume that they are humic variants of the red clays, i.e. Humic Ferralsol or Humic Rhodic Eutrustox. However the very deep mixing and the persistence of friable crumb structures to considerable depths suggests that they are similar to the non-volcanic Andosols of Eastern Nepal (Baumler & Zech 1994).

AppC 3.5 Shallow brown sandy loam (GS)

The shallower of the gneissic hill soils fit well into the Inceptisols of ST or the Leptosols of FAO. Most of the dark topsoils are thin (< 18 cm) and the profiles qualify for the suborder of Ochrepts in ST. In FAO these soils mostly qualify as Lithic (where very shallow) or other subgroups within the Leptosols.

AppC 3.6 Brown sandy loam (GD and some GS)

Most of these soils are developed in mobile and polycyclic colluvium, and they could be correlated with the Regosols (FAO) or Orthents (ST). However applying the same principles as in the Tsang Chhu high terrace soils, the degree of weathering is assumed to overrule the depositional layering and most of them, are better correlated with Cambisols or Ustochrepts.

AppC 3.7 Quartzite soils (QO and QG)

Although these soils are coarser textured than the gneissic brown sandy loams (GS and GD), theY are not sandy enough to qualify as Arenosols or Psamments. They therefore mostly correlate with the same Cambisols and Ochrept classes as the gneiss soils. However, the orange sandy loams (QO) may be leached enough to qualify as Acrisols or Ustults. As with the red clays, there are doubts about the presence and degree of development of argillic horizons, so that this correlation is tentative.

APPENDIX D: BSSP MAIN SOIL SURVEYS AND REPORTS

BSSP No.	Title	Status April 1999
1 & 1(a)	General & Technical reports of detailed soil survey of Yusipang RNR-RC	Final, distributed 7/98
2 & 2(a)	General & Technical reports of detailed soil survey of Bathpalathang site, Jakar RNR-RC	Final, distributed 9/98
SS 3 & SS 3(a)	General & Technical reports of detailed soil survey of Bajo RNR-RC	Final, distributed 12/98
SS 4 & SS 4(a)	General & Technical reports of detailed soil survey of Khangma RNR-RC	Final, distributed 3/99
SS 5 & SS 5(a)	General & Technical reports of semi-detailed soil survey of Lingmutey Chhu watershed	This survey. Final reports distributed 4/99
SS 6 & SS 6(a)	General & Technical reports of semi-detailed soil survey of Radhi geog	Draft in progress
SS 7 & SS 7(a)	General & Technical reports of semi-detailed soil survey of Lame Gompa Research Forest	Draft in progress
SS 8	Report of reconnaissance of soils of Merak and Sakten	Draft in progress
SS 9 & SS 9(a)	General & Technical reports of semi-detailed soil survey of arable lands of middle Tsang Chhu valley	Fieldwork in progress
SS 10	Report of semi-detailed soil survey of Nyakalumphu Chhu valley, Punakha	Draft in progress

APPENDIX E: SOIL MAP OF LINGMUTEY CHHU