Royal Government of Bhutan

Soil Survey Unit (SSU)
National Soil Services Centre, Semtokha
Council for RNR Research of Bhutan (CoRRB)
Ministry of Agriculture

TECHNICAL REPORT ON THE SEMI-DETAILED SOIL SURVEY OF NYAKULUMPA VALLEY, PUNAKHA

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SUMMARY

The fieldwork for a semi-detailed soil survey for the Nyakulumpa Valley was carried out from 24th February to 19th March, 1999. This was the tenth soil survey done by the Soil Survey Unit, and was mainly to train the new graduate in field techniques.

The survey area occupies 314 ha (about 775 acres) on the true right (= west) bank in the main valley of Mo Chhu about 0.5 km north of Punakha Town. The survey area mostly comprises of hillslopes and alluvial fan of the Nyakulumpa Chhu. The Mo Chhu's lower and middle alluvial terraces occupy about 7% of the total survey area. There are also small areas of fan terrace along the Nyakulumpa Chhu flowing through the alluvial fan. Apart from the hill soils, the soils are derived from the alluvial parent materials. These originate from the upper catchments of the Nyakulumpa Chhu and the Mo Chhu, and are of mixed lithological origin.

The survey area is under extensive wetland cultivation. There are only a few areas under rainfed cultivation and most of these are terraced and are under fruit trees. During winter season the wetlands are used for growing vegetables and other crops. Most of the available lands are cultivated to its maximum and there is little scope for further expansion for wetland. However Kamshing (rainfed) can be extended to certain extent.

The most extensive soils of the survey area are located on the hill slopes and on the alluvial fan. The soils of the hill slopes are greyish brown to dark brown with light textures of loamy sand to sandy loam. The depth of these soil, vary from 90 cm to 150 cm to the weathered rock. There are also red hill soils consisting of strong brown over dark reddish brown sandy clay loam. These are located on the hill above Punakha Police Station.

The fan soils are mapped into soil classes, depending whether they have red or greyish brown subsoils. They both have greyish brown as topsoils. They have varied textures of sandy loam to sandy clay. The soils of the middle terrace along the Mo Chhu consist of olive grey to greyish brown silty upper part overlying a yellowish brown to brown, weathered, more sandy and more friable lower section with layered textures of sand, sandy loam and sandy clay loam. The soils of the lower terrace also have a grey and greyish brown, silty upper part. This tends to be finer textured than in middle terrace soils. The lower section of the lower terrace soils is loose, pale fine sand with lenses of silt, similar to the white sand currently being deposited by the river.

The Nyakulumpa Valley soils are correlated with the classes of the international systems of soil classification. The hill soils are mostly Haplustept in the American Soil Taxonomy and Dystric and Eutric Cambisols in the WRB system. The middle terrace soils have similar correlations, but the less weathered and more contrasting layered soils of the lower terrace are Entisols (Orthents and Fluvents) in Soil Taxonomy and Fluvisols in the WRB system.

The results of the soil survey indicate the confirmation of erodibility of red soil noted in the Lingmutey Chhu Survey. These soils in this survey area are highly eroded and gullied.

However the red soil found in the alluvial fan are no more erodible than the fan soil with brown subsoil. This requires systematic investigation.

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ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometery
AHT	Agrar - und HydrotechniK, GmbH, (Germany).
AIT	Asian Institute of Technology, Bangkok
Alluvial fan	Poorly stratified and sorted material deposited in side valley
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
Av	Available
AvP, AP	Available Phosphate
AWC	Available water capacity (= MC% FC – MC% WP)
amsl	Above mean sea level
asl	Above sea level
BP	Before present
BS%	Base saturation percentage
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
CoRRB	Council for RNR Research of Bhutan
Creep	Slow gravitational mass movement of colluvium downslope
DAO	District Agriculture Officer
Danida	Danish International Development Assistance
Dzongda	District Officer or Administrator
Dzongkhag	Administrative district
EC	Electrical conductivity
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FC	Field capacity (0.1 bar)
fe	fine earth (particle size < 2mm)
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
GPS	Global positioning system
GSI	Geological Survey of India
GTZ	Gesellschaft fur Technische Zusammenarbeit (German development cooperation agency)
Gully wash	Rapid movement of coarse, commonly bouldery, unlayered materials down steep streams.
Gup	Head of the geog
ha	Hectare
HCl	Hydrochloric acid
JICA	Japanese International Cooperation Agency
Kamsing, Kamshing	Rainfed agriculture
Krotovina	Old faunal burrow filled with dark soil from topsoil
L	Loam
LUSS	Land Use and Statistics Section, in PPD

MC%	Moisture content % (w/w)
me	milliequivalent (unit of exchangeable cations)
me%	milliequivalents per 100 g fine earth
MoA	Ministry of Agriculture
mS/cm	milliSiemens per centimetre (unit of electrical conductivity)
MTI	Ministry of Trade and Industry
Nd	No data
NH_4OAc	Ammonium acetate
NS	Not suitable (in land suitability classification)
NSSC	National Soil Services Centre, REID, Semtokha
OC	Organic carbon
OM	Organic matter
P	Precipitation, rainfall
P	Phosphate
PCI	Pacific Consultants International (Japan)
pH	Measure of acidity - alkalinity
PM	Parent material
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
SDA	Sustainable Development Agreement (RGOB & Netherlands)
Si	Silt
Sk	Skeletal (high stone content)
SMU	Soil mapping unit
SoB	Survey of Bhutan
SoI	Survey of India
Sokshing	Forest from which needle or leaf litter is collected for livestock bedding and FYM.
Solum	True soil, in which soil processes have removed many traces of parent material structure
sp, spp	Species (singular & plural)
SPAL	Soils and Plant Analysis Laboratory, NSSC, REID, Semtokha.
SSS	Soil Survey Staff (of USDA)
SSU	Soil Survey Unit
ST	Soil Taxonomy (US system of soil classification)
Surface wash	Movement of individual soil particles by running surface water.
Thixotropic	Solid soil changing to semi-liquid state on vigorous agitation
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)
USDA	United States Department of Agriculture
v/v	% by volume
WP	Permanent wilting point
WR	Weathered rock
WRB	World Reference Base for Soil Resources (ISRIC development of FAO system of soil classification)
w/w	% by weight
X	Exchangeable (for cation)
Z,Zi	Silt

1. INTRODUCTION

The Nyakulumpa Valley in Punakha is a part of Tsang Chhu Valley semi-detailed soil survey. It was especially allotted to the new graduate surveyor who has been permanently placed in SSU to intensify his field training.

The Nyakulumpa Chhu is a small perennial stream, which drains from Sinchula section of the Wang - Tsang interfluve into the Mo Chhu. The survey area covers the main arable lands of the lower part of this valley, which extends from Mo Chhu to Kyelikha. This includes mostly, the lower valley, consisting of main alluvial fan and the Mo Chhu terraces. The true right bank (south) of this valley has got more arable lands than the left true bank. Most of the arable lands are under wet land cultivation. However they also grow some vegetables and other seasonal crops. This valley has a large alluvial fan, which extends more than a km up stream from the lower river terrace of the main Tsang Chhu.

Aims of the Nyakulumpa Valley Soil Survey

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

- Intensive field work training for the graduate Surveyor.
- Providing detailed information on the nature and distribution of the soils of Nyakulumpa valley.
- Provide data for the ongoing semi-detailed soil survey of the whole of the middle section of the Tsang Chhu Valley.
- Providing SSU with further data for the development of a national soil classification, and for national and regional soil maps.

2. SURVEY AREA

2.1 Location and extent

Nyakulumpa Valley is located on the true right (west) bank of the Mo Chhu and is about 0.5 km northwest of Punakha Dzong. It stretches from about 27° 34.6'to 27° 35.5' N latitude and from 89° 49.4' to 89° 51.9' E longitude. It is under Guma geog of Punakha Dzongkhag. The survey area extends about 3 km approximately up the Nyakulumpa Chhu from the main valley of the Mo Chhu. The width of the survey area stretches to about 0.5 km wide. It mostly consists of the lower part of the main valley of Nyakulumpa Chhu.

2.2 Climate

The survey area stretches from 1200 to 1700m asl., and has a subtropical - warm temperate climate. Since there is no meteorological station in the survey area, we have taken the data for Punakha, as it is the nearest meteorological station to the survey area, at about 1km to the southeast. Table 2.1 summarises the available meteorological data for Punakha.

Mean maximum temperatures range from about 18° C in January to about 30-31° C in June - August. Mean minimum temperatures range from about 5° C in January to about 20° C in July – September. Mean annual rainfall totals about 750 mm, of which 74% (ca 600 mm) fall during the monsoon months of May – September, but showers can occur in all other months. The spring (March – April) appears to be somewhat wetter than the autumn and early winter (October – December). Due to the warm summer temperatures, evapotranspiration can exceed precipitation at any time of the year. However the rainfall and soil moisture replenishment in the monsoon are sufficient to sustain rainfed cropping. Some rainfed crops are also grown in winter.

2.3 Geology and soil parent materials

The most recent geological description of Bhutan (Bhargava, 1995) indicates that the solid geology of the valley is the Thimphu Group. This accords with earlier general accounts (ESCAP, 1991) and with the original geological survey reports (Ray & Ganesan, 1983; Ray & Razan, 1975). The dominant rock types in the Thimphu Group are highly metamorphosed gneisses, with mixed muscovite and biotite micas, plagioclase feldspars, and quartz as the main minerals. These rocks were greatly affected by the folding and shearing that occurred in the thrusting from the north during the intense Himalayan compressions and uplifts in the Tertiary.

Only a few of the soils on this survey area are residual and have shallow soils overlying weathered metamorphics. Most of the soil parent materials are hillwash (colluvium) and alluvial deposits (alluvium). The colluvium has been moved locally downslope by wash and creep. It is poorly sorted, with a range of particle sizes including many stones and boulders, which are not layered. The large alluvial fan which is formed of short-travel alluvium, is intermediate in sorting and layering between the unsorted colluvium on hill slopes and the stratified long distance alluvium of the deposits of the main Mo Chhu. The alluvial fan has a lower proportion of stones and boulders than the colluvium, although there are a few boulders on the surface. There are true fluvial long distance deposits along Mo Chhu at the lower end of the valley. Two groups of terraces have been identified. Both have surface layers that are mainly silty, and lower layers that are mainly sandy, with lenses of stones, boulders and silt. The parent material is of mixed geological origin as it has been transported for a considerable distances by Mo Chhu.

2.4 Topography and drainage

The valley of Nyakulumpa Chhu extends from Sinchula on the Thim Chhu / Mo Chhu interfluve ridge to Mo Chhu where the Nyakulumpa Chhu joins the main river. However the Nyakulumpa Valley survey area does not include the whole valley. It stretches from about 1700 m asl at Pachekha to about 1200 m asl at Chang Yu (lower terrace), giving a total relief of about 500m. Slope gradients are moderately steep to steep, mostly in the range 20% - 60% towards the upper part of the valley. In the alluvial fan and river terraces, the slope gradients are quite gentle and range from 3% to 15%. The survey area is mostly located in lower part of the valley. The stream acts as a boundary on the north side of the survey area.

2.5 Land use and vegetation.

The upper part of the survey area, which is quite steep has climatically and ecologically different north - and south - facing slopes. The main alluvial fans and terraces face east but they are relatively flat. The survey area is in sub-tropical ecoclimatic zone, with sub-tropical vegetation like chir pine, oak, etc. as its natural vegetation. The natural vegetation has been exploited for timber and fuel wood. The arable lands in the survey area are mostly under paddy cultivation. During winter season, these wet lands are irrigated for wheat and mustard. They are also use for vegetables and other seasonal crops. Apart from the wetlands, there are some patches of rainfed cultivation mostly for fruit trees.

Table 2.1 Climatic summary for Punakha 1985-1998

Months	J	F	M	A	M	J	J	A	S	O	N	D	Year mean / total
Temperature (^{0}C)													
n (number of complete records)	9*	9*	12*	11*	11*	11*	11*	11*	13*	13*	13*	13*	10
Mean	12	14	17	19	22	20	25	26	25	22	17	14	20
Mean minimum	5	7	10	13	16	19	20	20	20	17	11	8	14
Absolute minimum	1	2	4	8	9	14	17	13	15	7	3	1	7
Mean maximum	18	20	24	25	27	30	30	31	29	27	23	20	25
Absolute maximum	25	26	30	34	35	36	35	35	35	32	30	29	36
Rainfall (mm)													
n (number of complete records)	12*	12*	12*	11*	11*	11*	11*	11*	13*	13*	13*	13*	11
Mean	14	8	22	41	63	117	179	159	95	48	5	5	762
Monthly maximum	40	27	67	103	101	172	263	239	152	144	19	20	907
Monthly minimum	0	0	0	20	68	77	97	0	64	6.4	0	0	549
Highest daily rainfall	16	18	44	30	44	57	80	40	35	65	19	17	80

* Includes records with monthly summaries but incomplete daily data
Source: Data from MTI

3. PREVIOUS SOIL INFORMATION

3.1 Introduction

As far as is known, the Nyakulumpa Valley has not been covered by any previous soil surveys. However there are four previous data sets or studies which are relevant to the survey area.

3.2 Land resources of Thedtsho and Baap blocks (Drukpa, 1996)

Drukpa (1996) did a multidisciplinary land evaluation study of the Baap and Thedtsho geogs (both in Thimphu Dzongkhag), making use of GIS for mapping and analysis. This area is about 8 km further down Tsang Chhu from Nyakulumpa. It covers the low arable lands on either side of the main river and ranges in altitude from about 1200 m to about 1400 m asl As part of the ground truthing and base data collection, 22 soil profiles were described and sampled for laboratory analysis.

3.3 Wangdi groundwater study (PCI 1996)

The second study is the Wangdi Groundwater study by Pacific Consultants International for MoA and JICA (PCI 1996). Their mapping stretches from Bajothangka to Wangdi in the main Tsang Chhu Valley. It therefore lies about 10 km south of Nyakulumpa Valley. They did not map soils but their output included helpful contour, landform, and geological maps at scale 1:10 000. The geological maps are actually of surface materials, with rock types indicated only for the shallower soils on hills. The other hill slopes are mapped as landslides, colluvium or 'slided blocks'. The text does not define or describe these materials.

3.4 Bajo RNR-RC (SSU Report 3 (a) 1998)

Although not covering or adjoining the survey area, the detailed soil survey of Bajo RNR-RC (SSU Report 3(a), 1998) is relevant. It includes details of 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. All of these soils have been in wetland rice for many years. The analytical data indicate that all of the river terrace soils are slightly alkaline and fully base-saturated.

3.5 Lingmutey Chhu Watershed Survey

Lingmutey Chhu is a true (east) left bank tributary of Tsang Chhu. The survey covers the whole catchment area (32 km^2) at semi-detailed (1: 25 000) scale. This is the nearest SSU survey to Nyakulumpa Valley, and is only 8 km to the southeast. This survey is relevant to Nyakulumpa soil survey with many similar soils. About half of the soil classes found in Lingmutey Chhu are also found in Nyakulumpa Valley. The major common soil classes are lower and middle terrace soils, red clay, brown hill loams from gneiss, and brown over red clay. There is some middle terrace and grey stony sandy loam soils in Nyakulumpa Valley but to a lesser extent than at Lingmutey Chhu. The upper terrace is missing in Nyakulumpa, as the lower terrace mostly abuts immediately with the large alluvial fan up slope. The limited areas of middle terrace abut directly on to hill slopes. The deep bright orange and reddish yellow loamy sand-sandy loam soils found over quartzite in Lingmutey Chhu have not been seen in Nyakulumpa Valley.

4. METHODS

4.1 Field

The fieldwork for this survey was done in February-March, 1999. As this survey area was allotted for the intensive fieldwork training for the new graduate surveyor, he did all of the routine fieldwork independently, with consultation to the Soil Survey Specialist and occasionally with other soil surveyors. The time taken for the fieldwork was almost a month.

The soils were examined on a routine basis at 82 sites, mainly with a 1.2 m Edelman auger, fitted with a 7cm combination head where possible, but switching to a 7cm stony soil head wherever necessary. Duplicate augerings were done at 5 of the sites, where the first attempt was stopped by stones at less than 50 cm. The routine sites were located at measured intervals (usually 50 m) along compass traverses, which started at points that could be identified on the base map. The locations of the start points, some intermediate way-points, and the ends of the traverses were checked with a Magellan GPS.

For routine soil observations the following site data were collected:

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

The soils were described by natural 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 15 sites. All of these detailed descriptions were done by digging the pits to 1.5+ m if possible. 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, cracks, faunal activity, and capping.

The soils 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 structures; number and size of pores, presence, thickness and continuity of cutans (shiny 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); and clarity and shape of lower boundary.

The main horizons of all profiles described in detail were sampled for analysis.

4.2 Mapping

The site is covered by the Survey of Bhutan (SoB) topographic sheet # 78 E/14SW, at scale 1:25 000 (1998).

As our soil map will be incorporated into the semi-detailed map of the arable soils of the survey of the Tsang Chhu Valley, it has not been separately entered into the LUSS's GIS. The present map is interim until the full Tsang Chhu survey report is produced.

4.3 Laboratory

The 67 soil samples collected from the main horizons of the 15 detailed described profiles were analysed by the Soil and Plant Analytical Laboratory (SPAL) of the Research, Extension and Irrigation Division (REID) of the Ministry of Agriculture, at Semtokha. The methods of analysis used by SPAL are summarised in Appendix A.

The only methodological points that need to be mentioned here concern the measurement of cation exchange capacity (CEC) and calculation of base saturation (BS%). CEC is usually measured by saturating the soil with ammonium cations, and measuring the quantity 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 aluminum. This is known as the 'effective cation exchange capacity' (TEB + Extr Al = ECEC). SPAL does not currently measure extractable Al in soils with pH (in water) greater than 4.5. As none of Nyakulumpa samples are that acid, there are no determinations for extractable Al. In such cases the ECEC identical with the TEB, is not informative, and 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 aluminum), the 'effective base saturation' (EBS %) is automatically 100 %. Such values are also not informative, and have not been given in this report. The base saturations in the soil class descriptions in Section 5.2 and in the soil profile data in Appendix B refer to TEB/CEC (NH_4OAc).

5. SOIL CLASSIFICATION, CHARACTERISTICS AND CORRELATION

5.1 Soil classification

As SSU is still in its early stages, soil classification is being done in an interim and ad hoc way for the present. Until we have formulated and tested a national system of soil classification, we are treating each survey as a separate task, and setting up simple local soil classes.

The soils of the survey area are divided into three main groups based on geomorphologic location. They are further subdivided on the basis of soil profile features to give a total of nine soil classes, as summarised in Table 5.1. Further details of individual profiles of the soil classes are given in Appendix B.

Table 5.2 summarises the main chemical characteristics of the soil classes, as determined from the profile sample collected during this survey. The detailed analyses for individual profiles are also given in Appendix B.

5.2 Characteristics of soil classes at Nyakulumpa Valley

5.2.1. Deep hill soil (HD)

These soils are not extensive. They are found in the deep colluvium on the lower slope above the middle terrace and Punakha Police Station. There is one fully described and sampled profile (see PT015 in the Appendix B).

By definition the sola of these soils are greater than 150 cm deep to weathered rock. They have light grey topsoils with common medium and fine distinct yellowish orange mottles, and silty loam textures. In profile PT015, the topsoil has moderate medium subangular blocky structure. It contains fine and medium soft and hard quartz and gneiss stones. It grades into a brownish grey to brown subsoil, which varies in texture from fine sandy loam to fine sandy clay loam+. The structure of the subsoils range from moderate medium subangular blocky to moderate fine subangular blocky, breaking to moderate fine crumb.

Profile PT015 has a very acid top soil but grades through slightly acid and is neutral by 100cm depth, and continues thus to the base. Top soil organic carbon content and total nitrogen levels are low, and become very low with depth. This is probably an effect of the prolonged cultivation of wetland rice. C:N ratio is favourable. Cation exchange capacities are very low but increase with depth. Available P levels are low in the topsoil but are very low in the subsoil (25-100cm depth). However it increases after 100cm depth. The BS% (base saturation percentage) is very low in the topsoil but increases with depth. At 120-140cm depth, the BS% is very high.

Table 5.1 Soil classes of Nyakulumpa Valley

SOIL CLASS		Main Features	Representative profile and analyses (see Appendix B)
Code	Name		
Hill Soil			
HD	Deep hill soil	Greyish brown to dark brown silty loam to sandy clay loam+; more than 1.5m deep to the weathered gneiss.	PT015
HM	Moderately deep hill soil	Very dark greyish brown to reddish brown over variable texture - loamy coarse sand to fine sandy clay; 1m - 1.5m deep to the weathered gneiss.	PT002 PT003 PT006
HS	Shallow hill soil	Pale brown to greyish brown over pale brown coarse sand to medium sandy loam+; less than 1m deep to the weathered gneiss.	PT001
HR	Red hill soil	Strong brown over dark reddish brown fine sandy clay loam to fine sandy clay loam+.	PT010
Fan Soil			
FR	Red sub-soil	Grey brown to dark greyish brown sandy loam; over reddish brown to yellowish red; over dark red, with textures ranging from coarse sandy loam to silty clay loam and sandy clay.	PT005 PT011 PT012
FB	Greyish brown sub-soil	Light to dark grey fine sandy loam; over greyish brown over dark yellowish brown, with variable textures ranging from very fine sandy loam to coarse sandy clay loam.	PT004 PT007 PT013
FT	Fan terrace soil	Olive grey to dark greyish brown fine sandy loam; over yellowish brown to dark grey with textures of fine sandy loam to sandy clay loam.	-
Terrace Soil			
TM	Middle terrace soil	Olive grey to dark greyish brown fine sandy loam to silty loam; over dark grey to dark yellowish brown with textures of coarse sandy loam to fine sandy clay loam.	PT014
TL	Lower terrace soil	Grey to yellow brown fine sandy loam to silty loam ; over greyish brown to grey mainly fine sand with lenses ranging from very fine sand to silty clay .	PT008 PT009

5.2.2 Moderately deep hill soil (HM)

These soils are extensive in the upper part of the survey area. These soils stretch from the top end of the survey area, down to the upper edge of the alluvial fan. They have been described in detail and sampled in three profiles (see PT002, PT003 and PT006 in Appendix B).

These soils are moderately deep by definition, with hard or weathered gneiss at 100-150 cm from the surface. In the described profiles, the topsoil is pale brown to greyish brown fine sandy loam. Its structure is moderate medium subangular blocky breaking to weak and moderate fine crumb. It grades into greyish brown subsoil, which varies in texture from medium sandy loam to fine sandy clay loam. The lower subsoils of these described profiles are dark greyish brown to brown with fine to medium sandy loam to fine and medium sandy clay loam. They have weak and moderate subangular blocky structures, breaking to weak and moderate fine crumb.

These soils are slightly acid (5.5) at the surface, going to neutral (pH 7.8) in the subsoil. The organic carbon is low to moderate and total nitrogen is very low to low. C:N ratio is unfavourable. The available P is very low to low with a range of 1-13 ppm. They have very low to moderate cation exchange capacities, in the range of 2.2-11.6 me%. The BS% ranges from moderate to very high.

5.2.3 Shallow hill sands (HS)

These are not extensive soils, and occur on both banks of the Nyakulumpa Chhu in the upper part of the survey area. These soils are considerably disturbed, by terrace construction and other human activities. They are described in detail and sample in one profile (see PT001 in Appendix B).

By definition these soils are less than 100cm deep to weathered rock. The topsoils are pale brown- greyish brown loamy medium sand to loamy medium sand+ and about 10 - 20 cm deep. The subsoil is dark greyish brown or pale brown loamy medium sand+ to coarse medium sand. The structure varies from moderate medium subangular blocky to weak fine subangular blocky, the coarser units sometimes breaking to weak fine subangular blocky.

Profile PT001 has a very acid top soil and a neutral subsoil pH. The total nitrogen and organic carbon are low. TEB ranges from 2.2-6.2 me%. The BS% in the top soil and subsoil are low and high respectively. The available P is low (11 me%). The available K and C:N ratio are low.

5.2.4 Red hill soil (HR)

These soils are not extensive. They are located on the southern side of the alluvial fan and upslope from the middle terrace. Hills with these soils are intensively gullied. They are described in detail and sampled in one profile (see PT010 in Appendix B).

These soils are mostly 100 – 150 cm deep to weathered rock. The described profile has a strong brown fine sandy clay loam topsoil. The topsoil has a moderate fine subangular structure with worm burrows. The subsoil of this profile grades to dark reddish brown to reddish brown fine sandy clay loam+ to fine sandy clay. It has moderate medium subangular blocky structures breaking to moderate medium to fine crumb.

The pH value of this profile ranges from neutral at the top horizon to slightly acid in the lower horizons. Organic carbon and total nitrogen are low and very low respectively. The available P is very low throughout the profile. The TEB varies from 6.0-7.5 me/100g and are relatively well supplied with exchangeable bases. The CEC is low with the range of 4.7-6.6 me% and Ca^{++} is the dominant cation. The BS% is also very high throughout the horizons.

5.2.5 Fan soil with red subsoil (FR)

These soils are moderately extensive soils on the southern (true right bank) edge of the alluvial fan. They have been described in detail and sampled for analysis in three profiles (see PT005, PT011 and PT012 in Appendix B).

These soils are alluvial and are more than 100 cm deep. The topsoils are greyish brown to grey sandy loams. They have moderate medium subangular blocky breaking to moderate fine subangular blocky structures. The subsoil is dark reddish brown to dark red sandy clay loam to sandy clay. It contains stones of various size and shapes, consisting of quartz and gneiss. The structure of the subsoils varies from moderate angular blocky to subangular blocky, breaking to moderate medium subangular blocky to weak fine crumb.

These profiles have low to moderate organic carbon and very low total nitrogen. The available P in these profiles range from 1-8 me% which is very low to low. TEB vary from 2.2-3.7 me% in the topsoil and 4.2-7.5 me% in the subsoil. The BS% is moderate to high. The cation balance is variable but Ca^{++} is usually the dominant exchangeable cation. The cation exchange capacity is low.

5.2.6 Fan soil with greyish brown / brown subsoil (FB)

These soils are the most extensive soils of the alluvial fan. They are mostly located in the middle and northern (true left bank) side of the alluvial fan. These soils were described in detail and sampled for analysis in two profiles (see PT004 and PT013 in Appendix B)

These soils are alluvial, and are more than 100 cm deep. The topsoils are very dark grey-greyish brown to pale red sandy loams. In some profiles they extend downward by merger with shallow buried topsoils (e.g. PT013). They have moderately developed subangular blocky structures, which have a tendency to break into crumb. The subsoils are dark greyish brown - yellowish brown to dark grey sandy clay loam with some horizons containing a few stones of soft and hard quartz and gneiss. The structure is moderate to weak medium subangular blocky, often breaking into fine crumb.

The organic carbon is low and the total nitrogen is very low. C:N ratios are favourable. The topsoils of these profiles are very acid to neutral, and the pH values of the subsoil horizons are neutral to slightly alkaline. The available P is very low to low. The TEB is low with 3.0-5.7 me%. The exchangeable cations are variable with Ca^{++} dominant. The BS% is very high and the available K is higher in the top soil than the subsoil, even though they both are low.

5.2.7 Fan terrace soil (FT)

These soils are found in small patches of terrace along the Nyakulumpa stream where it cuts through the alluvial fan. Since the area is very small, no profiles of these soils have been described in detail. However they were seen in routine auger descriptions.

These soils are similar to the brown fan soils. The topsoils are olive grey to dark greyish brown text, over subsoils of yellowish brown to dark grey brown over very dark grey fine sandy loam to fine and medium sandy clay loam. There are few to rare stones of angular hard quartz and soft gneiss.

As there are no analysed profiles, there are no chemical data for these inextensive soils.

5.2.8 Middle terrace soil (TM)

These soils occur in isolated patches above the lower terrace along Mo Chhu. These soils are not extensive, and only one profile has been examined in detail and sampled for analysis (see PT014 in Appendix B).

The topsoil consists of olive grey to grey silty loam to sandy clay loam, which tends to have strong medium subangular blocky structures. The first three horizons (up to 55 cm deep) do not have any stones but however some are found in the lower horizons. The subsoil horizons are dark greyish brown, dark grey to brown with a band of dark brown and brownish yellow brown in the middle. The texture varies from fine sandy clay loam to medium sandy loam+ over loamy medium sand to coarse sandy loam. The texture varies within the horizons. There are a few hard round stones in some lower horizons.

The profile PT014 is neutral in pH value at the top horizon and is very acid at 50 cm. The pH value increases to neutral and then to alkaline (8.4) in the lower horizons. The TEB is 4.6 me% in the topsoil and 5.2 me% in the subsoil. The BS% is very high in the subsoil and it is high in the topsoil, but the available P is very low.

5.2.9 Lower terrace soil (TL)

These soils cover most of the Chang Yu area next to Mo Chhu and are not extensive. There are sub-terraces within this unit but they differ in elevation by less than 1 metre. The breaks of slope are not distinguished easily, because of agricultural terrace construction. Two profiles were described in detail and sampled for analysis in these soils (see PT008 and PT009 in Appendix B).

There are some basic profile features common to both of this and the middle terrace soils. The topsoil has grey to greyish brown silty and sandy loams. It grades in structure from moderate fine and medium subangular blocky to moderate medium and fine angular blocky. The stone content ranges from few to rare in the topsoil. The subsoils of these profiles are greyish brown to dark brown and dark grey with varying textures of coarse sandy loam to silty clay. Some subsoils are thixotropic and have sandy horizons. They contain both angular and rounded hard stones and boulders.

The distinct differences between upper and lower sections are attributed to different phases of alluvial deposition. The greyish and finer grained material forming the upper horizons are thought to have been deposited by less turbulent flows than those that deposited the lower layers, although some of the sands horizons are fine grained. The difference may be due to local changes in the juxtaposition of the turbulent main channel and relatively placid floodplain backwater. Alternatively, it may be a more regional difference and due to changes in the general nature of the river from turbulent glacio-fluvial in the late Holocene to more gentle and fluvial conditions that have appeared to prevailed in the past millenium or so. The prolonged use of these soils for irrigated rice has affected the colour and consistence of the surface horizons, but has had little effect on textures.

The topsoils of the two analysed profile have low (0.9 %) to moderate (1.2 %) contents of organic carbon and low C:N ratios (10-15). These soils are neutral to alkaline (pH 7.0-8.2) throughout. Base saturation ranges from high (67-85%) in the topsoil to very high (82-93%) in the subsoil. The TEB varies from low to moderate (2.8-11.6 me%). The available P is very low in the topsoil but is moderate in the subsoil. Available K is low in both the top and subsoils.

5.2.10 Analytical summary

The chemical characteristics of the soil classes are summarised in Table 5.2. Organic matter, nitrogen and available P levels vary from very low to low and appear to be affected by local variations in management. The soil reaction and base status indicators are fairly consistent in the fan and hills soils, with acid to slightly acid and moderately base deficient topsoils over neutral base-saturated subsoils. The terrace soils are neutral and highly base-saturated throughout. K status is mostly low.

Table 5.2 Range of chemical analyses, by soil classes, Nyakulumpa

SOIL CLASS (number of profiles analysed)	TOPSOIL ONLY				TOPSOIL AND SUBSOIL (T/S)				
	Org. C (%)	Total N (%)	C:N	AvP (ppm)	pH	TEB me %	BS (%)	Exch K (me %)	AvK (ppm)
HS (1)	1.1	0.1	12	11	5.1/7.3	2.2/6.2	28/83	0.2/0.2	47/35
HM (3)	0.4-1.3	0.07-0.12	6-13	1-13	5.5-5.8 /6.2-7.8	2.2-8.6 /4.0-9.5	54-100 /90-100	0.3-1.1 /0.2-1.2	55-221 /48-200
HD (1)	1.2	0.1	13	11	5.5/6.7	4.1/6.7	62/100	0.5/0.3	101 /51
HR (1)	0.7	0.06	12	1	6.4/5.9	6.0/7.5	100/100	0.2/0.3	33/44
FR (3)	0.4-1.5	0.05-0.09	8-19	1-8	5.0-5.2 /5.6-7.6	2.2-3.7 /4.2-7.5	46-93 /71-96	0.2-0.6 /0.2-0.3	28-57 /32-36
FB (3)	0.2-1.0	0.05-0.1	2-14	3-7	5.2-6.8 /6.9-7.6	3.1-5.4 /3.7-5.7	66-100 /100 (both)	0.2-0.3 /0.1-0.3	44-75 /22-43
TM (1)	1.1	0.08	14	1	7.7/6.8	4.6/5.2	79/100	0.2/0.5	42/29
TL (2)	0.9-1.2	0.06-0.12	10-15	1-16	7.0-7.9 /7.1-8.2	2.8-6.9 /2.8-11.6	67-85 /82-93	0.3-0.4 /0.02-0.1	58-96 /50-83

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

5.3 Soil correlation

5.3.1 Correlation with international soil classifications

The local classification used in Table 5.1 and in section 5.2 aims to be simple and to indicate the main soil features to those interested in the soils of Bhutan and Nyakulumpa Valley. 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. There is further discussion of the correlations in Appendix C.

Table 5.3 International correlation of soil classes at Nyakulumpa

Nyakulumpa soil class		Subunit in FAO World Reference Base for Soil Resources. (FAO 1998)	Great group in USDA Soil Taxonomy (Soil Survey Staff 1975 & 1998) [Family in italics]
Code	Name		
HD	Deep hill soil	Dystric & Eutric Cambisol; Hydragric Anthrosol	Dystric, anthraquic or typic Haplustept.
HM	Moderately deep hill soil	Dystric & Eutric Cambisol; Hydragric Anthrosol	Dystric, (anthraquic) or typic Haplustept, or Haplanthrept.
HS	Shallow hill soil	Dystric & Eutric Cambisol	Dystric or typic Haplustept.
HR	Red hill soil	Ferralic & Chromic Cambisol; Haplic Luvisol & Lixisol; Rhodic Ferralsol	Dystric & typic Rhodustalf, Rhodustox or Rhodustult
FR	Red subsoil	Eutric Cambisol; Hydragric Anthrosol	Typic Haplanthrept; (Anthraquic) Haplustept.
FB	Greyish brown subsoil	Eutric Cambisol; Hydragric Anthrosol	Typic Haplanthrept; (Anthraquic) Haplustept.
FT	Fan terrace soil	Eutric Cambisol; Hydragric Anthrosol	Typic Haplanthrept; (Anthraquic) Haplustept.
TM	Middle terrace soil	Eutric Cambisol; (Eutric Fluvisol); Hydragric Anthrosol	Typic Haplanthrept; (Anthraquic) Haplustept.
TL	Lower terrace soil	Eutric Fluvisol; Hydragric Anthrosol	Typic Haplanthrept; (Anthraquic) Haplustept.

5.3.2 Correlation with other Bhutan soils

As SSU has now done fieldwork for ten soil survey areas in Bhutan. It is becoming possible to correlate the Nyakulumpa soils with others seen elsewhere in the country.

The Lingmutey Chhu terrace soils are clearly similar to our soils with the same class names. The Lingmutey Chhu red clay and brown over red soils are also found in Nyakulumpa as HS and FR. The Bajo RNR-RC middle and lower terrace soils are similar to the similarly named terrace soils of Nyakulumpa. The grey and brown sandy loam hill soils derived from gneissic parent materials (HS, HM and HD) in Nyakulumpa are similar to the main hill soils of Yusipang RNR-RC and to the gneissic hill soils (GS, GM and GD) at Lingmutey Chhu. These correlations are summarised in Table 5.4.

Table 5.4 correlating the soils of Nyakulumpa with the soils of previous SSU survey areas

Nyakulumpa soil class	Bajo RNR-RC Soils. [(SSU Report (3a)]	Lingmutey Chhu Soils. [SSU Report (5a)]	Yusipang RNR-RC Soils. [SSU Report (1a)]
TL	TL	TL	-
TM	TM	TM	-
HR	-	RC	-
FR	-	BR	-
HS	-	GS	HS
HM	-	GM	HM
HD	-	GD	HD

5.3.3 Correlation with geotechnical classification of soils

Stability of soil terraces and water conveyance systems are critical features of soils for agricultural development in Bhutan. The Irrigation Section of REID of MoA has prepared a geotechnical classification of soils specifically for canal and terrace stability in Bhutanese conditions (CIP, 1993). Table 5.5 correlates the soils of Nyakulumpa Valley with the geotechnical classification. The rock classifications have been omitted because nearly all of the Nyakulumpa alluvial soils appear to be derived from mixed lithologies. The hillslope soils are derived from rocks of the CIP gneiss group.

Table 5.5 Geotechnical correlation of soils of Nyakulumpa

Nyakulumpa soil class	REID Irrigation Section Geotechnical Soil Classification	
	Land unit	Soil class
HD	3A/B	ML Low liquid limit loam
HM		
HS	3B	
HR	3A/B	CL Low liquid limit clay
FR	4D	ML Low liquid limit loam
FB		
FT	5C	
TM	5A	
TL	5C	SC/ML Low liquid limit loam over dirty sand.

Source for class criteria: CIP (1993)

6. SOIL DISTRIBUTION AND MAPPING

6.1 Soil distribution

Some of the soil classes are related to particular topographic locations. The red soils are found on the red hills and the fan soils are in the alluvial fan of the main valley. The distributions of the deep, moderately deep, and shallow hill soils do not show an obvious topographic pattern. Their boundaries on the soil map are based mainly on our routine soil observations, and not on topographic interpretation and extrapolation. The boundaries of the red and brown fan soils are based on field observations. The lower and the middle terrace soils show an obvious topographic pattern and the soil boundaries on the map are drawn on the topographic interpretation and also on our soil observations.

6.2 Soil mapping units

It is possible to map only part 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. Much of the area is mapped as a complex, which is units with two or more classes that are more or less co-equal. In Nyakulumpa almost two thirds of the area is mapped as complex (HX) which contains an intricate mixture of moderately deep (HM) and shallow (HS) grey and brown medium textured soils derived from gneiss. The fan soils are mapped as FB (fan soils having greyish brown or brown subsoils) and FR (fan soils having red subsoils). The river terrace soils are mapped as middle terrace (TM) and lower terrace (TL). The compositions of the mapping units are summarised in Table 6.1.

The areas and proportions of the soil mapping units are summarised in Table 6.2. This shows that the complex hill soils, which includes the moderately deep and shallow hill soils, is the most extensive, accounting for 66% of the survey area. The middle terrace soil and the deep hill soils are not extensive and account for less than 2% each.

Table 6.1 Composition of soil mapping units at Nyakulumpa

Map unit	Type	Main soil classes	Minor soil classes
HD	Consociation.	HD	HM
HX	Complex	HM, HS	HD
HR	Consociation.	HR	HD
FR	"	FR	FB
FB	"	FB	FR
FT	"	FB	"
TM	"	TM	-
TL	"	TL	-

Table 6.2 Areas of soil mapping units, Nyakulumpa Valley

Soil Mapping Unit	Area		
	Ha	Acre	% of survey area
HD	6	15	1.9
HX	207	513	66.0
HR	27	66	8.5
FR	11	27	3.5
FG	41	100	13.1
TM	3	8	0.9
TL	19	46	6.1
TOTAL	314	775	100.0

7. OVERVIEW AND IMPLICATIONS

7.1 Overview of soils

Nyakulumpa is located on wide ranges of soils, with mixed moderately deep and shallow hill soils as the most extensive. Many of the soils in the area are under wetland cultivation. Most of the arable land is on soils of medium texture, moderate depth, and good drainage.

7.2 Implications of survey

The implication of the survey will be more fully discussed in the Tsang Chhu Soil Survey. For the present the Nyakulumpa survey indicates:

The erodibility of the red soils noted at Lingmutey Chhu is confirmed with the Red hill (HR) soils at Nyakulumpa being severely gullied.

However the incorporating of red hill material into the parent material of the southern edge of the alluvial fan does not appear to cause excessive gulling or terrace instability. This needs systematic investigation.

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APPENDIX A: SUMMARY OF METHOD OF SOIL ANALYSIS

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

The SPAL methods vary slightly according to soil pH. The methods summarized below are those for soils of pH (water) both > 7 and < 7, as samples of both types were collected during this survey. However there are no samples of pH (water) < 4.5.

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 (both 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.
- For the soils with pH (water) < 4.5, extractable Al and H are extracted from 5 g fine earth with 100 ml of 1 M acidified KCl.

Assays of extracts

The NH_4 in the extracts 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 different 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 Unicam Atomic Adsorption Spectrophotometer.

For acid soils, extractable acidity (Al + H) in the KCl leachate are measured by titration with 0.05 M NaOH, and extractable Al alone is measured by a second titration with 0.05 M HCl, after the addition of NaF.

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 dispersion with sodium hexametaphosphate.

TEB, ECEC, BS and C:N

Total exchangeable bases, effective cation exchange capacity, base saturation, and C:N ratios are derived by computation, i.e.;

TEB = Exchangeable Ca + Mg + K + Na.

ECEC = TEB + Extractable Al.

BS (NH_4OAc) = TEB / CEC (NH_4OAc).

EBS = TEB / ECEC.

C:N = Organic C / Total N.

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

Table AppA.1 Summary of 1995 recommendations for 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
Ca:Mg	> 20	13 - 19.9	7 - 12.9	3 - 6.9	< 3
AvK ppm	> 300	200 - 299	100 - 199	40 - 99	< 40
AvP ppm	> 30		15 - 29	5 - 14	< 5
Org. C %	> 5	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 of the soil profiles. The profiles appear in the order summarised in Table AppB.I.

Table AppB.1 Summary of soil profiles

Profile Number	Nyakulumpa soil class	Number of horizons analysed.
PT001	HS	3
PT002	HM	5
PT003	HM	4
PT005	FR	4
PT006	HM	5
PT007	FB	4
PT009	TL	4
PT010	HR	4
PT011	FR	5
PT012	FR	4
PT013	FB	4
PT015	HD	4
PT004	FB	6
PT008	TL	6
PT014	TM	5
TOTAL Profiles/ Samples	15	67

Profile:	PT001	
Map unit:	HX	
Soil Classification:	Provisional Bhutan soil series:	Dompola
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley.	
Location:	ca 150m (S) away from the main stream near Kyelikha.	
GPS:	27^0 34.95' N, 89^0 49.90' E.	
Altitude:	1520 m a.s.l	
Described & sampled:	26.2.99, Tshering Dorji.	
Climate:	General:	Sub-tropical, P = ca 800 mm p.a.
	Recent weather:	Sunny.
Regional topography:	Low mountain	
Site position:	Lower part of the spur slope between two streams.	
Slope:	20%, ca 500m long, terraced concave, aspect E (90^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss.
	Drift:	Colluvium
Land use:	Wetland fallow	
Vegetation:	Rice stubble with grasses on bunds.	
Surface:	Litter:	Discontinuous patches of cow dung.
	Outcrops:	None.
	Stones:	Many coarse and few medium angular hard gneiss.
	Cracks:	None
	Roots:	None
	Microrelief:	Irregular cattle poaching, 3cm deep.
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 - 10	10YR 6/3 (pale brown) with common medium faint yellow and orange mottles; loamy medium sand; moderate medium subangular blocky breaking to weak fine crumb; common medium pores; moist & slightly firm; many medium & fine roots; HCl negative; diffuse boundary to: [Sample PT001/1 @ 0-10]
10 - 26	10YR 5/2 (greyish brown) with abundant coarse distinct yellow, orange & grey mottles; loamy medium sand+; moderate medium subangular blocky breaking to weak fine crumb; few fine pores; moist & slightly friable; many fine roots; HCl negative; gradual regular boundary to: [Sample PT001/2 @ 15-20]
26 - 52	10YR 4/2 (dark greyish brown) with abundant coarse distinct greyish brown mottles; medium sandy loam +; moderate medium subangular blocky breaking to weak fine crumb; common medium & few fine pores; moist & slightly friable; few fine roots; common fine hard quartz & gneiss gravel; HCl negative; gradual regular boundary to: [Sample PT001/3 @ 30-40]
52 - 90+	10YR 6/3 (pale brown) with no mottles; coarse medium sand; weak fine subangular blocky breaking to weak fine crumb; few medium & fine pores; moist & very friable; rare fine roots; few coarse soft weathered gneiss & few hard quartz stones; HCl negative: [Not sampled]

Comments: Deeper variant of shallow hill soil, possibly moderately deep hill soil. Typical but stone content decreases below 50cm.

SPAL analytical results for SSU Profile PT001 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT001 /1	0-10	5992	5.5	4.0	1.5	0.01	11	1.2	0.09	13
PT001 /2	15-20	5993	6.5	4.7	1.8	0.01	9	0.6	0.06	10
PT001 /3	30-40	5994	6.7	4.7	2.0	0.01	8	0.6	0.05	12

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT001 /1	2.8	0.7	0.5	0.1	4.1	Nd	6.6	Nd	62	Nd
PT001 /2	2.9	1.7	0.3	0.1	5.0	Nd	6.0	Nd	83	Nd
PT001 /3	4.4	1.9	0.3	0.1	6.7	Nd	6.5	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT001 /1	Nd	Nd	Nd	Nd	Nd	56.4	6.5	18.7	25.2	18.4	SL
PT001 /2	Nd	Nd	Nd	Nd	Nd	52.3	14.4	18.3	32.7	15.1	SL
PT001 /3	Nd	Nd	Nd	Nd	Nd	55.0	9.9	19.8	29.7	15.3	SL

Profile:	PT002	
Map unit:	HX	
Soil Classification:	Provisional Bhutan soil series:	Kyelikha
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Kilekha area, 50m up & down slope from AT0018 & AT0017 respectively	
GPS:	27^0 35.08' N, 89^0 50.59' E	
Altitude:	1440 m a.s.l	
Described & sampled:	1.3.1999, Tshering Dorji	
Climate:	General:	Sub-tropical, P = ca 800 mm p.a
	Recent weather:	Sunny
Regional topography:	Low mountain	
Site position:	Lower part of the spur slope	
Slope:	10%, 500m+ long, convex, aspect NNE (30^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Colluvial
Land use:	Fallow wetland	
Vegetation:	Artemisia myriantha, rice stubble with grasses on bunds	
Surface:	Litter:	Discontinuous few dried cow dung & rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	2-3 cm wide, discontinuous
	Roots:	None
	Microrelief:	Irregular cattle poaching, 3-5 cm deep
	Faunal activity:	None

Profile description: (Colours are moist unless indicated)

cm	
0 - 15	2.5Y 4/2 (very dark greyish brown) with common medium distinct yellow & orange mottles; fine sandy loam; moderate medium subangular blocky breaking to moderate fine crumb; few fine pores; moist & slightly friable; many medium & fine roots; HCl negative; diffuse boundary to: [Sample PT002/1 @ 0-10]
15 - 35	2.5Y 3/2 (very dark greyish brown) with common fine faint yellow & orange mottles; fine sandy loam; moderate medium subangular blocky breaking to weak fine crumb; few fine & medium pores; moist & slightly friable; many fine roots; HCl negative; diffuse boundary to: [Sample PC002/2 @ 20-30]
35 - 75	2.5Y 4/2 (very dark greyish brown) with abundant medium distinct reddish brown, yellow & orange mottles; medium sandy loam+; moderate medium subangular blocky breaking to moderate fine crumb; few medium and fine pores; moist & slightly friable; no roots; HCl negative; many fine muscovite flakes; HCl negative; distinct regular boundary to: [Sample PT002/3 @ 50-60]
75 – 100	2.5Y 4/2 (very dark greyish brown) with few fine faint yellow & orange mottles; medium sandy loam+; moderate medium subangular blocky; few fine & medium pores; moist & slightly friable; no roots; HCl negative; many fine muscovite flakes; distinct regular boundary to: [Sample PT002/4 @ 80-90]
100 - 120+	10YR 4/3 (brown) with abundant coarse distinct reddish brown & black mottles; medium sandy clay loam; moderate medium subangular blocky; many medium & fine pores; moist & slightly friable; no roots; few hard quartz & soft gneiss gravel; HCl negative; muscovite flakes: [Sample PT002/5 @ 100-110]

Comments: Typical moderately deep hill soil. Fine sand in upper two horizons may be aeolian. Subsoil neutral in pH value.

SPAL analytical results for SSU Profile PT002 Survey area: Nyakulumpa Valley.

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT002 /1	0-10	5995	5.8	4.0	1.8	0.01	1	0.9	0.07	13
PT002 /2	20-30	5996	7.5	5.1	2.4	0.01	1	0.3	0.04	8
PT002 /3	50-60	5997	7.3	4.7	2.6	0.01	2	0.3	0.03	10
PT002 /4	80-90	5998	7.1	4.4	2.7	0.03	1	0.4	0.02	20
PT002 /5	100-110	5999	7.2	4.4	2.8	0.02	2	0.4	0.02	20

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT002 /1	2.5	0.8	0.3	0.2	3.8	Nd	4.8	Nd	79	Nd
PT002 /2	2.7	1.7	0.2	0.2	4.8	Nd	10.2	Nd	47	Nd
PT002 /3	4.5	1.6	0.2	0.2	6.4	Nd	5.2	Nd	100	Nd
PT002 /4	3.9	1.6	0.2	0.2	5.8	Nd	5.2	Nd	100	Nd
PT002 /5	3.7	1.7	0.2	0.2	5.8	Nd	6.0	Nd	96	Nd

Fine earth granulometric

SSU 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		
PT002 /1	Nd	Nd	Nd	Nd	Nd	45.4	11.4	24.7	36.1	18.5	L
PT002 /2	Nd	Nd	Nd	Nd	Nd	55.0	6.9	20.3	27.2	17.8	SL
PT002 /3	Nd	Nd	Nd	Nd	Nd	56.9	10.1	19.6	29.7	13.5	SL
PT002 /4	Nd	Nd	Nd	Nd	Nd	60.1	5.2	15.1	20.3	19.6	SL
PT002 /5	Nd	Nd	Nd	Nd	Nd	52.2	12.9	15.8	28.7	19.1	SL

Profile:	PT003	
Map unit:	HX	
Soil Classification:	Provisional Bhutan soil series:	Kyelikha
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Mid point in traverse TT8 (AT0025) Majaphakha.	
GPS:	27^0 34.27' N, 89^0 49.68' E	
Altitude:	1710 m a.s.l	
Described & sampled:	2.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 800 mm p.a
	Recent weather:	Sunny
Regional topography:	Low mountain	
Site position:	Lower slope.	
Slope:	35%, terraced rectilinear, ca 500 m long, aspect NNW (350^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Colluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble, weeds & Artemisia on bunds.	
Surface:	Litter:	Scattered rice straw
	Outcrops	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Recently ploughed
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 8	2.5Y 4/2 (dark greyish brown) with common fine & medium distinct orange & yellow mottles; fine sandy loam; moderate medium subangular blocky breaking to weak fine crumb; common fine pores; dry & slightly hard; many medium & fine roots; HCl negative; clear & slightly wavy boundary to: [Sample PT003/1 @ 0-8]
8 - 21	2.5Y 5/2 (greyish brown) with many fine faint reddish brown mottles; fine sandy loam; weak medium subangular blocky breaking to weak fine subangular blocky; few fine pores; moist & friable; few medium & fine roots; few fine hard quartz stones; abundant muscovite flakes; HCl negative; gradual & wavy boundary to: [Sample PT003/2 @ 10-20]
21 - 48	2.5Y 4/2 (dark greyish brown) with common medium & fine distinct reddish brown & orange mottles; very fine sandy loam+; weak medium subangular blocky breaking to weak fine crumb; common fine pores; moist & slightly firm; few fine roots; few fine & medium hard quartz and fine soft weathered gneiss stones; HCl negative; diffuse boundary to: [Sample PT003/3 @ 30-40]
48 - 65/74	2.5Y 5/2 (greyish brown) with common medium distinct & fine faint reddish brown mottles; medium sandy loam; weak medium subangular blocky breaking to weak fine crumb; moderate continuous grey clayskins; many medium pores; moist & firm; no roots; few fine & medium hard quartz & fine soft weathered gneiss gravel; few biotite flakes; HCl negative; clear oblique boundary to: [Sample PT003/4 @ 50-60]
65/74-102	10YR 5/4 (yellowish brown) with many medium faint greyish brown mottles; medium sandy loam+; weak medium subangular blocky breaking to weak fine crumb; many medium & fine pores; moist & slightly firm & plastic; common fine old dead root channels; common medium weathered gneiss and hard quartzite stones; few coarse soft dark brown & black FeMn concretions; HCl negative; clear wavy boundary to: [Not sampled]
102 – 115	Mixed Grey, white & pale yellow; hand textured as loamy coarse sand; soft weathered gneiss & common hard medium & fine quartz stones; pores not seen; moist & friable; no roots; HCl negative: [Not sampled]
115+	As above but colours predominantly more brownish. [Not sampled]

SPAL analytical results for SSU Profile PT003 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT003 /1	0-8	6000	5.5	3.9	1.6	0.01	13	0.4	0.1	6
PT003 /2	10-20	6001	5.4	4.0	1.4	0.01	10	0.5	0.1	8
PT003 /3	30-40	6002	6.2	4.4	1.8	0.01	9	0.3	0.1	5
PT003 /4	50-60	6003	6.6	4.7	1.9	0.01	5	1.2	Tr	60

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT003 /1	1.5	0.3	0.3	0.1	2.2	Nd	4.0	Nd	54	Nd
PT003 /2	1.4	0.3	0.2	0.1	2.0	Nd	3.6	Nd	56	Nd
PT003 /3	2.9	0.8	0.3	0.1	4.0	Nd	3.9	Nd	100	Nd
PT003 /4	3.1	0.8	0.3	0.1	4.3	Nd	4.1	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT003 /1	Nd	Nd	Nd	Nd	Nd	63.5	14.0	13.3	27.3	9.2	SL
PT003 /2	Nd	Nd	Nd	Nd	Nd	61.4	12.9	15.0	27.9	10.7	SL
PT003 /3	Nd	Nd	Nd	Nd	Nd	65.4	9.1	13.5	22.6	12.0	SL
PT003 /4	Nd	Nd	Nd	Nd	Nd	67.8	9.5	13.8	23.3	8.9	SL

Profile:	PT004	
Map unit:	FB	
Soil Classification:	Provisional Bhutan soil series:	Thara
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	ca 0.6 km up slope from Thara	
GPS:	27^0 35.27' N, 89^0 50.82' E	
Altitude:	1360 m a.s.l	
Described & sampled:	3.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Dry sunny
Regional topography:	Low mountain	
Site position:	Top end of the alluvial fan	
Slope:	Ca 10%, 40m length, terraced convex, aspect NNW (340^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Fan alluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble and scattered forb weeds	
Surface:	Litter:	Scattered rice straw and few cow dung patches
	Outcrops:	None
	Stones:	Rare boulders
	Cracks:	Common, almost continuous up to 5mm wide
	Roots:	None
	Microrelief:	Moderate cattle poaching (3cm deep)
	Faunal activity:	None
	Other features:	Thin & almost continuous capping

Profile description: (Colours are moist unless indicated)

cm	
0 – 8	2.5Y 5/2 (greyish brown) with few fine faint orange & reddish brown mottles; very fine sandy loam+; weak fine subangular blocky breaking to weak fine crumb; few fine pores; slightly moist and friable; common fine and medium roots; HCI negative; gradual regular boundary to: [Sample PT004/1 @ 0-8]
8 – 15	5Y 4/1 (dark grey) with common medium, coarse and fine distinct orange mottles; very fine sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; few fine pores; moist & friable; common fine & medium roots; HCI negative; clear regular boundary to: [Not sampled]
15 – 26	2.5Y 4/2 (dark greyish brown) with many fine & common medium distinct orange mottles; very fine sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; common fine pores; moist & slightly friable; few fine & medium roots; few fine hard angular quartz & soft weathered gneiss stones; HCl negative; clear regular boundary to: [Sample PT004/2 @ 15-25]
26 – 35	5Y 4/1 (dark grey) with many medium faint reddish brown & orange mottles; fine sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; pores not seen; moist & friable; few fine roots; rare fine gneiss stones; HCI negative; clear regular boundary to: [Not sampled]
35 – 45	10YR 4/4 (dark yellowish brown) with many medium distinct black, orange & red mottles especially at top of the horizon; fine sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; strong continuous clayskins on crack faces and root pores; abundant fine pores; moist & slightly friable; common fine dead & few fine live roots; few fine hard quartz grit; HCI negative; clear regular boundary to: [Sample PT004/3 @ 35-45]
45 – 54	5Y 4/1 (dark grey) with many to abundant coarse distinct brown & reddish brown mottles; medium sandy clay loam; moderate medium subangular blocky; strong continuous grey clayskins on cracks & pores walls; abundant fine pores; moist & firm; no roots; few fine hard black & red, iron & manganese concretions; HCI negative; clear regular boundary to: [Sample PT004/4 @ 45-54]

54 – 62 Mixed colours of grey, orange, black & brown; medium sandy clay loam; moderate medium subangular blocky; strong continuous grey silty cutans; few fine & medium roots; moist & firm; rare fine hard quartz & gneiss gravel; few fine hard red & black iron & manganese concretions; clear regular boundary to:
[Not sampled]

62 – 81 2.5Y 4/2 (dark greyish brown) with abundant medium distinct brown, dark brown & reddish brown mottles; coarse sandy clay loam; moderate medium subangular blocky; strong continuous grey silty cutans; many fine & moderate pores; moist & very firm (compact); few fine hard & soft of quartz & gneiss stones; few medium & fine soft orange & black manganese concretions; HCI negative; gradual regular boundary to:
[Sample PT004/5 @ 65-75]

81 – 93 10YR 4/3 (brown) with many medium faint grey & many fine distinct reddish brown mottles; coarse sandy loam +; moderate medium subangular blocky; strong continuous grey silty cutans; many fine pores; moist & firm; many fine & few medium black concretions; HCI negative; clear regular boundary to:
[Not sampled]

93-109+ 2.5Y 4/2 (dark greyish brown) with many medium distinct dark brown mottles; coarse sandy loam+; weak medium subangular blocky breaking to weak fine subangular blocky; strong continuous to discontinuous clay skins; common fine & medium pores; moist & friable; few fine hard quartz stones; many medium soft black concretions; HCI negative: [Sample PT004/6 @ 95-105]

Comments: Same pH value pattern of acid topsoil over neutral subsoil as hill soils. Topsoil may also be aeolian. Compact horizon at 62-81cm is too deep to be a plough pan, probably natural.

SPAL analytical results for SSU Profile PT004 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT004 /1	0-8	6004	5.5	3.8	1.7	0.01	3	0.7	0.1	14
PT004 /2	15-25	6005	6.3	4.4	1.8	0.02	2	0.5	Tr	13
PT004 /3	35-45	6006	6.9	4.9	2.0	0.01	1	0.1	Tr	3
PT004 /4	45-54	6007	7.0	4.9	2.1	0.02	3	0.6	Tr	20
PT004 /5	65-75	6008	7.1	5.0	2.1	0.03	3	0.2	Tr	10
PT004 /6	95-105	6009	7.4	4.9	2.5	0.01	3	0.9	Tr	45

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT004 /1	2.3	0.7	0.2	0.1	3.4	Nd	5.1	Nd	66	Nd
PT004 /2	3.5	1.3	0.2	0.1	5.1	Nd	5.1	Nd	100	Nd
PT004 /3	3.4	1.1	0.1	0.1	4.8	Nd	4.2	Nd	100	Nd
PT004 /4	4.4	1.3	0.2	0.1	6.0	Nd	5.3	Nd	100	Nd
PT004 /5	3.5	1.2	0.2	0.1	5.0	Nd	4.8	Nd	100	Nd
PT004 /6	4.5	1.3	0.2	0.1	6.1	Nd	6.7	Nd	91	Nd

Fine earth granulometric.

SSU 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		
PT004 /1	Nd	Nd	Nd	Nd	Nd	54.1	12.2	17.1	29.3	16.5	SL
PT004 /2	Nd	Nd	Nd	Nd	Nd	52.4	12.4	18.0	30.4	17.1	SL
PT004 /3	Nd	Nd	Nd	Nd	Nd	58.7	6.7	15.4	22.1	19.1	SL
PT004 /4	Nd	Nd	Nd	Nd	Nd	56.4	9.0	16.4	25.4	18.2	SL
PT004 /5	Nd	Nd	Nd	Nd	Nd	61.8	6.0	14.3	20.3	17.9	SL
PT004 /6	Nd	Nd	Nd	Nd	Nd	55.0	13.0	14.7	27.7	17.3	SL

Profile:	PT005	
Map unit:	FR	
Soil Classification:	Provisional Bhutan soil series:	Kubji
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol ‘
Survey area:	Nyakulumpa Valley	
Location:	150m SE (150^0) from Thara	
GPS:	27^0 35.25’ N, 89^0 51.16’ E	
Altitude:	1360 m a.s.l	
Described & sampled:	3.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Dry sunny
Regional topography:	Low mountain	
Site position:	Mid lower section of alluvial fan	
Slope:	ca 7%, 1 km long, slightly convex, aspect ENE (72^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Fan alluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses on bunds	
Surface:	Litter:	Scattered rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	Common discontinuous, up to 8mm wide
	Roots:	None
	Microrelief:	Dense cattle poaching to 7cm deep
	Faunal activity:	None
	Other features:	Continuous grey & red patches of capping

Profile description: (Colours are moist unless indicated)

cm	
0 - 7	10YR 8/3 (dry) (very pale brown), 10YR 5/2 (moist) (greyish brown) with medium & fine distinct reddish brown & yellowish red mottles; fine sandy loam+; moderate to strong medium angular blocky; moderate discontinuous clayskins; rare fine pores; dry & hard; common fine roots; HCl negative; clear regular boundary to: [Sample PT005/1 @ 0-7]
7 – 20	2.5Y 5/2 (greyish brown) with abundant medium & fine reddish yellow & orange mottles; very fine sandy clay loam; moderate medium subangular blocky; few fine pores; slightly moist and firm; few fine roots; rare fine hard quartz gravel and skarn; HCl negative; clear regular boundary to : [Not sampled]
20 – 47	10YR 4/2 (dark greyish brown) with abundant medium & fine distinct reddish brown & black mottles; fine sandy clay loam; strong medium angular blocky breaking to subangular blocky; moderate continuous grey clayskins; many fine & medium pores; moist & very firm; rare fine roots; common fine & medium soft black FeMn concretions; HCl negative; diffuse boundary to: [Sample PT005/2 @ 30-40]
47 – 69	10YR 4/2 (dark greyish brown) with common fine faint brown mottles; fine sandy clay loam+; moderate medium subangular blocky; strong continuous clayskins; many fine and medium pores; moist & slightly firm; no roots; few fine soft weathered gneiss stones; common fine & medium soft black FeMn concretions; HCI negative; abrupt regular boundary to: [Sampled PT005/2 @55-65]
69-140+	2.5YR 3/6 (dark red) with few medium distinct brownish yellow mottles; fine sandy clay; moderate medium subangular blocky breaking to moderate fine crumb; weak discontinuous clayskins; many medium & fine pores; moist & firm; rare medium hard quartzite stones; many medium soft black FeMn concretions; HCI negative: [Sample PT005/4 @ 90-100]

Comments: The grey over red subsoil was probably one horizon originally but due to intensive wetland cultivation the colour of the top layer of the soil has been converted to gley soil. The pH pattern of the soil remains as the hill soils with acid topsoil over neutral – alkaline subsoil. The texture becomes heavier with depth.

SPAL analytical results for SSU Profile PT005 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT005 /1	0-7	6010	5.2	3.9	1.3	0.01	3	0.4	0.1	8
PT005 /2	30-40	6011	7.6	5.8	1.8	0.01	2	0.4	Tr	20
PT005 /3	55-65	6012	8.1	6.1	3.0	0.01	2	0.1	Tr	10
PT005 /4	90-100	6013	8.3	6.6	1.7	0.01	1	1.5	Tr	38

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT005 /1	1.5	0.4	0.2	0.2	2.2	Nd	4.8	Nd	46	Nd
PT005 /2	5.3	1.8	0.3	0.1	7.5	Nd	10.6	Nd	71	Nd
PT005 /3	5.2	1.2	0.2	0.2	6.8	Nd	11.1	Nd	61	Nd
PT005 /4	5.1	1.1	0.5	0.3	10.0	Nd	14.3	Nd	70	Nd

Fine earth granulometric

SSU 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		
PT005 /1	Nd	Nd	Nd	Nd	Nd	53.3	11.9	16.9	28.8	18.0	SL
PT005 /2	Nd	Nd	Nd	Nd	Nd	50.0	12.0	17.7	29.7	20.3	SCL
PT005 /3	Nd	Nd	Nd	Nd	Nd	51.7	11.5	15.3	26.8	21.4	SCL
PT005 /4	Nd	Nd	Nd	Nd	Nd	32.2	5.0	14.5	19.5	48.4	C

Profile:	PT 006	
Map unit:	HX	
Soil Classification:	Provisional Bhutan soil series:	Kyelikha
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	80m down slope from AT 0037 above the ruins upslope from Thara	
GPS:	27^0 35.18 N, 89^0 50.98 E	
Altitude:	1420 m	
Described & sampled:	4.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 800 mm p.a
	Recent weather:	Dry sunny
Regional topography:	Low mountain	
Site position:	Lower slope	
Slope:	15%, ca 500m long, terraced concave, aspect NNE (15^0)	
Site drainage	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Colluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses.	
Surface:	Litter:	Scattered rice straw & cow dung
	Outcrops:	None
	Stones:	A few - common medium gneiss boulders
	Cracks:	2-3 mm wide, discontinuous
	Roots:	None
	Microrelief:	3 cm deep cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 14	10YR 6/2 (dry) (light brownish grey), 10YR 4/2 (moist) (dark greyish brown) with many medium & fine distinct yellow & orange mottles; very fine sandy clay loam; moderate medium angular blocky breaking to fine subangular blocky; many medium & fine pores; dry & firm; common medium & fine roots; HCl negative; clear regular boundary to : [Sample PT006/@ 0-10]
14 – 28	10YR 3/3 (dark brown) with common medium & few fine distinct reddish brown, orange & yellow mottles; fine sand clay loam; moderate medium angular breaking to moderate fine subangular blocky; many fine pores; slightly moist & firm; rare fine roots; HCl negative; clear regular boundary to: [Not sampled]
28 – 57	10YR 5/3 (brown) with many to abundant distinct reddish brown & orange mottles; fine sandy clay loam; moderate medium subangular blocky; moderate continuous clayskins; many fine pores; slightly moist & firm; no roots; few fine hard quartz & soft gneiss stones; HCl negative; clear slightly wavy boundary to: [Sample PT006/2 @ 40-50]
57 – 79	10YR 7/4 (very pale brown) with common fine faint black & orange mottles; fine sandy clay loam; moderate medium subangular blocky breaking to moderate fine crumb; moderate continuous clayskins; many fine pores; moist & friable; no roots; few fine hard quartz & soft gneiss stones; many medium hard black FeMn concretions; HCl negative; clear regular boundary to: [Sample PT006/3 @ 60-70]
79 – 116	10YR 4/3 (brown) with common fine faint reddish brown & orange mottles; fine sandy clay loam; moderate medium subangular blocky breaking to fine crumb; moderate continuous clayskins; few fine & medium pores; moist & friable; no roots; many medium hard black FeMn concretions; HCl negative; clear regular boundary to: [Sample PT006/4 @ 80-90]

116-130+ 5YR 4/4 (reddish brown) with common medium distinct grey & orange mottles; fine sandy clay; moderate medium subangular blocky breaking to moderate fine crumb; moderate continuous clayskins; many medium & fine pores; moist & friable; no roots; few fine hard quartz & soft gneiss stones; many medium hard black FeMn concretions; HCl negative: [Sampled PT006/5 @ 115-120]

Comments: The texture gets heavier with depth. It is a typical moderately deep hill soil. The pH of the soil follows the pattern of other hill soils getting alkaline with depth. Below 116 cm, the soil gets distinctively redder, probably formed from skarn.

SPAL analytical results for SSU Profile PT006 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT006 /1	0-10	6055	5.7	3.7	2.0	0.01	7	1.3	0.1	11
PT006 /2	40-50	6056	7.8	5.5	2.3	0.01	2	0.3	0.1	6
PT006 /3	60-70	6057	8.3	6.4	1.9	0.04	2	0.5	Tr	13
PT006 /4	80-90	6058	8.3	6.4	1.9	0.03	4	0.3	Tr	10
PT006 /5	115-120	6059	8.1	6.3	1.8	0.02	1	0.1	Tr	5

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT006 /1	6.2	1.2	1.1	0.1	9.0	Nd	7.5	Nd	100	Nd
PT006 /2	6.1	2.0	1.2	0.2	9.5	Nd	10.5	Nd	90	Nd
PT006 /3	6.4	1.9	1.2	0.2	9.6	Nd	10.1	Nd	95	Nd
PT006 /4	6.1	2.2	1.4	0.2	9.9	Nd	11.8	Nd	84	Nd
PT006 /5	7.5	2.6	1.0	0.2	11.3	Nd	10.4	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT006 /1	Nd	Nd	Nd	Nd	Nd	36.5	11.7	20.7	32.4	31.1	CL
PT006 /2	Nd	Nd	Nd	Nd	Nd	37.8	12.3	17.5	29.8	32.4	CL
PT006 /3	Nd	Nd	Nd	Nd	Nd	42.0	10.4	17.7	28.1	30.0	CL
PT006 /4	Nd	Nd	Nd	Nd	Nd	40.4	10.6	17.1	27.7	31.9	CL
PT006 /5	Nd	Nd	Nd	Nd	Nd	29.2	8.6	13.2	21.8	48.9	C

Profile:	PT 007	
Map unit:	FB	
Soil Classification:	Provisional Bhutan soil series:	Thara
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Ca 50m away from the ruins & ca 100m up slope from Thara.	
GPS:	27^0 35.12' N, 89^0 51.12' E	
Altitude:	1330 m	
Described & sampled:	5.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 800 mm p.a
	Recent weather:	Sunny
Regional topography:	Low mountain	
Site position:	Northern side slope of top end of alluvial fan.	
Slope:	10% terraced concave, ca1.5km long, aspect NE (40^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Fan alluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses on bunds	
Surface:	Litter:	Few dried cow dung
	Outcrops	None
	Stones:	None
	Cracks:	Discontinuous, 2-3cm wide
	Roots:	None
	Microrelief:	Irregular 2-3cm deep cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 17	2.5Y 6/2 (light brownish grey) with common medium distinct yellow & orange mottles; very fine sandy clay loam; moderate medium subangular blocky breaking to moderate fine crumb; few fine & medium pores; slightly dry & firm; common medium & fine roots; HCl negative; diffuse boundary to: [Sample PT007/1 @ 0-10]
17 – 78	10YR 5/1 (grey) with abundant medium & fine distinct reddish brown & yellow orange mottles; fine sandy clay loam; moderate medium subangular blocky; many medium & fine pores; moist & firm; few fine roots; HCl negative; clear regular boundary to: [Sample PT007/2 @ 40-50]
78 – 94	10YR 5/1 (grey) with many medium & few fine distinct reddish mottles; fine sandy clay loam; moderate medium subangular blocky breaking to weak fine crumb; moderate continuous clayskins; many medium & fine pores; moist & friable; no roots; few fine hard quartz & few fine soft gneiss stones; HCl negative; clear regular boundary to: [Sample PT007/3 @ 80-90]
94-100	10YR 6/1 (grey) with abundant medium distinct yellow & orange mottles; fine sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; moderate continuous clayskins; many medium & fine pores; slightly wet & friable; no roots; few fine hard quartz & soft gneiss stones; HCl negative; clear regular boundary to: [Not sampled]
100-119	10YR 5/1 (grey) with common medium & fine distinct reddish brown & orange mottles; fine sandy clay loam; weak medium subangular blocky breaking to medium fine crumb; moderate continuous clayskins; common medium & fine pores; slightly wet & plastic; no roots; few fine hard quartz & soft gneiss stones; HCl negative; clear regular boundary to: [Sample PT007/4 @ 105-115]
119 – 124	10YR 4/4 (dark yellowish brown) with many medium & fine distinct grey mottles; medium sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; common medium & fine pores; slightly wet & plastic; no roots; HCl negative; clear regular boundary to: [Not sampled]

124-130 10YR 4/1 (dark grey) with few fine faint reddish brown mottles; fine sandy clay loam; weak medium subangular blocky breaking to weak fine crumb; moderate continuous clayskins; common medium and fine pores; slightly wet, friable & plastic; no roots; HCl negative; clear regular boundary to: [Not sampled]

130 – 137 10YR 5/4 (yellowish brown) with common fine distinct grey mottles; medium sandy loam+; weak moderate subangular blocky breaking to weak fine crumb; moderate continuous clayskins; common medium & fine pores; no roots; HCl negative; clear regular boundary to: [Not sampled]

137-155+ 10YR 4/1 (dark grey) with few fine faint reddish brown mottles; medium sandy clay loam; moderate medium subangular blocky breaking to moderate fine crumb; moderate continuous clayskins; many fine pores; slightly wet & friable; no roots; HCl negative: [Not sampled]

Comments: The pH value follows the same pattern as the hill soils with acid topsoil over neutral subsoil. Sand size gets coarser with depth. Aeolian deposit in the topsoil is possible. It is a typical fan soil.

SPAL analytical results for SSU Profile PT007 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU	Depth	SPAL	pH			EC	Avail.	Organic	Total N	C:N
No.	cm	Lab No	H2O	KCl	Diff	mS/cm	P ppm	C%	%	
PT007/1	0-10	6060	5.2	3.3	1.9	0.01	7	0.2	0.1	2
PT007/2	40-50	6061	7.0	4.3	2.7	0.01	5	0.5	Tr	13
PT007/3	80-90	6062	7.5	5.7	1.8	0.02	2	0.7	Tr	35
PT007/4	105-115	6063	7.6	5.6	2.0	0.01	4	0.6	Tr	20

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT007/1	4.4	0.6	0.3	0.1	5.4	Nd	5.4	Nd	100	Nd
PT007/2	3.8	1.5	0.3	0.1	5.7	Nd	4.5	Nd	100	Nd
PT007/3	2.9	1.5	0.3	0.1	4.8	Nd	9.6	Nd	50	Nd
PT007/4	3.7	1.6	0.3	0.2	5.7	Nd	1.2	Nd	51	Nd

Fine earth granulometric

SSU 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		
PT007/1	Nd	Nd	Nd	Nd	Nd	45.4	13.6	20.6	34.2	20.4	L
PT007/2	Nd	Nd	Nd	Nd	Nd	50.0	11.7	19.7	31.4	18.7	L
PT007/3	Nd	Nd	Nd	Nd	Nd	51.9	11.0	18.7	29.7	18.3	L
PT007/4	Nd	Nd	Nd	Nd	Nd	53.1	12.2	18.5	30.7	16.2	SL

Profile:	PT008	
Map unit:	TL	
Soil Classification:	Provisional Bhutan soil series:	Bajothangka
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Chang Yu, near the bridge over Mo Chhu.	
GPS:	27^0 35.51' N, 89^0 51.65' E.	
Altitude:	1220 m a.s.l.	
Described & sampled:	12.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Dry and hazy
Regional topography:	Main valley	
Site position:	Low terrace along Mo Chhu	
Slope:	2%, terraced rectilinear, ca 130 m long, aspect ENE (85^0)	
Site drainage:	Good	
Parent material:	Solid:	Mixed
	Drift:	Alluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble, grasses on bunds.	
Surface:	Litter:	Scattered rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	Ca 1 cm wide, discontinuous
	Roots:	None
	Microrelief:	Cattle poaching, 4 cm deep
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 10	2.5Y 5/1 (grey) with few fine faint yellow & orange mottles; fine sandy loam+; weak very fine platy for top 1cm over moderate medium and fine subangular blocky; many medium & fine pores; moist & friable; many medium & fine roots; HCl negative; gradual regular boundary to: [Sample PT008/1 @ 0-10]
10 – 20	2.5Y 5/1 (grey) with common medium & fine distinct yellow, reddish brown and orange mottles; medium sandy loam; moderate medium angular blocky; few medium & fine pores; moist & very friable; few fine roots; few fine hard & angular quartz gravel; HCl negative; clear regular boundary to: [Sample PT008/2 @ 10-20]
20-30	2.5Y 5/1 (grey) many coarse faint dark brown & reddish brown mottles; coarse sandy loam+; moderate medium subangular blocky; few fine & rare medium pores; moist & very friable; rare fine roots; few fine hard angular quartz & hard rare granite stones; HCl negative; abrupt regular boundary to: [Not sampled]
30-41/48	10YR 5/4 (yellowish brown) with common coarse faint dark brown mottles; coarse sand; single grain; moist and loose; no roots; HCl negative; clear wavy boundary to: [Not sampled]
41/48-56/63	7.5YR 4/6 (strong brown) with many medium faint yellowish brown mottles; medium sand; weak medium subangular blocky breaking to single grain; moist & very friable; rare fine roots; HCl negative; clear wavy boundary to; [Not sampled]
58/63-95/109	10YR 5/3 (brown) with no mottles; gravel & coarse sand; very weak coarse subangular blocky breaking to single grain; many fine pores; moist & loose; no roots; common fine grey quartz and granite mixed stones; HCl negative; clear wavy boundary to: [Sample PT008/3 @ 70-90]
95/109-111	10YR 5/4 (yellowish brown) with no mottles; loamy medium sand; weak medium subangular blocky breaking to single grain; moist to slightly wet & very friable; few fine pores; no roots; HCl negative; clear regular boundary to: [Not sampled]

111-116	10YR 5/2 (greyish brown) with thin band of dark brown; loamy fine sand; weak medium angular blocky; weak discontinuous clayskins on pore walls; few fine pores; slightly wet and plastic; HCl negative; clear regular boundary to: [Not sampled]
116 – 127	10YR 5/2 (greyish brown) with many medium distinct reddish brown mottles; loamy fine sand; very weak medium subangular blocky breaking to single grain; common fine pores; wet & loose; rare medium hard & platy gneiss; HCl negative; clear regular boundary to: [Not sampled]
127-135	10YR 4/4 (dark yellowish brown) with many medium distinct reddish brown mottles; medium sand+; very weak medium subangular blocky breaking to single grain; few medium & fine pores; wet & loose; no roots; HCl negative; abrupt regular boundary to: [Not sampled]
135 – 149	2.5Y 5/1 (grey) with common fine faint reddish brown & dark brown mottles; medium sandy loam+; moderate medium subangular blocky; few medium & fine pores; wet & slightly plastic & sticky; no roots; common medium and fine rounded hard quartz gravel; HCl negative; clear regular boundary to: [Sample PT008/4 @ 140-145]
149 – 157	10YR 5/2 (greyish brown) with common fine faint reddish brown & dark brown mottles; coarse sandy loam+; weak medium subangular blocky; few medium & fine pores; wet & loose; no roots; common medium & fine rounded hard quartz stones; HCl negative; clear regular boundary to: [Not sampled]
157 – 172	Banded grey & brown; very fine sand; very weak medium angular blocky; moisture film; few fine pores; wet, plastic & loose and thixotropic; no roots; HCl negative; clear regular boundary to: [Sample PT008/5 @ 160-170]
172-184	2.5Y 5/1 (grey) with common fine distinct reddish brown mottles; fine sandy loam; moderate medium subangular blocky; few fine & medium pores; wet & slightly plastic; no roots; few fine hard & slightly round quartz stones; HCl negative; [Sample PT008/6 @ 170-180]
Comments:	It's a typical lower terrace soil with gley colour and loamy textures for the first 40 cm followed by bands of fine and coarse sand alluvial deposits. The pH value stays neutral throughout. The very fine sand at 157-172 cm is thixotropic.

SPAL analytical results for SSU Profile PT008 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT008 /1	0-10	6072	7.0	3.6	2.4	0.01	16	0.9	0.1	15
PT008 /2	10-20	6073	7.1	4.5	2.6	0.01	15	0.3	Tr	10
PT008 /3	70-80	6074	7.1	4.5	2.6	0.01	7	0.1	Tr	10
PT008 /4	140-145	6075	7.1	5.6	1.5	0.01	16	0.1	Tr	5
PT008 /5	160-170	6076	7.1	5.8	1.3	0.01	35	0.1	Tr	10
PT008 /6	170-180	6077	6.1	5.3	1.8	0.01	11	0.3	Tr	15

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT008 /1	2.0	0.4	0.4	0.1	2.8	Nd	3.3	Nd	85	Nd
PT008 /2	2.1	0.4	0.3	0.1	2.8	Nd	3.4	Nd	83	Nd
PT008 /3	0.4	0.3	0.1	0.1	0.8	Nd	0.7	Nd	100	Nd
PT008 /4	3.0	0.9	0.1	0.1	4.1	Nd	2.7	Nd	100	Nd
PT008 /5	2.3	0.5	0.2	0.1	3.1	Nd	1.6	Nd	100	Nd
PT008 /6	5.5	1.5	0.2	0.1	7.3	Nd	2.2	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT008 /1	Nd	Nd	Nd	Nd	Nd	65.9	9.3	13.5	22.8	11.2	SL
PT008 /2	Nd	Nd	Nd	Nd	Nd	74.0	7.9	10.1	18.0	7.9	SL
PT008 /3	Nd	Nd	Nd	Nd	Nd	87.4	5.6	5.6	11.2	1.5	LS
PT008 /4	Nd	Nd	Nd	Nd	Nd	68.8	10.9	12.9	23.8	7.4	SL
PT008 /5	Nd	Nd	Nd	Nd	Nd	43.2	44.2	11.2	55.4	1.5	Zi L
PT008 /6	Nd	Nd	Nd	Nd	Nd	64.3	12.1	14.1	26.2	9.6	SL

Profile:	PT009	
Map unit:	TL	
Soil Classification:	Provisional Bhutan soil series:	Bajothangka
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Chang Yu, near the bridge end.	
GPS:	27^0 35'.31 N, 89^0 51'.57 E.	
Altitude:	1250 m a.s.l	
Described & sampled:	12.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Dry & hazy
Regional topography:	Main valley	
Site position:	Lower terrace along Mo Chhu	
Slope:	15%, 100 m long, terraced rectilinear, aspect E (90^0)	
Site drainage:	Poor, wet below 60cm and water table at about 1.3 m.	
Parent material:	Solid:	Mixed
	Drift:	Alluvial
Land use:	Fallow wetland	
Vegetation:	Rice stubble, forb weeds; grasses on bunds.	
Surface:	Litter:	Rice straw, horse & cow dung
	Outcrops	None
	Stones:	None
	Cracks:	0.5 cm wide, discontinuous
	Roots:	None
	Microrelief:	4 cm deep, Cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-13	2.5Y 6/1 (grey) with many medium & fine distinct yellow & orange mottles; silty loam+; strong medium subangular blocky; many medium & fine pores; dry & hard; many medium & fine roots; HCl negative; gradual regular boundary to: [Sample PT009/1 @ 0-10]
13-25	2.5Y 5/2 (greyish brown) with many fine & medium distinct reddish brown & orange mottles; silty loam+; strong fine & medium angular blocky; many medium & fine pores; slightly moist & very hard; few medium & fine roots; HCl negative; clear regular boundary to: [Not sampled]
25-51	5Y 4/1 (dark grey) with few medium & fine distinct orange & reddish brown mottles; very fine sandy clay loam+; strong medium subangular blocky; common fine pores; slightly moist & firm; no roots; HCl negative; gradual regular boundary to: [Sample PT009/2 @ 30-40]
51-62	5Y 4/1 (dark grey) with few medium & fine faint orange mottles; medium sandy loam; weak medium subangular blocky; moderate discontinuous clayskins on pore walls; few fine pores; moist & friable; HCl negative; abrupt regular boundary to: [Not sampled]
62-120	2.5Y 6/1 (grey) with prominent medium bands of 10YR 5/6 (yellowish brown) mottles; medium sand; single grain; wet & firm; no roots; HCl negative: [Sample PT009/3 @ 90-100]
120-150+	4/N (dark grey) with no mottles; silty clay; wet & very plastic & sticky; pores not seen; no roots; rounded boulders excavated; HCl negative; [Sample PT009/4 sampled by auger under water table]

Comments: It's a typical lower terrace soil with gley soils on the top and layered sand and rounded stone deposits. The soil is very deep and the texture gets heavier to silty clay at the lower horizons. The pH of the soil stays neutral through out the depth. Water table was met at the depth of 130cm. Very high exchangeable Ca++ in lowest horizon beneath the water table. High organic C in lowest horizon may be due to imported deposited organic matter.

SPAL analytical results for SSU Profile PT009 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT009 /1	0-10	6078	7.9	5.3	2.6	0.01	1	1.2	0.1	10
PT009 /2	30-40	6079	8.2	6.8	1.4	0.01	1	0.5	Tr	13
PT009 /3	90-100	6080	7.4	5.6	1.8	0.01	5	0.1	Tr	10
PT009 /4	ca 130	6081	6.8	4.3	2.5	0.01	1	3.6	0.2	16

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT009 /1	4.8	1.3	0.3	0.5	6.9	Nd	10.2	Nd	67	Nd
PT009 /2	8.8	2.3	o.2	0.3	11.6	Nd	12.4	Nd	93	Nd
PT009 /3	1.6	0.4	0.02	0.1	2.2	Nd	11.2	Nd	100	Nd
PT009 /4	20.2	4.7	0.5	0.3	25.7	Nd	9.6	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT009 /1	Nd	Nd	Nd	Nd	Nd	45.3	20.9	17.2	38.1	16.6	L
PT009 /2	Nd	Nd	Nd	Nd	Nd	39.0	13.0	20.3	33.3	27.7	CL
PT009 /3	Nd	Nd	Nd	Nd	Nd	89.0	4.3	4.9	9.2	1.7	S
PT009 /4	Nd	Nd	Nd	Nd	Nd	26.8	9.2	20.0	29.2	44.0	C

Profile:	PT010	
Map unit:	HR	
Soil Classification:	Provisional Bhutan soil series:	Walakha
	Soil Taxonomy:	Typic Rhodustalf
	WRB:	Rhodic Luvisol
Survey area:	Nyakulumpa Valley	
Location:	Red hill above the police station (ca 0.5 km upslope)	
GPS:	27^0 35.14' N, 89^0 51.23' E.	
Altitude:	1440 m a.s.l	
Described & sampled:	12.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 800 mm p.a.
	Recent weather:	Dry, hazy & windy
Regional topography:	Low mountain	
Site position:	Badland on the lower slope	
Slope:	28%, 500 m long, badlands; aspect ESE (110^0)	
Site drainage:	Good	
Parent material:	Solid:	Skarn
	Drift:	Colluvium
Land use:	Waste land, some fuel wood	
Vegetation:	Much red soil bare land, as pillars; scattered shrubs.	
Surface:	Litter:	Discontinuous lichen coating
	Outcrops	None
	Stones:	Common fine quartz & skarn gravel
	Cracks:	Few, less than 2 mm wide
	Roots:	None
	Microrelief:	ca 10 m deep gullies
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-12	7.5YR 5/6 (dry) (strong brown), 5YR 4/4 (moist) (reddish brown) with very few fine faint weathered pink and yellow specks of mottles; fine sandy clay loam; moderate fine subangular blocky; common coarse & medium pores; dry & very hard; few to many medium & fine roots; few fine quartz & gneiss stones; HCl negative; worm burrows; diffuse boundary to: [Sample PT010/1 @ 0-10]
12-41	2.5YR 4/6 (dry) (red); 2.5YR 3/4 (moist) (dark reddish brown) with no mottles; fine sandy clay loam+; moderate medium subangular blocky; many medium & fine & few coarse pores; dry & hard; common medium & fine roots; few quartzite & angular gneiss stones; HCl negative; worm burrows; diffuse boundary to: [Sample PT010/2 @ 20-30]
41-111	2.5YR 4/4 (dry) (reddish brown), 2.5YR 3/4 (moist) (dark reddish brown); fine sandy clay; moderate medium subangular blocky; weak discontinuous clayskins; many medium, fine & few coarse pores; slightly moist, firm in hand & friable in face; common medium & fine roots; few quartz & gneiss & angular granite stones; common fine FeMn stains and concretions; HCl negative; worm burrows; diffuse boundary to: [Sample PT010/3 @ 60-70]
111-155+	2.5YR 3/4 (dark reddish brown) with many fine pink, yellow and orange weathered rock spots; fine sandy clay loam+; strong medium subangular blocky breaking to medium fine crumb; very discontinuous weak clayskins; many medium & few fine coarse pores; slightly moist, firm in face & friable in hand; common medium & fine roots down the cracks together with clayskins; common coarse, medium & fine weathered sugary quartz & gneiss stones; common fine manganese stains and concretions; HCl negative; [Sample PT010/4 @ 120-130]

Comments: Highly eroded red soil with small soil pillars formed. The red soil is formed from skarn rock. The pH stays neutral or slightly acid throughout and soil is fully base saturated. The texture gets heavier with the depth.

SPAL analytical results for SSU Profile PT010 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT010 /1	0-10	6082	6.4	4.3	2.1	0.01	1	0.7	0.1	12
PT010 /2	20-30	6083	6.3	4.6	1.7	0.01	1	0.1	Tr	10
PT010 /3	60-70	6084	5.9	4.2	1.7	0.01	1	0.7	Tr	70
PT010 /4	120-130	6085	5.7	4.3	1.4	0.01	1	0.4	Tr	20

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT010 /1	4.0	1.7	0.2	0.1	6.0	Nd	4.7	Nd	100	Nd
PT010 /2	4.8	2.0	0.3	0.1	7.2	Nd	5.8	Nd	100	Nd
PT010 /3	5.2	1.9	0.3	0.1	7.5	Nd	6.6	Nd	100	Nd
PT010 /4	4.7	1.8	0.3	0.1	6.9	Nd	5.3	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT010 /1	Nd	Nd	Nd	Nd	Nd	55.3	9.1	9.9	19.0	25.7	SCL
PT010 /2	Nd	Nd	Nd	Nd	Nd	54.6	5.0	9.9	14.9	30.5	SCL
PT010 /3	Nd	Nd	Nd	Nd	Nd	31.2	7.6	11.2	18.8	50.0	C
PT010 /4	Nd	Nd	Nd	Nd	Nd	41.3	7.1	12.0	19.1	39.7	CL

Profile: PT011

Map unit: FR

Soil Classification: Provisional Bhutan soil series: Kubji
Soil Taxonomy: (Anthraquic) Haplustept
WRB: Hydragric Anthrosol

Survey area: Nyakulumpa Valley
Location: Thara, below TT16 & about 10 m below AT0057.
GPS: 27^0 35.34' N, 89^0 51.15' E.
Altitude: 1440 m a.s.l

Described & sampled: 15.3.1999, Tshering Dorji

Climate: General: Subtropical, P = ca 750 mm p.a
Recent weather: Sunny

Regional topography: Low mountain
Site position: Middle section of alluvial fan.

Slope: 28%, 500 m long, terrace rectilinear; aspect E (100^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Fan alluvium

Land use: Fallow wetland
Vegetation: Rice stubble with grasses on bunds.

Surface: Litter: Few scattered cow dung
Outcrops None
Stones: None
Cracks: 2-3 mm wide, discontinuous
Roots: None
Microrelief: Irregular cattle poaching (1-2 cm deep)
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0-14 2.5Y 7/2 (dry) (light grey), 2.5Y 5/1 (moist) (grey) with common medium & fine distinct reddish brown & orange mottles; fine sandy loam; moderate medium subangular blocky; few fine & medium pores; slightly dry & slightly friable; many fine & medium roots; HCl negative; diffuse boundary to: [Sample PT011/1 @ 0-10]

14-24 2.5Y 6/2 (light brownish grey) with abundant medium & fine distinct reddish brown & orange mottles; fine sandy loam; moderate medium subangular blocky; few fine & medium pores; moist & slightly friable; many fine & medium roots; HCl negative; slightly diffuse boundary to: [Sample PT011/2 @ 15-20]

24-32 10YR 4/4 (dark yellowish brown) with few medium & fine distinct grey mottles; fine sandy clay loam; moderate medium subangular blocky breaking to weak medium crumb; weak discontinuous clayskins on pore walls; many fine & medium pores; moist & slightly friable; few fine & rare medium roots; HCl negative; clear regular boundary to: [Not sampled]

32-44 10YR 5/6 (yellowish brown) with few medium & fine distinct grey mottles; fine sandy clay loam; moderate medium subangular blocky breaking to weak moderate crumb; weak discontinuous clayskins on pore walls; many fine & medium pores; moist & slightly friable; no roots; HCl negative; clear regular boundary to: [Not sampled]

44-61 10YR 3/3 (dark brown) with few medium & fine orange & black mottles; medium sandy clay loam; moderate medium subangular blocky breaking to weak moderate crumb; moderate discontinuous clayskins; few fine pores; moist & friable; no roots; few fine hard angular quartz & soft gneiss stones; HCl negative; clear regular boundary to: [Sample PT011/3 @ 50-60]

61-74 2.5Y 5/2 (greyish brown) with few medium distinct brown & black mottles; coarse sandy loam; weak fine subangular blocky breaking to weak fine crumb; few fine & medium pores; moist & friable; few fine hard angular quartz & soft gneiss stones; few medium soft FeMn concretions; HCl negative; clear regular boundary to: [Sample PT011/4 @ 65-70]

74-98 5YR 4/4 (reddish brown) with abundant medium distinct grey mottles; fine sandy clay; weak fine subangular blocky breaking to weak fine crumb; weak discontinuous clayskins; many medium & fine pores; moist & plastic; no roots; few fine hard angular quartz & soft gneiss stones; few medium soft FeMn concretions; HCl negative; diffuse boundary to: [Sample PT011/5 @ 80-90]

98-130+ 2.5YR 3/6 (dark red) with abundant medium distinct grey mottles; fine sandy clay; weak fine subangular blocky breaking to weak fine crumb; weak discontinuous clayskins; many medium & fine pores; moist & plastic; few fine hard angular quartz & soft gneiss stones; few medium soft FeMn concretions; HCl negative: [Not sampled]

Comments: The mature soil may originally have been reddish throughout but due to prolonged wetland cultivation the colour of the top layer soil changed to gley. The pH value changes from acid to neutral with depth, typical for fan soils.

SPAL analytical results for SSU Profile PT011 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT011 /1	0-10	6123	5.2	3.8	1.4	0.01	8	1.5	0.1	19
PT011 /2	15-20	6124	5.8	4.3	1.5	0.01	2	0.9	0.1	11
PT011 /3	50-60	6125	7.0	5.2	1.8	0.01	1	0.3	Tr	30
PT011 /4	65-70	6126	7.4	5.4	2.0	0.01	3	0.2	Tr	20
PT011 /5	80-90	6127	7.3	5.7	1.6	0.01	1	0.4	Tr	20

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT011 /1	2.3	2.4	0.3	0.2	3.2	Nd	4.9	Nd	65	Nd
PT011 /2	2.5	1.0	0.2	0.3	3.9	Nd	4.9	Nd	80	Nd
PT011 /3	2.5	1.3	0.3	0.2	4.2	Nd	4.4	Nd	96	Nd
PT011 /4	1.6	1.0	0.3	0.2	3.0	Nd	2.4	Nd	100	Nd
PT011 /5	2.7	2.0	0.6	0.1	5.4	Nd	6.1	Nd	89	Nd

Fine earth granulometric

SSU 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		
PT011 /1	Nd	Nd	Nd	Nd	Nd	47.7	11.8	21.0	32.8	19.5	L
PT011 /2	Nd	Nd	Nd	Nd	Nd	50.6	11.4	22.4	33.8	15.6	L
PT011 /3	Nd	Nd	Nd	Nd	Nd	60.9	9.2	13.2	22.4	16.7	SL
PT011 /4	Nd	Nd	Nd	Nd	Nd	72.2	8.3	9.3	17.6	10.2	SL
PT011 /5	Nd	Nd	Nd	Nd	Nd	35.4	12.4	21.8	34.2	30.4	CL

Profile:	PT012	
Map unit:	FR	
Soil Classification:	Provisional Bhutan soil series:	Kubji
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Thara traverse # TT 3.	
GPS:	27^0 35.43' N, 89^0 51.31' E.	
Altitude:	1260 m a.s.l	
Described & sampled:	18.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Misty & dry
Regional topography:	Low Mountain	
Site position:	Side valley, middle alluvial fan.	
Slope:	4%, 1.5 km long, terraced rectilinear aspect ENE (70^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Fan alluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses on bunds.	
Surface:	Litter:	Few scattered cow dung & rice straw
	Outcrops	None
	Stones:	None
	Cracks:	Discontinuous 2-3 mm wide.
	Roots:	Non
	Microrelief:	Irregular cattle poaching (1-2 cm deep)
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-15	5Y 5/2 (olive grey) with common medium & fine distinct orange & yellow mottles; very fine sandy clay loam; moderate medium subangular blocky breaking to moderate fine subangular blocky; moderate very discontinuous clayskins only in burrows; many medium & fine pores; slightly moist & slightly friable; many medium & fine roots; HCl negative; gradual regular boundary to: [Sample PT012/1 @ 0-10]
15-31	5Y 5/1 (grey) with many coarse & medium distinct orange & yellow mottles; silty clay loam +; strong medium angular blocky; moderate, almost continuous clayskins; few fine pores; moist & very firm; few fine roots; HCl negative; abrupt regular boundary to: [Sample PT012/2 @ 20-30]
31-38/44	Mixed dark brown, reddish brown & vesicular iron & manganese pan; brittle; vesicles (voids) with continuous grey to dark grey cutans; occasional gravelly and gritty but concretions are not stone-cored; HCl negative; wavy gradual boundary to: [Not sampled]
38/44-59	10YR 3/3 (dark brown) with many coarse distinct grey mottles; medium sandy loam +; moderate medium subangular blocky breaking to weak moderate crumb; moderate almost continuous cutans; many medium & fine pores; moist & firm; few soft & hard gneiss with hard quartz stones; HCl negative; abrupt regular boundary to: [Sample PT012/3 @ 40-50]
59-93	10YR 5/6 (yellowish brown) with abundant medium distinct grey, pale brown & orange mottles; medium sandy clay; moderate medium angular breaking to moderate fine subangular blocky; strong continuous grey clayskins & brown organic cutans; abundant medium & fine pores; moist & friable; common medium slightly round & angular soft & hard gneiss & quartz stones; many medium & coarse black & dark brown hard and soft iron & manganese concretions; HCl negative; diffuse boundary to: [Sample PT012/4 @ 70-80]
93-128+	5YR 4/6 (yellowish red) with abundant medium prominent grey & pale brown mottles; stony medium sandy clay; moderate fine & medium subangular blocky breaking to moderate fine crumb; very strong discontinuous clayskins; common medium pores; slightly wet & friable; many medium slightly round & angular, soft & hard gneiss & quartz

stones; common medium & fine reddish brown & dark brown slightly hard & soft FeMn concretions; HCl negative: [Not sampled]

Comments: Two possible parent materials i.e aeolian deposit on the top with silty & fine sand and alluvial fan in the subsoil. it is a good rice profile. Iron and manganese concretions are almost cemented. The pH changes from acid to neutral with depth but base saturation is high throughout.

SPAL analytical results for SSU Profile PT012 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU	Depth	SPAL	pH			EC	Avail.	Organic	Total N	C:N
No.	cm	Lab No	H2O	KCl	Diff	mS/cm	P ppm	C%	%	
PT012 /1	0-10	6128	5.0	3.8	1.2	0.01	1	1.4	0.1	16
PT012 /2	20-30	6129	6.7	4.9	1.8	0.01	1	0.6	Tr	15
PT012 /3	40-50	6130	7.6	5.6	2.0	0.01	5	0.2	Tr	20
PT012 /4	70-80	6131	7.9	5.7	2.2	0.01	6	0.2	Tr	10

Exchangeable base status

SSU	Exchangeable				TEB	Extr Al	CEC		BS%	
No.	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT012 /1	2.8	0.5	0.3	0.1	3.7	Nd	4.0	Nd	93	Nd
PT012 /2	2.9	1.6	0.2	0.1	4.8	Nd	4.9	Nd	98	Nd
PT012 /3	3.0	1.1	0.2	0.1	4.4	Nd	4.0	Nd	100	Nd
PT012 /4	3.1	1.6	0.4	0.1	5.3	Nd	4.4	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT012 /1	Nd	Nd	Nd	Nd	Nd	44.6	11.8	23.4	35.2	20.3	L
PT012 /2	Nd	Nd	Nd	Nd	Nd	45.1	11.7	18.8	30.5	24.4	L
PT012 /3	Nd	Nd	Nd	Nd	Nd	51.0	12.7	16.6	29.3	19.6	L
PT012 /4	Nd	Nd	Nd	Nd	Nd	65.3	10.1	12.0	22.1	12.5	SL

Profile:	PT013	
Map unit:	FB	
Soil Classification:	Provisional Bhutan soil series:	Thara
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Chang Yu traverse # TT2.	
GPS:	27^0 35.25' N, 89^0 51.39' E.	
Altitude:	1260 m a.s.l	
Described & sampled:	18.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Misty but dry
Regional topography:	Main valley	
Site position:	Front side valley, edge side valley fan.	
Slope:	4%, 1 km long, terraced rectilinear aspect SE (120^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Alluvial fan.
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses on bunds.	
Surface:	Litter:	Few scattered cow dung & rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	Network of fine cracks (3 mm wide).
	Roots:	None
	Microrelief:	Irregular cattle poaching (1-2 cm deep)
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-16	2.5Y 7/3 (dry) (pale yellow); 2.5Y 5/2 (moist) (greyish brown) with common medium & fine distinct yellow mottles; very fine sandy loam; moderate medium subangular blocky; many medium & fine pores; dry & slightly firm; many medium & fine roots; HCl negative; gradual regular boundary to: [Sample PT013/1 0-10]
16-35	2.5Y 6/2 (pale yellow) with abundant medium & fine distinct yellowish red & orange mottles; fine sandy loam+; moderate medium subangular blocky; few medium & many fine pores; slightly moist & slightly firm; rare fine roots; HCl negative; gradual regular boundary to: [Sample PT013/2 20-30]
35-78	2.5Y 5/1 (grey) with many medium & fine distinct reddish brown & orange mottles; medium sandy loam+; weak coarse subangular breaking to moderate fine subangular blocky; continuous moderate clayskins; many medium & fine roots; moist & slightly friable & brittle; few medium soft black & reddish brown concretions; HCl negative; clear regular boundary to: [Sample PT013/3 @ 50-60]
78-86	Mixed fine grey & brown with common medium distinct orange mottles; medium sandy loam; weak medium subangular blocky breaking to weak fine crumb; common medium & fine pores; moist & slightly wet & friable; HCl negative; clear regular boundary to: [Not sampled]
86-102	10YR 4/2 (dark greyish brown) with common medium & fine distinct reddish brown & red mottles; medium sandy clay loam; weak medium subangular blocky; very weak discontinuous cutans; medium & fine pores; slightly wet & slightly friable; few round hard quartz & common quartz & granite gravel; few medium soft dark brown concretions; HCl negative; gradual regular boundary to: [Sample PT013/4 @ 90-100]
102-150	10YR 4/2 (dark grey brown) with no mottles; common sand silty loam+; weak medium subangular blocky breaking to weak medium subangular blocky; rare medium very discontinuous cutans; many medium & fine pores; slightly wet & friable; few fine hard round quartz & gneiss gravel; continuous medium hard black concretions; HCl negative; few fine shards; clear wavy boundary to: [Not sampled]

150-165+ 10YR 4/4 (dark yellowish brown) with common fine distinct red & reddish brown mottles; medium sandy clay loam; moderate fine subangular blocky; moderate discontinuous brownish grey silty cutans; many medium & fine pores; slightly wet & slightly friable; few round medium & fine hard quartz &rare slightly hard manganese coated weathering sand stone; common medium hard black concretions; HCl negative; common rounded shard;
[Not sampled]

Comments: Fan soil with greyish brown subsoil. Shards found below 100cm of depth. The pH changes from neutral to acid with depth.

SPAL analytical results for SSU Profile PT013 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT013 /1	0-10	6132	6.8	3.8	3.0	0.01	4	1.0	0.1	14
PT013 /2	20-30	6133	7.4	4.7	2.7	0.01	2	0.3	Tr	10
PT013 /3	50-60	6134	7.6	5.3	2.3	0.01	3	0.3	Tr	15
PT013 /4	90-100	6135	5.2	4.5	0.7	0.01	2	0.3	Tr	30

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT013 /1	2.2	0.5	0.3	0.1	3.1	Nd	2.9	Nd	100	Nd
PT013 /2	1.9	0.9	0.2	0.1	3.2	Nd	3.0	Nd	100	Nd
PT013 /3	2.4	1.2	0.1	0.1	3.7	Nd	3.3	Nd	100	Nd
PT013 /4	3.4	1.7	0.2	Nd	Nd	Nd	5.3	Nd	Nd	Nd

Fine earth granulometric

SSU 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		
PT013 /1	Nd	Nd	Nd	Nd	Nd	51.3	13.4	18.6	32.0	16.6	L
PT013 /2	Nd	Nd	Nd	Nd	Nd	55.8	12.3	17.6	29.9	14.3	SL
PT013 /3	Nd	Nd	Nd	Nd	Nd	62.8	9.3	12.5	21.8	15.4	SL
PT013 /4	Nd	Nd	Nd	Nd	Nd	62.2	7.8	12.7	20.5	17.2	SL

Profile:	PT014	
Map unit:	TM	
Soil Classification:	Provisional Bhutan soil series:	Wangjokha
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Chang Yu. ca 100 m NE of police station	
GPS:	27^0 35.19' N, 89^0 51.52' E.	
Altitude:	1250 m a.s.l	
Described & sampled:	18.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Misty & dry
Regional topography:	Main valley	
Site position:	Middle terrace	
Slope:	4%, 0.5 km long, terraced rectilinear, aspect NE (55^0)	
Site drainage:	Good	
Parent material:	Solid:	Mixed
	Drift:	Alluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses on bunds.	
Surface:	Litter:	Few scattered cow dung & rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	Continuous up to 1 cm
	Roots:	None
	Microrelief:	Very slight old poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-13	2.5Y 7/2 (dry) (light grey); 5Y 5/2 (moist) (olive grey) with common medium & fine distinct orange & yellow mottles; silty loam; strong medium subangular blocky; many medium & fine pores; dry slightly hard; common medium & fine roots; HCl negative; gradual regular boundary to: [Sample PT014/1 @ 0-10]
13-31	2.5Y 5/1 (grey) with common fine distinct yellowish red mottles; very fine sandy clay loam; strong medium subangular blocky; common fine pores; slightly moist & firm; few fine & medium roots; HCl negative; clear regular boundary to: [Sample PT014/2 @ 15-25]
31-55	2.5Y 5/1 (grey) with many medium distinct orange & reddish brown mottles; fine sandy clay loam; strong coarse angular breaking to strong medium angular blocky; moderate continuous clayskins; common medium & fine pores; moist & very firm; rare fine roots; HCl negative; clear regular boundary to: [Sample PT014/3 @ 35-50]
55-76	10YR 4/2 (dark greyish brown) with common medium & few fine reddish brown mottles; medium sandy loam+; moderate medium subangular blocky breaking to moderate fine crumb; strong discontinuous clayskins; few fine pores; moist & friable; few fine hard round gneiss gravels; common fine soft black concretions at top of horizon; HCl negative; clear regular boundary to: [Not sampled]
76-99	2.5Y 5/3 (light olive brown) with no mottles; coarse sandy loam; weak fine subangular blocky breaking to weak fine crumb; strong discontinuous clayskins; few fine pores; moist & friable; few fine hard quartz & gneiss stones; common fine soft black concretions in all the horizons; HCl negative; abrupt regular boundary to: [Sample PT014/4 @ 80-90]
99-120	Banded dark brown & brownish yellow brown with pale brown and light grey mottles; loamy medium sand; very weak medium platy breaking to single grain; moist & very friable; rare angular & hard quartz & gneiss stones; common fine & medium soft, black & dark brown concretions; HCl negative; abrupt regular boundary to: [Sample PT014/5 @100-115]

120-140	2.5Y 4/1 (dark grey) with common medium & fine distinct reddish brown mottles; fine sandy loam; weak medium subangular blocky; few fine pores; slightly wet & plastic & friable; HCl negative; abrupt regular boundary to: [Not sampled]
140-147	10YR 4/4 (dark yellowish brown) with common medium distinct light grey mottles; very fine sandy loam; weak medium subangular blocky; moderate very discontinuous cutans on pore walls; few medium & fine pores; slightly wet & friable; HCl negative; abrupt boundary to: [Not sampled]
147-158	10YR 4/3 (brown) with common medium & few fine dark brown mottles; coarse sandy loam; moderate medium subangular blocky; common medium & fine pores; slightly wet & friable; common medium hard black concretions; HCl negative; clear regular boundary to: [Not sampled]
158-176+	2.5Y 5/2 (greyish brown) with common medium & few faint reddish brown and orange mottles; medium sandy loam +; weak medium subangular blocky; continuous moisture film; common fine & medium pores; slightly wet & slightly firm; many clayskins & medium soft black & dark brown manganese concretions; HCl negative: [Not sampled]
Comments:	Clearly alluvial even through high stony layering of sand sizes. Sand layer is very banded. Good rice profile with manganese at 50cm and also at deeper level.

SPAL analytical results for SSU Profile PT014 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT014 /1	0-10	6136	7.7	4.8	2.9	0.01	1	1.1	0.1	14
PT014 /2	15-25	6137	5.1	4.7	0.4	0.01	1	0.6	0.1	10
PT014 /3	35-50	6138	6.8	5.8	1.0	0.01	2	0.4	Tr	20
PT014 /4	80-90	6139	8.1	6.3	1.8	0.01	4	0.1	Tr	10
PT014 /5	100-115	6140	8.4	6.3	2.1	0.01	4	0.1	Tr	5

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT014 /1	3.5	0.7	0.2	0.2	4.6	Nd	5.9	Nd	78.6	Nd
PT014 /2	3.6	1.5	0.2	0.2	5.4	Nd	4.8	Nd	100	Nd
PT014 /3	2.7	1.8	0.5	0.2	5.2	Nd	4.4	Nd	100	Nd
PT014 /4	3.6	1.1	0.2	0.3	5.1	Nd	5.4	Nd	95	Nd
PT014 /5	1.7	1.7	0.1	0.2	2.5	Nd	3.8	Nd	65	Nd

Fine earth granulometric

SSU 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		
PT014 /1	Nd	Nd	Nd	Nd	Nd	44.3	13.4	22.9	36.3	19.4	L
PT014 /2	Nd	Nd	Nd	Nd	Nd	43.3	19.2	18.7	37.9	18.7	L
PT014 /3	Nd	Nd	Nd	Nd	Nd	50.4	7.1	19.8	26.9	22.7	SCL
PT014 /4	Nd	Nd	Nd	Nd	Nd	53.8	24.2	9.6	33.8	12.4	SL
PT014 /5	Nd	Nd	Nd	Nd	Nd	89.0	4.3	2.9	7.2	3.7	S

Profile:	PT015	
Map unit:	HD	
Soil Classification:	Provisional Bhutan soil series:	Kyelikha
	Soil Taxonomy:	(Anthraquic) Haplustept
	WRB:	Hydragric Anthrosol
Survey area:	Nyakulumpa Valley	
Location:	Beopighakha, & about 100 m west of police station.	
GPS:	27^0 35.11' N, 89^0 51.43" E.	
Altitude:	1260 m a.s.l	
Described & sampled:	19.3.1999, Tshering Dorji	
Climate:	General:	Subtropical, P = ca 750 mm p.a
	Recent weather:	Sunny
Regional topography:	Low mountain	
Site position:	Lower slope	
Slope	10%, 0.5 km long, terraced rectilinear; aspect NS (70^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Colluvium
Land use:	Fallow wetland	
Vegetation:	Rice stubble & grasses on bunds.	
Surface:	Litter:	Few scattered cow dung & rice straw
	Outcrops:	None
	Stones:	None
	Cracks:	Continuous up to 1 cm
	Roots:	None
	Microrelief:	Rare irregular cattle poaching
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0-19	2.5Y 5/2 (dry) (greyish brown), 2.5Y 7/2 (moist) (light grey) with common medium & fine distinct yellowish orange mottles; silty loam; moderate medium subangular blocky; few medium & fine pores; dry & very hard; common medium & fine roots; few fine & medium hard gneiss stones; HCl negative; gradual regular boundary to: [Sample PT015/1 @ 0-10]
19-50	2.5Y 6/2 (light brownish grey) with many fine distinct orange & yellow mottles; fine sandy loam; moderate medium subangular blocky; common medium & fine pores; slightly moist & very hard; rare fine roots; HCl negative; clear regular boundary to: [Sample PT015/2 @ 30-40]
50-78	10YR 4/3 (brown) with common medium & fine distinct grey mottles; medium sandy clay loam; moderate fine subangular blocky breaking to moderate fine crumb; medium distinct clayskins; common medium & fine pores; moist & slightly friable; HCl negative; clear regular boundary to: [Not sampled]
78-98	10YR 5/6 (yellowish brown) with common medium & fine distinct grey mottles; medium sandy clay loam; moderate fine subangular blocky breaking to moderate fine crumb; moderate distinct clayskins; few medium & fine pores; moist & slightly friable; few fine hard & soft quartz & gneiss stones; HCl negative; clear regular boundary to: [Not sampled]
98-113	2.5Y 5/1 (grey) with common medium & fine distinct reddish brown mottles; medium sandy clay loam +; moderate fine subangular blocky breaking to moderate fine crumb; moderate almost continuous clayskins; common medium & fine pores; moist & slightly wet & friable; few fine hard & soft quartz & gneiss stones; HCl negative: [Sample PT015/3 @ 100-110]
113-150+	10YR 3/3 (dark brown) with no mottles; medium sandy clay loam +; moderate fine subangular blocky breaking to moderate fine crumb; moderate almost continuous clayskins; common medium & fine pores; moist & slightly wet & friable; common medium & fine hard quartz & soft gneiss; HCl negative: [Sample PT015/4 @ 120-130]

Comments: Texture gets heavier with depth and good clayskins. Typical deep hill soil. The pH value changes from very acid to neutral with depth, with accompanying increase in BS%.

SPAL analytical results for SSU Profile PT015 Survey area: Nyakulumpa Valley

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PT015 /1	0-10	6141	5.1	3.7	1.4	0.01	11	1.1	0.1	12
PT015 /2	30-40	6142	5.9	4.2	1.7	0.01	3	0.5	0.1	10
PT015 /3	100-110	6143	7.3	5.4	1.7	0.01	3	0.3	Tr	10
PT015 /4	120-130	6144	7.3	5.5	1.8	0.01	5	0.3	Tr	15

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT015 /1	1.3	0.4	0.2	0.3	2.2	Nd	7.9	Nd	28	Nd
PT015 /2	3.0	0.9	0.2	0.3	4.4	Nd	7.5	Nd	58	Nd
PT015 /3	4.4	1.3	0.2	0.3	6.2	Nd	7.4	Nd	83	Nd
PT015 /4	4.7	1.4	0.2	0.3	6.6	Nd	6.5	Nd	100	Nd

Fine earth granulometric

SSU 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		
PT015 /1	Nd	Nd	Nd	Nd	Nd	54.5	10.1	17.4	27.5	18.0	SL
PT015 /2	Nd	Nd	Nd	Nd	Nd	54.2	11.7	18.3	30.0	15.9	SL
PT015 /3	Nd	Nd	Nd	Nd	Nd	59.3	11.9	14.3	26.2	14.5	SL
PT015 /4	Nd	Nd	Nd	Nd	Nd	56.9	12.8	14.1	26.9	16.2	SL

APPENDIX C: CORRELATION OF NYAKULUMPA SOILS

AppC.1 Soil classification and correlation in Bhutan

Table 5.3 in the main report summarises the correlation of the Nyakulumpa soil classes with the international soil classifications. This appendix discusses the correlations assigned. This is necessary because SSU is still in its formative stages, and the soil correlations need to be worked out. Some of the correlations will undoubtedly be revised in the future, as we learn more about the soils of Bhutan, and as the international systems are modified.

There are two main international systems of soil classification. The USDA Soil Taxonomy was originally developed to meet the needs of soil survey in the continental United States. It has been extended since then, but it is still stronger on temperate than on tropical soils. It is detailed and comprehensive. The FAO system is more globally oriented, and is less detailed but quite comprehensive. It has the advantage that it uses more traditional and comprehensible soil names.

Pedologists working in Nepal have mostly used the Soil Taxonomy but previous consultants in Bhutan have preferred the FAO system. At this stage it is not necessary for Bhutan to decide which, if either, of the two systems to adapt. For the present, SSU will use local soil classes and names within Bhutan, and will correlate them against both of the international systems (AHT 1995).

AppC.2 General Criteria

Before considering the individual soil classes, there are some environmental characteristics that need to be determined before the application of Soil Taxonomy.

AppC 2.1 Soil moisture regime

This is necessary for the assignment to suborders or great groups in Soil Taxonomy. In the absence of soil moisture data, soil moisture regimes are approximated from rainfall totals and distribution.

The lower part of the survey area has distinctively 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. Even though moister, the upper part of the area probably also has an ustic SMR. This has been assumed in the correlations in Table 5.3, and in Appendix B. However the SMR may grade to udic, which also has summer rainfall but the soils are dry for less than 90 consecutive days.

AppC 2.2 Soil temperature regime

This is a criterion for classification at family level in Soil Taxonomy. In the absence of soil temperature data, atmospheric temperatures are used. Punakha has a thermic atmospheric

temperature regime, with an annual mean between 15^0 C and 22^0 C and a summer – winter difference greater than 5^0 C. All of the soils at Nyakulumpa are assumed to have thermic soil temperature regimes.

AppC 2.3 Mineralogy class

This is another family criterion in Soil Taxonomy. Although muscovite is a highly visible component in many soils at Bajo, mica contents are less than 40 % of the sand and gravel fractions, so that the soils do not qualify as micaceous, and have to be classified in the mixed mineralogy class.

AppC 2.4 Particle size class

This family criterion in ST varies with stone content and fine earth texture, and is therefore varies for the different soil classes at Nyakulumpa, although most are coarse, medium or fine loamy.

AppC.3 Correlation of Nyakulumpa soils

AppC 3.1 Shallow hill soil (HS)

The shallower of the gneissic hill soils fit well into the Inceptisols of ST or Leptosols of FAO. Most of the top soils are shallow (<18cm) and the profiles qualify for the suborder of Ustepts in ST. In FAO these soils are mostly deeper than the Lithic subgroups.

AppC 3.2 Deep and moderately deep hill soils

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 terrace soils, the degree of weathering is assumed to overrule the depositional layering, and most of them are better as Cambisols or Ustepts.

AppC 3.3 Red clay (HR)

This class is difficult to correlate for two main reasons:

We know from Lingmutey Chhu that these soils are chemically heterogeneous, with different profiles qualifying a dystric (<50% base saturation) or eutric (>50%).

Their erodibility, 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, these soils 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.

AppC 3.4 Fan soils (FR & FB)

The fan is fairly young (it postdates the middle terrace). However the soils appear sufficiently weathered and developed to qualify as Cambisols or Ustepts rather than as raw Regosols or Entisols. Both appear to eutric rather than dystric.

AppC 3.5 Middle and lower terrace soils (TM and TL)

These alluvial soils are of different ages and therefore different degrees of weathering since deposition. The older soils on the middle terrace are less obviously layered, and are more weathered and have redder colours. They probably therefore qualify as Typic Eutrustepts in Soil Taxonomy or Eutric Cambisols in WRB. The soils of the lower terrace are more distinctly layered and less weathered. They appear to qualify as Entisols in Soil Taxonomy. The low levels of organic matter in the subsoils make some of them Orthents rather than Fluvents, despite the obviously fluvial origin of the alluvium. Other profiles (eg. PT008 and PT009) have erratic subsoil Organic C contents, and are therefore Ustifluvents.

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 of the middle and

lower terrace soils have probably been artificially gleyed to a sufficient degree to quality as anthraquic horizons, and the subsoils with black manganese mottling may qualify as hydragric horizons. This qualifies these soils as Hydragric Anthrosols. However the full implications of the FAO (1998) modifications have not yet been fully assimilated and they are not yet being applied by SSU. In ST there are Anthraquic subgroups of the Fluvents. There is also a Haplanthrept group in the Inceptisols, but there is not yet any provision for an aquic subgroup with in it.

APPENDIX D: SOIL SURVEY UNIT

AppD.1 Soil Survey Unit (SSU)

The Soil Survey Unit (SSU) 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 has been 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. SSU reports 1, 2, SS3, and SS4). They enabled soil patterns to be worked out by direct observation with the minimum of extrapolation and assumptions.

This is the tenth soil survey undertaken by Project. Its training objective is to acquaint the new graduate surveyor 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.

AppD.2 SSU main surveys and reports

SSU No.	Title	Status October, 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 & SS4(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	Final 5(a) distributed 4/99. #5 finalised (not yet distributed)
SS 6 & SS 6(a)	General & Technical reports of semi-detailed soil survey of Radhi geog	Draft distributed for feedback, 8/99.
SS 7 & SS 7(a)	General & Technical reports of semi-detailed soil survey of Lame Gompa Research Forest	Draft distributed for feedback, 4/99.
SS 8	Report of reconnaissance survey of soils of Merak and Sakten	Draft distributed for feedback, 8/99.
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 & 10 (a)	General and Technical reports of semi-detailed soil survey of arable lands of Nyakulumpa valley, Punakha	This report final, distributed 10/'99