

CONTENTS

SUMMARY	3
S.1 Background	3
S.2 Location and Environment	3
S.3 Soils	4
<i>Table S.1 Summary of soil series in Sangma Ri watershed</i>	<i>4</i>
<i>Figure S.1 Soil map of Sangma Ri Watershed, Dremetse</i>	<i>5</i>
S.4 Implication of results	6
ACKNOWLEDGEMENTS	7
ABBREVIATIONS AND GLOSSARY	8
1. INTRODUCTION	11
1.1 Sangma Ri Watershed integrated research and extension area	11
1.2 Aims of the Sangma Ri semi-detailed soil survey	11
2. SURVEY AREA	12
2.1 Location and extent	12
<i>Figure 2.1 Location map of the survey area</i>	<i>12</i>
2.2 Climate	13
2.3 Geology and soil parent materials	13
2.4 Topography and drainage	14
2.5 Land Use and Vegetation	14
3. PREVIOUS SOILS INFORMATION	16
3.1 LUPP (1995)	16
3.2 Sinclair Knight (1983)	16
4. METHODS	17
4.1 Field	17
<i>Figure 4.1 Distribution of soil survey sites (profiles) in Sangma Ri watershed</i>	<i>17</i>
4.2 Mapping	18
4.3 Laboratory	18
5. SOIL CLASSIFICATION, CHARACTERISTICS AND CORRELATION	19
5.1 Soil classification	19
5.2 Characteristics of soil series in Sangma Ri watershed	19
5.2.1 Dremetse series	19
5.2.2 Gashari series	19
5.2.3 Shadang series	20
5.2.4 Bageng series.....	20
5.2.5 Sulukphu series	21

5.2.6	Zangkhar series	21
5.2.7	Debari series	21
5.2.8	Phungtshing series	22
5.2.9	Sangma series	22
5.2.10	Yayang series	23
	<i>Table 5.1 Summary of soil series in Sangma Ri watershed</i>	23
5.2.11	Analytical characteristics of soil classes	24
	<i>Table 5.2 Ranges of chemical analyses, by soil series, Sangma Ri</i>	24
5.3	Soil correlation	24
5.3.1	Correlation with LUPP (1995)	24
5.3.2	Correlation with Sinclair Knight (1983)	25
	<i>Table 5.3 Correlations with LUPP (1995) Dremetse on Shumar phyllite and quartzite</i>	25
	<i>Table 5.4 Approximate correlations with Sinclair Knight (1983) soil classes</i>	26
5.3.3	Correlation with soils at Wengkhar	26
5.3.4	Correlations with international systems	26
	<i>Table 5.5 International correlations of soil series at Sangma Ri</i>	27
5.3.5	Correlation with geotechnical classification of soils	28
	<i>Table 5.6 Geotechnical correlation of Sangma Ri soil series</i>	28
6.	SOIL DISTRIBUTION AND MAPPING	29
6.1	Soil distribution	29
6.2	Soil mapping units	29
	<i>Table 6.1 Composition of soil mapping units at Sangma Ri watershed</i>	29
	<i>Figure 6.1 Soil map of Sangma Ri Watershed, Dremetse</i>	30
7.	OVERVIEW AND IMPLICATIONS	31
7.1	Overview of soils	31
7.2	Implication of results	31
	REFERENCES	32
	APPENDIX A: LABORATORY METHODS	34
	<i>Table A.1 Summary of current interpretation of SPAL soil analyses</i>	36
	APPENDIX B: SOIL PROFILE DESCRIPTIONS AND ANALYSES	37
	<i>Table B.I. Summary of Radhi soil profiles</i>	37

SUMMARY

S.1 Background

This is the technical report of semi-detailed soil survey of Sangma Ri watershed in Dremetse geog under Monger Dzongkhag. This survey was done in October 2000 by Soil Survey Unit, National Soil Services Centre.

This watershed has been selected by RNR-RC Khangma (now RNR-RC Wengkar) to carry out multidisciplinary research activities for various subsectors. The main focus is to be on soil management research sites, which eventually will help in understanding and improvement of land degradation in the Eastern region.

S.2 Location and Environment

The survey area covers the whole of Sangma Ri watershed from Dangme Chhu to the top of the watershed under Dremetse geog. The geog is now smaller than that covered by the LUPP study (1995), because of the splitting of the old Dremetse geog into new Dremetse and Balam geogs. The survey area stretches from latitude 27°16'20" to 27°19'26" N, and from longitude 91°24'38" to 91°26'43" E. The survey covers about 788 ha (about 1947 acres). The area is asymmetrical, with more land on the west bank of Sangma Ri.

The survey area stretches from 780m to 2700m a.s.l. with subtropical to warm temperate climatic conditions. The upper part of the watershed is under broadleaf forest while the lower part is dominated by chirpine woodland and lemon grass. The survey area has mainly west-southwest and east-northeast facing slopes.

Since, there is only a defunct meteorological station at Dremetse, the climatic data from Kanglung is been used as an equivalent. Kanglung is slightly lower (about 1800m a.s.l) than Dremetse Lhakang, and slightly warmer. Mean temperatures rise from about 7°C in January to about 20°C in June and remain at about that level until September. Mean minimum temperatures are about 3°C in January, with only rare nights below freezing. Mean maxima are about 23 – 24°C in June – September, and an absolute maximum of > 30°C has been recorded in September. The mean annual rainfall at Kanglung is just under 1200mm, ranging from 965 to 1350mm for individual years. The rainfall is seasonal, with a mean of about 917mm (77%) falling in the monsoon months of May – September. The winter months are characterised by low rainfalls, and November – December are very dry. Winter monthly means range from about 20 mm in November and December to about 70mm in January – April. The transition months of April and October are variable, being quite dry in some years, with April totals ranging from 30 to 125mm, and October totals from 7 to 180mm. The heaviest daily rainfalls, of about 130mm/day, occur in the monsoon months of June and July but there are occasional heavy storms in October (up to 80mm/day).

The temperatures for the lower Sangma Ri are thought to be several degrees warmer than those shown in Table 2.1, with annual means well above 15°C. Rainfall in the lower Sangma Ri is probably considerably less than 1000mm, possibly as low as 700mm p.a.

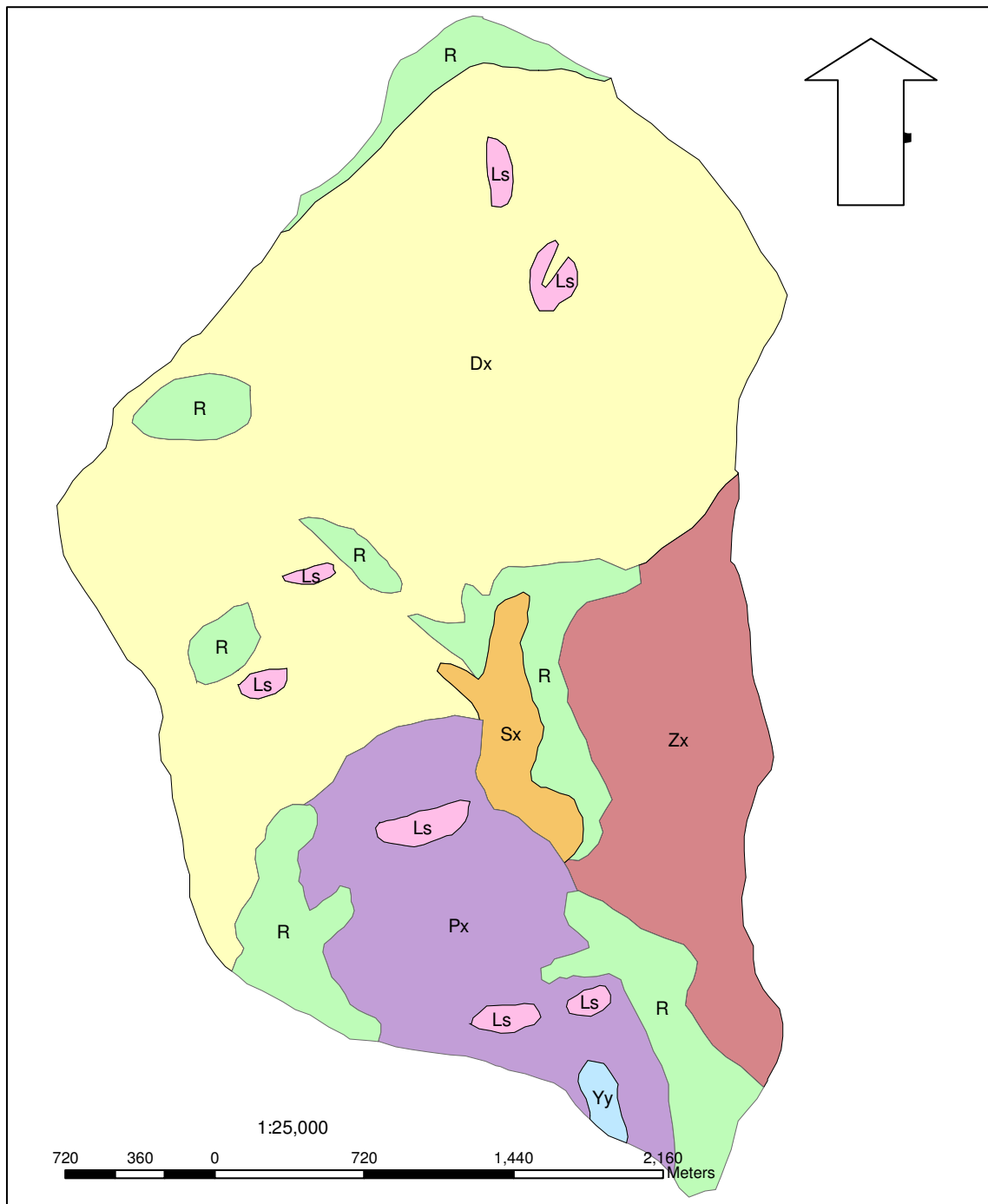
S.3 Soils

The Sangma Ri watershed falls under the Shumar geological formation which is mainly characterized by the presences of phyllites and quartzite. Due to same geological formation and similar landforms, there is not much variation of soils within the watershed area. However, a total of ten soil series was formed and their details are given in Table S.1. In general the watershed has shallow and stony soils with very limited soil development.

Table S.1 Summary of soil series in Sangma Ri watershed

Soil series	Main features
Dremetse	Grey stony silty loam topsoil; over yellowish brown stony silty loam; over weathered phyllite at 50 -150 cm
Gashari	Dark grey silty clay loam topsoil; over stony brown sandy clay loam; over weathered phyllite at 60-145 cm
Shadang	Black stony sandy loam > 25 cm; over greyish brown sandy loam; over weathered phyllite at >50 cm.
Bageng	Stony dark greyish brown silty loam; over greyish brown silty clay loam over marble & phyllite at >100cm
Sulukphu	Grey stony sandy loam – loam; over hard rock < 50cm
Zangkhar	Dark brown silty – fine sandy loam; over reddish – strong brown silty loam – clay loam; over weathered quartzite/ schist/ limestone > 1 m
Debari	Strong brown very stony clay – stony loam; over hard schist/quartzite > 1 m
Phungtshing	Stony yellowish brown silty – fine sandy clay loam; over very compact yellowish – strong brown silty clay; over brown moderately firm silty clay
Sangma	Deep mottled dark grey silty clay loam; over stony brown sandy clay loam
Yayang	Greyish brown sandy loam; over firm brown – reddish brown silty clay loam; over strong brown sandy loam

Figure S.1 Soil map of Sangma Ri Watershed, Dremetse



Legend

- | | | | |
|-------------------|---------------------|-----------|--------|
| Dremetse complex | Phungtshing complex | Landslips | Yayang |
| Zangkhar complex. | Sangma complex | Cliff | |

Table S.2 *Soil mapping units of Sangma Ri Watershed*

Mapping unit		Type	Main soil series	Minor soil series	Area		
Code	Name				Ha	Acre	%
Sx	Sangma complex	Complex	Sangma, Dremetse & Phungtshing	Sulukphu	0.35	0.87	0.05
Dx	Dremetse complex	Complex	Dremetse, Gashari & Shadong	Sulukphu & Bageng	714.99	1766.04	90.71
Px	Phungtshing complex	Complex	Phungtshing & Dremetse	Gashari & Bageng	1.06	2.63	0.13
Zx	Zangkhar complex	Complex	Zangkhar & Debari	Sulukphu	0.72	1.79	0.09
Yy	Yayang	Consociation	Yayang	-	0.1	0.25	0.01
R	Rock (cliff)	MLT	Sulukphu, & bare rock	Landslip debris	67.14	165.83	8.52
Ls	Landslips	MLT			3.83	9.46	0.49
Total					788.19	1946.87	100

S.4 Implication of results

The steep slope and stony rather dry soil limits the range of cropping system. The soils are more susceptible to run off and erosion and may experience moisture stress during the dry season, even though there is sufficient rooting depth. They are slightly acid and have moderate inherent fertility; therefore soil nutrient status is sufficient for low-input cropping system. The available K and P are variable, ranging from low to very high throughout the survey area.

The suitability of the watershed for multidisciplinary research activity is partly affected by the characteristics of the soils. In particular the results of the soil survey can contribute to the following:

- ❖ Are these soils typical of the soil management problems in some of the poorer soils in the East?
- ❖ Are the soils typical of large areas of forest and agricultural land in Eastern Bhutan, so that research findings can be extrapolated and the RNR-RC can fulfil its regional mandate?
- ❖ Are the soils likely to create major difficulties for the new infrastructure?

The first two points can be taken together. For useful research it is not required that the site should have good soils for the enterprise. In fact this is a disadvantage, as the researchers may achieve production levels that cannot be reached off the station. They may also under-estimate some of the management problems encountered by farmers in these soils. Soils that are typical, rather than excellent, are required for useful research. This is the second SSU study after Radhi in eastern Bhutan. However, comparisons with the above study area indicate that the soil conditions in the Sangma Ri watershed are similar to the region in respect of erodible phyllite and hillwash deposits derived from phyllite and quartzite. Therefore, research findings should be practicable and applicable.

ACKNOWLEDGEMENTS

The fieldwork for this survey was done by Ian Baillie, Tshering Dorji, Tsheten Dorji and H B Tamang. The report was drafted by H. B Tamang and Ian Baillie and compiled by Pema Wangmo. The final soil map was digitised by Sangita Pradhan.

We are particularly grateful to Mr. Thinlay Wangchuk, Research Officer of RNR-RC Wengkhari for his logistic arrangement and deputing the RNR-RC staff to guide us during our field survey.

We are also grateful to RNR-EC staff of Dremetse geog for providing us their office rooms for our accommodation.

The analysis of the soil samples were done by the Soil and Plant Analytical Laboratory (SPAL), Ministry of Agriculture, Simtokha.

The supply of meteorological data from the Ministry of Trade and Industry is gratefully acknowledged.

ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometry
aeolian	Windblown deposit. Usually high in coarse silt and very fine sand, i.e. 20-100 microns, stone-free, and sometimes ultraporous
Alluvial fan	Poorly stratified and sorted material deposited on floor of side valley
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
AvP, AP	Available Phosphate
AWC	Available water capacity (amount of water held in soil at suctions low enough for root uptake, = MC% FC – MC% WP)
a.s.l.	Above sea level
BS%	Base saturation percentage
C	Clay (finest mineral particles in soils, > 2um in diameter, important store for some nutrients and water, make soils sticky & heavy to work)
ca	Approximately
CCC	Central crystalline complex
CEC	Cation exchange capacity
Chhuzhing,	Terrace Irrigated paddy rice 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
Concave	Slope form of dip on slope, with steep gradient upslope and gentle gradient downslope. Tends to accumulate water & be imperfectly or poorly drained.
Consociation	Soil mapping unit with one soil class dominant but others as minor constituents
Convex	Slope form of protuberance on slope, with gentle gradient upslope and steep gradient downslope. Tends to shed water & be droughty.
Creep	Slow gravitational mass movement of colluvium downslope.
Crotovina	see 'krotovina'
Cv	Concave
Cx	Convex
Danida	Danish International Development Assistance
DoA	Department of Agriculture
EBS%	Effective base saturation (= TEB/ECEC)
EC	Electrical conductivity
ECEC	Effective cation exchange capacity (=TEB + Extr Al + Extr H)
Eluvial	Soil horizon formed by the washing out of some components
ET	Evapotranspiration
Evapotranspiration	Sum of evaporation from soil and other surfaces, and transpiration from leaves
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FC	Field capacity (MC% at suction of 0.1 atmospheres)
fe	fine earth (particle size < 2mm)

FeMn	Ferri-managaniferous, dark red - reddish brown - black stains and soft concretions with high contents of ferric iron and manganese in horizons with seasonally impeded drainage
Freely drained	Soils in which most large pores drain their water soon after rain or irrigation at all times of the year. Identified by moist or dry feel, and warm brown, reddish or yellowish colours and absence or grey, rust or orange mottles
FYM	Farmyard manure
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.
GLCE	General land capability evaluation
GPS	Global positioning system
Gully wash	Rapid movement of coarse, commonly bouldery, unlayered materials down steep streams.
ha	Hectare
HCl	Hydrochloric acid
Horizon	Soil layer
Illuvial	Soil horizon formed by enrichment of some components washed in from eluvial horizon(s) above
Imperfectly drained	Soils in which most large pores drain their water soon after rain or irrigation for much of the year, but remain filled for long spells in summer Identified by moist or wet feel, and grey or brown colours and many grey, rust or orange mottles.
<i>In situ</i>	In original position or place (Latin)
Interfluve	Land between two rivers, include halves of two valleys and ridge between them, (from Latin <i>inter</i> = between, <i>fluvius</i> = river)
Kamzhing	Rainfed agriculture
Knickpoint	Steep section in long profile of river bed, separating 2 concave sections
L	Loam (Mixed soil with substantial quantities of all three particle size classes, i.e. clay, silt and sand)
Lamella (pl. = -ae)	Discontinuous horizontal subsoil layer or lens of deposited silt or clay (usually from deposition of parent material, not argilluviation)
LUSS	Land Use and Statistics Section, in PPD
MLT	Miscellaneous Land Type
Munsell	System of standard soil colour notation, operated by matching soil against standard charts. Colour described by 'hue' (Spectral composition, red, yellow, blue, green); 'value' (dilution with white), & 'chroma' (darkness)
Nd	No data.
NS	Not sampled (in soil profile descriptions)
NSSC	National Soil Services Centre, DRDS, Simtokha
OC	Organic carbon
OM	Organic matter
P	Precipitation, rainfall
P	Phosphate
pH	Measure of acidity - alkalinity
Profile	Sequence of horizons from surface down to unaltered parent material
Rectilinear	Straight slope with more or less similar gradients up- and downslope

Ri	Stream or river (Sharchop)
RNR-EC	Renewal Natural Resource Extension Centre
RNR-RC	Renewal Natural Resource Research Centre
SCB	Soil classification of Bhutan
Series	Main group of soil classes in Bhutan. Also sixth highest level of subdivision in USDA Soil Taxonomy
Shrub	Broad-leaved plant with short woody stem, generally < 8 m high
Si	Silt (intermediate sized mineral particles in soils, 2 - 50 um in diameter, important store for plant available water, make soils slippery & vulnerable to surface erosion and capping, aka Z, Zi)
SK	Sinclair Knight (authors of first known soil survey in Bhutan)
SMU	Soil mapping unit
SoB	Survey of Bhutan
Sokshing	Forest from which needle or leaf litter is collected for livestock bedding and FYM.
Solifluction	Summer movement of saturated thawed surface material over top of permanently frozen subsoil. Occurs in periglacial conditions
Solum	True soil, in which soil processes have removed many traces of parent material structures
sp, spp	Species (singular & plural)
SPAL	Soils and Plant Analysis Laboratory, NSSC, DRDS, Simtokha.
Spur	Plunging ridge off side of mountain or main ridge down to valley, alternates with re-entrants
SS	Soil Surveyor
SSU	Soil Survey Unit
ST	Soil Taxonomy (USDA system of soil classification)
Surface wash	Movement of individual surface soil particles by running surface water.
Tr	Trace
TEB	Total exchangeable bases (= exchangeable Ca + Mg + Na + K)
Terrace, river	Bench along side of river valley where old alluvium has been left by downcutting of river bed
Terrace	Flat field created by levelling sloping land. Used for wetland rice, & enclosed by bund to retain irrigation water.
TN	Total nitrogen
WT	Water table
Zi	Silt (intermediate sized mineral particles in soils, 2 - 50 um in diameter, important store for plant available water, make soils feel slippery & vulnerable to surface erosion and capping, aka Si)

1. INTRODUCTION

1.1 Sangma Ri Watershed integrated research and extension area

This survey was undertaken by the Soil Survey Unit, NSSC at the request of RNR-RC Khangma (now RNR-RC Wengkhar), to initiated research at the Sangma Ri watershed, Dremetse. The Centre wants to focus on practical research and research-based extension efforts by different groups of sub-sector professionals at the watershed. It is anticipated that the research outputs will enable integration of investigation on crop production, animal production, and the management of forest, land and water resources. The findings can be evaluated in the context of the demographic, cadastral, the availability and gender partitioning of labour, trading relations, and other socio-economic cultural features of the area. This is particularly important in Bhutan where present agricultural practices and future developments depend on the management of labour, water, biomass energy, nutrients, livestock and land between sub-sectors. SSU hopes to contribute to these activities by establishing the range and distribution of soil conditions and resources within the area.

1.2 Aims of the Sangma Ri semi-detailed soil survey

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

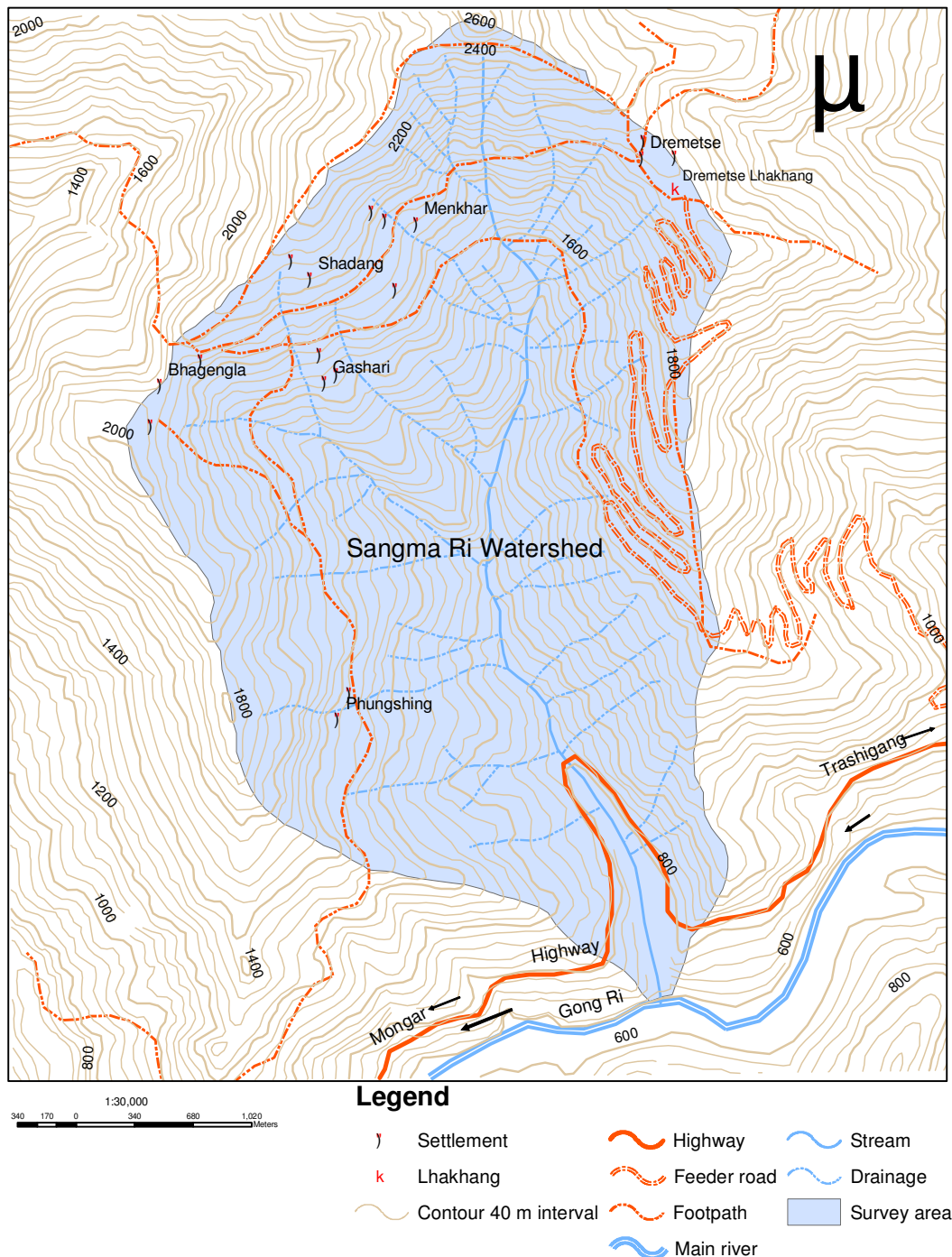
- ❖ Providing detailed information on the nature and distribution of soils of the area for research trials and the extent to which the findings can be extrapolated to other parts of the region.
- ❖ Adding to the SSU data for the development of a national soil classification and national and regional soil maps.

2. SURVEY AREA

2.1 Location and extent

The survey area covers the whole of Sangma Ri watershed from Dangme Chhu to the headwaters in Dremetse geog. The geog is now smaller than that covered by the LUPP study (1995), because of the splitting of the old Dremetse geog into new Dremetse and Balam geogs.

Figure 2.1 Location map of the survey area



The survey area stretches from latitude 27°16'20" to 27°19'26" N, and from longitude 91°24'38' to 91°26'43"E. It is located in the eastern part of Mongar Dzongkhag, on the north (true right) bank of Dangme Chhu (Gong Ri). The Sangma Ri watershed is about two-hour drive from Mongar along the national highway towards Trashigang. It is connected to the east–west national highway by an 18km feeder road up to the Dremetse Lhaxhang. The survey area covers about 788 ha (about 1947 acres). The area is asymmetrical, with more land on the west bank of Sangma Ri.

2.2 Climate

The area spans an altitudinal range of 2000m, stretching from about 780m a.s.l. at its lowest point along the Dangme Chhu to about 2700m a.s.l. at the top of the watershed. There is therefore considerable variation in climate, despite the small size of the area. The prevailing climate is subtropical in the lower part through to warm temperate in the upper section.

There are no climatic data from within the survey area available at present. There is a meteorological station in Dremetse Junior High school, which was established in 1996. However, in many years the data are missing for December – February, the main school holiday. The nearest appropriate stations for climate information is Kanglung. Kanglung is about the same altitude but is on the opposite side of the entrenched valley of Dangme Chhu. This climatic data may not be completely appropriate for microclimates, but give a general impression of the climate of upper Sangma Ri.

The data from Kanglung are summarised in Table 2.1. Kanglung is slightly lower (about 1800m a.s.l.) than Dremetse Lhaxhang, and slightly warmer. Mean temperatures rise from about 7°C in January to about 20°C in June and remain at about that level until September. Mean minimum temperatures are about 3°C in January, with only rare nights below freezing. Mean maxima are about 23 – 24°C in June – September, and an absolute maximum of > 30°C has been recorded in September. The mean annual rainfall at Kanglung is just under 1200mm, ranging from 965 to 1350mm for individual years. The rainfall is seasonal, with a mean of about 917mm (77%) falling in the monsoon months of May – September. The winter months are characterised by low rainfalls, and November – December are very dry. Winter monthly means range from about 20 mm in November and December to about 70mm in January – April. The transition months of April and October are variable, being quite dry in some years, with April totals ranging from 30 to 125mm, and October totals from 7 to 180mm. The heaviest daily rainfalls, of about 130mm/day, occur in the monsoon months of June and July but there are occasional heavy storms in October (up to 80mm/day).

The temperatures for the lower Sangma Ri are thought to be several degrees warmer than those shown in Table 2.1, with annual means well above 15°C. Rainfall in the lower Sangma Ri is probably considerably less than 1000mm, possibly as low as 700mm p.a.

2.3 Geology and soil parent materials

The Sangma Ri watershed is underlain by Pre-Cambrian rocks of the Lesser Himalayan Shumar Formation. The formation is mainly composed of quartzites and phyllites. The quartzite is mostly flaggy, and coarse grained. The phyllites are mainly compact and sericitic-chloritic, with a silvery sheen from the sericitic (fine-grained muscovite) mica. Weathered surfaces lose the greenish tinge imparted by the chlorite but this is clear in fresh sections. Because of their relative weatherability

and softness there are few outcrops of the phyllites. There is much quartzite intercalation in the phyllite. Due to this intimate association of these two rocks, it is difficult to map them separately. The rocks of the survey area are tectonically disturbed and faulted. Highly jointed and fractured rocks are observed along the highway below Phungtshing and in cuttings on the Dremetse Lhaxhang feeder road down the Zangkhar spur.

LUPP (1995) reports that there are two bands of limestone within the survey area:

Between Dremetse and Bageng, where it is overlain by flaggy quartzite and phyllite; Along the Dremetse feeder road where there are inliers of black graphite in milky white - light grey limestone

There are few landslips on the slopes of the Sangma Ri valley. There is virtually no river alluvium on Sangma Ri. Most of the soils are formed in colluvium (hillwash), with few residual parent materials. There is a small old alluvial fan deposited by the main river, Dangme Chhu, on the eastern side of the mouth of Sangma Ri.

2.4 Topography and drainage

Sangma Ri watershed is a deeply dissected valley. It runs roughly north – south, with mainly west-southwest and east-northeast facing slopes. Most of them are steep and there are many rocky bands. Due to the steep gradient of the valley, the sediment carrying capacity of the drainage system is high. As a result, most of the streambeds are deeply cut down. The overall gradient of the main streambed is 35%. The gradients range from 45% to 73%, with an average of 56%. The survey area appears to have undergone several cycles of erosion due to periodic renewal of river down cutting. Most slopes are irregular, but there appears to be a dip slope around Phungtshing, structurally controlled by the dip of the Shumar Formation.

2.5 Land Use and Vegetation

At present, about 25% of the total survey area is arable land. Most of the arable land is kamzhing which are located mostly on crests and side slopes of the spurs. However, there are small areas of chhuzhing, concentrated along the lower part of Sangma Ri. Crops like maize, buckwheat, some upland rice, potatoes, mustards, beans and *Amaranthus* are grown in the area. There are no orchards except few fruit trees (oranges, guavas and persimmons) grown around the house.

The remaining part of the survey area (75%) is under forest cover. There are mainly two types of forest present in the survey area i.e. broadleaf and chirpine forests. The broadleaf forest is present on the upper cooler part of the watershed whereas the chir pine forest predominates in the lower warm and dry parts. The main broadleaf tree species are *Quercus griffithii* and *Castanopsis indica*. The chirpine forest includes the lemon grass (*Cympogpogn flexus*), which is harvested in late summer and autumn for oil extraction.

Table 2.1 Climatic summary for Kanglung 1990-1998

Temperature °C

	J	F	M	A	M	J	J	A	S	O	N	D	Year mean or Total
n (number of complete records)	9*	9*	9*	6*	8*	8*	8*	8*	8*	7*	7*	8*	4*
Mean	7.4	8.8	12.1	15.6	17.5	19.6	20.2	20.2	20.1	15.3	12.4	9.0	14.9
Mean minimum	3.1	4.8	7.1	11.3	13.2	16.0	16.7	16.5	17.1	10.2	6.8	3.9	10.6
Absolute minimum	-0.5	-0.5	0.0	2.5	7.0	11.0	13.5	14.5	11.0	4.0	2.5	0.5	-0.5
Mean Maximum	11.7	12.8	17.0	19.9	21.8	23.2	23.6	23.9	23.0	20.3	17.9	14.1	19.1
Absolute Maximum	17.0	19.5	23.0	26.0	27.0	29.9	28.5	28.0	30.1	25.0	22.8	19.0	30.1

Rainfall (mm)

n (number of complete records)	9*	9*	9*	6*	8*	8*	8*	8*	8*	7*	7*	8*	5*
Mean	22.3	31.3	46.6	71.6	115.5	255.7	257.3	216.3	127.3	60.4	2.3	7.3	1214
Monthly maximum	57.7	96.7	99.3	124.7	176.8	353.2	372.1	269.6	175.8	178.9	16.0	21.8	1354
Monthly minimum	0.3	4.8	6.5	28.4	50.7	167.4	150.6	125.3	25.6	7.4	0.0	0.0	965
Highest daily rainfall	34.4	32.0	31.2	24.2	43.6	129.4	129.4	63.7	45.8	80.5	5.4	12.0	129.4

* Includes records with monthly summaries but incomplete daily data.

Data source: MTI

3. PREVIOUS SOILS INFORMATION

3.1 LUPP (1995)

The only soil report for the area so far is by Land Use & Planning Project of Planning and Policy Division of Ministry of Agriculture. It was a land resources survey of the old and larger Dremetse geog. It was a semi-detailed survey (1:25 000 scale). The Sangma Ri watershed falls within their area. As this was only a land resources study, the report focussed on land evaluation. The soils were described and analysed but not classified, correlated, or mapped. Seventeen pits out of a total 39 are located in the Sangma RI watershed. Soil samples were collected and were analysed in the Soil and Plant Laboratory (SPAL) at Semtokha. The only available soil map is that of pit location.

The correlation of the LUPP (1995) soil profiles with our soil series is given in section 5.3.

3.2 Sinclair Knight (1983)

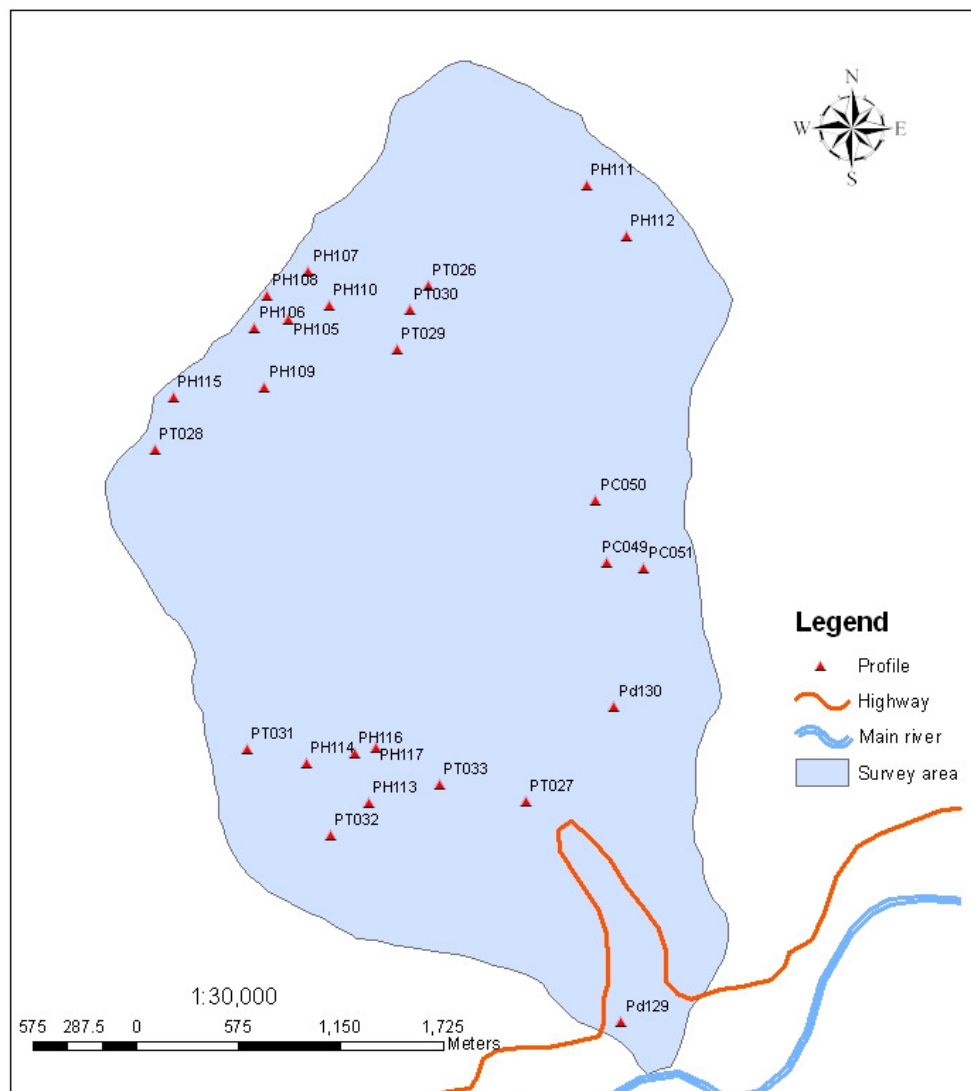
The first soil survey in Bhutan was in 1983 by the Australian consultancy company, Sinclair Knight. They surveyed four areas in Eastern Bhutan, two of which are located on the Shumar Formation. The Chaskar area is located about 4 km to the southwest of Sangma Ri, in the valley of Sheri Chhu, the next main true right bank (TRB) tributary of Dangme Chhu (Gong Ri) downstream. The Chaling area lies about 30km west of Dremetse, in the valley of Ku Ri. The soil series at Sangma Ri and the soil classes of Sinclair Knight are correlated in Section 5.3.

4. METHODS

4.1 Field

This was the fourth semi-detailed soil survey undertaken by Soil Survey Unit (SSU). The fieldwork was done in October 2000. The soils were examined along traverse lines. The observations were sited at fixed altitude intervals (30 or 50m), as measured with a hand-held Thommen altimeter. The altitude-based traverses were sited along footpaths that run up-and-down slopes, mostly along the crests of spurs. The soils were examined on a routine basis at 72 sites, mainly with a 1.2m Edelman auger fitted with a 7cm combination head where possible, but switching to a 7cm stony soil head where necessary. Duplicate augerings had to be done at 37 sites (51%) where the first attempt was stopped by stones at less than 50cm. This is a high proportion, due to the predominance of stony soils. Six of the routine examinations were done in cuttings. The distribution of soil survey sites (soil profiles) can be seen in Figure 4.1 below.

Figure 4.1 Distribution of soil survey sites (profiles) in Sangma Ri watershed



For routine soil observations the following site data were collected:

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

The soil profiles were described according to their natural layering (horizons) in the upper one metre, and not at fixed depths. The following data were 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 26 sites. Three of the detailed descriptions were done in freshly cleaned-back cuttings, and the remaining 23 in purpose-dug profile pits. The site data were the same as for the routine sites, with the addition of a detailed description of surface features, including:

Microrelief, rock outcrops, litter, cracks, faunal activity, sand wash, and capping.

The soils were again described by horizons. The data collected for each horizon were the same as in the routine descriptions, with the addition of:

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

Samples were collected for laboratory analysis from 66 of the main horizons of the 25 described profiles.

4.2 Mapping

The topographic map (1:50,000) from the Department of Survey and Land Records was used as a base map for the survey. By photomagnification, an interim soil map was produced at 1:25,000 scale.

Later, the interim soil map was finally digitised using the 1:25,000 topographic map (not available during the survey time) and produced the final soil map at 1:25,000 scale.

4.3 Laboratory

The 66 soil samples collected from the main horizons of the 26 detailed profiles were analysed by the Soil and Plant Analytical Laboratory (SPAL) of the National Soil Services Centre, (NSSC) of the Council for RNR Research of Bhutan (CoRRB) of the Ministry of Agriculture at Simtokha. The methods of analysis used by SPAL are summarised in Appendix A.

5. SOIL CLASSIFICATION, CHARACTERISTICS AND CORRELATION

5.1 Soil classification

Soil classification was done in an *ad hoc* way in the early stages of SSU. Survey areas were treated separately, and sets of local soil classes were defined for each area (see Reports SS1-8 and SS10-13, SSU, 1998-2000). With increasing field experience, we have built up a preliminary outline of the soils of the mid-latitude part of Bhutan, and have formulated a provisional framework for their classification. The assumptions and procedures of a provisional version of the proposed system will be given in Technical Working Paper WP3 (SSU 2001).

The soils of the Sangma Ri watershed are classified into soil series, mostly on the basis of features that can be identified in the field. A few series are separated on chemical features. The field features used to define series are morphological (i.e. soil profile), parent material, landform and land use. The series are named after places at or near where profiles have been described and analysed. The series of Sangma Ri are summarised in Table 5.1.

5.2 Characteristics of soil series in Sangma Ri watershed

5.2.1 Dremetse series

These are extensive soils in the upper part of the watershed. Some are under forest, but they are also used for kamzhing. They occur on the steep crest and side slopes of the spurs. Seven profiles of this series were described (see PH105, PH106, PH112, PH113, PH115, PC051 & PT033 in Appendix B). There are also seven LUPP (1995) profiles of this series (see section 5.3).

The dominant features of these soils are the relatively bright subsoil colours, and high contents of stones and silt throughout the profile. The stone content makes augering difficult and gives a false impression of very shallow depths. In fact these soils are moderately deep, with weathered phyllite at 50 - 150 cm. The topsoil consists of grey - dark grey stony silt loam. This grades to yellowish brown – brownish yellow stony loam, over the weathered phyllite. The structures and consistence in these soils are dominated by the high stone contents. However the interstitial fine earth is not compact.

These soils have slightly acid to neutral pH. Organic matter contents are moderate to high. Total nitrogen is mostly moderate. C:N ratios are good to very good. Exchangeable and available K are both moderate to high, due to the micaceous minerals. Available P contents are variable, ranging from low to very high. Exchangeable base status is low to very high, with base saturation 30-87% in topsoils to 38-100% in subsoils.

5.2.2 Gashari series

These are extensive soils in the upper part of the watershed. Most are under forest, but they are also used for kamzhing. They occur on the steep crest and side slopes of the spurs. There are five fully described and sampled profiles in these soils (see PH109, PH114, PT026, PT031 and PT032) in Appendix B. There are also six LUPP (1995) profiles in this series (see section 5.3).

These soils differ from those of Dremetse series, in that their subsoils are duller coloured, presumably because they are less weathered. The dominant features of these soils are the greyish coloured subsoils. They also have high contents of stones and silt throughout the profile as in Dremetse series. The stone content makes augering difficult and gives a false impression of very shallow depths. In fact these soils are moderately deep, with weathered phyllite at 50 - 150 cm. The topsoil consists of grey brown silt loam. This grades to grey – greyish brown – brown stony loam, which may also have high silt contents. The structures and consistence in these soils are dominated by the high stone contents, but the interstitial fine earth is not compact.

Three of the profiles in these soils have neutral pH, but PT031 and PT032 are slightly acid. Available P contents are variable, ranging from moderate to high. Topsoil organic carbon contents are moderate to high, probably due to FYM application. Total nitrogen is low to very low. C:N ratios are good to very good, ranging from 8-13. Exchangeable status are moderate in topsoils and are low to very high in subsoils, with base saturation 70-100% in topsoils and 30-89% in subsoils. Topsoil exchangeable and available K contents are moderate to very high, but are low in subsoils. In Profile PT032 the acid pH values do not accord with the high base saturation (>89%).

5.2.3 Shadang series

These soils are not extensive, and were mostly encountered in the Shadang area, but there are also patches on the Zangkhar spur. Some are under forest, but they are also used for kamzhing. There are four fully described and sampled profiles in these soils (see PH0107, PH108, PH110 and PH111 in Appendix B). There is also one LUPP (1995) profile in this series. (see section 5.3).

The main feature of these soils is the deep and black (or very dark grey) topsoil. This is thought to be mainly due to presence of carbonaceous phyllite in the local parent material. The soils do not have particularly high organic matter contents and the underlying rock is dark. These soils have high stone contents, and textures are gravelly sandy loam throughout the profile. The stones are colluvial. Augering was difficult due to high density of stones. The profiles in these soils are very deep (130-155cm). Beneath the deep dark topsoil, the subsoil is greyish sandy loam, with variable contents of stones. Structures are moderate subangular blocky, and consistence is often dominated by the stones. However, the interstitial fine earth is friable or only slightly firm.

Organic carbon contents are moderate in all profiles. Soils are slightly acid (pH in water 5.1-6.4) except PH108 which is neutral. Available P contents are variable. Total N nitrogen contents are very low, reading as a trace or zero in several horizons, but C:N ratios are good, ranging from 8 to 12. The exchangeable and available K contents are low to high. The total exchangeable base content (Ca++) particular in some horizons are high, possibly from calcareous minerals.

5.2.4 Bageng series

These are moderately extensive soils in the upper part of the watershed. They are found mostly in the Bageng and Gashari areas. Most of them are under kamzhing. There are four fully described and sampled profiles in these soils (see PT028, PT029, PT030 and Pd130 in Appendix B). There are also two LUPP (1995) profiles in this series (see section 5.3).

These soils are similar in morphology and appearance to Dremetse and Gashari series, consisting of dark grey- greyish brown stony fine topsoils over grey – brownish yellow stony fine subsoils. The distinctive feature is the presence of marble and the effect this has on the soil chemistry. These soils

have high stone contents, with silty clay loam interstitial textures throughout profile. These soils are very deep (135cm+) despite the steep (25-55%) slopes. Their stones include substantial proportions of marble, and the profile often sits directly on top of hard marble bedrock.

Organic matter levels are variable, low to moderate. Total nitrogen is low in all profiles. Available P contents are low to high, except for trace levels in PT028. Soils are neutral throughout. Exchangeable and available K are high. Base saturations are high both in top and subsoils, ranging from 80-100%. Ca⁺⁺ contents are high in PT029, PT031 and Pd129 profiles, due to the contribution from the marble.

5.2.5 Sulukphu series

These soils are found scattered throughout survey area and are extensive on the steep slopes at the top of watershed, above the Dremetse - Bageng path. They mostly occur on the barren steep slopes of the spurs and also in landslips. Few augerings were done in these areas due to the very steep gradients. These soils have stony grey sandy loam topsoils over hard rock within 50cm depth. There are no described or analysed profiles in these soils. However there are two LUPP (1995) profiles which are transitional to this series. These indicate that the chemical characteristics of this series are similar to those of Dremetse and Gashari series.

5.2.6 Zangkhar series

These soils occur along the crest and steep side slopes of the main eastern spur, below Zangkhar village, down to the mouth of the watershed. They occur mostly over quartzitic rocks and micaceous schist. However the parent material also includes limestone. Some of these soils are under forest, but they are also used for kamzhing. There are two fully described and sampled profiles in these soils (see PC049 and PC050 in Appendix B). These soils were also examined in three profiles by LUPP (see section 5.3).

The dominant feature of these soils is the bright reddish colour in the moderate to deep subsoils. These soils have variable contents of stones, and have silt loam or heavier fine earth texture throughout the profile. The topsoil consists of stony light yellowish brown silt loam. This grades to strong – reddish brown silt loam – clay loam. The consistence is friable to below 1m. Subsoil structures are compound blocky to crumb or simple crumb. These soils resemble the red fine textured soils of Serbithang series over quartzite and schist in western Bhutan. These two series may be amalgamated in the future.

Organic carbon levels are moderate to high but total nitrogen is low to very low. However, C:N ratios are moderate. In PC050, the soil is slightly acid but PC049 is neutral. Available P, exchangeable and available K are low to very low. The base status is moderate in topsoils but drops in subsoils.

5.2.7 Debari series

These soils are the shallow and very stony equivalents of Zangkhar series. They occur on the steep side slopes of the lower section of the eastern (Zangkhar) spur. These soils are on such steep slopes that they are mostly under chir pine forest, and only small areas are cultivated. These soils were only seen in augerings. The topsoil is dark brown- brown stony clay over strong brown very stony loam.

There are no described or analysed profiles. There are however two LUPP (1995) profiles in this series (see section 5.3).

5.2.8 Phungtshing series

These soils mostly occur around Phungtshing on the slopes of the lower section of the western spur and extend down to the national highway. Most of these soils are under forest, but there are also areas of kamzhing around Phungtshing. There are two fully described and sampled profiles in these soils (see PH116 and PH117 in Appendix B). There are also two LUPP (1995) profiles in this series (see section 5.3).

The most striking feature of these soils is the very compact consistence in the upper subsoil. Silty textures are predominant throughout the profiles. There are variable but mostly high contents of stones in the subsoils. This makes augering and pit digging difficult. These soils are moderately deep (100-120+cm). The topsoils are fairly friable, yellowish brown to brown, silt loam - silty clay loam. The subsoils are reddish yellow - strong brown. The upper part of the subsoil is very firm to compact and extends down to 50 - 60cm depth. The yellow - brown silt loam- silty clay loams of the lower subsoils are only firm. The soil overlies weathered phyllite.

These soils are neutral (pH in water 6.5-7.5) throughout. Organic matter is low to very low. Total nitrogen contents are very low but C:N ratios are mostly satisfactory. Available P is moderate in topsoil but low in subsoil. Available K is low throughout. Exchangeable K is high in Profile PH116 but moderate to low in PH117. Base saturation status is low to moderate, ranging from 54-73% in topsoils to 26-53% in subsoil.

5.2.9 Sangma series

These soils are not extensive. They are located mostly along the Sangma Ri stream bed. They are presently under wetland rice (chhuzhing) cultivation. There is one fully described and sampled profile in this soil (see PT027 in Appendix B). There are also two LUPP (1995) profiles that are somewhat similar to these soils (see section 5.3).

These soils are similar to many other chhuzhing soils in Bhutan in having greyish, slightly cloddy topsoils over grey mottled upper subsoils. Although these soils are deep (80-120+cm), they are stonier than most chhuzhing soils seen elsewhere in Bhutan. The stones are mostly quartzite and phyllite. The fine earth texture is clay loam in all horizons. The topsoil consists of stony dark grey – brown clay loam. It grades into mottled dark grey – brown silty clay loam – clay loam. The lower subsoils are redder than the horizons above. This contrast might be due to prolonged surface gleying by irrigation. The structures and consistence in these soils are dominated by the high contents of stones.

PT027 is the only analysed profile in this soil. It is chemically similar to Profile Pd129 of Yayang series, as both of these profiles are under chhuzhing. Profile PT027 is neutral throughout, ranging from pH 6.6 to 7.4. There is a slight increase of pH with depth. Organic matter content is moderate in the topsoil but drops in subsoil. Total N and available P are low to very low in the topsoil but available P is high in subsoil. C:N ratios are satisfactory throughout, ranging from 11-16. The contents of exchangeable and available K are both low, despite of abundance of K-bearing minerals. The exchangeable base status is very low throughout, and decreases with depth, with base saturation dropping from 14% in the topsoil to 4% below.

5.2.10 Yayang series

This is not an extensive soil. There is only one small area on the remnant of the high fan below the highway at the lower end of the watershed. This soil appears to be formed in fan alluvium over old main river alluvium. This area was previously used for irrigated crops, but has since been abandoned due to shortage of water. There is one fully described and sampled profile in this soil (see Pd129 in Appendix B).

The dominant feature of this soil is the high content of colluvial stones and fine sandy loam texture throughout the profile. The depth of the soils ranges from 100 to 160cm. They have very dark greyish brown topsoils over reddish brown sandy loam subsoils. The structures and consistence in these soils are dominated by the high stone contents. However the interstitial fine earth is not compact.

The only analysed profile in this soil is chemically similar to Sangma series in some respects (see 5.2.9 above). Thus the Yayang profile is neutral throughout. However, exchangeable base status is moderate to high, with high exchangeable Ca⁺⁺ in the top horizon possibly derived either from limestone in the fan stones or imported in the irrigation water. The organic carbon content is moderate in the topsoil but low in subsoil. Total N is low throughout, but C: N ratios are good to moderate in the range 11-16. Available P content, exchangeable and available K are all low throughout.

Table 5.1 Summary of soil series in Sangma Ri watershed

Soil series	Main features	Profiles and analyses (see App .B)
Dremetse	Grey stony silty loam topsoil; over yellowish brown stony silty loam; over weathered phyllite at 50 -150 cm	PC051, PH105, PH106, PH112, PH113, PH115 PT033
Gashari	Dark grey silty clay loam topsoil; over stony brown sandy clay loam; over weathered phyllite at 60-145 cm	PH109, PH114, PT026, PT031, PT032
Shadang	Black stony sandy loam > 25 cm; over greyish brown sandy loam; over weathered phyllite at >50 cm.	PH107, PH108 PH110, PH111
Bageng	Stony dark greyish brown silty loam; over greyish brown silty clay loam; over marble & phyllite at >100cm	PT028, PT029 PT030, Pd130
Sulukphu	Grey stony sandy loam – loam; over hard rock < 50cm	-
Zangkhar	Dark brown silty – fine sandy loam; over reddish – strong brown silty loam – clay loam; over weathered quartzite/ schist/ limestone > 1 m	PC049 PC050
Debari	Strong brown very stony clay – stony loam; over hard schist/quartzite > 1 m	-
Phungtshing	Stony yellowish brown silty – fine sandy clay loam; over very compact yellowish – strong brown silty clay; over brown moderately firm silty clay	PH116 PH117
Sangma	Deep mottled dark grey silty clay loam; over stony brown sandy clay loam	PT027
Yayang	Greyish brown sandy loam; over firm brown – reddish brown silty clay loam; over strong brown sandy loam	Pd129

5.2.11 Analytical characteristics of soil classes

Table 5.2 summarizes the ranges of chemical characteristics of the soil series in the Sangma Ri area, derived from the analyses of the profile samples collected during the survey.

Table 5.2 Ranges of chemical analyses, by soil series, Sangma Ri

Soil series (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)
Dremetse (7)	1.3-3.2	0.06-0.26	9-17	5 - 102	6.-7.0/ 6.5-7.4	7-19/ 1-14	30-100/ 8-100	0.2-2.6/ 0.1-0.9	14-299/ 7-193
Gashari (5)	1.3-3.2	0.4-0.17	10-14	28 - 82	6.5-7.3/ 6.5-7.4	8-23/ 2-11	74-100/ 40-89	0.8-2.8/ 0.3-1.4	99-348/ 52-303
Shadang (4)	0.1-6.5	0.20-3.47	8-12	1 - 21	5.1-7.1/ 6.1-7.4	5-16/ 6-20	58-94/ 50-92	0.1-1.5/ 0.1-1.1	16-255/ 11-122
Bageng (4)	0.8-3.2	0.07-0.12	9-12	13 - 65	6.8-7.3/ 6.7-7.5	6-20/ 3-17	85-100/ 80-100	0.3-0.4/ 0.1-0.2	69-148/ 19-153
Zangkhar (2)	1.6-3.2	0.1-0.2	16-18	2 - 3	6.6-6.8/ 6.4-6.9	8-12/ 0.9-5	73-89/ 33-63	0.1-0.8/ 0.1-0.3	33-139/ 13-45
Phungtshing (2)	1.1-1.8	0.09-0.10	12-18	2 - 22	6.7-6.7/ 6.5-7.1	8-10/ 5-7	54-73/ 26-53	0.5-0.7/ 0.3-0.6	43-47/ 36-44
Sangma (1)	1.7	0.17	16	3	6.6/ 7.5	14/ 12	14/ 12	0.3/ 0.3	64/ 40
Yayang (1)	2.3	0.14	16	3	7.2/ 7.5	16/ 8	100/ 100	0.5/ 0.5	37 /28

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

5.3 Soil correlation

In order to see how the soils of Sangma Ri fit into the regional and national context, it is necessary to correlate them with other soils in Bhutan and elsewhere.

5.3.1 Correlation with LUPP (1995).

The closest correlations with previous soil data in Bhutan are with the profiles described and analysed in the LUPP (1995) Dremetse study. Table 5.3 summarises the correlations of our Sangma Ri series with the LUPP profiles for soils derived from the quartzites, phyllites and schists of the Shumar Formation. The LUPP profiles on the Thimphu Formation in the north-eastern part of their survey area are not correlated.

5.3.2 Correlation with Sinclair Knight (1983)

Two of the four survey areas in the irrigation study by Sinclair Knight (1983), i.e. Chaskar and Chali, are located on outcrops of the Shumar Formation. These are in much less rugged topography than Sangma Ri. They are on moderately gentle slopes, as expected for areas already irrigated for rice and being considered for further development. Their grey chhuzhing soils are generally deeper and less stony than Sangma series. There are parallels between some of the Sangma Ri series and their non-chhuzhing soils, as summarised in Table 5.4

Table 5.3 Correlations with LUPP (1995) Dremetse on Shumar phyllite and quartzite

Sangma Ri soil series	Dremetse profiles (LUPP 1995)	In or Out of Sangma Ri survey area	Notes
Dremetse	DP1	In	Parent materials described as gneiss, but located on Shumar outcrop on map
	DP7	In	
	DP 27	Out	
	DP 28	Out	
	DP8	In	Transitional to Sulukphu series
	DP12	Out	
	DP17	Out	
Gashari	DP6	Out	Transitional to Sulukphu series. Parent material described as gneiss
	DP13	Out	
	DP14	In	
	DP16	Out	
	DP26	Out	
	DP39	Out	Transitional to Bageng series
Shadang	DP9	In	Transitional to Bageng series. Parent material described as gneiss
Bageng	DP9	In	Transitional to Shadang series. Parent material described as gneiss
	DP10	In	Colours transitional to Zangkhar series
Sulukphu	DP6	Out	Transitional to Gashari series. Parent material described as gneiss
	DP8	In	Transitional to Dremetse series.
Zangkhar	DP5	In	Parent materials described as gneiss, but located on Shumar outcrop in Zangkhar area
	DP10	In	Ca status is transitional to Bageng series
	DP37	In	Texture is SCL
Debari	DP2	In	Parent materials described as gneiss, but located on Shumar outcrop on map
	DP3	In	Parent materials described as gneiss, but located on Shumar outcrop on Dremetse feeder road
Phungtshing	DP15	In	Near Phungtshing kamzhing area
	DP30	In	Profile includes old landslip debris
Sangma	DP11	In	Shallow & stony. High Ca status
	DP29	In	Gravelly subsoil
Yayang	-	-	(DP4 is on a colluvial footslope rather than a true fan)

Table 5.4 Approximate correlations with Sinclair Knight (1983) soil classes

Sangma Ri soil series	Approximate equivalent Sinclair – Knight (1983) class.
Dremetse	# 4 Brown clay loam # 6 Grey micaceous sandy clay loam
Gashari	# 6 Grey micaceous sandy clay loam
Shadhang	
Bageng	
Sulukphu	# 1 Shallow stony soils
Zangkhar	# 3 Reddish clay
Debari	#5 Reddish sandy clay loam
Phungtshing	# 5 Reddish yellow sandy clay loam
Sangma	# 6 Grey micaceous sandy clay loam
Yayang	More or less with # 8, Silty alluvial soil, but this is located main river alluvial terraces, not fans

1 etc: East Bhutan Soil Group, Sinclair-Knight (1983)

5.3.3 Correlation with soils at Wengkhar

The only area previously surveyed by SSU on Shumar Formation parent materials is at Wyengkhar, near Mongar, and is about 20 km west of Dremetse. The Shumar Formation there differs from that underlying Sangma Ri in that the quartzite and phyllite are less intercalated and form thick discrete beds. This means that many of the soils at Wyengkhar are formed in almost wholly phyllitic parent material. They are therefore deeper, less stony, and have higher clay contents than any soils seen at Sangma Ri. However, they do show some similarities, especially with Phungtshing series, in that many of the Wyengkhar clays have very compact layers in their upper subsoils.

5.3.4 Correlations with international systems

Table 5.5 summarises the provisional correlations of the Sangma Ri soil series with the 1998 version of the World Reference Base for Soil Resources (FAO, with ISSS and ISRIC) and with the 2nd edition (1999) of the USDA Soil Taxonomy (ST). Precise correlations, especially with ST, require complex data. This accounts for the multiple correlations in Table 5.5

The correlations in Table 5.5 assume that:

- ❖ The lower watershed has an ustic soil moisture regime. The cultivation of autumn and winter crops in the upper watershed suggests that the soils there have residual soil moisture after the monsoon that is sufficient and lasts long enough for the SMR's to be udic. The distributions of chir pine woodland in the drier areas and broadleaf forest in the upper watershed are taken as indicators of ustic and udic SMR. However the high contents of stones in many of the soils in the upper areas reduce their available water capacities and the SMR may need revision.

- ❖ All of the soils are assigned to thermic soil temperature regime (STR) families. Small parts of the upper catchment may have mesic STR's, but we need further climatic data to confirm this.
- ❖ Only a few of the deeper red clays in Zangkhar series seem to have progressed beyond the early stages of horizon development. All of the other soils are shallow or stony or subject to colluvial disturbance, and have been assigned to the immature classes of Cambisols (WRB) or Inceptisols (ST).
- ❖ Some of the series have base saturations close to 50%, so that they can qualify for both dystric and eutric subdivisions, in both systems.
- ❖ Most of Sulukphu series are deeper than 10 cm but less than 50 cm to hard bedrock.

There are no provisions in the 1999 edition of ST for a fragic subgroup of the Haplustepts, or for an Anthraquic subgroup in the Haplanthrepts. However Phungtshing and Sangma series appear to fit the concepts of such taxa and have been bracketed as such in Table 5.5

Table 5.5 International correlations of soil series at Sangma Ri

Sangma Ri soil series	Subunit in World Reference Base for Soil Resources (FAO 1998)	Subgroup in USDA Soil Taxonomy (Soil Survey Staff 1998) [<i>Family in italics</i>]
Dremetse	Skeletal, Dystric or Haplic Cambisol	Typic Eutrudept or Dystrudept [<i>thermic, loamy – loamy skeletal, mixed</i>]
Gashari	Skeletal, Dystric or Haplic Cambisol	Typic Eutrudept or Dystrudept [<i>thermic, loamy– loamy skeletal, mixed</i>]
Shadang	Skeletal, Dystric or Haplic Cambisol	Typic Eutrudept or Dystrudept [<i>thermic, loamy– loamy skeletal, mixed</i>]
Bageng	Skeletal or Haplic Cambisol	Typic Eutrudept [<i>thermic, loamy– loamy skeletal, mixed</i>]
Sulukphu	Lithic or Haplic Leptosol; Leptic, Skeletal, Dystric or Haplic Cambisol	Lithic or Typic Eutrudept or Dystrudept [<i>thermic, skeletal - loamy skeletal, mixed</i>]
Zangkhar	Chromic or Haplic Luvisol or Cambisol	Dystric or Typic Dystrustept [<i>thermic, fine loamy - clay, mixed</i>]
Debari	Leptic, Chromic, Dystric or Haplic Cambisol	Lithic or Typic Dystrustept or Haplustept [<i>thermic, loamy skeletal, mixed</i>]
Phungtshing	Chromic, Dystric or Haplic Cambisol	Dystric (or Fragic*) Haplustept [<i>thermic, loamy skeletal, mixed</i>]
Yayang	Dystric or Haplic Cambisol	(Anthraquic*) or Typic Haplustept [<i>thermic, loamy skeletal, mixed</i>]
Sangma	Hydragric Anthrosol	(Aquic*) Haplanthrept & Anthraquic Dystrustept [<i>thermic, loamy skeletal, mixed</i>]

* No provision for these subgroups in the 1999 2nd Edition of Soil Taxonomy but these series seem to require them.

5.3.5 Correlation with geotechnical classification of soils.

Stability of soil terraces and water conveyance systems are important for irrigated agriculture in Bhutan. Table 5.6 correlates the soil classes of Sangma Ri with the geotechnical classification of the Irrigation Section of DoA of MoA. The classes are useful as general indicators of site stability. The stone contents in most soils at Sangma Ri are taken to be high enough to qualify most series as dirty gravels. The less stony soils mostly qualify as low plasticity clays.

Table 5.6 Geotechnical correlation of Sangma Ri soil series

Sangma Ri soil series	DoA Irrigation Section Geotechnical Soil Classification	
	Land unit	Soil class
Dremetse	3A/B & 4B/C/D (upper & mid hillslopes & valley side slopes, including slips and debris deposits)	GM/CL (dirty gravels with low plasticity clay)
Gashari		
Shadang		
Bageng		
Sulukphu		CL/ML (low plasticity clay & loam)
Zangkhar		
Debari		
Sangma	3A/B & 4A/B/C/D (lower hillslopes & valley side slopes, including debris deposits)	GM/CL (dirty gravels with low plasticity clay)
Yayang	5A (lower slope debris fan & terrace)	CL(low plasticity clay)

Source for class criteria: CIP (1993)

6. SOIL DISTRIBUTION AND MAPPING

6.1 Soil distribution

The soils on the upper part of the watershed are determined by the lithology of the parent materials and their distributions are not neatly tied in with particular landforms. The soils tend to be stony and shallow on the slopes and the spurs that run down to Dangme Chhu. The soils of these areas have grey to brown colours and fine textures with high silt contents, with a high proportion of phyllite in their parent materials. There are red soils on the lower section of the main eastern (Zangkhar) spur.

6.2 Soil mapping units.

Because of the complex soil pattern, it is not possible to map most of the area as simple units (consociations), in which one soil series is dominant. Most of the watershed is mapped as complexes, in which two or more series are about coequal. Most of the phyllite-derived silty clay loams in the upper watershed are mapped as the Dremetse complex (Dx), which accounts for slightly more than half of the survey area. The streambeds are mapped as the Sangma complex of chhuzhing soils (Sx). The red soil spurs are mapped as the Zangkhar complex (Zx). The lower watershed is mapped as the Phungtshing complex (Px).

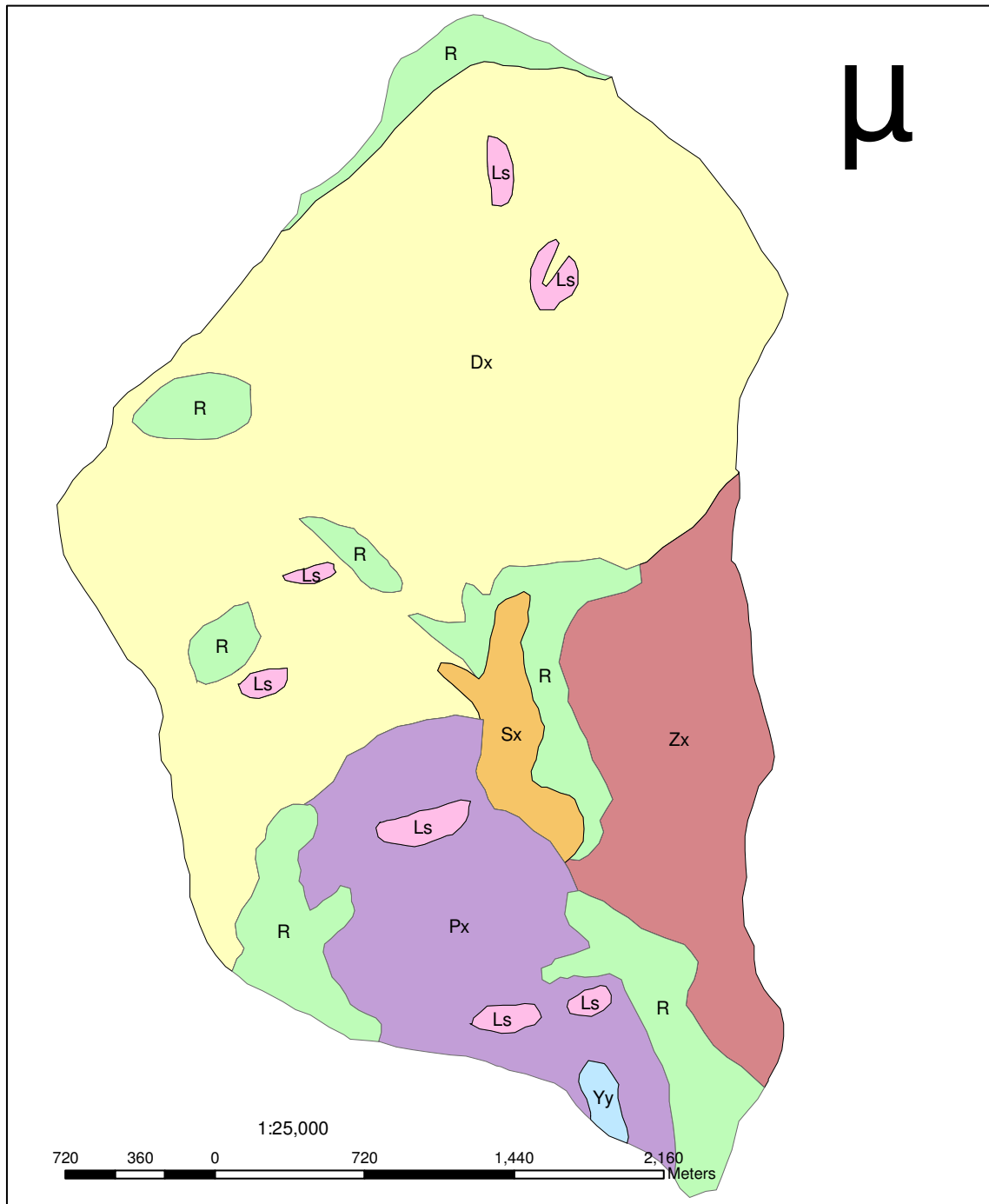
There are two miscellaneous land types (MLT), for the bare rock (cliff) and for the landslip areas. These units are defined in terms of surface features rather than soil profile characteristics.

The compositions of the soil map units (SMU) and their areas are summarised in Table 6.1.








Table 6.1 *Composition of soil mapping units at Sangma Ri watershed*

Mapping unit		Type	Main soil series	Minor soil series	Area		
Code	Name				Ha	Acre	%
Sx	Sangma complex	Complex	Sangma, Dremetse & Phungtshing	Sulukphu	0.35	0.87	0.05
Dx	Dremetse complex	Complex	Dremetse, Gashari & Shadong	Sulukphu & Bageng	714.99	1766.04	90.71
Px	Phungtshing complex	Complex	Phungtshing & Dremetse	Gashari & Bageng	1.06	2.63	0.13
Zx	Zangkhar complex	Complex	Zangkhar & Debari	Sulukphu	0.72	1.79	0.09
Yy	Yayang	Consociation	Yayang	-	0.1	0.25	0.01
R	Rock	MLT	Sulukphu, & bare rock	Landslip debris	67.14	165.83	8.52
Ls	Landslips	MLT			3.83	9.46	0.49
Total					788.19	1946.87	100

Figure 6.1 Soil map of Sangma Ri Watershed, Dremetse



Legend

- | | | | |
|---|---|---|--|
|  Dremetse complex |  Phungtshing complex |  Landslips |  Yayang |
|  Zangkhar complex. |  Sangma complex |  Cliff | |

7. OVERVIEW AND IMPLICATIONS

7.1 Overview of soils

Sangma Ri watershed is the third watershed study and is the second area on Shumar formation geology surveyed by Soil Survey Unit. This watershed contains a limited range of soils, on account of its small size and homogeneous geology.

In general much of the arable land is on soils of medium texture, moderate depth and with good drainage. The main variations are in the depth to weathered rock and stone content. These features are randomly distributed which makes it difficult to map them separately. There are shallow soils on steep crests and side slopes (mapped as R and Ls), and compact soils around Phungtshing (mapped as Px). However, this compact soil is of limited extent.

In a regional context, Phungtshing soils are similar to the soils in the new RNR-RC site at Wyengkhar in Monger. The bright reddish coloured soils of Zangkhar appear similar to Serbithang series over quartzite and schist in western Bhutan. The chhuzhing soil of Sangma is similar to many other chhuzhing soils of Bhutan with greyish and slightly cloddy topsoil over grey mottled upper subsoil.

7.2 Implication of results

The steep slope and stony rather dry soil limits the range of cropping system. The soils are more susceptible to run off and erosion and may experience moisture stress during the dry season, even though there is sufficient rooting depth. They are slightly acid and have moderate inherent fertility; therefore soil nutrient status is sufficient for low-input cropping system. The available K and P are variable, ranging from low to very high throughout the survey area.

The suitability of the watershed for multidisciplinary research activity is partly affected by the characteristics of the soils. In particular the results of the soil survey can contribute to the following:

- ❖ Are these soils typical of the soil management problems in some of the poorer soils in the East?
- ❖ Are the soils typical of large areas of forest and agricultural land in Eastern Bhutan, so that research findings can be extrapolated and the RNR-RC can fulfil its regional mandate?
- ❖ Are the soils likely to create major difficulties for the new infrastructure?

The first two points can be taken together. For useful research it is not required that the site should have good soils for the enterprise. In fact this is a disadvantage, as the researchers may achieve production levels that cannot be reached off the station. They may also under-estimate some of the management problems encountered by farmers in these soils. Soils that are typical, rather than excellent, are required for useful research. This is the second SSU study after Radhi in eastern Bhutan. However, comparisons with the above study area indicate that the soil conditions in the Sangma Ri watershed are similar to the region in respect of erodible phyllite and hillwash deposits derived from phyllite and quartzite. Therefore, research findings should be practicable and applicable.

REFERENCES

- AHT (1995). *Report on the interpretation of soil analytical results from the Soil and Plant Analytical Laboratory, Simtokha, and the formulation of a national soil classification system.* Agrar- und Hydrotechnik GmbH, Essen for REID, MoA & EU.
- Bhargava O N (ed.) (1995). *The Bhutan Himalaya; a geological account.* Spec. Publ. 39 GSI, Calcutta viii + 245
- Bhargava O N (1995). Geology of Bhutan –a synoptic view. pp 13-18 in '*The Bhutan Himalay; a geological account*'. (ed. O N Bhargava). GSI
- SSU (1998). *A preliminary application of soil horizon typology in Bhutan.* Working Paper WP 2, Soil Survey Unit, Ministry of Agriculture, Thimphu.
- SSU (1999). *Report on the soils of Merak and Sakten.* Report SS 8, Soil Survey Unit, Ministry of Agriculture, Thimphu.
- Chaturvedi R K, Misra S N & Mulay V V (1983). On the fossiliferous Ordovician rocks of Black Mountain Region, Bhutan Himalaya, and their significance in stratigraphic correlation. *Rec. GSI* 113 (2) 35-47.
- CIP (1993). *Geotechnical manual.* Community Irrigation Project, Irrigation Section, REID, MoA.
- Dasgupta S. (1995). Shumar Formation. Pp 64-78 in '*The Bhutan Himalaya: a geological account*'. (ed O N Bhayava). GSI.
- Dorji Y & Thapa T P (1995). *Report on the landslide investigation, 0 to 1 Km on the Trashigang - Riju feeder road.* DGM, MTI, Thimphu.
- Eguchi T (1997). *Regional and temporal variations in precipitation in the Eastern Himalayas.* Faculty of Humanities and Economics, Kochi University (Japan).
- Eguchi T (1987). Topographic features in the central part of the Bhutan Himalayas. Pp 185 - 208 in '*Life Zone ecology of the Bhutan Himalaya*'. (Ed. M. Ohsawa). Laboratory of Ecology, Chiba University (Japan).
- Eguchi T (1997). *Regional and temporal variations in precipitation in the Eastern Himalayas.* Faculty of Humanities and Economics, Kochi University (Japan).
- ESCAP (1991). *Atlas of mineral resources of the ESCAP region.* Economic and Social Commission for Asia and the Pacific, with Department of Geology and Mines, Thimphu.
- FAO(1990). *Guidelines for soil description.* Food & Agriculture Organisation of United Nations, Rome.

FAO (1998). *World reference base for soils*. World Soil Resource Report 84. Food & Agriculture Organisation of United Nations, Rome, with International Society of Soil Science & International Soils Reference & Information Centre, Wageningen.

Ganesan T M & Bose M N (1982). Plant remains of Mesozoic age from Lingshi Basin, Bhutan. *Geophytology* 12 (2) 279-286.

LUPP (1994). *Rainfall in Bhutan*. LUPP, PPD, MoA.

LUPP (1995). *Land resources survey of Dremetse gewog. The soils annex. Findings from the soil survey*. LUPP, PPD, MoA.

Parker C (1992). *Weeds of Bhutan*. NPPC, REID, MoA, Thimphu

Sarkar A & Dasgupta S (1995). The granitic rocks. pp 143-172 in '*The Bhutan Himalaya: a geological account*.' (Ed. Bhargava O N) Special Publ. 39 GSI, Calcutta. ISSN 0254-0436

Sinclair Knight (1983). *Soil and land capability survey, Bhutan. Tashigang and Mongar districts. FAO Project RAS 79/123*. Sinclair Knight & Partners for RGOB & FAO. (SSU/NSSC library, Simtokha)

Soil Survey Staff (1998). *Keys to Soil Taxonomy: Eighth edition*. US Department of Agriculture, Washington, DC.

SPAL (1993). *Soil analysis*. Soil and Plant Analytical Laboratory, REID, MoA.

Tangri S K & Pande A C (1995). The Tethyan sequence. pp 109-142 in '*The Bhutan Himalaya: a geological account*.' (Ed. Bhargava O N) Special Publ. 39 GSI, Calcutta. ISSN 0254-0436

Verma P N (1972). *Geology of parts of Lhuntshi and Tashigang districts, Eastern Bhutan, and adjacent parts of Kameng frontier division, NEFA, India, 1971-1972*. GSI.

APPENDIX A: LABORATORY METHODS

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 , so that there are no determinations of extractable acidity or Al, nor computations of ECEC or EBS%.

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 1M 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 1M ammonium acetate (NH_4OAc).

For the soils with pH (water) < 7.5 , the ammonium is extracted by leaching the soil with excess 1 M KCl, and measured to give the Cation Exchange Capacity. For the soil with pH (water) > 7.5 , the ammonium is extracted by leaching with excess 1 M sodium acetate.

Assays of extracts

The NH_4 in the 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.

Organic carbon

OC is measured by the Walkley – Black method of low temperature oxidation with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ 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. They are dispersed 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.

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

C:N = Organic C / Total N. [NB High ratios indicate low availability of N]

Note that the BS% values for the Radhi samples refer to TEB/CEC (NH_4OAc)

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

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

	Very High	High	Moderate	Low	Very 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 ₄ OAc) 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 ₄ OAc)	> 80	65 - 79	50 - 64	35 - 49	< 35
EBS %	> 80	50 - 79	35 - 49	20 - 34	< 20
AvK ppm	> 300	200 - 299	100 - 199	40 - 99	< 40
AvP ppm	> 30		15 - 29	5 - 14	< 5
Org. C %	> 5	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 (very poor)	20 - 49 (poor)	15 - 19 (moderate)	10 - 14 (good)	< 10 (very good)

Source: AHT 1995.

APPENDIX B: SOIL PROFILE DESCRIPTIONS AND ANALYSES

This appendix includes the detailed descriptions and analyses of the 12 soil profiles. The profiles are in the sequence in Table B.I.

Table B.I. Summary of Radhi soil profiles

Soil series	Main features	Profiles and analyses (see App .B)
Dremetse	Grey stony silty loam topsoil; over yellowish brown stony silty loam; over weathered phyllite at 50 -150 cm	PC051 PH105 PH106 PH112 PH113 PH115 PT033
Gashari	Dark grey silty clay loam topsoil; over stony brown sandy clay loam; over weathered phyllite at 60-145 cm	PH109 PH114 PT026 PT031 PT032
Shadang	Black stony sandy loam > 25 cm; over greyish brown sandy loam; over weathered phyllite at >50 cm.	PH107 PH108 PH110 PH111
Bageng	Stony dark greyish brown silty loam; over greyish brown silty clay loam over marble & phyllite at >100cm	PT028 PT029 PT030 Pd130
Sulukphu	Grey stony sandy loam – loam; over hard rock < 50cm	-
Zangkhar	Dark brown silty – fine sandy loam; over reddish – strong brown silty loam – clay loam; over weathered quartzite/ schist/ limestone > 1 m	PC049 PC050
Debari	Strong brown very stony clay – stony loam; over hard schist/quartzite > 1 m	-
Phungtshing	Stony yellowish brown silty – fine sandy clay loam; over very compact yellowish – strong brown silty clay; over brown moderately firm silty clay	PH116 PH117
Sangma	Deep mottled dark grey silty clay loam; over stony brown sandy clay loam	PT027
Yayang	Greyish brown sandy loam; over firm brown – reddish brown silty clay loam; over strong brown sandy loam	Pd129

Profile:	PC051	
Map unit:	Dx	
Soil Classification:	Bhutan Provisional soil series: Zangkhar Soil Taxonomy: Dystric or Typic Haplustept [thermic, fine loamy skeletal, mixed] WRB: Haplic Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Road cutting below Zangkhar village	
GPS:	27° 17'53.52"N, 91° 26'28.12" E	
Altitude:	1600m a.s.l	
Described & sampled:	25.10.2000, I. C Baillie	
Climate:	General:	Warm Temperate, P = ca 1000 mm p.a
	Recent weather:	Sunny
Regional topography	Deeply dissected valley, ca 1000m relief	
Site position:	Side of main gully at upper side lope of main spur	
Slope:	65%, 1km, irregular, aspect S (175°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation quartzite & phyllite
	Drift:	Colluvium
Land use:	Forest	
Vegetation:	Chir pine & thick lemon grass	
Surface:	Litter:	Very discontinuous pine litter, grass & broad leaves
	Outcrops:	None
	Stones:	Common fine & medium phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	5cm steps behind grass tussocks
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0 - 14	10YR 3/2 (very dark greyish brown) dry & 10 YR 6/3 (pale brown) moist with no mottles; stony silt loam; stony & interstitial moderate fine crumb; moderate fine interstitial; dry & slightly hard; many fine roots; many fine & medium hard angular quartzite & phyllite stones; HCl negative; gradual regular boundary to: [Sample PC051/1 @ 0-10cm]
14 – 33	10YR 7/4 (very pale brown) dry & 10YR 6/3 (yellowish brown) moist with no mottles; silt loam-loamy silt; patches of stony medium subangular blocky breaking to moderate fine crumb; abundant medium & fine pores; slightly dry, very friable & loose; common fine roots; common fine & medium angular hard quartzite & phyllite stones; old ant nest; HCl negative; gradual regular boundary to: [Sample PC051/2 @ 20-30 cm]
33 – 99	10YR 5/6 (yellowish brown) with rare fine faint orange mottles; stony fine sandy loam; stony interstitial weak medium subangular blocky breaking to moderate fine crumb; many medium & fine pores; moist & stony interstitial & very friable; common fine & few medium roots; many medium & fine hard angular quartzite & phyllite stones; HCl negative; gradual regular boundary to: [Sample PC051/3 @ 50-60 cm]
99 – 158	10YR 5/6 (yellowish brown) with no mottles; stony fine sandy clay loam; weak fine subangular blocky; many coarse, medium & fine pores; moist & very friable; few fine & medium roots; common fine & medium hard angular quartzite & phyllite stones; HCl negative: [Sample PC051/4 @ 110-120 cm]

Comment: Yellowish colour in deep phyllitic colluvium.

SPAL analytical results for SSU Profile PC051 Survey area: Sangma Ri watershed

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					
PC051 /1	0.10	8783	6.5	5.3	1.2	nd	4.5	2.4	0.1	16
/2	15-25	8784	6.5	4.7	1.8	nd	2.2	1.0	0.1	15
/3	50-60	8785	6.5	5.0	1.5	nd	1.0	0.3	Tr	nd
/4	120-130	8786	7.1	5.0	2.1	nd	1.0	0.1	0.1	5

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PC051 /1	9.1	1.3	0.3	0.1	10.8	nd	17.0	nd	66	nd
/2	4.0	1.0	0.2	0.1	5.3	nd	9.0	nd	51	nd
/3	3.0	1.2	0.2	0.1	4.5	nd	1 2.0	nd	38	nd
/4	4.0	2.0	0.2	0.1	6.3	nd	7.2	nd	84	nd

Profile:	PH105	
Map unit:	Dx	
Soil Classification:	Provisional Bhutan soil series: Dremetse Soil Taxonomy: Typic Eutrudept [<i>thermic, loamy-loamy skeletal, mixed</i>] WRB: Haplic Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Sulukphu under main Shadang viilage	
GPS:	27° 18'43.8"N, 91° 25'16.52" E	
Altitude:	2080m a.s.l	
Described & sampled:	20.10.2000, H B Tamang	
Climate:	General:	Warm temperate, P = ca 1000 mm p.a
	Recent weather:	Clear & sunny
Regional topography	Mid mountain, 300m relief	
Site position:	Midslope of side valley	
Slope:	30%, 300m long, rectilinear, aspect NE (85°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar phyllite & quartzite
	Drift:	Colluvium
Land use:	Fallow after rainfed maize	
	Vegetation:	<i>Ageratum conyzoides, Persicaria runcinata</i>
Surface:	Litter:	None
	Outcrops:	Common hard subangular quartzite & phyllite
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	Hummock near maize stubble
	Faunal activity:	None
	Other features:	None
Profile description: (Colours are moist unless indicated)	cm	
0-11	7.5YR 4/1 (dark grey) with no mottles; silt loam+; weak medium subangular blocky; common fine pores; moist & friable; many fine roots; common coarse hard subangular phyllite & common fine quartzite gravel; HCl negative; gradual regular boundary to: [Sample PH105/1 @ 0-10cm]	
11-50	7.5YR 3/1 (very dark grey) with few fine faint yellowish brown mottles; silty clay loam; moderate medium subangular blocky breaking to weak fine crumb; few medium & common fine pores; moist & slightly firm; common very fine roots; common medium hard angular quartzite; HCl negative; few krotovinas; clear regular boundary to: [SamplePH105/2 @ 25-35cm]	
50-78	10YR 4/3 (brown) with common fine faint dark brown mottles; silty clay loam; moderate medium subangular blocky breaking to weak fine crumb; weak discontinuous clayskins; moist & slightly firm; rare fine roots; few coarse hard angular quartzite & layer of weathered phyllite & quartzite; HCl negative; diffuse boundary to: [Not sampled]	
78-140+	10YR 4/3 (brown) with no mottles; silty loam; weak fine subangular blocky; few fine pores; moist & friable; no roots; common fine weathered phyllite; HCl negative: [Sample PH105/3 @ 100-110cm]	
Comment:	Moderately deep soil despite 30% slope.	

SPAL analytical results for SSU

Profile PH105

Survey area: Sangma Ri watershed

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					
PH105 /1	0-10	8721	6.7	5.5	1.2	nd	83.5	2.8	0.2	14
/2	25-35	8722	6.5	4.9	1.6	nd	34.6	2.3	0.2	11
/3	100-110	8723	6.5	4.3	2.2	nd	4.0	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH105 /1	14.8	1.6	2.6	0.1	19.2	nd	22.5	nd	85	nd
/2	12.3	1.0	0.7	0.1	14.2	nd	23.4	nd	61	nd
/3	2.5	0.5	0.8	0.1	3.9	nd	8.4	nd	47	nd

Profile:	PH106
Map unit:	Dx
Soil Classification:	Provisional Bhutan soil series: Dremetse Soil Taxonomy: Typic Dystrudept [<i>thermic, loamy – loamy skeletal, mixed</i>] WRB: Dystric Cambisol
Survey area:	Sangma Ri watershed
Location:	Ca 75m WNW of Shadang village
GPS:	27° 18'45.6"N, 91° 25'9.29" E
Altitude:	2080m a.s.l
Described & sampled:	20.10.2000, H B Tamang
Climate:	General: Warm temperate, P = ca 1000 mm p.a
Recent weather:	Sunny
Regional topography	Mid mountain, 300m relief
Site position:	Midslope of side valley
Slope:	20%, 300m+long, irregular aspect ESE (105°)
Site drainage:	Good
Parent material:	Solid: Shumar quartzite Drift: Colluvium
Land use:	Fallow after rainfed maize
Vegetation:	<i>Ageratum conyzoides</i> , <i>Persicaria runcinata</i> & <i>Crassocephalum crepidoides</i>
Surface:	Litter: None Outcrops: Few hard subangular quartzite & phyllite Stones: None Cracks: None Roots: None Microrelief: Hummock near maize stubble Faunal activity: None Other features: None

Profile description: (Colours are moist unless indicated)

cm

0 – 20	7.5YR 4/1 (dark grey) with common fine faint yellowish brown mottles; silt loam; moderate medium subangular blocky; many fine & medium pores; moist & slightly friable; many fine roots; few medium & common fine hard angular blocky quartzite & phyllite stones; HCl negative; clear regular boundary to: [Sample PH106/1 @ 0-10cm]
20-145+	10YR 4/4 (dark yellowish brown) with no mottles; loamy fine sand; very weak fine subangular blocky; many fine pores; moist & very friable; few fine roots; common medium partially weathered phyllite stones; HCl negative; common beetles: [SamplePH106/2 @ 70-80cm]

SPAL analytical results for SSU Profile PH106 Survey area: Sangma Ri watershed

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					
PH106 /1	0-10	8724	6.7	5.3	1.4	nd	53	2.6	0.3	9
/2	70-80	8725	7.2	5.0	2.2	nd	22	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH106/ 1	11.3	1.4	1.7	0.1	14.5	nd	21.3	nd	68	nd
/2	2.6	0.3	1.0	0.2	4.1	nd	9.1	nd	44	nd

Profile:	PH112	
Map unit:	Dx	
Soil Classification:	Provisional Bhutan soil series: Dremetse Soil Taxonomy: Typic Dystrudept [<i>thermic, loamy - loamy skeletal, mixed</i>] WRB: Dystric Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Ca 500m west of Dremetse Lhakhang & 20m NE of PH111	
GPS:	27° 18'53.89" N, 91° 26'25.72" E	
Altitude:	2000m a.s.l	
Described & sampled:	21.10.2000, H B Tamang	
Climate:	General:	Warm temperate, P = ca 1000 mm p.a
	Recent weather:	Sunny
Regional topography	Mid mountain, 350m relief	
Site position:	Midslope	
Slope:	80%, 350 m long, rectilinear, aspect S (179°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation quartzite & phyllite
	Drift:	Colluvium
Land use:	Abandoned dry land	
Vegetation:	<i>Artemisia myriantha, Pteridium aquilinum & Rubia Cordifolia</i>	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Few coarse phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)
cm

0 – 28	7.5YR 4/1 (dark grey) with no mottles; fine sandy loam; stony moderate medium crumb; interstitial pores; moist & friable; many fine & few coarse roots; few medium hard angular phyllite & quartzite stones; HCl negative; clear regular boundary to: [Sample PH112/1 @ 0-10cm]
28 – 105	7.5YR 4/4 (brown) with no mottles; medium sandy loam; weak fine subangular blocky; many fine pores; moist & friable; many fine roots; common medium quartzite & phyllite stones; HCl negative; common termites; common termite nests; diffuse boundary to: [SamplePH0112/2 @ 60-70cm]
105 – 140	7.5YR 4/3 (brown) with no mottles; stony loamy medium sand; stony & massive; interstitial pores; moist, stony & interstitial friable; few fine roots; many medium soft weathered phyllite stones; HCl negative: [Not sampled]
Comment:	High faunal activities mainly termite despite compacted topsoil.

SPAL analytical results for SSU Profile PH112 Survey area: Sangma Ri watershed

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					
PH112 /1	0-10	8740	6.1	4.4	1.7	nd	0.9	3.2	0.3	11
/2	60-70	8741	6.2	4.4	1.8	nd	0.4	0.7	0.1	7

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH112 /1	5.6	1.2	0.2	0.1	7.1	nd	23.6	nd	30	nd
/2	0.5	0.1	0.1	0.1	0.8	nd	93	nd	8	nd

Profile:	PH113	
Map unit:	Dx	
Soil Classification:	Provisional Bhutan soil series:Dremetse	
	Soil Taxonomy:	Typic Eutrudept [<i>thermic, loamy - loamy skeletal, mixed</i>]
	WRB:	Skeletal Cambisol
Survey area:	Sangma Ri watershed	
Location:	Ca 200m south east of Phungtshing village on side spur	
GPS:	27° 17' 11.55" N, 91° 25' 32.15" E	
Altitude:	1260m a.s.l	
Described & sampled:	23.10.2000, H B Tamang	
Climate:	General:	Warm temperate, P = ca 1000 mm p.a
	Recent weather:	Cloudy
Regional topography	Deeply dissected valley	
Site position:	Upper slope of major spur	
Slope:	16%, 300 m+long, banded regular, aspect NE (30°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation phyllite & quartzite
	Drift:	Colluvium
Land use:	Fallow after rainfed maize	
Vegetation:	Sweet buckwheat	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Many medium hard phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	Traces of ploughing
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0-24	2.5Y 6/2 (light brownish grey) with few medium faint brown & yellow mottles; stony silt loam; stony with weak fine subangular blocky breaking to moderate fine crumb; many fine pores; moist stony & interstitial very friable; common fine roots; many fine & medium hard angular phyllite & quartzite stones; HCl negative; abrupt slightly wavy boundary to: [Sample PH113/1 @ 0-10cm]
24-44	2.5YR 7/4 (light reddish brown) with no mottles; silty loam; weak medium breaking to fine subangular blocky; many fine & medium pores; moist & friable; few fine roots; common medium quartzite & phyllite stones; HCl negative; diffuse boundary to: [Sample PH113/2 @ 30-40cm]
44-82	2.5Y 6/4 (light yellowish brown) with common fine very faint grey mottles; very stony silty loam; very stony with interstitial weak medium breaking to fine subangular blocky; weak discontinuous clayskins; many coarse & fine pores; moist stony & friable; common medium & fine roots; abundant medium subangular weathering phyllite; HCl negative; rare charcoal; diffuse boundary to: [Sample PH113/3 @ 60-70cm]
82-94/102	2.5Y6/6 (olive yellow) with weathering rock mottles red, grey & brown; hand textured as silty clay loam; stony fine crumb; weak discontinuous clayskins; common medium pores; moist & stony slightly firm; rare fine & medium roots; weathering phyllite stones; HCl negative; gradual slightly wavy boundary to: [Not sampled]
94/102-135+	Mixed grey brown, red, & black; silt as hand texture (fine earth) between rocks; discontinuous clayskins; interstitial pores; no roots; moist & stony friable; common medium quartzite gravel; HCl negative: [Not sampled]

Comment: Third horizon looks like faint old forest topsoil buried by colluviation and cultivation, although quite pale.

SPAL analytical results for SSU Profile PH113 Survey area: Sangma Ri watershed

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					
PH113 /1	0-10	8742	6.5	5.3	1.2	nd	65.0	1.3	0.1	13
/2	30-40	8743	6.9	5.2	1.7	nd	64.2	0.2	Tr	nd
/3	60-70	8744	6.9	5.1	1.8	nd	62.2	0.2	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH113 /1	6.0	0.8	0.2	0.1	7.1	nd	8.2	nd	86	nd
/2	2.3	0.6	0.2	0.1	3.2	nd	5.1	nd	60	nd
/3	2.2	0.6	0.1	0.1	3.0	nd	5.3	nd	57	nd

Profile:	PH115	
Map unit:	Dx	
Soil Classification:	Provisional Bhutan soil series: Dremetse Soil Taxonomy: Typic Eutrudept [<i>thermic, loamy – loamy skeletal, mixed</i>] WRB: Skeletic Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Top end of Gashari transect	
GPS:	27 ⁰ 18'25.70"N, 91 ⁰ 25'52.96" E	
Altitude:	2000m a.s.l	
Described & sampled:	24.10.2000, H B Tamang	
Climate:	General:	Warm temperate, P = ca 1000 mm p.a
	Recent weather:	Cloudy
Regional topography	Deeply dissected valley, 1000m	
Site position:	Upper slope of minor spur	
Slope:	30% down, 400m, banded rectilinear, aspect (150 ⁰)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation phyllite & quartzite
	Drift:	Colluvium
Land use:	Fallow after rainfed maize	
Vegetation:	Maize stubble & few weeds	
Surface:	Litter:	Discontinuous maize stubble
	Outcrops:	Few boulders to 1m
	Stones:	Few medium & fine hard phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	Very slight remnants of cultivation
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)
cm

0-11	10YR 6/3 (pale brown) dry & 7.5YR 4/2 (brown) moist with no mottles; stony fine sandy loam; stony with interstitial moderate fine subangular blocky breaking to crumb; many fine pores; dry & slightly hard; common fine roots; many medium & fine hard angular phyllite & quartzite stones; HCl negative; few ants; gradual regular boundary to: [Sample PH115/1 @ 0-10cm]
11-32	10YR 5/4 (yellowish brown) dry & 10YR 7/4 (very pale brown) moist with no mottles; silt loam; weak medium subangular blocky breaking to fine crumb; many fine & medium pores; dry & very hard; few fine roots; common medium & fine hard angular phyllite & quartzite stones; HCl negative; clear regular boundary to: [Sample PH115/2 @ 16-26cm]
32-52	10YR 6/4 (light yellowish brown) with no mottles; very stony silt loam; stony with interstitial weak medium breaking to fine crumb; many medium & fine pores; moist, stony & friable; rare fine roots; abundant coarse, medium & fine phyllite stones; HCl negative; diffuse boundary to: [Sample PH115/3 @ 35-45cm]
52-79	10YR 5/6 (yellowish brown) with no mottles; very stony medium sandy clay loam; stony with interstitial moderate fine crumb; many fine pores; moist, stony & very friable; rare fine roots; abundant coarse, medium & fine phyllite stones; HCl negative; diffuse boundary to: [Not sampled]
79-107	7.5YR 5/4 (brown) with common medium faint dark brown & black mottles; very stony silty loam; stony moderate fine crumb; many fine pores; moist, stony & very friable; abundant coarse, medium & fine angular phyllite stones; HCl negative; diffuse boundary to: [Not sampled]

107-130+ 10YR 5/6 (yellowish brown) with grey weathering rock colour as mottles; hand textured as gravelly silty clay loam; weak fine crumb; interstitial pores; moist, stony & friable; no roots; many flakes of weathering rock; HCl negative: [Not sampled]

SPAL analytical results for SSU Profile PH115 Survey area: Sangma Ri watershed

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					
PH115 /1	0-10	8747	6.7	5.4	1.3	nd	13.5	1.7	0.1	17
/2	16-26	8748	6.8	4.8	2.0	nd	3.3	0.4	Tr	nd
/3	35-45	8749	7.0	4.7	2.3	nd	4.3	0.2	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH115 /1	8.7	1.0	0.5	0.1	10.3	nd	13.5	nd	77	nd
/2	4.5	0.5	0.3	0.1	5.4	nd	9.4	nd	58	nd
/3	4.2	0.5	0.2	0.1	5.0	nd	10.2	nd	48	nd

Profile: PT033

Map unit: Dx

Soil Classification: Provisional Bhutan soil series:Dremetse
Soil Taxonomy: Typic Eutrudept [*thermic, loamy – loamy skeletal, mixed*]
WRB: Skeletic Cambisol

Survey area: Sangma Ri Watershed
Location: ca 6 m W from the last house of Debari Village.
GPS: 27° 17' 13.73" N, 91° 25' 46.32" E
Altitude: 1080 m a.s.l

Described & sampled: 25.10.2000, Tshering Dorji

Climate: General: Sub tropical, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain
Site position: Lower slope

Slope: 36%, ca 1 km long, rectilinear, aspect ESE (100°)
Site drainage: Good

Parent material: Solid: Shumar phyllite & quartzite
Drift: Colluvium

Land use: Kamzhing
Vegetation: *Artemisia myriantha*, *Ageratium conizoide*, *Euphorbia hirta*, citrus & Lemon grasses.

Surface: Litter: None
Outcrops: Few subangular phyllite rockouts
Stones: Common fine, medium & coarse angular platy phyllite.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: **(Colours are moist unless indicated)**
cm

- 0 - 18 10YR 6/2 (light brownish grey) dry & 10YR 4/2 (dark greyish brown) moist with no mottles; silty clay loam; moderate medium crumb; many fine & medium pores; dry & slightly friable; common fine roots; common fine & medium & few coarse angular quartzitic phyllite & common gravels; HCl negative; clear regular boundary to: [Sample PT033/1 @ 0 - 10 cm]
- 18 - 63 10YR 7/4 (very pale brown) dry & 10YR 5/4 (yellowish brown) moist with common medium faint yellowish brown mottles; gravelly fine sandy clay loam; stony medium subangular blocky; many fine & common medium pores; dry & friable; rare fine roots; many fine, medium & coarse angular & platy quartzitic phyllite & common gravels; HCl negative; gradual regular boundary to: [Sample PT033/2 @ 30 - 40 cm]
- 63 - 170+ 10YR 5/6 (yellowish brown) with common coarse distinct brown & greyish brown mottles; hand texture as silty clay loam; moderate medium subangular blocky; common fine & rare medium pores; moist, stony & friable; few coarse roots; abundant fine, medium & coarse hard angular & platy quartzitic phyllite stones; HCl negative: [Not sampled]

SPAL analytical results for SSU

Profile PT033

Survey area: Dremetse

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT033 /1	0-10	8775	7.0	5.8	1.2	nd	102.5	1.7	0.2	9
PT033 /2	30-40	8776	7.4	5.4	2.0	nd	101.0	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT033 /1	8.5	2.1	0.9	0.1	11.6	nd	13.4	nd	86	nd
PT033 /2	1.4	0.5	0.9	0.1	2.9	nd	1.8	nd	100	nd

Profile: PH109

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Gashari
Soil Taxonomy: Typic Eutrudept [*thermic, loamy - loamy skeletal, mixed*]
WRB: Haplic Cambisol

Survey area: Sangma Ri watershed
Location: Ca 15m WSW of Omghari village & ca 10m NNW of main footpath to Bageng
GPS: 27° 18' 27.57" N, 91° 25' 11.46" E
Altitude: 1680m a.s.l

Described & sampled: 21.10.2000, H B Tamang

Climate: General: Warm temperate P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain, 300m relief
Site position: Midslope of side spur

Slope: 32%, 1km+long, irregular, aspect SES (170°)
Site drainage: Good

Parent material: Solid: Shumar Formation quartzite & phyllite
Drift: Colluvium

Land use: Fallow after rainfed maize
Vegetation: *Ageratum conyzoides*, *Amarantus spp.*, nettles & *Siegesbeckia orinatalis*

Surface: Litter: None
Outcrops: Few hard angular quartzite & phyllite
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

cm

- 0-17 7.5YR 4/1 (dark grey) with common fine faint yellowish brown mottles; silty clay loam; strong medium subangular blocky; common fine & medium pores; slightly dry & slightly hard; common medium & fine roots; common fine hard quartzite & phyllite gravel; HCl negative; few grubs; few charcoal; gradual regular boundary to: [Sample PH109/1 @ 0-10cm]
- 17-60 7.5YR 4/3 (brown) with common medium distinct dark brown & yellowish brown mottles; medium sandy loam; weak fine subangular blocky breaking to medium crumb; common fine pores; moist & friable; few fine roots; common medium soft weathered phyllite & few fine hard quartzite gravel; HCl negative; diffuse boundary to: [Sample PH109/2 @ 30-40cm]
- 60-145+ 10YR 5/4 (yellowish brown) with common fine faint dark brown mottles; coarse sandy loam+; weak fine subangular blocky; interstitial pores; moist & friable; rare fine roots; few coarse phyllite & common hard angular quartzite; HCl negative: [Sample PH109/3 @ 90-100cm]

SPAL analytical results for SSU Profile PH109 Survey area: Sangma Ri watershed

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					
PH109 /1	0-10	8732	7.3	6.0	1.3	nd	27.9	3.2	0.4	8
/2	30-40	8733	7.4	5.4	2.0	nd	2.7	0.7	0.1	7
/3	90-100	8734	7.3	5.3	2.0	nd	25.0	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH109 /1	18.5	2.3	2.8	0.1	23.7	nd	25.5	nd	93	nd
/2	8.7	1.5	0.9	0.1	11.2	nd	15.7	nd	71	nd
/3	3.2	0.5	0.4	0.2	4.4	nd	14.7	nd	30	nd

Profile:	PH114	
Map unit:	Dx	
Soil Classification:	Gashari soil series: Soil Taxonomy: Typic Eutrupt [<i>thermic, loamy - loamy skeletal, mixed</i>] WRB: Haplic Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Near top of Phungtshing village	
GPS:	27° 17' 18.39"N, 91° 25' 18.17" E	
Altitude:	1440m a.s.l	
Described & sampled:	23.10.2000, H B Tamang	
Climate:	General:	Sub tropical, P = ca 1000 mm p.a
Recent weather:	Shower	
Regional topography	Deeply dissected valley	
Site position:	Upper slope of major slope	
Slope:	14% down, 1km, banded convex, aspect (30°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation phyllite & quartzite
	Drift:	Colluvium
Land use:	Fallow after rainfed maize	
Vegetation:	Maize, beans & <i>Amaranthus spp</i>	
Surface:	Litter:	Scattered maize stoves
	Outcrops:	None
	Stones:	Abundant medium & fine hard angular phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	Very slight cultivation
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0-10	7.5Y 4/1 (dark grey) with no mottles; very stony medium sandy loam; very stony moderate medium crumb; interstitial pores; moist, stony & friable; many fine roots; abundant medium & fine hard angular quartzite & phyllite stones; HCl negative; common ants; gradual regular boundary to: [Sample PH114/1 @ 0-10cm]
10-20	10YR 5/2 (greyish brown) with no mottles; very stony medium sandy loam+; very stony weak fine subangular blocky; many medium & fine pores; moist & stony friable; abundant medium & fine angular hard quartzite & phyllite stones; HCl negative; clear regular boundary to: [Not sampled]
20-38	10YR 4/1 (dark grey) with no mottles; silt loam; stony with interstitial moderate medium subangular blocky breaking to medium crumb; abundant medium & fine pores; moist, stony & friable; few medium & many fine roots; abundant coarse subangular phyllite stones; HCl negative; clear regular boundary to: [sample PH114/2 @ 25-35cm]
38-72	10YR 5/4 (yellowish brown) with no mottles; very fine sandy loam; very stony massive; interstitial pores; moist, very stony & friable; common fine roots; abundant very hard medium phyllite stones; common ants; HCl negative; diffuse boundary to: [Not sampled]
72-105	10YR 4/2 (dark greyish brown) with no mottles; very stony silt loam; very stony massive; interstitial pores; moist, stony & very friable; few medium & fine roots; abundant angular phyllite stones; HCl negative; few charcoals: [Not sampled]

Comment: Several phases of colluviation shows in dark subsoil colour & differences in stone sizes, and deep charcoal.

SPAL analytical results for SSU**Profile PH114****Survey area: Sangma Ri watershed**

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					
PH114 /1	0-10	8745	6.7	5.8	0.9	nd	74.9	2.3	0.2	12
/2	25-35	8746	6.9	5.6	1.3	nd	53.2	1.2	0.1	12

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH114 /1	8.9	2.1	0.8	0.1	11.9	nd	16.1	nd	74	nd
/2	7.2	1.4	0.3	0.1	9.0	nd	12.0	nd	76	nd

Profile:	PT026	
Map unit:	Dx	
Soil Classification:	Provisional Bhutan soil series:Gashari	
	Soil Taxonomy:	Typic Eutrudept [<i>thermic, loamy – loamy skeletal, mixed</i>]
	WRB:	Skeletal Cambisol
Survey area:	Sangma Ri watershed	
Location:	Ca 20 m ESE from Gaenang village & ca 30 m SWS from Mankhar village	
GPS:	27° 18'45.28" N, 91° 25'45.18" E	
Altitude:	1760m a.s.l	
Described & sampled:	23.10.2000, Tshering Dorji	
Climate:	General:	Sub tropical, P = ca 1000 mm p.a
	Recent weather:	Partially sunny
Regional topography	Mid mountain, relief ca 1km	
Site position:	Lower slope	
Slope:	35%, ca 1 km long, irregular, aspect E (90°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar phyllite & quartzite
	Drift:	Colluvium
Land use:	Kamzhing	
Vegetation:	Maize stubble, <i>Artemisia myriantha</i> , <i>Rubia cordifolia</i> , <i>Ageratium conizoide</i> , <i>Crasase phyllum</i> <i>crypizoid</i> <i>Bedens philosa</i> , <i>Sagesbicia orantalis</i>	
Surface:	Litter:	None
	Outcrops:	Few subangular blocky phyllite out crops
	Stones:	Common medium & coarse hard angular & platy phyllite
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (**Colours are moist unless indicated**)

cm

0 - 37	10YR 4/2 (dark greyish brown) with no mottles; silt loam; moderate medium subangular blocky; many fine & few medium & coarse pores; moist & slightly firm; common fine roots; common fine & medium hard angular & platy phyllite & quartzitic phyllite stones & gravel; HCl negative; diffuse boundary to: [Sample PT026/1 @ 0-10 cm]
37 -125+	10YR 3/3 (dark brown) with no mottles; fine sandy clay loam; weak medium subangular blocky breaking to moderate fine crumb; many fine pores; moist & friable; common fine & medium & few coarse roots; many fine & medium & few coarse quartzitic phyllite stones; HCl negative. [Sample PT026/2 @ 50-60 cm]
Comment:	There is not much soil development.

SPAL analytical results for SSU

Profile PT026

Survey area: Sangma Ri watershed

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT026 /1	0-10	8759	7.2	6.0	1.2	nd	72.0	1.3	0.1	13
PT026 /2	50-60	8760	7.9	6.7	1.2	nd	115.0	0.7	0.1	7

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAC	EBS%
PT026 /1	6.9	1.2	1.5	0.1	9.7	nd	8.3	nd	100	nd
PT026 /2	9.2	0.5	1.4	0.1	11.2	nd	nd	nd	nd	nd

Profile: PT031

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Gashari
Soil Taxonomy: Typic Eutrudept [*thermic, loamy – loamy skeletal, mixed*]
WRB: Skeletic Cambisol

Survey area: Sangma Ri Watershed, Dremetse
Location: ca 15 m NNE from the only house in Jamtshokpa village/ Just below the main path to Lu from Jamtshokpa.
GPS: 27° 17' 20.84 N, 91° 25' 6.28" E
Altitude: 1680m a.s.l

Described & sampled: 25.10.2000, Tshering Dorji

Climate: General: Warm temperate, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain
Site position: Upper slope

Slope: 18%, ca 1 km long, Concave, aspect ESE (117°)
Site drainage: Good

Parent material: Solid: Shumar formation
Drift: Colluvium

Land use: Kamzhing
Vegetation: Maize stubble, *Artemisia myriantha*, ferns & grasses

Surface: Litter: None
Outcrops: None
Stones: Common fine & medium hard platy & angular quartzitic phyllite.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (**Colours are moist unless indicated**)

cm

- 0 - 17 10YR 6/2 (light brownish grey) dry & 10YR 4/2 moist (dark greyish brown) with common medium faint greyish brown & distinct yellowish brown mottles; silty clay loam; stony moderate medium subangular blocky & single grain; abundant fine & few medium pores; slightly moist, stony & friable; common fine roots; many fine, medium & few coarse hard angular & platy quartzitic phyllite; HCl negative; abrupt regular boundary to:
[Sample PT031/1 @ 0 - 10 cm]
- 17 - 105+ 7.5YR 5/6 (stony brown) with common coarse faint greyish brown mottles; silty clay loam; stony weak medium subangular blocky & single grain; interstitial pores; moist, stony & friable; few fine medium & rare coarse roots; abundant fine medium & coarse hard angular & platy quartzitic phyllite stones; HCl negative:
[Sample PT031/2 @ 50 - 60 cm]
- Comments: Very shallow soil with lots of hard angular & platy quartzitic phyllite. There is no sign of multicolluviation.

SPAL analytical results for SSU

Profile PT031

Survey area: Sangma Ri watershed

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT031 /1	0-10	8771	6.6	5.2	1.4	nd	81.8	1.6	0.2	10
PT031 /2	30-40	8772	6.5	4.6	1.9	nd	1.8	0.2	0.1	4

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT031 /1	7.4	1.6	0.8	0.1	9.9	nd	14.2	nd	70	nd
PT031 /2	2.9	1.5	0.6	0.1	5.1	nd	12.6	nd	41	nd

Profile: PT032

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Gashari
Soil Taxonomy: Typic Eutrudept [*thermic, loamy – loamy skeletal, mixed*]
WRB: Haplic Cambisol

Survey area: Sangma Ri Watershed, Dremetse
Location: ca 15 m SES from the only house in Wongphay & about 50 m WSW from Theybari.
GPS: 27° 17'4.93" N, 91° 25'23.69" E
Altitude: 1340m a.s.l

Described & sampled: 25.10.2000, Tshering Dorji

Climate: General: Sub tropical, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain
Site position: Mid slope

Slope: 27%, ca 1 km long, Concave, aspect E (94°)
Site drainage: Good

Parent material: Solid: Shumar phyllite and quartzite
Drift: Colluvium / Residual

Land use: Kamzhing
Vegetation: *Oroxylum indica*, *Mangifera indica*, *Phasitica bulgaris* & Lemon grasses

Surface: Litter: None
Outcrops: Few subangular phyllite
Stones: Common fine & medium hard angular & platy phyllite & quartzitic phyllite.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: **(Colours are moist unless indicated)**

cm

- 0 - 27 10YR 4/2 (dark greyish brown) with no mottles; silt loam; weak medium subangular blocky breaking to moderate fine crumb; many fine & few medium pores; slightly moist & friable; few fine, medium & coarse roots; few fine & medium hard angular quartzite & phyllite stones; HCl negative; few earthworm seen; clear regular boundary to:
[Sample PT032/1 @ 0 - 10 cm]
- 27 - 110+ 2.5Y 5/2 (greyish brown) with common medium & coarse distinct greyish brown mottles; hand textured as silt loam; weak medium & fine subangular blocky; many fine pores; moist stony & friable; common medium, coarse and few fine roots; highly weathered insitu phyllite & many fine, medium & coarse hard angular & platy phyllite & quartzitic phyllite; HCl negative:
[Sample PT032/2 @ 50 - 60 cm]

SPAL analytical results for SSU

Profile PT032

Survey area: Sangma Ri watershed

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT032 /1	0-10	8773	6.5	5.3	1.2	nd	30.4	1.6	0.1	14
PT032 /2	30-40	8773	6.3	4.0	2.3	nd	3.8	0.2	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT032 /1	6.3	1.4	0.5	0.1	8.3	nd	7.2	nd	100	nd
PT032 /2	1.0	0.6	0.1	0.1	1.8	nd	2.1	nd	89	nd

Profile: PH107

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Shadang
 Soil Taxonomy: Typic Eutrudept [*thermic, loamy-loamy skeletal, mixed*]
 WRB: Skeletic Cambisol

Survey area: Sangma Ri watershed
 Location: Ca 300m NW of Shadang village
 GPS: 27° 18'48.37" N, 91° 25'20.39" E
 Altitude: 2160m a.s.l

Described & sampled: 20.10.2000, H B Tamang

Climate: General: Warm temperate, P = ca 1000 mm p.a
 Recent weather: Sunny

Regional topography: Mid mountain, 350m relief
 Site position: Midslope

Slope: 7%, 350m+long, rectilinear, aspect, SE (125°)
 Site drainage: Good

Parent material: Solid: Shumar Formation phyllite & some quartzite
 Drift: Colluvium

Land use: Waste land
 Vegetation: *Artemisia myriantha, Ficus spp & Solanum khasainum*

Surface: Litter: None
 Outcrops: Common hard subangular quartzite & phyllite
 Stones: Few hard angular & platy quartzite
 Cracks: None
 Roots: None
 Microrelief: None
 Faunal activity: None
 Other features: None

Profile description: (Colours are moist unless indicated)

cm

- 0-58 7.5YR 4/4 (brown) with no mottles; stony medium sandy loam; stony with interstitial weak fine subangular blocky breaking to fine crumb; many fine pores; moist, stony & interstitial friable; many fine & rare coarse roots; many medium hard angular quartzite & phyllite stones; HCl negative; clear wavy boundary to:
 [Sample PH107/1 @ 0-10cm]
- 58-120 Mixed, 10YR 5/2 (greyish brown), 2.5Y 4/1 (dark grey) & 5Y 2.5/1 (black) gravelly sandy loam+; stony with interstitial moderate medium subangular blocky; interstitial pores; moist & firm; rare very fine roots; many medium & fine angular quartzite & phyllite stones; HCl negative; clear regular boundary to:
 [Sample PH107/2 @ 80-90cm]
- 120-157+ 2.5YR 5/3 (reddish brown) with common fine faint grey & yellow mottles; silty clay loam; stony with interstitial medium subangular blocky; interstitial pores; moist & very firm; common fine & medium soft phyllite & hard quartzite stones; HCl negative:
 [Sample PH107/3 @ 140-150cm]

SPAL analytical results for SSU Profile PH107 Survey area: Sangma Ri watershed

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					
PH107 /1	0-10	8726	6.4	4.7	1.7	nd	0.5	1.0	0.1	10
/2	80-90	8727	7.1	4.8	2.3	nd	1.0	0.3	Tr	nd
/3	140-150	8728	7.9	6.1	1.8	nd	1.1	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH107 /1	4.9	0.2	0.1	0.1	5.3	nd	9.3	nd	58	nd
/2	11.5	0.7	0.1	0.1	12.4	nd	14.0	nd	88	nd
/3	5.7	0.2	0.2	0.1	6.2	nd	nd	nd	nd	nd

Profile:	PH108
Map unit:	Dx
Soil Classification:	Provisional Bhutan soil series: Shadang Soil Taxonomy: Typic Eutrudept [<i>thermic, loamy-loamy skeletal, mixed</i>] WRB: Haplic Cambisol
Survey area:	Sangma Ri watershed
Location:	Ca 10m WNW of Shadang village
GPS:	27° 18'44.07" N, 91° 25'11.67" E
Altitude:	2120m a.s.l
Described & sampled:	20.10.2000, H B Tamang
Climate:	General: Warm temperate, P = ca 1000 mm p.a Recent weather: Sunny
Regional topography	Mid mountain, 300m relief
Site position:	Midslope
Slope:	45%, 200 m long, irregular, aspect ESE (109°)
Site drainage:	Good
Parent material:	Solid: Shumar Formation phyllite & quartzite Drift: Colluvium
Land use:	Waste land
Vegetation:	<i>Atremesia myriantha, Crassocephalum crepidoides</i>
Surface:	Litter: None Outcrops: Common hard angular quartzite & phyllite Stones: Few hard angular & platy quartzite Cracks: None Roots: None Microrelief: None Faunal activity: None Other features: None
Profile description: (Colours are moist unless indicated)	
cm	
0-22	7.5YR 3/1 (very dark grey) with no mottles; stony silt loam; weak fine subangular blocky; many fine & few coarse pores; moist & friable; common medium & fine roots; many fine, medium & coarse hard quartzite & phyllite stones; HCl negative; gradual regular boundary to: [Sample PH108/1 @ 0-10cm]
22-80	7.5YR 2.5/1 (very dark grey) with no mottles; stony silty clay loam; moderate medium subangular blocky; many medium & fine pores; moist & friable; common fine roots; many fine, medium & coarse hard quartzite & phyllite stones; HCl negative; clear regular boundary to: [SamplePH108/2 @ 50-60cm]
80-150	10YR 5/4 (yellowish brown) with no mottles; very stony medium sandy loam; stony weak fine subangular blocky; interstitial pores; moist & stony friable; rare fine roots; abundant fine, medium & coarse phyllite & quartzite stones; HCl negative: [Sample PH108/3 @ 110 -120cm]
Comment:	Black two top horizons are not associated with high contents of organic matter. The colour probably comes from carbonaceous phyllite. The profile is stony throughout.

SPAL analytical results for SSU Profile PH108 Survey area: Sangma Ri watershed

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					
PH108 /1	0-10	8729	7.1	5.7	1.4	nd	21.3	2.1	0.2	11
/2	50-60	8730	7.3	5.9	1.4	nd	47.1	1.4	0.1	14
/3	110-120	8731	7.7	5.8	1.9	nd	49.9	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH108 /1	13.9	0.9	0.7	0.1	15.6	nd	16.5	nd	94	nd
/2	18.1	0.9	0.5	0.1	19.6	nd	21.2	nd	92	nd
/3	7.9	0.8	0.3	0.1	9.1	nd	nd	nd	nd	nd

Profile: PH110

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Shadang
Soil Taxonomy: Typic Eutrudept [*thermic, loamy - loamy skeletal, mixed*]
WRB: Haplic Cambisol

Survey area: Sangma Ri watershed
Location: Ca 50m east of Shadang village
GPS: 27° 18'42.40" N, 91° 25'24.36" E
Altitude: 2040m a.s.l

Described & sampled: 21.10.2000, H B Tamang

Climate: General: Warm temperate, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain, 300m relief
Site position: Midslope of the spur

Slope: 70%, 100 m long, irregular, aspect SE (138°)
Site drainage: Good

Parent material: Solid: Shumar Formation phyllite & quartzite
Drift: Colluvium

Land use: Fallow after rainfed maize
Vegetation: *Ageratum conyzoides*, *Amarantus spp*, nettles; *Crassocephalum crepidoides*

Surface: Litter: None
Outcrops: Few hard angular quartzite & phyllite
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

cm

0-40 7.5YR 4/1 (dark grey) moist & 10YR 5/1 (grey) dry with no mottles; stony medium sandy loam; stony with interstitial moderate medium subangular blocky; common fine & medium pores; dry, stony & interstitial hard; common fine roots; many medium hard angular phyllite & quartzite stones; HCl negative; gradual regular boundary to: [Sample PH110/1 @ 0-10cm]

40-130+ 7.5YR 3/1 (very dark grey) with no mottles; coarse sandy loam; stony interstitial weak fine subangular blocky; interstitial pores; moist, stony & friable; rare fine roots; common fine soft weathering phyllite boulders; HCl negative: [SamplePH110/2 @ 80-90cm]

SPAL analytical results for SSU Profile PH110 Survey area: Sangma Ri watershed

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					
PH110 /1	0-10	8735	7.1	5.6	1.5	nd	7.0	1.3	0.2	5
/2	80-90	8736	7.2	5.1	2.1	nd	2.8	0.2	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH110 /1	9.8	0.8	0.9	0.1	11.6	nd	11.8	nd	98	nd
/2	5.1	0.2	0.1	0.1	5.5	nd	10.5	nd	52	nd

Profile: PH111

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Shadang
Soil Taxonomy: Typic Eutrudept [*thermic, loamy - loamy skeletal, mixed*]
WRB: Skeletic Cambisol

Survey area: Sangma Ri watershed
Location: Ca 300m north east of Shadang village & 20m SW of PH112
GPS: 27° 19'3.52" N, 91° 26'17.18" E
Altitude: 2120m a.s.l

Described & sampled: 21.10.2000, H B Tamang

Climate: General: Warm temperate, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain, 350m relief
Site position: Midslope

Slope: 80%, 350+long, rectilinear, aspect S (179°)
Site drainage: Good

Parent material: Solid: Shumar Formation quartzite with phyllite
Drift: colluvium

Land use: *Waste land*
Vegetation: *Atremesia myriantha, Rubia eleptica & Rubica cordifolia*

Surface: Litter: None
Outcrops: Few hard angular quartzite & phyllite
Stones: Common medium & coarse phyllite & quartzite
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0-16 7.5YR 2.5/2 (black) moist & 7.5YR 4/1 (dark grey) dry with no mottles; stony humic sandy loam; bouldery with interstitial weak fine crumb; interstitial pores; dry & loose; many coarse, medium & fine roots; common medium & coarse angular quartzite & phyllite stones & boulders; HCl negative; few ants; clear regular boundary to:
[Sample PH111/1 @ 0-10cm]

16-57 7.5YR 4/6 (strong brown) with no mottles; medium sandy loam; stony with interstitial massive; interstitial pores; moist & slightly friable; few coarse, common fine & medium roots; common medium & coarse quartzite & phyllite stones; HCl negative; gradual regular boundary to: [SamplePH111/2 @ 25-35cm]

57-100 7.5YR 5/6 (strong brown) with no mottles; very gravelly sandy loam; stony & massive; interstitial pores; moist, stony & slightly friable; many fine roots; abundant fine & medium hard angular phyllite & quartzite stones; HCl negative; gradual wavy boundary to: [Sample PH111/3 @ 70-80cm]

100-145+ 7.5YR 4/4 (brown) with no mottles; gravelly sand; stony & massive; interstitial pores; dry, stony & interstitial friable; many fine roots; abundant medium & fine soft weathered phyllite stones; HCl negative:
[Not sampled]

SPAL analytical results for SSU Profile PH111 Survey area: Sangma Ri watershed

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					
PH111 /1	0-10	8737	6.4	5.2	1.2	nd	3.9	6.5	3.7	2
/2	25-35	8738	6.5	4.9	1.6	nd	0.6	2.7	0.2	13
/3	70-80	8739	6.8	5.2	1.6	nd	22.8	0.40	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH111 /1	20.1	3.9	1.5	0.2	25.7	nd	13.2	nd	77	nd
/2	6.2	1.8	1.1	0.1	9.2	nd	18.3	nd	50	nd
/3	0.7	0.6	0.7	0.1	2.1	nd	6.8	nd	30	nd

Profile: PT028

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Bageng
Soil Taxonomy: Typic Eutrudept [*thermic, loamy – loamy skeletal, mixed*]
WRB: Skeletic Cambisol

Survey area: Sangma Ri Watershed
Location: ca 30 m SES of Bageng Community School & ca 50 m+ NE of top ridge prayer flags
GPS: 27° 18' 16.71" N, 91° 24' 48.80" E
Altitude: 1680m a.s.l

Described & sampled: 24.10.2000, Tshering Dorji

Climate: General: Sub tropical, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain, relief ca 0.5km
Site position: Mid slope

Slope: 55%, ca 0.5 km long, irregular, aspect ENE (82°)
Site drainage: Good

Parent material: Solid: Shumar phyllite and quartzite
Drift: Colluvium

Land use: Kamzhing
Vegetation: Maize stubble, *Artemisia myriantha* & *Ageratium conizoide*

Surface: Litter: None
Outcrops: None
Stones: Common medium & coarse hard angular and platy phyllite
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: **(Colours are moist unless indicated)**

cm

- 0 - 25 10YR 4/2 (brown) with no mottles; very fine sandy loam+; moderate medium subangular blocky; interstitial pores; moist & friable; common fine, medium & coarse roots; common fine & medium hard angular phyllite stones; HCl negative; clear regular boundary to: [Sample PT028/1 @ 0-10 cm]
- 25 - 57 2.5Y 5/3 (light olive brown) with few strips of distinct dark greyish brown mottles; silt loam; moderate medium subangular blocky; interstitial pores; moist & friable; few fine & common coarse roots; common medium & coarse hard angular & platy phyllite, quartzitic phyllite & weathered phyllite stones & gravel; HCl negative; clear regular boundary to: [Sample PT028/2 @ 30-40 cm]
- 57 - 100 7.5YR 4/2 (brown) with no mottles; silty clay loam; moderate fine & medium subangular blocky; weak discontinuous clayskins; many fine pores; moist & friable; rare fine & coarse roots; many medium & coarse hard angular platy phyllite, quartzitic phyllite & weathered phyllite stones & gravel; HCl negative; clear regular boundary to: [Sample PT028/3 @ 70-80 cm]
- 100 -142+ 7.5YR 3/2 (moist) (dark brown) & 2.5Y 5/3 (dry) (light olive brown) with no mottles; silt loam+; moderate fine & medium subangular blocky; many fine pores; moist & friable; rare coarse roots; common medium & few coarse hard angular & platy phyllite & weathered phyllite stones & gravel; HCl negative; [Not sampled]

Comment: Deep stony soil with hard & soft Shumar phyllite & hard quartzitic phyllite & gravel.

SPAL analytical results for SSU

Profile PT028

Survey area: Sangma Ri watershed

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT028 /1	0-10	8764	7.3	5.8	1.5	nd	1.5	1.0	0.1	8
PT028 /2	30-40	8765	7.5	5.1	2.4	nd	1.0	0.2	Tr	nd
PT028 /3	70-80	8766	7.1	5.3	1.8	nd	2.0	0.4	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT028 /1	9.9	0.5	0.3	0.1	10.8	nd	11.2	nd	96	nd
PT028 /2	8.2	0.4	0.1	0.1	8.8	nd	5.8	nd	100	nd
PT028 /3	11.3	0.9	0.1	0.1	12.4	nd	8.8	nd	100	nd

Profile: PT029

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Bageng
Soil Taxonomy: Typic Eutrudept [*thermic, loamy – loamy skeletal, mixed*]
WRB: Skeletic Cambisol

Survey area: Sangma Ri Watershed
Location: ca 10 m NE of Lu Village & ca 50 m SE of Wangkha Village
GPS: 27° 18'33.75"N, 91° 25'38.11" E
Altitude: 1760 m a.s.l

Described & sampled: 24.10.2000, Tshering Dorji

Climate: General: Warm temperate, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain, relief ca 0.5km
Site position: Mid slope

Slope: 25%, ca 0.5 km long, convex; aspect NE (65°)
Site drainage: Good

Parent material: Solid: Shumar phyllite and quartzite
Drift: Colluvium

Land use: Kamzhing
Vegetation: Maize stubble, *Artemisia myriantha*, *Amaranthus sp*

Surface: Litter: None
Outcrops: None
Stones: Few medium & coarse hard angular and platy phyllite & quartzitic phyllite
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: **(Colours are moist unless indicated)**
cm

0 - 19 10YR 3/2 (very dark greyish brown) moist & 10YR 5/2 (greyish brown) dry with no mottles; silt loam; weak fine subangular blocky & crumb; interstitial pores; dry, stony & friable; abundant fine roots; abundant medium & coarse hard angular & platy quartzitic phyllite stones; HCl negative; abrupt regular boundary to:
[Sample PT029/1 @ 0-10 cm]

19 - 125+ 2.5Y 7/4 (pale yellow) with weathering rock colour of yellowish brown mottles; stony very fine sandy loam; single grain; interstitial pores; moist, stony & friable; few fine & rare medium roots; abundant fine, medium, coarse & bouldery platy & angular quartzitic phyllite & highly weathered insitu quartzitic phyllite; HCl negative:
[Sample PT029/2 @ 30-40 cm]

Comments: Very shallow soil with quartzitic phyllite dominant & some highly weathered insitu phyllite from 19 cm.

SPAL analytical results for SSU

Profile PT029

Survey area: Sangma Ri watershed

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT029 /1	0-10	8767	6.9	6.0	0.9	nd	64.7	3.2	Tr	nd
PT029 /2	50-60	8768	7.2	5.5	1.7	nd	31.9	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT029 /1	16.6	2.1	0.8	0.1	19.6	nd	15.6	nd	100	nd
PT029 /2	2.0	0.3	0.3	0.1	2.7	nd	1.2	nd	100	nd

Profile: PT030

Map unit: Dx

Soil Classification: Provisional Bhutan soil series: Bageng
Soil Taxonomy: Typic Eutrudept [*thermic, loamy – loamy skeletal, mixed*]
WRB: Skeletic Cambisol

Survey area: Sangma Ri Watershed, Dremetse
Location: ca 10 m SWS of Wangkha Village & ca 50 m NW of PT029
GPS: 27° 18'41.19" N, 91° 25'41.09" E
Altitude: 1800m a.s.l

Described & sampled: 24.10.2000, Tshering Dorji

Climate: General: Warm temperate, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Mid mountain, relief ca 0.5km
Site position: Mid slope

Slope: 50%, ca 400 m rectilinear aspect ESE (97°)
Site drainage: Good

Parent material: Solid: Shumar phyllite and quartzite
Drift: Colluvium

Land use: Kamzhing
Vegetation: Maize stubble and grasses

Surface: Litter: None
Outcrops: None
Stones: Many fine, medium & common coarse hard platy & angular phyllite.
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: **(Colours are moist unless indicated)**

cm

- 0 - 28 10YR 4/2 (brown) with no mottles; medium sandy clay loam; moderate medium breaking to fine subangular blocky; many fine & interstitial pores; moist, stony & friable; rare fine roots; abundant fine & medium hard angular phyllite & quartzitic phyllite stones; HCl negative; diffuse boundary to:
[Sample PT030/1 @ 0 - 10 cm]
- 28 - 143+ 10YR 3/2 (very dark greyish brown) with no mottles; silty clay loam; stony moderate medium subangular blocky; many fine interstitial pores; moist, stony & friable; rare fine roots; abundant fine, medium, coarse & bouldery angular & platy phyllite & quartzitic phyllite stones; HCl negative: [Sample PT030/2 @ 50 - 60 cm]
- Comments: Moderately deep stony soil with two indistinct horizons.

SPAL analytical results for SSU

Profile PT030

Survey area: Dremetse

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT030 /1	0-10	8769	7.0	6.1	0.9	nd	57.6	2.8	0.3	9
PT030 /2	50-60	8770	7.5	6.1	1.4	nd	23.5	1.5	0.1	15

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PT030 /1	18.1	1.8	0.9	0.1	20.9	nd	17.5	nd	100	nd
PT030 /2	15.3	1.2	0.3	0.1	16.9	nd	14.4	nd	100	nd

Profile: Pd130

Map unit: Dx

Soil classification: Provisional Bhutan soil class: Dremetse
Soil Taxonomy: Typic Eutrudept [*thermic, loamy - loamy skeletal, mixed*]
WRB: Haplic Cambisol

Survey area: Sangma Ri watershed
Location: Ca 10 m WNW of Ngamri village/ ca 700 m+ NE of Phungtshing village across Sangma Ri
GPS: 27° 17' 28.36" N, 91° 26' 21.73" E
Altitude: 1200m a.s.l.

Described & sampled: 27.10.2000 Tsheten Dorji

Climate: General: Warm temperate, P = 800 mm pa
Recent weather: Clear sunny

Regional topography: Mid mountain
Site position: Mid slope of the side spur
Slope: 22%, ca 1 km, Dangme Chhu, rectilinear, aspect SW (216°)
Site drainage: Good

Parent material: Solid: Shumar formation
Drift: Colluvium

Land use: Rainfed maize
Vegetation: *Xanthium indicum*, *Ageratum Conyzoides*, *Euphorbia hirta* & *Bidens philosa*.

Surface: Litter: None
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: Hummock near maize stubble
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

cm

- 0 - 27 10YR 5/4 (yellowish brown) dry & 10YR 4/3 (brown) moist with no mottles; fine sandy loam+; moderate fine crumb; common fine pores; dry & hard; many fine & medium roots; common medium hard angular phyllite & quartzitic phyllite; HCl negative; gradual regular boundary to: [Sample Pd130/1 @ 0 - 10 cm]
- 27 - 68 10YR 3/4 (dark yellowish brown) with few fine faint dark brown mottles; medium sandy clay loam; moderate medium subangular blocky; many fine & medium pores; moist & slightly friable; few fine roots; common medium hard angular phyllite & quartzitic phyllite; HCl negative; diffuse boundary to: [Sample Pd130/2 @ 35 - 45 cm]
- 68 - 115+ 10YR 4/6 (dark yellowish brown) with common fine distinct dark brown mottles; medium sandy loam+; moderate medium subangular blocky; common fine & medium pores; moist & friable; rare fine roots; few coarse hard platy phyllite & common fine & medium hard angular quartzite stones; HCl negative: [Not sampled]

Comment: Moderately deep stony strong brown soil. Textures are fairly uniform. Few colluvial boulders at depth.

SPAL analytical results for SSU Profile Pd130 Survey area: Sangma Ri watershed***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					
Pd130 /1	0 - 10	8757	6.8	5.2	1.6	nd	13.5	0.8	0.1	11
/2	35 - 45	8758	6.7	4.5	2.2	nd	5.5	0.4	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pd130 /1	4.0	1.0	0.4	0.1	5.5	nd	6.5	nd	85	nd
/2	5.2	1.4	0.2	0.1	6.9	nd	8.6	nd	80	nd

Profile: PC049

Map unit: Zx

Soil Classification: Bhutan Provisional soil series: Zangkhar
Soil Taxonomy: Typic Haplustept [thermic, fine loamy skeletal, mixed]
WRB: Haplic Cambisol

Survey area: Sangma Ri watershed
Location: Down hill from Zangkhar village (road cutting)
GPS: 27° 17'55.15"N, 91° 26'20.92" E
Altitude: 1440m a.s.l

Described & sampled: 25.10.2000, I. C Baillie

Climate: General: Warm Temperate, P = ca 1000 mm p.a
Recent weather: Sunny

Regional topography: Deeply dissected valley, ca 1000m relief
Site position: Upper slope on middle section of major spur

Slope: 75%, 1km, rectilinear, aspect SSW (200°)
Site drainage: Good

Parent material: Solid: Shumar Formation quartzite & schist
Drift: Colluvium

Land use: Forest

Vegetation: Chir pine & lemon grass

Surface: Litter: Very discontinuous pine litter
Outcrops: None
Stones: Few medium & fine hard phyllite & quartzite stones
Cracks: None
Roots: None
Microrelief: Stepping behind boulders
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

Cm

- 0-2 7.5YR 5/4 (brown) moist & 10YR 6/5 (brownish yellow) dry with no mottles; very stony medium sandy loam; stony with interstitial weak fine crumb; many fine pores; dry, stony & interstitial loose; common fine roots; abundant fine angular schist & quartzite stones; HCl negative; clear regular boundary to: [Not sampled]
- 2-9 7.5YR 4/4 (brown) moist & 7.5YR 6/4 (light brown) dry with no mottles; stony fine sandy loam+; stony with interstitial weak – moderate fine subangular blocky; common fine pores; dry, stony & slightly hard; common fine roots; many fine hard angular quartzite & schist stones; HCl negative; abrupt regular boundary to:
[Not sampled]
- 9-33 7.5YR 3/2 (dark brown) moist & 7.5YR 6/3 (light brown) dry with no mottles; very stony silt loam; stony with interstitial moderate fine crumb; common medium & fine pores; dry, stony & soft; many fine roots; abundant medium hard angular phyllite & quartzite stones; HCl negative; gradual regular boundary to:
[Sample PC049/1 @ 15-25cm]
- 33-70 7.5YR 6/4 (light brown) moist & 7.5YR 7/4 (pink) dry with no mottles; very stony silt loam+; stony with interstitial weak subangular blocky; common fine medium pores; dry, stony soft; common fine roots; abundant medium hard angular quartzite & schist stones; HCl negative; diffuse boundary to:
[Sample PC049/2 @ 40-50cm]
- 70-110 7.5YR 5/4 (brown) moist & 7.5YR 6/5 (reddish yellow) dry with no mottles; very stony silt loam; stony, weak fine crumb; interstitial pores; moist & stony loose – very friable; common fine & few medium roots; abundant medium hard angular schist & quartzite stones; HCl negative; diffuse boundary to:

[Sample PC049/ 3 @ 80-90cm]

110-190+ 7.5YR 5/4 (brown) moist & 7.5YR 6/5 (reddish yellow) dry with no mottles; very stony silty loam; stony with interstitial weak fine crumb; interstitial pores; moist & stony loose – very friable; few medium & fine roots; abundant medium angular hard schist & quartzite stones; HCl negative: [Not sampled]

Comment: Grey looking soil surface, 20m from red soil surface of PC050.

SPAL analytical results for SSU Profile PC049 Survey area: Sangma Ri watershed

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					
PC049 /1	15-25	8777	6.8	5.4	1.4	nd	2.6	1.6	0.1	16
/2	40-50	8778	6.9	5.1	1.8	nd	1.4	0.5	Tr	nd
/3	80-90	8779	6.9	5.2	1.7	nd	0.5	0.2	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PC049 /1	6.9	1.2	0.2	0.1	8.4	nd	9.4	nd	89	nd
/2	2.3	0.7	0.1	0.1	3.2	nd	2.7	nd	100	nd
/3	1.8	0.9	0.1	0.1	2.9	nd	4.5	nd	63	nd

Profile:	PC050
Map unit:	Zx
Soil Classification:	Bhutan Provisional soil series: Zangkhar Soil Taxonomy: Typic Dystrudept [thermic, fine loamy skeletal, mixed] WRB: Chromic Cambisol
Survey area:	Sangma Ri watershed
Location:	Road cutting, 20m north of PC049, Zangkhar village
GPS:	27° 18'6.26"N, 91° 26'18.18" E
Altitude:	1520m a.s.l
Described & sampled:	25.10.2000, I. C Baillie
Climate:	General: Warm Temperate, P = ca 1000 mm p.a Recent weather: Sunny
Regional topography	Deeply dissected valley, ca 1000m relief
Site position:	Upper side midslope of midsection of major spur
Slope:	70%, 1km, rectilinear, aspect SSW (250°)
Site drainage:	Good
Parent material:	Solid: Shumar Formation quartzite & schist Drift: Colluvium
Land use:	Chir pine & grass
Vegetation:	Chir pine & lemon grass
Surface:	Litter: Very discontinuous pine litter & grass Outcrops: Rare 30m away Stones: Few medium & fine hard phyllite & quartzite Cracks: None Roots: None Microrelief: 10cm steps behind grass tussocks Faunal activity: None Other features: None

Profile description: (Colours are moist unless indicated)

cm

0-13	10YR 6/3 (pale brown) moist & 10YR 4/3 (dark greyish brown) dry with no mottles; silt loam; moderate fine subangular blocky breaking to moderate medium crumb; common medium pores; dry & soft; many medium & fine roots; common fine angular schist & quartzite stones; HCl negative; gradual regular boundary to: [Sample PC050/1 @ 0-10cm]
13-25	5YR 5/4 (reddish brown) with mottles; silt loam+; weak medium subangular blocky breaking to moderate medium crumb; many fine & medium pores; moist & slightly friable; common fine & medium roots; common fine angular phyllite & quartzite stones; HCl negative; diffuse boundary to: [Not sampled]
25-94	5YR 5/6 (yellowish red) with no mottles; clay loam; moderate medium subangular blocky breaking to strong fine crumb; abundant fine & medium pores; moist & very friable; common fine medium & fine roots; few fine angular schist & quartzite stones; two coarse krotovinas; HCl negative; clear regular boundary to: [Sample PC050/2 @ 50-60cm]
94-155+	5YR 5/6 (yellowish red) with common fine faint dark, reddish brown & black mottles; very stony clay loam; stony with interstitial moderate medium subangular breaking to strong fine crumb; abundant medium & fine pores; moist & stony firm; few fine roots; abundant hard flat weathered rock; common fine black slightly hard ferromanganese concretion; HCl negative: [Sample PC050/3 @ 110-120cm]

Comment: The flat weathering quartzite boulders at 94+cm depth but are bed rock. There is no any sign of HCl reaction in any stones. This red soil is fairly narrow and down side of spur. It appears to be due to quartzite, not marble. Soils are similar to Serbithang possibly due to associated schist rather than phyllite. Only 20cm from grey looking soil (PC049).

SPAL analytical results for SSU Profile PC050 Survey area: Sangma Ri watershed

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					
PC050 /1	15-25	8780	7.0	5.3	1.7	nd	2.2	3.2	0.2	18
/2	40-50	8781	6.3	4.7	1.6	nd	1.0	1.0	0.2	10
/3	80-90	8782	7.0	4.6	2.4	nd	0.1	0.3	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PC050 /1	9.1	2.1	1.0	0.1	12.3	nd	16.4	nd	74	nd
/2	3.0	2.0	1.0	0.1	6.1	nd	14.0	nd	37	nd
/3	2.0	2.0	1.0	0.1	5.1	nd	12.0	nd	33	nd

Profile:	PH116	
Map unit:	Px	
Soil Classification:	Provisional Bhutan soil series: Phungtshing Soil Taxonomy: Haplustept [<i>thermic, loamy skeletal, mixed</i>] WRB: Chromic Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Bottom of cultivated area, Phungtshing	
GPS:	27° 17' 22.0" N, 91° 25' 18.0" E	
Altitude:	1280m a.s.l	
Described & sampled:	26.10.2000, H B Tamang	
Climate:	General:	Subtropical, P = ca 1000 mm p.a
	Recent weather:	Cloudy
Regional topography	Deeply dissected valley, ca 700m	
Site position:	Mid nose of broad spur	
Slope:	39% down, 700m, rectilinear, aspect NNE (24°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation
	Drift:	Colluvium
Land use:	Fallow kamzhing	
Vegetation:	Lemon grass & few weeds	
Surface:	Litter:	1cm continuous mixed
	Outcrops:	None
	Stones:	Common medium & fine hard phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0-20	10YR 5/4 (yellowish brown) moist & 10YR 4/4 (dark yellowish brown) dry with no mottles; stony silty clay loam; strong with interstitial medium subangular blocky; common medium & fine pores; dry & very hard; few coarse & common fine roots; many medium & fine platy phyllite & quartzite stones; HCl negative; common ants; diffuse boundary to: [Sample PH116/1 @ 0-10cm]
20-50	10YR 5/3 (brown) moist & 10YR 4/4 (dark yellowish brown) dry with no mottles; stony silty clay Loam; very strong with interstitial medium angular to subangular blocky; common medium & fine pores; dry & very hard; (cemented); rare very fine roots; many medium & fine weathered phyllite & few hard quartzite stones; HCl negative; gradual regular boundary to: [Not sampled]
50-78	10YR 6/6 (brownish yellow) with common medium distinct dark brown mottles; silty clay loam; moderate medium subangular blocky; few coarse & common medium & fine pores; moist & firm; common medium & fine hard quartzite & few soft weathered phyllite stones; HCl negative; clear regular boundary to: [Not sampled]
78-120+	7.5YR 4/6 (strong brown) with common medium distinct dark brown & reddish brown mottles; silty clay; weak medium subangular blocky breaking to fine crumb; very weak discontinuous clayskins; few coarse & many fine pores; moist & slightly firm; few fine roots; few hard quartzite & common medium weathered phyllite stones; HCl negative: [Sample PH116/2 @ 90-100cm]
Comment:	Very compact consistence in upper subsoil, especially at 20-50cm.

SPAL analytical results for SSU Profile PH116 Survey area: Sangma Ri watershed

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					
PH116 /1	0-10	8750	6.7	5.3	1.4	nd	22.2	1.1	0.1	11
/2	90-100	8751	7.1	5.3	1.8	nd	2.9	0.2	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH116 /1	5.6	1.7	0.7	0.1	8.1	nd	14.9	nd	54	nd
/2	4.7	1.9	0.6	0.1	7.3	nd	13.8	nd	53	nd

Profile:	PH117	
Map unit:	Px	
Soil Classification:	Provisional Bhutan soil series:Phungtshing	
	Soil Taxonomy:	Dystric [<i>thermic, loamy skeletal, mixed</i>]
	WRB:	Chromic Cambisol
Survey area:	Sangma Ri watershed	
Location:	Forest below Phungtshing	
GPS:	27° 17'22.4" N, 91° 25'22.4" E	
Altitude:	1200m a.s.l	
Described & sampled:	26.10.2000, H B Tamang	
Climate:	General:	Sub tropical, P = ca 800 mm p.a
	Recent weather:	Sunny
Regional topography	Deeply dissected valley, 700m relief	
Site position:	Lower midslope of broad spur	
Slope:	29%, 700m, rectilinear aspect ENE (56°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar Formation
	Drift:	Colluvium
Land use:	Forest	
Vegetation:	Lemon grass & chir pine	
Surface:	Litter:	1cm discontinuous pine needles
	Outcrops:	None
	Stones:	Few medium & fine hard phyllite & quartzite
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0-10	10YR 6/3 (pale brown) & 10YR 5/2 (greyish brown) moist with fine faint yellowish brown mottles; fine sandy loam; strong medium angular to subangular blocky; common medium & fine pores; dry & hard; many medium & fine roots; common medium weathered phyllite & few fine hard quartzite stones; HCl negative; diffuse boundary to: [Sample PH171/1 @ 0-10cm]
10-50	10YR 6/4 (light yellowish brown) with few medium faint reddish brown mottles; stony silty clay loam; stony with interstitial moderate medium angular to subangular blocky; common medium & fine pores; dry & hard; rare fine & coarse roots; many medium & few angular hard quartzite & phyllite stones; HCl negative; gradual regular boundary to: [Sample PH117/2 @ 30-40cm]
50-93	10YR 6/6 (brownish yellow) dry & 7.5YR 4/4 (brown) moist with no mottles; silty clay; moderate medium subangular blocky; common medium & fine pores; slightly moist & slightly friable; few fine & coarse roots; few coarse phyllite & many medium & fine hard quartzite & phyllite stones; HCl negative; common worms; clear regular boundary to: [Sample PH117/3 @ 60-70cm]
93-120+	10YR 7/4 (very pale brown) dry & 10YR 6/4 (light yellowish brown) moist with no mottles; very fine sandy loam; weak fine subangular blocky' interstitial pores; dry & friable few medium & fine roots; common medium hard quartzite & phyllite stone (a layer at the base of the profile); HCl negative: [Not sampled]
Comment:	Compact layer in the upper subsoil. Similar compaction was noted in Wyenkhar soil under Shumar formation.

SPAL analytical results for SSU

Profile PH117

Survey area: Sangma Ri watershed

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					
PH117 /1	0-10	8752	6.7	5.4	1.3	nd	2.1	1.8	0.1	18
/2	30-40	8753	6.5	4.6	1.9	nd	22.5	0.5	Tr	nd
/3	60-70	8754	6.5	4.5	2.0	nd	58.8	0.1	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH117 /1	8.7	1.0	0.5	0.1	10.3	nd	9.2	nd	73	nd
/2	4.5	0.5	0.3	0.1	5.4	nd	15.3	nd	26	nd
/3	4.2	0.5	0.2	0.1	5.0	nd	9.9	nd	37	nd

Profile:	PT027	
Map unit:	Sx	
Soil Classification:	Provisional Bhutan soil series: Sangma	
	Soil Taxonomy:	(Aquic*) Haplanthrept [<i>thermic, loamy skeletal, mixed</i>]
	WRB:	Hydragric Anthrosol
Survey area:	Sangma Ri watershed	
Location:	Ca 1 km NWN from Tsangphay village/lower foot slope chhuzhing of the spur	
GPS:	27° 17' 10.98" N, 91° 26' 3.03" E	
Altitude:	880m a.s.l	
Described & sampled:	23.10.2000, Tshering Dorji	
Climate:	General:	Sub tropical, P = ca 1000 mm p.a
	Recent weather:	Partially sunny
Regional topography	Mid mountain, relief ca 1km	
Site position:	Lower slope	
Slope:	24%, ca 1 km long, rectilinear, aspect S (180°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar phyllite and quartzite
	Drift:	Colluvium
Land use:	Chhuzhing	
Vegetation:	Rice stubble, <i>Euphorbia Hirta</i> and grasses on bunds	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: **(Colours are moist unless indicated)**

cm

0 - 23	7.5YR 4/1 (dark grey) with many medium and coarse prominent dark red mottles; silty clay loam; moderate medium subangular blocky; many fine & few medium pores; moist & friable; many fine paddy roots; few fine hard platy & angular phyllite & quartzitic phyllite stones; HCl negative; gradual regular boundary to: [Sample PT027/1 @ 0-10 cm]
23 - 50	7.5YR 4/2 (brown) with many fine distinct brown mottles; silty clay loam; moderate medium subangular blocky; many fine & few coarse pores; moist & friable; rare fine roots; common fine hard platy & angular phyllite & quartzitic phyllite stones; HCl negative; clear regular boundary to: [Sample PT027/2 @ 50-60 cm]
50 - 80	7.5YR 4/3 (brown) with common coarse faint yellowish brown mottles; silty clay loam+; moderate medium subangular blocky; common fine & few medium & coarse pores; moist & slightly firm; no roots; many fine, medium & coarse hard platy & angular phyllite & quartzitic phyllite stones; HCl negative; diffuse boundary to: [Not sampled]
80 - 120+	7.5YR 4/4 (brown) with few coarse faint greyish brown mottles; very fine sandy clay loam; moderate medium subangular blocky; common fine & few medium pores; moist & slightly firm; no roots; many fine, medium & coarse hard platy & angular phyllite & quartzitic phyllite stones; HCl negative: [Sample PT027/3 @ 90-100 cm]

Comment: The last two horizons are redder than the above ones. This might be due to soil colour changed because of intensive chhuzhing cultivation. There is 2 cm thick regular manganese and iron pan between 2nd and 3rd horizons.

SPAL analytical results for SSU Profile PT027 Survey area: Sangma Ri watershed

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H ₂ O	KCl	Diff					
PT027 /1	0-10	8761	6.6	5.6	1.0	nd	3.41	1.70	0.17	16
PT027 /2	30-40	8762	7.2	5.6	1.6	nd	2.12	0.80	0.08	11
PT027 /3	90-100	8763	7.5	5.9	1.6	nd	51.13	0.10	Tr	nd

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAC	EBS%
PT027 /1	13.0	0.9	0.4	0.1	14.4	nd	14.6	nd	97	nd
PT027 /2	10.8	0.7	0.3	0.1	11.9	nd	12.1	nd	98	nd
PT027 /3	2.1	0.1	0.2	0.2	2.6	nd	3.6	nd	74	nd

Profile:	Pd129	
Map unit:	Yy	
Soil classification:	Provisional Bhutan soil class: Yayang Soil Taxonomy: Anthraquic [<i>thermic, loamy skeletal, mixed</i>] WRB: Dystric Cambisol	
Survey area:	Sangma Ri watershed	
Location:	Ca 500 m south of Rividhang & ca 50 m WNW of confluence of Sangma Ri & Dangme Chhu	
GPS:	27° 16' 30.57" N, 91° 26' 22.43" E	
Altitude:	760m a.s.l.	
Described & sampled:	27.10.2000, Tsheten Dorji	
Climate:	General:	Sub tropical, P = 800 mm pa
	Recent weather:	Clear sunny
Regional topography:	Mid mountain	
Site position:	Front edge of the fan	
Slope:	15%, ca 50 m, rectilinear, aspect SSE (161°)	
Site drainage:	Good	
Parent material:	Solid:	Shumar formation
	Drift:	Colluvium over old alluvial fan
Land use:	Abandoned wet land	
Vegetation:	<i>Dodonia</i> spp, <i>Euphorbia hirta</i> , bare & lemon grasses	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	None
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

Cm

0 – 20	10YR 4/1 (dark grey) dry & 10YR 3/2 (very dark greyish brown) moist with common fine faint reddish brown mottles; fine sandy loam; strong medium subangular blocky; few coarse, many fine & medium pores; dry & slightly hard; many fine roots; few medium hard platy phyllite & quartzite stones; HCl negative; gradual regular boundary to: [Sample Pd129/1 @ 0 – 10 cm]
20 – 80	5YR 5/6 (yellowish red) dry & 2.5Y 4/4 (olive brown) moist with common fine faint dark yellowish brown mottles; silty clay loam; moderate medium subangular blocky breaking to weak fine crumb; few coarse, many fine & medium pores; slightly dry & hard; many fine roots; few coarse & common medium hard angular quartzite & soft weathered phyllite; HCl negative; diffuse boundary to: [Sample Pd129/2 @ 45 – 55 cm]
80 – 160+	7.5YR 4/6 (strong brown) dry & 7.5YR 4/4 (brown) moist with common medium distinct yellowish brown mottles; medium sandy loam+; moderate medium subangular blocky breaking to weak fine crumb; many fine pores; dry & hard; many fine roots; common coarse, many medium & fine soft weathered phyllite & hard angular quartzite stones; HCl negative: [Not sampled]
Comments:	Abrupt change in textures indicates colluviation over old alluvial fan deposit. Fan deposits are probably from Gang Ri. The land has been abandoned for the last six years due to the lack of irrigation facilities. Major landslide occurred on the front edge of the fan.

SPAL analytical results for SSU Profile Pd129 Survey area: Sangma Ri watershed

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					
Pd129 /1	0 - 10	8755	7.2	5.8	1.4	nd	2.8	2.3	0.1	23
/2	45 - 55	8756	7.5	5.8	1.7	nd	1.2	0.7	0.1	7

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pd129 /1	13.5	1.5	0.5	0.1	15.6	nd	15.3	nd	100	nd
/2	6.8	1.0	0.5	0.1	8.4	nd	nd	nd	nd	nd