Royal Government of Bhutan

Research, Extension, and Irrigation Division, Semtokha
Ministry of Agriculture
Bhutan Soil Survey Project

TECHNICAL REPORT ON THE DETAILED SOIL SURVEY OF YUSIPANG RNR RESEARCH CENTRE

Report No. 1(a)

August 1998

CONTENTS

SUMMARY

A detailed soil survey of the Renewable Natural Resources Research Centre, Yusipang was carried out during June - September 1997. The survey was the first done by the newly formed Bhutan Soil Survey Project, and was undertaken as an extended field training exercise.

The Centre covers about 95 ha (about 235 acres) in a side valley of Ola Rong Chhu. It is located about 8 km northeast of the Semtokha junction on the Thimphu-Wangdi section of the national East-West Highway. The Centre occupies the sloping depositional floor of the side valley and the lower slopes of the hills to each side. The soils are formed in residual and colluvial materials on the hills, and in the fan alluvium of the valley floor. All of the soil parent materials are derived from the Thimphu gneiss. The valley land is mostly used for the cultivation of temperate vegetables and tree fruits. Most of this cultivation is for the agronomic trials and seed production work of the Centre. The rest is private cultivation by the staff of the Centre.

The soils of the Centre are subdivided into three main geomorphic-parent material groups, i.e. residual and colluvial soils of hill slopes, colluvial/slump soils of footslopes, and depositional soils of the valley floor. The soils of the area span a fairly narrow textural range, with sandy loams and sandy clay loams predominant.

The hillslope soils are divided into four types. Three of these are depth classes of the predominant well drained reddish yellow soils: shallow and moderately deep soils on open slopes and convexities, and deep well drained soils on open slopes and in concavities. There are also some soils of the fourth type, grey poorly drained sandy loams and sandy clays in steeply sloping but wet hillside declivities.

Nearly all of the footslope soils are wetter than the hill soils upslope and most of the valley floor soils downslope. They are divided into three drainage classes: a small group of reddish yellow well-drained soils; the most extensive mixed grey and brown imperfectly drained soils; and a limited area of dark grey, slightly peaty, wet soils. The footslope soils also include a small area of bouldery debris from a fairly recent landslip.

The valley floor soils are subdivided along similar lines: well drained reddish yellow soil on the crest of the alluvial fan; grey and brown imperfectly soils drained on the most of the fan; and poorly drained wet soils along the drainage lines at each side of the valley.

The correlations of the Yusipang soils with the classes of the international systems of soil classification are assigned and discussed. The hill soils are mostly Ochrepts in the American Soil Taxonomy and Dystic Cambisols in the FAO system. The footslope and valley floor soils are mostly Aquepts and Aquents in Soil Taxonomy, and Gleysols or gleyic subunits in the FAO system.

The results of the soils survey indicate that the present agronomic trials are located on appropriate soils, and that the results should be applicable to extensive similar soils in the rest of the region. It is not possible to conduct irrigated summer rice/winter wheat trials at Yusipang. If trials are required of this important cropping system at altitudes > 2000 m in the Western Region they will need to be located in the main valleys of Thim Chhu or Paro Chhu.

ACKNOWLEDGEMENTS

The fieldwork for this survey was done by Kado Tshering, Tsheten Dorji, H B Tamang and Ian Baillie of the Bhutan Soil Survey Project. We are grateful for the field guidance of Rebecca Pradhan on plant identification. The mapping was done by Ms Deki Wangmo of the Geographic Information System Unit in the Land Use and Statistics Section of the Planning and Policy Projects Division of the Ministry of Agriculture in Thimphu. The report was prepared by Ms Pema Wangmo.

We are grateful to the Officer in Charge, research staff, and labourers of the Yusipang RNR-RC for their support and assistance during the fieldwork and for the feedback on the draft map and report. The research staff also contributed in the development of the soil classification.

The analyses of the soil samples were done by the Soil and Plant Analytical Laboratory (SPAL) at Semtokha. SPAL also provided the records of the previous analyses of soil samples from Yusipang RNR-RC.

The supply of geological data by the Geological Survey of Bhutan, and of meteorological data by the Meteorological Unit, both of the Ministry of Trade and Industry, is gratefully acknowledged.

We are grateful to Chencho Norbu, Dennis Desmond, Phuntsho Namgay and Christopher Floyd for helpful and detailed comments on the draft text and map. All feedback is particularly important for this report, because it is the first produced by the new Project, and we wish to establish a format that makes the reports useful to researchers, planners and other soil managers.

ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometery
AHT	Agrar - and HydrotechniK, GmbH, (Germany).
Alluvial fan	Poorly stratified and sorted material deposited by mountain stream as it reaches flatter part of the valley.
AmoAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
Av	Available
AWC	Available water capacity
amsl	Above mean seal level
BS%	Base saturation percentage
BSSP	Bhutan Soil Survey Project
C	Clay
CEC	Cation exchange capacity
Chhu	Stream or river
CL	Clay loam
Colluvium	Local hill wash, moved by surface erosion or slow non-glacial creep processes.
Danida	Danish International Development Assistance.
Dzongkhag	Administrative district
EC	Electrical conductivity
ESCAP	Economic and Social Commission for Asia and the Pacific, United Nations.
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FAO	Food and Agriculture Organisation of United Nations
fe	fine earth (particle size < 2mm)
FYM	Farmyard manure
Gewog	Block or subdistrict, administrative subdivision of Dzongkhag.
GIS	Geographical information system
Gley	Soil that is permanently wet, poorly aerated and has predominantly greyish colours, due to reduction of free iron to ferrous valency state. May have local oxidising conditions giving rust - coloured mottles, especially around root channels.
Gompa	Monastery
GPS	Global positioning system
ha	Hectare
HCl	Hydrochloric acid
JICA	Japanese International Cooperation Agency
L	Loam
LUPP	Land Use Planning Project, in PPD
LUPS	Land Use Planning Section, in PPD
LUSS	Land Use and Statistics Section, in PPD
me%	miliiequivalents per 100 g fine earth
MoA	Ministry of Agriculture
mS/cm	milliSiemens per centimetre (unit of electrical conductivity)
MTI	Ministry of Trade and Industry.
NH_4OAC	Ammonium acetate
NRTI	National Resources Training Institute, Lobeysa
NS	Not suitable (in land suitability classification)
OC	Organic carbon

OM	Organic matter
P	Phosphate
PCI	Pacific Consultants International (Japan)
pH	Measure of acidity - alkalinity
PM	Parent material
PPD	Planning and Policy Division, MoA
ppm	Parts per million
PSC	Particle size class (Soil Taxonomy)
REID	Research, Extension and Irrigation Division (of MoA)
RGOB	Royal Government of Bhutan
RMS	Root mean square
RNR	Renewable natural resources - agriculture, animal husbandry and forestry.
RNR-RC	RNR Research Centre.
S	Sand
Saprolite	Soft weathered rock.
Sokshing	Forested land from which needle or leaves are collected for use as livestock bedding and compost.
Si	Silt
Sk	Skeletal (high stone content)
SMU	Soil mapping unit
SoB	Survey of Bhutan
Solifluction	Downslope movement in summer of saturated thawed topsoil over permafrost in periglacial areas.
SP	Super phosphate
Solum	True soil with no remaining rock structures.
SPAL	Soils and Plant Analysis Laboratory, Semtokha.
SSF&PNMP	Sustainable Soil Fertility & Plant Nutrition Management Project.
SSS	Soil Survey Staff (of USDA)
ST	Soil Taxonomy (US system of soil classification)
TE	Trace elements
TEB	Total exchangeable bases (= exchangeable Ca + Mg + Na + K)
Till	Material weathered and moved by the underside of a glacier. Not stratified and a wide range of grain sizes. Sometimes known as 'boulder clay'
TLB	True left bank (facing downstream)
TRB	True right bank (facing downstream)
USDA	United States Department of Agriculture
v/v	% by volume
WR	Weathered rock
w/w	% by weight
X	Exchangeable (for cation)
Z,Zi	Silt

1. INTRODUCTION

1.1 Bhutan Soil Survey Project

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

The emphasis in the initial stages of the Project is on the training of Bhutanese nationals as soil surveyors, and the establishment of a functioning Soil Survey Unit. The main method of training is by on-the-job instruction and close supervision of actual soil surveys, carried through from initial planning to final presentation. In the early stages detailed surveys are best for instruction purposes. They enable the soil pattern to be worked out by direct observation with the minimum of extrapolation and assumptions. This survey of the Yusipang Renewable Natural Resources (RNR) Research Centre (RNR-RC) is the first of these detailed surveys/training exercises. This is the full technical report of the survey. Those less interested in details will find a summary of the findings and their implications in the general report (BSSP 1998).

1.2 Yusipang RNR-RC

Yusipang is one of the four main RNR Research Centres in REID. It has a national mandate to coordinate all research in forestry in the whole country. It also has a regional mandate for all RNR research in the Western Region (Thimphu, Paro, Haa, Chhukha and Samtse Dzongkhas). On the agricultural side it specialises in the crops of higher altitudes, such as temperate vegetables and fruits. It is also the site of the Tissue Culture Laboratory, and is the main trial site for the cultivation of indigenous medicinal plants. There are plans for an outlying subcentre at Gedu, in Chhuka Dzongkhag, to specialise in subtropical fruit and fodder crops. There is a subcentre at Serbithang in Thimphu Dzongkhag, which specialises in temperate fodder crops but some of this work may be transferred to Yusipang. As with the other RNR-RC's, it coordinates its research with extension activities in the region (REID March/April 1995 & May/June 1997).

1.3 Aims of the Yusipang soil survey

The detailed soil survey was undertaken with objectives of:

- Preliminary training in soil survey techniques for BSSP staff.
- Adjusting standard soil survey practice to suit Bhutan conditions.
- Providing Yusipang RNR-RC with detailed information on the nature and distribution of their soils.
- Indicating the extent of the applicability of research results on Yusipang soils to other parts of the region.
- Providing the first BSSP data towards the development of a national soil classification, and of national and regional soil maps.

2. THE SURVEY AREA

2.1 Location and extent

The centre is located on the main Thimphu-Wangdi highway about 8 kilometers by road northeast of the Semtokha junction. The Research Centre straddles the road but the bulk of the area is above, i.e. north and west, of the Highway. It stretches from latitude 27 ° 27.5' to 27 ° 28.2' N and from longitude 89 ° 42.5' to 89 ° 42.8' E. It is in Chang gewog in Thimphu Dzongkhag, and within the Western Agricultural Region.

The Centre covers about 95 ha (235 acres). The imprecision is due to the uncertainties about the cadastral status of the bed of the main stream and the exact boundaries of the Highway reserve. The area mapped in this soil survey is 86.4 ha (213 acres).

The Centre was established in 1969 as a demonstration farm and the land is owned by Ministry of Agriculture, RGOB. Before then the land was one large private holding and was mostly used for the commercial production of irrigated field crops in the valley and rainfed arable crops on the hill slopes, which were formerly more extensively terraced than now.

2.2 Climate

The Centre spans an altitude range of 2600 - 3000 m asl, and is in the cool temperate climatic zone, with Blue Pine coniferous woodland as the dominant natural vegetation. It is located along a south – west flowing stream. The valley lands have a more or less southerly aspect and most of the hill slopes face SE or SW. The local microclimate therefore tends to be relatively warm, dry and well insolated for its altitude.

Table 2.1 summarises the main features of the climate of the Centre

Mean minimum temperatures drop to about 0^0C in December – January, with the lowest recorded at – 9^0 C. The mean maximum rises from about 9^0 C in January to 21^0 C during June – September. The mean annual rainfall is about 800 mm, of which about 600 mm falls in the monsoon months of May – September. Humidities and cloud cover are high during the monsoon, but clear skies and dry air predominate during the rest of the year (PCI 1996; data from Meteorological Unit, MTI).

Table 2.1 Climatic summary for Yusipang RNR-RC (1985 – 1995)

Period	J	F	M	A	M	J	J	A	S	O	N	D	**Year mean total**
Mean Minimum Temperature ^{0}C	-1	0	3	7	10	13	15	15	13	8	4	1	**7**
Mean Maximum Temperature ^{0}C	9	11	11	17	18	21	21	21	21	17	14	12	**16**
Mean rainfall (mm)	11	16	26	44	87	137	185	160	100	35	14	6	**821**

Source: Data supplied by Meteorological Unit, Ministry of Trade and Industry

2.3 Geology and soil parent materials

The most recent geological description of the Thimphu area indicates that the area is wholly underlain by the Thimphu Gneiss formation (Geology and Mines/UNDP, nd). This is a highly metamorphosed rock, with muscovite and biotite micas, plagioclase feldspars, and quartz as the main minerals. However Gansser (1983) maps the area as the older Paro Formation gneiss, which is less intensely metamorphosed. Both of these formations were formed by the folding and shearing that occurred in the thrusting from the north during the intense Himalayan compressions and uplifts in the Tertiary.

Many of the soils on the hills are residual and have shallow sola overlying weathered gneiss. Considerable quantities of ferric iron compounds have been liberated by the weathering, and give red-orange-yellow colours. It is probable that the weathering was more intense during periods in the late Pleistocene and/or Holocene when the climate of the area was warmer and more humid than now.

There are also considerable areas of the hill slopes that are mantled with local hillwash (= colluvium). This is discontinuous and mostly only shallow or of moderate depth (1.5 m or less) on the main spurs and minor interfluves. It accumulates to greater depths in the shallow depressions and drainage lines. Many of the deeper colluvial profiles have what appear to be a buried topsoil (e. g. Profile PH002 in Appendix B). This suggests that the deposition has been spasmodic, with prolonged periods of stability during which organic topsoils have been able to develop. These have been interrupted by rapid burial, probably by landslips or similar sudden mass movements. Solifluction during cold phases of the late Pleistocene and of the Holocene, and accelerated hill wash in dry phases, may also have contributed.

The colluvial deposits on the gentler, slightly concave lower slopes are thicker in places but are still mostly less than 2 m deep. Some of these appear to be slump or landslip deposits, but the slump topography is masked in many places by cultivation terraces.

Most of the valley is floored by deep bouldery deposits with sandy, gravelly and loamy interstitial fines. The surface of these is now about 6-10 m above the current level of the main stream. The upper 0.5 – 1.5 m is often more or less stone-free and shows some textural stratification, It may be normal fluvial alluvium, or it is possibly aeolian material

deposited during cold dry phases at the end of the Pleistocene or during the Holocene. The origin of the bouldery lower layer is also not clear. It is thought to be a glacio-fluvial fan deposit, laid down by the large and powerful meltwater streams coming out of a retreating valley glacier upstream. It might conceivably be a till, moved and deposited by the ice underneath a valley glacier. However this would require some revision of the accepted glacial history of this part of Bhutan (Gansser 1983).

2.4 Topography and drainage

The Centre is located in a True Right Bank (north western) side valley that runs into the Ola Rong Chhu. The side stream is not named on the SOB 1: 50 000 topographic map but is referred to hereafter as Yusipang Chhu. The cross - section of this part of the main valley of Ola Rong Chhu, is a steep V, with no significant floodplain or terraces.

Most of the hill sides in the survey area are middle and lower slopes of low spurs. Only along the eastern boundary are there extensive sections of the crest and upper slopes of a plunging spur. The slopes are predominantly straight (= rectilinear) with gradients in the range 20 – 50 %. More gently graded sections occur on the convex upper and concave lower slopes.

The slopes are drained by substantial second order valleys. There are also shallow first order declivities running downslope. These probably have surface runoff for short spells during wet weather. However they appear to act mainly as drainage routes for subsoil throughflow for substantial periods. The wet subsoils may predispose the colluvial deposits in these declivities to slump. Several of them appear to have had former mass movements.

In contrast to the main valley of Ola Rong Chhu, the side valley has a well-defined valley floor. This is a distinct depositional surface, with a longitudinal slope downstream of about 10-15%. The surface has a domed cross profile, with the apex more or less in the middle, and dips outwards to depressions along the bases of the hills at the valley sides. The main stream of Yusipang Chhu cuts through the centre of the valley floor and dissects the domed surface. The depth of incision increases downstream, and the stream is entrenched to a depth of about 10 m near its lower end, where it crosses the Highway. The stream has deposited a narrow and discontinuous low terrace within the trench cut into the main valley floor. Yusipang Chhu is mainly fed from the steeper parts of the watershed in the mountains upstream. The hill slopes and also much of the valley floor of the Centre do not drain into it, but rather into the non-entrenched small streams that run along the bases of the hills at each side of the valley.

The mixed and non-layered deposits, steep longitudinal slope, doming, and marginal drainage suggest that the valley floor is not a normal fluvial terrace. Similar deposits and landforms elsewhere in Bhutan and other parts of the Himalayas have been referred to as alluvial fans. They differ from conventional fans in that the lower, chaotic deposits are probably glacio-fluvial, laid down by high energy meltwater torrents. The upper metre or so appears to be normal fluvial, aeolian, or mixed deposits.

A less likely possibility is that the valley floor deposit is a glacial till, transported and deposited under a valley glacier. This would account for the chaotic mix of grain sizes and lack of horizontal layering in the main lower part of the profile. It would also account for the doming and side drainage. When the glacier retreated after its last Pleistocene maximum, the ice would melt earliest at the edges where it was thinnest, so that the first streams would run along the foot-slopes, rather than in the centre of the valley. Once established these streams would be the local base levels for erosion, so that post-glacial fluvial erosion

would tend to be most effective at the margins and might account for the doming. However substantial intact valley tills are not common in Bhutan or elsewhere in the Himalayas. It appears that they mostly get swept away by the fierce meltwater streams that result from glacial retreat.

Both of these suggested origins suggest that the main bouldery deposit dates from the last major glacial retreat in the area. As the site is at a relatively low altitude, this is unlikely to have been from one of the more recent Himalayan glacial episodes in the Holocene, but more probably dates from the late Pleistocene (Gansser 1983).

2.5 Land use and vegetation

There are four main categories of land use in the Centre: research trials; apple orchard; private production plots operated by the Centre's staff and labour force; and land that is used for extensive pasture and/or natural forest regeneration.

The research trials are located on the valley floor and footslopes. There is a range of variety and management trials. The main crops investigated are temperate field crops, vegetables, soft fruits and fruit trees. The Centre's main production areas are located on the upper end of the valley floor, the footslopes, and sections of lower slopes of the eastern hills. The main crop is apples, but other temperate fruit tree crops, such as pears and plums, are also grown. The apples are harvested and marketed by contractors, and mostly go to Bangladesh.

The staff and labour force of the Centre cultivate plots on the upper end of the valley floor and footslopes, and on the hillslopes. The bouldery low terrace entrenched by Yusipang Chhu into the valley floor is cultivated intensively, entirely for staff plots. The privately run plots are used mostly for vegetables, especially cabbages. Fertiliser usage appears to be high. Much of the production is commercial, and is sold in the Thimphu vegetable market.

Most of the hill land of the centre is not managed for production at present. The original forest cover has been cleared, and the vegetation is now mostly scrub and grass. The scrub is mostly regeneration of the pioneer tree species for this attitudinal/ecological zone; i.e. blue pine (*Pinus wallichiana*) and poplar (*Populus sp*). There is a fairly dense ground cover. The commonest shrubs are rose (*Rosa sericea*), *Hypericon spp,, Leptodermis sp, Quercus spp, Rubus spp and Salix sp.* The common herbaceous species are *Cosmos bipinnatus, Artemisia vulgaris, Gnaphaline affine, Chenapodium album,* and *Rumex nepalensis.* It appears that this land was mainly used for the collection of firewood, fire splints, and some construction timber. There are incipient gullies along skid trails, but the timber now being moved along these originates from outside the survey area, on the higher slopes. There is some grazing of cattle on this land, but it is best characterised as regenerating blue pine. The poplar will eventually decline and be shaded out as the pine overtops it.

3. PREVIOUS SOILS INFORMATION

As far as is known, there have been no previous soil surveys of the Yusipang RNR-RC site.

The pilot study area at Gidakom (LUPP 1995) is the closest, both in distance and in altitudinal and ecological equivalence, of land resource evaluations undertaken by the Land Use Planning Project. The soils at Gidakom are influenced by substantial outcrops of limestone, and many of them are finer textured, redder, and have higher pH and exchangeable base status than those of Yusipang.

Soils data have been collected in the course of agronomic trials on the Centre. They are summarised in Table 3.1.

Table 3.1 Previous soils data from Yusipang RNR-RC (1993-1997)

Year	No.of samples	Depths (cm)	SPAL Nos.	Analyses completed
1993	22	0-15 60-75	258-278, 724.	Full - pH, OM, exchangeable, textures.
1993	63	Topsoil	148-210	Some full chemical, except for no N. Other have no exchangeable. No textures at all.
1995	31	Topsoil	1319-1349	pH, EC, some extractable Al and H.
1995	16	Topsoil and subsoil	2693-2708	Full chemical.
1997	6	Topsoil	4119-4124	Full chemical.

Sources: Yusipang ARC Annual Report 1993; SPAL records 1997.

The analyses show that the non-irrigated soils are very to slightly acid, with pH (water) values in the range 4.8 – 6.5. However they mostly appear to have good exchangeable base status, with base saturations of over 70%. Ca is the dominant exchangeable cation, but Mg levels are moderate and exchangeable K levels are moderate – high. Organic matter levels are low – moderate, with organic carbon contents of about 2.5% and C:N ratios are in the range 10-20. Available P levels are variable but are mostly moderate or high.

The land used for the horticultural trials has mostly been irrigated and fertilized for many years. This has affected the chemical characteristics, with decreases in pH values, decreased base saturation, decreased organic carbon but high contents available P and exchangeable K. Some of these enhanced nutrient effects presumably result from fertilizer, but some may have come in with the irrigation water.

4. METHODS

4.1 Field

This was the first fieldwork undertaken by the newly formed Soil Survey. The survey was primarily a field training exercise. All of the fieldwork was done as a group, with the emphasis on explanation and standardisation of methods. As the fieldwork overlapped with formal instruction sessions at Semtokha, and with the logistics involved with the initial establishment of the Soil Survey unit, much of the fieldwork was done as half days. As the fieldwork was done during June-September 1997, the half day working fitted in with the general monsoon weather pattern, as mornings were mainly fine and there was often rain in the afternoons. The time taken for this survey was longer (almost three months) than would normally be needed for a routine survey for this size of the area or for the amount of data.

The soils were examined on a routine basis at 151 sites, mainly with a 1.2 m Edelman auger, fitted with a 7 cm combination head where possible but switching to a 7cm stony soil head where necessary. At sites where the first attempt to auger was stopped by stones at less than 50 cm, a second attempt was made within a few metres. Some routine examinations were done in road cuttings, cut back at least 15 cm to expose fresh soil. The sites were located on a free survey basis in the cultivated areas where accurate location using plot boundaries was simple. In the uncultivated areas the routine sites were located at measured intervals along compass traverses started at points that could be confidently identified on the available large scale maps. In both free and traverse survey areas, locations were checked with a Magellan GPS. However, as the augering intervals were only 25 m in places, the GPS was operating close to the limits of its specified accuracy (ca 20 m horizontal), and the results were not always useful. In cases of disagreement, the location by compass + measuring tape was preferred.

For routine soil observations the following site data were collected:

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

The soils were described according to their natural layering (horizons), in the upper 1 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 auger.

The soils were described in more detail at 18 sites. Seven of the detailed descriptions were done in freshly cleaned-back road cuttings and the other 11 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; stones, litter, cracks, faunal activity, sand wash, and capping.

The soils were 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 boundaries.

Samples were collected for laboratory analysis from the main horizons of 14 of the detailed profiles.

4.2 Mapping

The Survey of Bhutan topographic mapping of the area is sheet # 78E-11 at scale 1:50 000. The current edition was produced in 1991 and includes updated data on settlements and infrastructure. However the basic topographic data are unchanged from an earlier version produced by the Survey of India in 1964. The available aerial photographs are at scale of 1:30 000, and date from 1986. The available satellite coverage of the area is a 1:50 000 composite of SPOT1 imagery from 1989.

The scales of these are too small for them to be useful as a base for 1:2500 soil mapping. However the RNR-RC has been mapped in two separate parts at large scale, although when and by whom is not indicated. The scale of the western section map is not given but measurements indicate that it is about 1:1550. The scale of the eastern map is 1:1000. Both maps appear to be accurate as to the infrastructure and cultivated areas. The eastern map shows contours at 2.5 m vertical intervals, but these are not related to a national datum, and are measured from an arbitrary local base, the identity of which is not given. However the form lines appear to be accurate and give a good indication of the topography, as apparent in the field. A problem is the absence of contours in the main east bank valley. The contours on the western map are at 4 m intervals, and appear to be related to altitudes, although this is not clear, because of labelling errors. However the form lines in the hill areas appear to be highly generalised and give a poor indication of the detailed topography.

Despite these deficiencies, the two maps were used as the base for the soil survey because of their suitably large scales and the apparent accuracy of their infrastructural detail. This means that the soil map shows infrastructural features to enable easy location by RNR-RC users. Another problem with both of the maps is that they are not tied into a national spatial frame or to each other, and no control points are shown. This means that, although they can be used as the basis of a free-floating map, it is difficult to place these in the national x – y spatial frame of the LUSS GIS. This would restrict the potential uses and value of the map.

In order to overcome this problem and to relate the two base maps to the national geo-referencing spatial frame in the GIS, and to each other, GPS readings (averages of 20) were taken on the ground at 22 easily identified stations. The steep topography restricts the sky view and choice of satellites and gave some readings with poor satellite geometry. When all of the GPS readings were entered in the GIS and compared with the initial digitisation of the base maps, the RMS error was unacceptably high, by several orders of magnitude. Selection of the better stations reduced this error to levels that were still high but are just about workable.

The infrastucture, soil boundaries, and the sites of the soil augerings and the profile pits were plotted on photo-reduced hard copies of the base maps. The data were then digitised into the GIS as three separate covers: infrastructure: soil inspection sites: and soil

boundaries. The printing scale of the map in the end pocket of this report is 1:2500.

4.3 Laboratory

The 56 soil samples collected from the main horizons of 14 of the detailed profiles were analysed by the Soil and Plant Analytical Laboratory (SPAL) of the Research, Extension and Irrigation Division (REID) of the Ministry of Agriculture at Semtokha. The methods of analysis used by SPAL are summarised in Appendix A.

The only chemical methodological points that need to be mentioned here concern the measurement of cation exchange capacity (CEC) and calculation of base saturation (BS%). CEC can be measured by saturating the soil with ammonium cations, and measuring them. This is referred to as CEC (NH_4OAC). An alternative is to estimate CEC by summing the exchangeable bases (Ca + Mg + K + Na = TEB) and the extractable aluminium. This is known as the 'effective cation exchange capacity (ECEC). SPAL does not measure extractable Al in soils with pH (water) greater than 4.5. As none of our Yusipang samples are that acid, there are no determinations for extractable Al. In such cases the ECEC is identical with the TEB. It is therefore not very useful, and has not been given in this report. Base saturation is the quotient TEB/CEC. If the TEB and the ECEC are identical (as is the case where there is no extractable aluminium), the 'effective base saturation' (EBS %) is automatically 100 %. These values add nothing, and have not been given in this report. The base saturations in the following soil class descriptions and in the profile data in Appendix B refer to TEB/CEC (NH_4OAC).

5. SOIL CLASSIFICATION, CHARACTERISTICS, AND CORRELATION

5.1 Soil classification

The soils of the survey area are classified into three main topographically-determined groups: - the residual and colluvial soils of the hills; the depositional soils of the sloping valley floor; and an intervening belt of foot-slope soils. These groups are further subdivided to give a total of 11 soil classes, which are summarised in Table 5.1. Textures vary relatively little and are not used to distinguish between the soils within the area. The main criteria for subdivision are depth, natural drainage and subsoil colour. These are fairly permanent features of the soils.

Some soil characteristics, such as topsoil organic matter content, colour and depth, and the occurrence of apparent buried topsoils, can be changed considerably by soil management practices, such land forming, irrigation, and organic fertilisation. They can vary substantially within a single terrace as narrow as 5 m, and therefore at too short a range to be mapped, even at a scale of 1:2500. The main effects of terrace construction on the profile morphology of soils on naturally sloping sites is for the topsoil to be removed or truncated from soils on the upper, inner margin of the terrace and for the topsoil to be buried in soils close to the lower, outer edge. The buried topsoil may still be clearly visible in the subsoil. Where flat terraces have created on a natural slope, the buried topsoil may incline obliquely downwards relative to the new, near-horizontal soil surface. This was clear in Profile PH001.

In the following descriptions of each soil class, the main features of the natural profile are described. Current and recent land use and land forming history are also mentioned, so as to give an indication of the likelihood of artificial profile modifications. More details of the morphologies for individual profiles are given in Appendix B.

Table 5.2 summarises the main chemical analytical results from the soil samples collected during the survey, and indicates the range of chemical properties within the soil classes. The detailed analytical and the granulometric data are given for each profile in Appendix B. The values in Table 5.2 can be interpreted by reference to Table APPA.1 in Appendix A.

5.2 Soil classes at Yusipang RNR-RC

5.2.1 Shallow and medium hill soils (Hs and Hm)

The well drained hill soils are subdivided into three depth classes, and there is a fourth class for the poorly drained soils of steep hillside depressions.

The shallow (Hs) (<50 cm to weathered rock) and medium (Hm) (50-100 cm deep) soils are morphologically similar. The topsoil is moderately dark (dark grey or dark brown), sandy loam in texture, with moderate or strong crumb structure and good porosity. It ranges in depth to 10 / 25 cm. It overlies a brightly coloured subsoil with a reddish yellow, yellowish red, or strong brown matrix, which tends to get slightly redder with depth. There are spots and mottles of other colours but many of these are thought to be due to incomplete weathering of mineral particles. Subsoil textures have a fairly narrow textural range from sandy loam to sandy clay, with sandy loam+ predominant. Although textures are often slightly finer than in the topsoils, subsoil cutans are absent or rare, and clay translocation is not thought to be important. The structures are mainly moderate subangular blocky, with moderate or high internal porosity.

Table 5.1 Summary of soil classes at Yusipang RNR-RC

Soil class		***Brief description***	***Profiles & analyses (Appendix B)***
Code	***Name***		
Hs	Shallow reddish yellow hill soil	Dark brown sandy loam topsoil over reddish yellow sandy loam-sandy clay loam over reddish soft weathered or hard rock within 50cm of surface; mostly on open slopes or convexities	Pd 001, PK 002
Hm	Medium reddish yellow hill soil	Dark brown sandy loam topsoil over reddish yellow sandy loam – sandy clay loam over red soft weathered or hard rock at 50-100 cm of surface; mostly on open slopes	PH003
Hd	Deep reddish yellow hill soil	Dark brown sandy loam topsoil over reddish yellow sandy loam- sandy clay with no weathered or hard rock within 100 cm of surface; mostly concavities	PH002 PK001
Hg	Poorly drained hillside gley	Black or grey wet sandy loam over wet grey variable loamy sand- sandy clay loam over moist grey weathered rock; hillside depressions and drainage lines	Pd005
Ff	Freely drained footslope soil	Brown or grey sandy loam over bright brown or reddish yellow sandy loam- sandy clay loam, moist, +/- stony; footslope	PH006
Fi	Imperfectly drained footslope soil	Grey sandy loam over grey or dull brown sandy loam- sandy clay loam, moist- wet, +/- stony; footslope	Pd002 (PK008) PK009
Fg	Dark poorly drained footslope Gley	Deep black or dark grey sandy loam over grey or dull brown sandy loam- sandy clay loam, wet, +/- stony; footslopes	(PK008)
Vf	Freely drained valley soil	Brown or grey sandy loam over bright brown or reddish yellow very compact sandy loam- sandy clay loam, moist, weak stone layers in top 1m; domed part of valley floor.	PK004
Vi	Imperfectly drained valley soil	Dark grey sandy loam over grey mottled moist- wet sandy loam- sandy clay loam, silty & stony layers in top 1m; middle part of valley floor.	PH001, PH004, PH005, PK003 & PK005
Vg	Poorly drained valley gley	Wet dark muchk or sandy loam over grey mottled very wet sandy loam –sandy clay loam, stone layers in top 1m; drainage lines on lower edges of valley floor	PK006
LT	Low terrace soil	Dark brown boulders sandy loam on low terrace/floodplain along main stream	PK007

Table 5.2 Ranges of chemical analyses, by soil classes

SOIL CLASS (no. of profiles analysed)	TOPSOIL ONLY				TOPSOIL AND SUBSOIL (T/S)				
	Organic C (%)	**Total N (%)**	**C:N**	**AvP (ppm)**	**pH**	**TEB me %**	**BS (%)**	**ExchK (me %)**	**AvK (ppm)**
Hs (1)	3.4	0.11	31	16	6.4 / 5.6	8.2 / 2.4	59 / 30	0.9 / 0.2	220 57
Hm (1)	9.5	0.33	29	14	5.8 / 6.2	15.9 / 2.7	53 / 28	1.0 / 0.4	224 / 54
Hd (2)	1.7-3.1	0.01-0.20	16	3-8	6.1 / 5.5-6.5	5.4-9.0/ 0.8-4.2	40-55/ 7-36	0.5-0.7 / 0.1-0.2	125-135/ 14-22
Hg (1)	3.1	0.13	24	16	5.9 / 6.1	9.5 / 1.1	63 / 22	0.6 / 0.1	141 / 27
Ff (1)	2.0	0.14	14	1	5.4 / 6.2	4.1 / 7.5	40 / 74	0.3 / 0.5	48 / 52
Fi (2)	0.4 - 3.8	0.12-0.23	3 - 16	3 - 21	5.8 - 6.3/ 5.7-6.2	7.4-13.6/ 4.6-5.4	68-73/ 28-45	0.6-0.7 / 0.3-0.5	108-158/ 44 -85
Fg (1)	3.8	0.23	16	21	6.3 / 6.2	13.6/ 5.4	68 / 28	0.7 / 0.3	158 / 44
Vf (1)	2.7	0.23	12	35	6.9 / 6.7	15.6/ 10.7	100 / 96	1.0 / 0.2	151 / 9
Vi (2)	4.0-4.1	0.21-0.22	18-20	13-35	6.2-6.4 / 5.8-6.7	11.6-12.1/ 1.6-3.4	63-64/ 12-34	1.1-1.4 / 0.2-0.3	269-395/ 32-38
Vg (2)	0.7-1.0	0.04-0.09	8-25	2-6	5.9 / 5.4 - 5.9	1.0-3.5/ 6.1-6.2	19-29/ 32-40	0.1-0.3 / 0.5-0.8	180-181/ 70-95
Lt (1)	2.2	0.14	16	35	6.4 / 6.5	5.5 / 5.1	49 / 54	0.1/ 0.3	180 / 70

See Table APPA.1 in Appendix A for interpretative criteria.

The solum (true soil) is underlain by highly weathered gneiss. This is highly coloured by free iron compounds and may be redder than the overlying soil. It tends to get more compact, harder, more clearly rock-structured and less red with depth. In some shallow profiles the depth of weathered rock is little more than a thin crust, and hard gneiss occurs within 1 m of the surface, but generally the rocks are weathered to considerable depths.

These are the dominant soils of the convex and rectilinear sections of the hill slopes. There does not appear to be a correlation between soil depth and slope angle, possibly because of the importance of locally variable mass movement processes.

A feature of these soils is that the sola are relatively shallow but the underlying rock is generally highly and deeply weathered. It appears that the parent material was well weathered during a previous prolonged warm and wet spell, presumably in the Pleistocene. The deep and highly leached soils that are assumed to have developed at the same time appear to have been more or less truncated during a later stage, possibly an arid phase when rainfall quantities were lower but intensities were probably higher, and the protective cover of vegetation was more sparse than at present.

The only sampled profile in the shallow soils (Pd001) is slightly acid (pH 5.5 - 6.5), has low cation exchange capacity, low base status, with subsoil base saturation values under 40%. However topsoil available P is moderate (16 ppm). The only sampled profile in the medium depth soils (PH003) is similar with respect to the subsoil chemical characteristics. However the topsoil has a higher organic matter content so that organic carbon is very high, at 9.5%, for a mineral soil. Total nitrogen (0.33%), available P (14 ppm), and the cation exchange capacity (about 30 me%) are moderate.

Most of these soils are on the upper sections of the hills, and very few of them have had their morphologies modified and complicated by terrace construction, nor have organic matter contents and general nutrient fertility been increased by organic fertilizers.

5.2.2 Deep hill soils (Hd)

These soils are similar to the shallow and medium hill soils in colour, texture and structures. They differ in that the colluvial parent material is deeper, and often appears to have been deposited in several distinct phases. This results in complex profiles, with what appear to be previous topsoils buried by later deposition. This interpretation is complicated by human land-forming activities on slopes that were previously terraced for arable cultivation, e.g. Profile PK001. However natural polycyclic profiles with buried topsoils also occur, e.g. Profile PH002.

The general profile consists of a dark, medium or coarse-textured, crumb-structured topsoil over a reddish yellow or strong brown, blocky subsoil. This may get slightly redder at depth but is often interrupted by the darker horizon of a buried topsoil, which grades into the brightly coloured subsoil of the buried profile. Both topsoil and subsoil textures are in the sandy loam – sandy clay range, with sandy loam+ predominant. The horizonation of textures is not marked, tends to be erratic, probably a result of irregular colluvial deposition and the relative unimportance of clay translocation.

These soils occur on the straight sections of the slopes (e.g. Profile PK001) but are more common in slight hillside depressions and other minor concavities (e.g. Profile PH002), where surface wash and soil creep material tends to collect. They are the dominant soils in the well-drained upper sections of shallow declivities that run down the hillsides.

There are two sampled profiles in these soils (PH002, PK001). Profile PK001 is fairly uniform with respect to base status, and has slightly acid pH in the range 6.0 - 6.5, and low cation exchange capacities. These are only moderately saturated with bases, with values in the 30 - 50% range and these are present in good ratios. The organic matter characteristics are more variable. The topsoil has low organic carbon content (1.7%) and very low total nitrogen (only 0.01%), and low available P (3 ppm). The organic carbon, total nitrogen and available contents increase in both of the buried topsoil horizons, although levels are still low. Profile PH002 is generally similar with respect to pH and base status, but its topsoil has better organic matter contents. Topsoil organic carbon (3%), total nitrogen (0.2%) and available P (8 ppm) are all low to moderate. Although a buried topsoil was noted in the field description of this profile, it hardly showed up in the analyses, with no increase in organic carbon or total nitrogen, and only slight rises in available P and the cation exchange capacity.

These soils also occur on lower slopes that were formerly terraced. Some of them have had their morphologies modified and complicated by terrace construction. The organic matter contents and general nutrient fertility of their current, and possibly also the buried, topsoils may have been enhanced by organic fertilisers, although this is not apparent in our data.

5.2.3 Poorly and imperfectly drained hill soils (Hg)

The lower parts of the moderately and steeply sloping hillside depressions are the drainage routes for substantial volumes of surface runoff and subsurface throughflow from the surrounding slopes. The soils are therefore wet for long periods, and are formed in largely

anaerobic conditions. This affects their morphology in three main ways:

- Organic matter decomposition is slowed down, and the surfaces are organically rich 9mucks, almost peats in places.
- Weathering is retarded and many of theses soils are shallow to weathered rock
- Free iron compounds are in their anaerobic reduced forms which give mainly grey matrix colours to the mineral subsoil and weathered rock horizons. Patches where aeration is better, such as around aerenchymatous roots, show as distinct rust-coloured mottles, which are often tubular.

As these soils are derived from the same bedrock as, and colluvium from, the surrounding slopes, the textures are, similar to those in the well drained hill soils. They range from loamy sand to sandy clay, with sandy loam predominant.

The only sampled profile in these soils (Pd005) is slightly acid, with pH values close to 6. The cation exchange capacity is low in the subsoil and base saturation declines from high (> 70%) in the upper subsoil to very low (about 20%) at depth. However the base ratios are good. Despite the dark subsoil colours, organic matter contents are low, with low organic carbon, total nitrogen and available K. The topsoil organic matter (organic C about 3%) and cation exchange capacity are only moderate and the total nitrogen content is low (only about 0.1%) and the C:N ratio is unfavourable (above 20).

Some of these soils have been cultivated and there are terraces below the western office. These are wet, and have been mostly abandoned and overrun by *Yushania sp.* bamboo and *Juncus* sedges. The riser faces show the shallow depths of these soils, with grey wet weathered rock exposed within 1 m of the surface. Buried topsoils and organic matter enhancement do not show in auger examination of these soils because of the masking effect of the naturally deep, wet and mucky topsoils.

5.2.4 Well drained footslope soils (Ff)

The soils of the footslopes are all deep, and have variable stone contents and textural layering due to discontinuities in the colluvial deposition. They are mostly fairly wet, and are subdivided into drainage classes. The water mostly comes from throughflow seepage from the hill slopes above.

There is one area in which relatively well drained soils predominate, on the upper section of the east bank footslope deposit in the north of the area. The profile described in detail (see Profile PH006) has a moderately developed dark brown topsoil which is 14 cm deep, and has a good crumb structure. There is also what appears to be a buried topsoil but this is thought to be artificial and to have been formed during terrace construction. The rest of the subsoil is a very heterogeneous succession of horizons that have been formed by the irregular deposition of successive layers of colluvium. Colours are predominantly in the range of brown to reddish yellow. There are some reddish ferruginous mottles and black manganese stains at depth, indicating occasionally impeded drainage and anaerobic conditions, but the upper metre appears to be well drained. Textures vary according to deposition, but within a fairly narrow range of sandy loam to sandy clay. Subsoil structures are mostly moderately developed subangular blocky, with moderate pores and few cutans.

Only one profile (PH006) has been sampled in these soils. It is moderately acid (5 - 5.5%) in the upper horizons but the pH increases to only slightly acid (about 6) in the deeper subsoil. This trend is paralleled in the total exchangeable bases and base saturation, which both increase with depth. The topsoil has low organic carbon (about 2%) total nitrogen

(about 0.15%) and very low available P (1ppm).

The only area where these soils predominate is cultivated for rainfed vegetables and maize. It has been terraced and receives organic fertilizers. As in profile PH006, the morphologies of most of these soils have been modified by land forming.

5.2.5 Imperfectly drained footslope soils (Fi)

These are the most extensive soils developed in the footslope deposits. Their profile shows that they have impeded drainage for substantial parts of the year. The topsoil is dark grey, dark greyish brown or black. It has a weak to moderately developed crumb or fine subangular blocky structure. The topsoil may be fairly deep, extending to 50 cm in some profiles. The subsoil is predominantly brown or greyish brown and usually has reddish brown ferruginous and sometime black manganese mottles. It has weak to moderate blocky structures, often with moisture films on their faces, but without clay skins. Although moist to wet, these soils do not have a water-table within the top metre. On the auger these soils sometimes appear to be shallow over weathered rock. However the pit profiles show that this is usually due to depositional layers with partially weathered gneiss stones and gravel. These are often interlayered with relatively stone-free colluvium.

There are two sample profiles in these soils (PK008 and PK009). In both of them the pH is only slightly acid (about 6), and the base status of the upper horizons is moderate, with moderate total exchangeable bases and base saturation. The lower subsoils have low base saturations, but these are not paralleled by low pH values. The wetter of the two profiles (PK008) has a moderate level of organic matter in the topsoil, as shown in the organic carbon (3.8%), total nitrogen (0.2%), available P (21 ppm), available and exchangeable K, and the cation exchange capacity (about 20 me%). In contrast the topsoil of the drier profile (PK009) has very low organic matter contents (less than 0.5%), presumable due to colluvial deposition and/or truncation by agricultural terrace formation.

These soils are intermixed with freely drained and poorly drained footslope soils in the larger orchards. Most of these are terraced so that these soils are modified by artificial land forming, and also by the application of fertilizers, both organic and inorganic. However these soils are mostly not now irrigated.

5.2.6 Poorly drained footslope soils (Fg)

These soils are similar to the imperfectly drained footslope soils, but are distinctly wetter. The topsoils are deep, dark, highly organic and wet, with some of them qualifying as muck. The subsoils have grey matrix colours, and are only rust mottled along current or recent root channels. Subsoil structures are generally weak. The textures are mainly in the loamy sand – sandy clay loam range. There are stone lines, some of which are well weathered. The subsoils are very wet, and the water tables were within the top metre during the period of our fieldwork (the wettest season of the year).

Profile PK008 is transitional between these soils and the imperfectly drained group. Its analytical characteristics are briefly discussed above (see 5.2.5).

Some of these soils have been cultivated in the past, judging from the abandoned agricultural terraces. However they are mostly now overgrown with dense sedges and bamboo, and the surface is waterlogged.

5.2.7 Well-drained valley soils (Vf)

These soils occur on the highest part of the downstream part of the slightly domed valley floor. The profile typically has a brown, friable, crumb structured topsoil. The subsoil is reddish yellow – strong brown with few, if any mottles. The structure is moderate subangular blocky, with few if, any clayskins or other types of cutans. A striking feature of these soils is their compact subsoil consistence. This is in strong contrast with the friable subsoils of the otherwise similar well-drained footslope soils. The textures vary within the fairly narrow range, sandy loam – sandy clay. The textural horizonation results from the alluvial deposition and clay translocation is not apparent. There is often a moderate stone line of partly weathered gneiss.

There is one sampled profile in these soils (PK004). The analyses show this soil to be chemically district from most others on the Centre. The soil of nearly neutral pH (6.5-7) and of very high base saturation (above 75% in all samples) throughout the profile. Topsoil organic carbon and total nitrogen contents are low to moderate, but available P (35 ppm) and K and exchangeable K (1.0 me%) are high. As expected from the bright colours, organic matter levels are low in the subsoil horizons.

These soils are used for pasture, tree fruit and grape trials. They have been terraced, fertilized and are irrigated. Their profiles have therefore been modified by soil management practices, but no buried topsoils were seen.

5.2.8 Imperfectly drained valley soils (Vi)

These soils occupy most of the valley floor. They slope down valley, and also have a moderate lateral slope down to the drainage lines along the margins of the valley.

The topsoil is dark grey – dark greyish brown, often with faint rust mottling. The texture is sandy loam to sandy clay loam, and the structure is usually a weak or moderate crumb. The subsoil shows alluvial layering in the alternation of dark and light grey and brown colours and in the erratic textural variations from loamy sandy to silty clay, although most are in the range sandy loam to sandy clay loam. Mottling is also variable. In the lower subsoil, below 50 cm, the soil becomes wetter but no water-table is found within the top metre. Grey matrix colours predominate and browns occur only as tubular rust mottles around current and previous root channels. The finer textured layers become increasingly plastic and sticky with increasing depth and moisture content.

These are important soils for the trials work of the Centre and there are two sampled profiles (PH004 and PH005). As is to be expected in soils developed in recently deposited, layered parent materials and with heterogeneous texture, the chemical characteristics are variable. The pH values vary from near neutral to slightly acid and base saturations from high to very low. The layering also shows up in the organic matter contents, with values for organic carbon, total nitrogen, available P and exchangeable K showing increases in some subsoil horizons.

These soils have been extensively modified by terrace construction, and clear buried topsoils were seen, e.g. profile PH001. The soils have also modified by fertilizer application and irrigation. They are the main vegetable soils of the Centre.

5.2.9 Poorly drained valley soils (Vg)

These are the soils of the drainage lines along the base of the hills at each side of the valley. They are waterlogged to the surface and some of them have standing water. The upper horizon is wet, sloppy, fibrous peaty muck, with the mineral fraction of sandy–sandy loam texture. The underlying mineral soil is dark bluish grey to grey mainly of 2.5Y – 5Y hues (the most yellow page in Munsell soil colour book) . There are some tubular rust mottles along root channels. The textures vary from coarse sandy loamy to silty day loam. The soils are too wet throughout for structures to be apparent, and also for sticky or plastic consistence.

There are two sampled profiles in these soils (PK005 and PK006). They are slightly acid but have low base saturation. Despite the dark colours, organic matter levels are generally low throughout, but vary with depth, as shown in the depth profiles of organic carbon, total nitrogen, available P and exchangeable potassium.

These soils are too wet ever to have cultivated and have a marshy vegetation of sedges and bamboos. Their profiles are not thought to have not been modified by land forming, irrigation or fertilizer applications.

5.2.10 Low terrace soil (Lt)

Yusipang Chhu has laid down a narrow and discontinuous floodplain and a low terrace in the trench that it has dissected into the main valley floor. In places the surface is bouldery. The topsoil consists of dark grey stony loamy sand – sandy loam. It has a friable consistence and moderate crumb structure. The subsoil is of similar colour and fine earth texture, but there are many boulders and it was not possible to auger beyond about 60cm, or dig beyond 90cm.

There is only one sampled profile of these soils (PK007). It has pH values near neutral (about 6.5) but base saturations are only moderate (at about 50%). The topsoil does not have high organic carbon (only about 2%) or total nitrogen (about 0.15%) but exchangeable potassium (0.8 me%) is moderate and available P (35 ppm) is high.

These soils occur in pockets that are too fragmented for trials or commercial production by the Centre, and have been used by the labour under small private plots and residences. They are intensively cultivated for vegetables, for domestic consumption and for sale. These soils have not been terraced, but their characteristics have been modified by heavy fertilizer application and some irrigation by hosepipe.

5.3 Soil correlation

5.3.1 Correlation with international soil classifications

The local classification used in Table 5.1 and Section 5.2 aims to be simple and to clearly indicate the main soil features to those specifically interested in soils in Bhutan and Yusipang. The classes and their names are too generally defined to convey much to people outside Bhutan. To facilitate international communication, the classes are correlated with the two main international system of soil classification in Table 5.3. There are further details of the correlations in Appendix C.

5.3.2 Correlation with CIP geotechnical classification of soils

The stability of soil terraces and water conveyance systems are critical features of soils for agricultural development in Bhutan. The Irrigation Section of REID of MOA has prepared a geotechnical classifications of soils specifically for canal and terrace stability in Bhutan conditions. Table 5.4 correlates the soil classes of Yusipang with their classification. The rock classifications have been omitted because all of the Yusipang soil parent materials quality for the same geotechnical lithological group, i.e. gneiss. The hill soils are relatively stable but can destabilised by excessive loading when wet.

Table 5.3 International correlation of soil classes at Yusipang RNR-RC

Soil class		**Subunit in FAO Soil Map of the World Legend of (FAO 1974 & 1988)**	**Great group in USDA Soil Taxonomy (Soil Survey Staff 1975 & 1992) *[Family in italics*]**
Code	**Name**		
Hs	Shallow reddish yellow hill soil	Humic or dystric Cambisol	Lithic, dystric or typic Ustochrept; [*mesic, coarse loamy, mixed*]
Hm	Medium reddish yellow hill soil	Humic or dystric Cambisol; dystric Regosol	Dystric or typic Ustochrept*; [mesic, coarse loamy, mixed]*
Hd	Deep reddish yellow hill soil	Dystric Regosol, Humic or dystric Cambisol;	Dystric or typic Ustochrept, Typic Ustorthent*; [mesic, coarse loamy, mixed]*
Hg	Poorly drained hillside gley	Mollic or dystric Gleysol; gleyic Cambisol	Mollic or humic Endoaquept, Typic Epiaquept, Cumulic Humaquept, Humaqueptic or mollic Endoaquent or Epiaquent*; [mesic, coarse loamy, mixed]*
Ff	Freely drained footslope soil	Eutric or dystric Regosol, dystric Cambisol	Dystric or typic Ustochrept,Typic Ustorthent*; [mesic, coarse loamy, mixed]*
Fi	Imperfectly drained footslope soil	Mollic or dystric Gleysol; Eutric or dystric Regosol	Typic or mollic Epiaquept, Cumulic Humaquept, Humaqueptic or Aquic Ustorthent; *[mesic, coarse loamy or loamy skletal, mixed]*
Fg	Dark poorly drained footslope gley	Mollic or dystric Gleysol	Typic Epiaquept or Cumulic Humaquept, Humaqueptic or Mollic Endoaquent or Epiaquent*; [mesic, coarse loamy or loamy skeletal, mixed]*
Vf	Freely drained valley soil	Eutric or dystric Fluvisol	Dystric or typic Ustochrept, Typic Ustorthent*; [mesic, coarse loamy, mixed]*
Vi	Imperfectly drained valley soil	Mollic or dystric Gleysol	Humaqueptic, Mollic Endoaquent or Epiaquent, Aquic Ustifluvent*; [mesic, coarse loamy or loamy skeletal, mixed]*
Vg	Poorly drained valley gley	Mollic or dystric Gleysol	Typic Humaqueptic or Mollic Endoaquent*; [mesic, coarse or fine loamy mixed]*
Lt	Low terrace soil	Eutric or dystric Fluvisol	Mollic or typic Ustifluvent or Udifluvent; *[mesic, coarse loamy or loamy skeletal, mixed]*

Table 5.4 Geotechnical correlation of soils of Yusipang RNR-RC

Yusipang soil class	REID Irrigation Section Geotechnical Soil Classification	
	Land unit	Soil class
Hs	3A	SC- clayey sand CL- low plasticity sandy clay.
Hm		
Hd	3B	
Hg		
Ff	4D	
Fi		
Fg		
Vf	5A	
Vi		
Vg		
Lt	5C/5D	SM - silty sand, and GC-clayey gravel

Source for class criteria: CIP (1993)

6. SOIL DISTRIBUTION AND MAPPING

6.1 Soil distribution.

Because the soil classification has a strongly geomorphological basis, the distribution of the soil classes is closely related to topography. The shallow and medium depth soils predominate on the open slopes, spurs and other convexities on the hills. The deep, well drained, colluvial soils are most frequent in the slight upper hillside declivities. The hillside gleys occur in the lower and more clearly defined lower sections of these depressions.

Most of the footslope soils are poorly drained, with only one area of the brighter coloured, well drained soils, on the upper section of a footslope at the northern end of the survey area. The well drained reddish yellow valley soils are restricted to the apex of the domed valley floor. Most of the valley floor soils on the outward sloping sections are imperfectly drained. The poorly drained valley floor soils are confined to the drainage lines along the outer edges of the valley floor.

The low terrace soils occur mainly along the main Yusipang Chhu stream, but there is a small depression with similar boulder sandy soils along the western drainage line in the southwestern corner of the survey area.

6.2 Soil mapping units.

Because of geomorphological emphasis in the definition of the soil classes and because of the detailed mapping scale, it is possible to map most of the area as simple units in which one class of soil is predominant (consociation). Although dominated by a single soil class, consociations are not pure. Profile PK005 is an example of an impurity in a consociation, as it is a Vg soil in an area of the mapping unit Vi. The only complex mapping units is on the open hillside where the shallow and moderately deep soil are co-equal and too intimately intermixed to be mapped separately. In the northern part of the footslope to the west of the stream the imperfectly and poorly drained footslope soils are also intimately intermixed, but have been mapped as consociation Fi, because the imperfectly drained soils predominate.

The compositions of the mapping units are summarised in Table 6.1. Their areas are summarised in Table 6.2. The 1:2500 soil map is located in the end pocket of this report.

Table 6.1 Soil mapping units at Yusipang RNR- RC

Mapping unit	Type	Main soil classes	Minor soil classes
Hx	Complex	Hs, Hm	Hd
Hd	Consociation	Hd	Hm, Hg
Hg	"	Hg	Hd
Ff	"	Ff	Fi
Fi	"	Fi	Ff, Fg
Fg	"	Fg	Fi
Vf	"	Vf	Vi
Vi	"	Vi	Vf, Vg
Vg	"	Vg	Vi
Lt	"	Lt	_

Table 6.2 Area of soil mapping units, Yusipang RNR- RC

Soil Mapping Unit	Area		
	Ha	acres	% survey area
Hx	42.4	104.8	49.2
Hd	2.0	4.9	2.3
Hg	7.7	19.0	8.9
Ff	1.3	3.3	1.5
Fi	11.2	27.6	12.9
Fg	0.6	1.5	0.7
Vf	1.4	3.6	1.7
Vi	12.4	30.8	14.4
Vg	1.6	3.9	1.8
L	5.7	14.1	6.6
TOTAL	**86.4**	**213.1**	**100.0**

Table 6.2 shows that the most extensive soils are those of the hillslopes, mainly the complex of the shallow and moderately deep classes (unit Hx). These include most of currently unused land, but much of this is on steep slopes.

The imperfectly drained soils of the footslopes (mapping unit Fi) are moderately extensive and occupy much of the unused gently sloping land of the Centre. The valley floor soils are not very extensive and are mostly already intensively used, except for the small areas of the really poorly drained marshy soils (unit Vg).

7. OVERVIEW AND IMPLICATIONS

7.1 Overview of soils

In general the soils of the Centre are light-medium textured, slightly acid and have only low moderate inherent nutrient fertility. However they are by no means very acid or nutrient infertile by global standards. Their nutrient status is sufficiently high to sustain low-input cropping systems, but low enough to give good responses to good nutrient management.

The moisture status of the soils varies considerably. The shallow and medium depth hill soils on steep, runoff-shedding convex sites on south facing slopes are liable to considerable moisture stress during periods of dry weather. At the other end of the range, the poorly drained soils in the lower hillslope declivities and in lowlying parts of the footslope and valley floor have excessive soil water and poor aeration for a large part of the year, especially during the main growing season in summer.

The soils that have the best balance of good drainage and sufficient depth to give substantial water holding capacity are the well drained footslope and valley floor soils (mapping units Ff and Vf). Unfortunately they cover only small areas. However the more extensive imperfectly drained footslope and valley floor soils have a reasonable balance, although a little on the wet side. The deep hill soils are probably also satisfactory, although occasionally droughty.

7.2 Implications of results

In addition to supplying general information on an important element of the production environment, the results of the soil survey can be applied to specific aspects of Centre's operations and effectiveness.

In particular the results can contribute to the following:

- Are the soils of the Centre found elsewhere, and to what extent can research findings on the soils of the Centre be applied to other parts of the Region?
- Are the current trials at the Centre located on appropriate soils?
- What is the best use of the Centre's unused or under – used land?

The Soil Survey unit is still in its first months of operations and this is its first systematic survey. It has not seen much of the soils elsewhere in the Western Region. It cannot therefore pronounce authoritatively on the first point listed above, i.e. the regional relevance of Yusipang's soils.

However the Yusipang – type hill soils are clearly very extensive in the altitudinal range of 2000 – 3500 m in the Thimphu area. Their main agricultural use is for extensive livestock foraging. Although not as extensive as the grazing, there are also important areas of apple orchards grown on these hill soils. Another extensive land use is forestry, especially close to settlements. Many of the hill soils on the Centre are not used, and are therefore potential trial areas for forestry and temperate fruit tree crops.

The kind of side valley alluvial fan that forms the bulk of the arable area of the Centre is quite common in the Thimphu area, and are important for arable cultivation. In the valley of Ola Rong Chhu, the Hongtsho area is formed on such fan, although it is wider and at slightly

higher altitude than Yusipang. Tributaries valleys of the main Wang Chhu between Dechencholing and Chhuzom that have alluvial fans include Taba, Samtelning, Motithang, Serbithang Tadolum (Danglu), Jome Rong Chhu (Jomesa), Bemang Rong Chhu (Gidakom, Tshalunang), and an apparent complex of fan along Geynitsang Chhu (Kharsumte – Geynikha).

The alluvial fans of the larger valleys are wider and more extensive than that at Yusipang. However they appear to have similar domed structures and slopes, and common features such as the drainage by lateral footslope streams. They are also used for similar crops and enterprises as the valley soils at Yusipang, i.e. temperate vegetables and fruit trees, but some of the fans at lower altitudes are irrigated for summer rice and winter wheat. However this cropping pattern is more common on the alluvial terrace and the main river than on the side valley fans. Altitude and temperature constraints prevent rice or winter cropping at the Yusipang Centre.

The summer rice - winter wheat/mustard cropping combination is already intensively researched at the Bajo RNR-RC in West-Central Region. However the main trials at Bajo are at about 1200-1300 m asl, which is about 1000 m lower than the Wang Chhu valley. If formal on–station trial of this farming system at altitudes > 2000 m in the Western Region are required, they would have to be located in the main Wang Chhu or Paro valleys, rather than at Yusipang.

The general conclusion is therefore that the current Yusipang trials are located on appropriate soils, and that the results are applicable to important cropping area is the Region. From a soils point of view, the main potential for expanding the Centre's on–station experimental programme is in the area of tree crops (forestry and temperate fruits) on the under-utilised hill soils.

Apart form these general point about the relevance of the Centre's current operations, the results of the soil survey also give some pointers to potential research topics in the future. As, the currently unutilised hill soils are mostly of low-moderate fertility and tend to seasonal droughtiness, future research trials or demonstration plots on the could focus on nutrient and water conservation. There are also unused areas of poorly and some of the imperfectly drained soils. Trials and/or demonstrations on them could focus on drainage techniques or hydrophilic species of trees, bamboos or other potentially useful plants.

The areas of Vi, Vf and some Fi soils that have been cultivated for long periods and have probably received prolonged and heavy rates of fertiliser application. This will complicate interpretation of nutrient budget type studies, and these areas are probably best put to other uses, such as variety trials, cultivation trials etc. Fertiliser trials are possible but care will required in their interpretation.

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.

ARC (1994) . *Annual Report 1993*. Agricultural Research Centre, Yusipang.

BSSP (1998). *General report on the detailed soil survey of Yusipang RNR Rearch Centre.* Report No. **1**. Bhutan Soil Survey Project, REID, MoA.

CIP (1993). *Geotechnical manual*. Community Irrigation Project, Irrigation Section, REID, MoA.

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 (1974). *Soil map of the world. Volume 1. Legend*. Food & Agriculture Organisation of United Nations, Rome.

FAO (1988). *Soil map of the world. Revised legend.* Food & Agriculture Organisation of United Nations, Rome.

FAO(1990(a)). *Guidelines for soil description*. Food & Agriculture Organisation of United Nations, Rome.

FAO(1990(b)). *Framework for land evaluation*. *Revised edition*. Food & Agriculture Organisation of United Nations, Rome.

Gansser A (1983). *Geology of the Bhutan Himalaya.* Birkhauser Verlag, Basel.

GSB (nd). *Geology and mineral resources of Thimphu district.* Geological Survey of Bhutan (with Geological Survey of India).

LUPP (1995). *Planning surveys of Gidakom Valley. Report on detailed surveys in the pilot study area. Vol.**II.** The soils annex . Soil profile descriptions and analysis results*. Vol. **IV**, Land Use Planning Project, Planning and Policy Division, MoA.

PCl. (1996). *Study on groundwater development in Wangduephodrang district, Bhutan.* Pacific Consultants International and Chuo Kaihatsu Crop, for JICA & RGOB.

Polunin O. & Stainton A (1984). *Flowers of the Himalayas*. OUP , Delhi.

REID (1995). Mandates of RNR Research Centres. *Agricultural Newsletter* March/April 1995, p.5.

REID (1997). Renewable Natural Resources Research Centre, Yusipang. *Agriculture Newsletter.* May/June 1997, p.7.

Soil Survey Staff (1975). *Soil Taxonomy*. US Department of Agriculture, Washington, DC.

Soil Survey Staff (1992). *Keys to Soil Taxonomy: Fifth edition*. US Department of Agriculture, Washington, DC.

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

WWCMP (1992*). Western watersheds conservation and management project*. Report 144/92 BHU 6. Asian Development Bank, Manila.

APPENDIX A: Soil Analysis Method

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) < 7, as these apply to all of the samples from Yusipang.

Sample preparation.

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

pH.

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

Soil extracts

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

Total N is extracted and converted into ammonium form by micro-Kjeldahl digestion with H_2SO_4 and a Se-based catalyst.

Ammonium – N and nitrate – N are extracted by shaking with 0.01 M $CaCl_2$ for two hours.

For soils with pH (water) < 7, available P is extracted by shaking 5 g of fine earth with 35 ml of the Bray and Kurtz extractant of 0.5 M HCl and 1 M NH_4F for 1 minute.

Available K is extracted by shaking 5 g of fine earth with 50 ml of 0.01 M $CaCl_2$ for 2 hours.

Exchangeable Ca, Mg, K and Na are extracted by leaching 5 g of fine earth with 100 ml of 1 M ammonium acetate (NH_4OAc).

The ammonium is extracted by leaching the soil with excess 1 M KCl, and measured to give the Cation Exchange Capacity.

Extractable Al and H are extracted from 5 g fine earth with 100 ml of 1 M acidified KCl.

Assays of extracts.

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

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

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

Organic carbon

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

Particle size analysis

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

TEB, ECEC, BS and C:N.

Total exchangeable bases, Effective cation exchange capacity, Base saturation, and C:N ratios are derived by simple computations, i.e.;

TEB = Exchangeable Ca + Mg + K + Na.

ECEC = TEB + Extractable Al.

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

EBS = TEB / ECEC.

C:N = Organic C / Total N.

The analytical results from SPAL are interpreted as indicated in Table AppA.1.

Table APPA.1 Summary of 1995 recommendations for interpretation of SPAL soil analyses

	V. High	**High**	**Moderate**	**Low**	**V. Low**
pH	> 7.6 * (alkaline)	6.6 - 7.5 (neutral)	5.6 - 6.5 (s. acid)	4.6 - 5.5 (v. acid)	< 4.5 (ext. acid)
EC (mS/cm)	> 2.00	0.8 - 1.99	0.4 - 0.79	0.15 - 0.39	< 0.15
CEC (NH_4OAC) (me%)	> 40	25 - 39.9	15 - 24.9	5 - 14.9	< 5
XCa (me%)	> 20	10 - 19.9	5 - 9.9	2 - 4.9	< 2
XMg (me%)	> 8	3 - 7.9	1.5 - 2.9	0.5 - 1.4	< 0.5
XK (me%)	> 1.2	0.6 - 1.19	0.3 - 0.59	0.1 - 0.29	< 0.1
XNa (me%)	> 2	0.7 - 1.99	0.3 - 0.69	0.1 - 0.29	< 0.1
TEB (me%)	> 30	15 - 29.9	7.5 - 14.9	3 - 7.4	< 3
XAl (me%)	> 10	5 - 9.9	2 - 4.9	0.5 - 1.9	< 0.5
ECEC (me%)	> 30	20 - 29.9	12 - 19.9	4 - 11.9	< 4
BS % (NH_4OAc)	> 80	65 - 79	50 - 64	35 - 49	< 35
EBS (%)	> 80	50 - 79	35 - 49	20 - 34	< 20
Ca:Mg	> 10	6 - 9.9	2 - 5.9	0.8 - 1.9	< 0.8
AvK (ppm)	> 300	200 - 299	100 - 199	40 - 99	< 40
AvP (ppm)	> 30		15 - 29	5 - 14	< 5
Org. C (%)	> 5	3.1 - 4.9	1.2 - 3	0.6 - 1.1	< 0.6
Total N (%)	> 1	0.5 - 0.99	0.2 - 0.49	0.1 - 0.19	< 0.1
C:N	> 50	20 - 49	15 - 19	10 - 14	< 10
NO_3 (ppm)	> 50	30 - 49	15 - 29	5 - 14	< 5
NH_4 (ppm)	> 50	30 - 49	15 - 29	5 - 14	< 5
Cu (ppm)	> 8	2.6 - 7.9	0.9 - 2.5	0.2 - 0.8	< 0.2
Fe (ppm)	> 175	35 - 174	18 - 34	3 - 17	< 3
Mn (ppm)	> 40	9 - 39	4 - 8	1 - 3	< 1
Zn (ppm)	> 10	3.5 - 9.9	2 - 3.4	0.8 - 1.9	< 0.8
B (ppm)	> 1	0.5 - 1	0.2 - 0.5	0.14 - 0.2	< 0.14
Mo (ppm)	> 1	0.1 - 1	< 0.1		
AWC (% v/v)	> 24	18 - 23	12 - 17	6 - 11	< 6

Source: AHT 1995.

APPENDIX B: Soil Profile description & Analysis

This appendix includes the detailed descriptions of all of the soil profiles, and the analyses from those sampled.

The profiles are in the order summarised in Table AppB.I.

Table App B.I. Summary of soil profiles.

Profile Number	Yusipang soil class	Number of horizons analysed
Pd 001	Hs	3
Pd 005	Hg	4
PH 002	Hd	5
PH 003	Hm	4
PH 004	Vi	3
PH 005	Vi	5
PK 004	Vf	4
PK 005	Vg	3
PK 006	Vg	3
PK 007	Lt	2
PK 008	Fi (Fg)	4
PK 009	Fi	5
PH 006	Ff	5
PK 001	Hd	6
Pd 002	Fi	Not sampled
PH 001	Vi	Not sampled
PK 002	Hs	Not sampled
PK 003	Vi	Not sampled

Profile: Pd001

Map unit: Hx

Soil classification: Provisional Yusipang class: Hs - shallow hill soil
Soil Taxonomy: Dystric Ustochrept
FAO: Dystric Cambisol

Survey area: Yusipang RNR-RC
Location: Cutting at lower end of hill road to E boundary
GPS: 27^0 27.94' N, 89^0 42.62' E,
Altitude: 2750 m a.s.l.

Described & sampled: 20.6.97, Tsheten Dorji

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers

Regional topography: Low mountains
Site position: Midslope of nose of spur

Slope: 35%, irregular rectilinear, ca 0.5 km long, NNW facing (330^0)
Site drainage: Good

Parent material: Solid: Thimphu Gneiss
Drift: Residual

Land use: Abandoned rainfed arable land, formerly terraced.
Vegetation: Bracken, blue pine, sedges, *Artemisia,* wild rose, and few grasses

Surface: Litter: Bracken fronds
Outcrops None.
Stones: Rare, fine, soft weathered gneiss.
Cracks: None.
Roots: None
Microrelief: Former cultivation terraces
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 – 16 10YR 3/3 (dark brown) with no mottles; medium sandy loam; moderate-weak fine & medium crumb; moist & friable; common very fine tubular pores; abundant fine & medium bracken roots; few fine medium soft gneiss stones and muscovite flakes; earthworm casts; HCl negative; clear regular boundary to: [Sample Pd001/1 @ 0-10]

16 –31 7.5YR 4/4 (brown) with no mottles; coarse sandy loam +; moderate fine – medium subangular blocky; moist, friable, common fine, medium & coarse tubular pores; many fine & medium bracken roots; common fine & medium soft gneiss stones, muscovite flakes; earthworm casts; HCl negative; clear regular boundary to: [Sample Pd001/2 20-30]

31 – 48 Mixed stripes of reddish brown reddish yellow or yellowish grey with no mottles; weathered rock hand textures as sandy loam, platy weathered rock structure; moist, firm in face, but friable in hand; common fine tubular pores; few fine roots; HCl negative; gradual regular boundary to: [Sample Pd001/3 35-45]

48 –92 Mixed stripes of reddish brown reddish yellow or yellowish grey with no mottles; weathered rock hand texture as loamy coarse sand, platy weathered rock structure; moist, very firm in face, but friable in hand; common fine pores; rare fine roots; HCl negative; gradual regular boundary to: [Not sampled]

92 –130+ Hard fractured gneiss, weathered down cracks.

Comment: This profile is typical of the shallow hill soils.

SPAL analytical results for BSS Profile Pd001 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
Pd001 /1	0-10	4196	6.4	4.3	2.1	nd	16	3.4	0.11	31
/2	20-30	4197	5.8	4.6	1.2	0.02	2	0.6	0.04	15
/3	35-45	4198	5.6	4.1	1.5	0.01	1	0.1	0.03	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pd001 /1	5.5	1.7	0.9	0.1	8.2	nd	13.9	nd	59	nd
/2	2.0	0.8	0.3	0.1	3.2	nd	9.1	nd	35	nd
/3	1.0	1.2	0.2	0.1	2.4	nd	8.1	nd	30	nd

Fine earth granulometric

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
Pd001 /1	nd	nd	nd	nd	nd	55.0	11.3	19.1	30.4	14.5	SL
/2	nd	nd	nd	nd	nd	55.4	10.1	19.5	29.6	15.0	SL
/3	nd	nd	nd	nd	nd	64.5	10.2	12.1	22.3	13.2	SL

Profile: Pd005

Map unit: Hg

Soil classification: Provisional Yusipang soil class: Hill gley (Hg).
Soil Taxonomy: Dystric Endoaquept
FAO: Dystric Gleysol

Survey area: Yusipang RNRRC
Location: *5 m below cabbage field (southwest from greenhouse)*
GPS: No data.
Altitude: ca. 2680 m a.s.l.

Described & sampled: 29.8.97, Tsheten Dorji

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers.

Regional topography: Low mountains
Site position: Floor of minor hillslope declivity.

Slope: 22%, slightly convex, ca 0.3 km long, NE facing (40^0)
Site drainage: Poor

Parent material: Solid: Gneiss and quartz
Drift: Colluvium

Land use: Waste land
Vegetation: *Artemisia vulgaris*, sedges and few native grasses

Surface: Litter: None.
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: Slightly irregular, stepping 3-5 cm high.
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 – 19 7.5YR 4/2 (brown) with no mottles; fine sandy loam+; weak medium subangular blocky breaking to crumb; wet or slightly friable; not sticky or plastic, abundant fine pores; abundant fine & medium sedges roots; few flakes of muscovite; earthworm casts; clear and regular boundary to: [Sample Pd005/1 @ 0 - 10]

19 – 34 10YR 5/2 (grayish brown) with common coarse to medium orange & yellowish brown mottles; loamy medium sand -; medium subangular blocky; moist and friable, many fine interstitial pores; common fine roots; abundant muscovite; diffuse boundary to: [Sample Pd005/2 @ 25 - 35]

34 – 59 Mixed weathered rock colours of reddish brown, dark grey, light grey, yellowish brown or orange; weathered rock (fine to medium sandy loam +); strong subangular blocky; moist to wet, slightly friable plastic; common fine tubular pores; common fine root; abundant slightly muscovite flakes; pockets of sand; diffuse boundary to: [Sample Pd005/3 @ 40 -50]

59 –92+ 2.5Y 6/1 (grey) with common coarse distinct yellowish brown mottles; loamy medium sand; moderate coarse to medium subangular blocky structure; moist to wet; not sticky or plastic; common pores; few fine roots; soft weathered rock with abundant muscovite flakes; [Sample Pd005/4 @ 70 – 80]

Comment: This site, possibly the upper end of an old landslip site, and receives much water from the surrounding hillslope, but it has not accumulated a significant depth of colluvium. This may have been removed by mass movements.

SPAL analytical results for BSS Profile Pd005 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
Pd005 /1	0-10	4199	5.9	4.2	1.7	nd	16	3.1	0.13	24
/2	25-35	4200	6.1	4.7	1.4	0.02	2	0.3	0.04	10.5
/3	40-50	4201	6.1	4.1	2.0	nd	3	0.5	0.03	17
/4	70-80	4202	5.9	3.9	2.0	nd	3	0.1	0.03	3.3

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pd005 /1	7.0	1.8	0.6	0.1	9.5	nd	15.0	nd	63	nd
/2	2.8	0.6	0.1	0.1	3.5	nd	4.9	nd	72	nd
/3	0.7	0.6	0.1	0.1	1.5	nd	6.8	nd	22	nd
/4	0.3	0.7	0.1	0.1	1.1	nd	5.0	nd	22	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
Pd005 /1	nd	nd	nd	nd	nd	55.4	11.6	19.0	30.6	13.9	SL
/2	nd	nd	nd	nd	nd	75.5	9.5	9.5	19.0	5.5	SL
/3	nd	nd	nd	nd	nd	56.9	-	-	30.4	1.2	SL
/4	nd	nd	nd	nd	nd	71.2	9.2	11.9	21.1	7.7	SL

Profile: PH002

Map unit: Hd

Soil classification: Provisional Yusipang soil class: Deep hill soil (Hd).
Soil Taxonomy: Dystric Ustochrept
FAO: Dystric Cambisol

Survey area: Yusipang RNR-RC
Location: Near of top of eastern feeder road.
GPS: $27^0$57.95' N. 89^0 42.76' E.
Altitude: 2830 m a.s.l

Described & sampled: 25.6.97, HB Tamang.

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Light showers

Regional topography: Low mountains
Site position: Slight depression on upper slope

Slope: 31%, slightly convex, ca 1 km long, S facing (191^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Alluvium

Land use: Abandoned potato field.
Vegetation: *Populus, Artemisia*, Blue pine, bracken and white clover.

Surface: Litter: 5cm bracken fronds
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 - 8 7.5YR 3/3 (dark brown) moist with few fine reddish brown mottles; loam; medium fine crumb; moist, friable; abundant fine tubular pores; few coarse bracken roots; few fine gneiss stones & few muscovite flakes; HCL negative; few old worm casts; gradual regular boundary to: [Sample PH002/1 @ 0-8]

8 - 36 7.5YR 4/4 (brown) moist with few fine faint reddish brown and orange mottles; medium sandy loam; moderate medium breaking to fine crumb subangular blocky; moist, friable; many fine & medium tubular pores; common fine & medium roots; few fine gneiss stones; common flakes of muscovite and charcoal; HCl negative; clear regular boundary to: [Sample PH002/2 @ 16 - 26]

36 -47 5YR 4/6 (yellowish red); medium sandy loam +; moderate medium subangular blocky; few weak discontinuous clayskins; moist and friable (brittle in hand); common fine tubular pores; few fine roots; few hard gneiss stones; few flakes of muscovite; few insect grass; HCl negative; gradual regular boundary to: [Not sampled]

47-109 7.5YR 4/6 dry, and 7.5YR 5/6 (both strong brown) moist, slightly lighter than above horizon with no mottles; fine sandy clay loam; medium subangular blocky; few weak discontinuous clayskins; moist & friable; abundant fine pores; few fine roots; few medium hard gneiss stones; few old wormcasts; many flakes of muscovite; few fine charcoal; HCl negative; clear, slightly wavy boundary to: [Sample PH002/3 @ 65-75]

109-125 7.5Y 3/2 (dark brown) with no mottles; silty loam, weak medium subangular blocky; weak discontinuous clayskins; moist, friable; abundant medium tubular pores; few fine roots; few fine hard gneiss stones; HCl negative; gradual regular boundary to: [Sample PH002/4 @ 115 -125]

125 –146 10YR 3/2 (very dark greyish brown) with no mottles; silty loam; weak medium subangular blocky; with weak discontinuous clayskins; moist, & friable; medium fine tubular pores; rare fine roots; few flakes of muscovite; few fine charcoal; HCl negative; clear slightly wavy boundary to: [Not sampled]

146 –181 10YR 5/6 (yellowish brown) with few fine faint reddish brown & orange mottles; medium sandy clay loam; moderate medium subangular blocky; weak discontinuous clayskins; moist, firm and slightly plastic; abundant fine tubular pores; rare fine roots; few medium hard gneiss stones; few flakes of muscovite; few fine charcoal; HCl negative; [Sample PH002/5 @ 160-170]

Comment: This is typical of the deep colluvial soils that occur in the slight dedivties in the hill slopes at Yusipang. Despite a steep downhill gradient (31%) this site appears to be a recipient of local colluvium. The buried topsoil at 109 – 125 cm is thought to be due to accretion of colluvium, not artificial terrace construction.

SPAL analytical results for BSS Profile PH002 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH002/1	0-8	4187	6.1	4.8	1.3	0.01	8	3.1	0.20	16.0
/2	16-26	4188	6.1	4.7	1.4	0.02	4	1.9	0.14	14.0
/3	65-75	4189	6.1	4.7	1.4	0.01	3	0.8	0.10	8.0
/4	115-125	4190	5.9	4.3	1.6	-	5	0.8	0.08	10.0
/5	160-170	4191	5.5	4.1	1.4	0.01	1	0.2	0.04	5.0

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH002/1	6.4	1.8	0.7	0.1	9.0	-	16.2	-	55	-
/2	5.1	0.8	0.2	0.1	6.2	-	13.1	-	47	-
/3	1.0	0.2	0.1	0.1	1.4	-	7.2	-	19	-
/4	0.5	0.1	0.1	0.1	0.8	-	11.3	-	7	-
/5	1.0	0.3	0.2	0.1	1.6	-	7.2	-	22	-

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PH002/1						49.0	11.8	19.3	31.1	19.9	L
/2						48.2	12.3	19.5	31.8	20.0	L
/3						40.9	12.2	22.4	34.6	24.5	L
/4						41.9	11.3	22.5	33.8	24.2	L
/5						42.5	8.9	22.7	31.6	25.9	L

Profile:	PH003	
Map unit	Hm	
Soil classification:	Provisional Yusipang soil class:	Medium depth hill soil (Hm)
	Soil Taxonomy:	Dystric Ustochrept
	FAO*:*	Dystric Cambisol
Survey area:	Yusipang RNR-RC	
Location:	Prayer flag, 5m down hill from AK004*.*	
GPS:	27^0 8.14′ N. 89^0 42.56′ E.	
Altitude:	*2940 m a.s.l*	
Described & sampled:	1.7.97, HB Tamang.	
Climate:	General:	Cool temperate, P = ca 800 mm p.a.
	Recent weather:	Rainy
Regional topography:	Lower mountain.	
Site position:	Crest of spur.	
Slope:	32%, convex, ca 1 km long, SE facing (130^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Residual
Land use:	Cleared forest	
Vegetation:	Scrub of *Populus* sp. *Quercus spp,* blue pine, bracken, grasses	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Common medium gneiss
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 - 3	10YR 2/2 (very dark brown) with common medium faint dark brown mottles; loam; medium fine crumb; moist, friable; medium pores; many medium and fine grass roots; few fine hard quartz stones & few fine flakes muscovite; HCl negative; few old ant nest; clear regular boundary to: [Sample PH003/1 @ 0-3]
3 - 19	7.5YR.5/6 (strong brown) with common medium faint brown mottles; medium sandy loam; moderate medium breaking to fine crumb - subangular blocky; moist, friable, many fine pores; many fine and medium grass roots; rare hard quartz stones; abundant flakes of muscovite; old worm casts; HCl negative; gradual regular boundary to: [Not sampled]
19 - 32	7.5YR 5/6 (strong brown) but slightly paler than above horizon; medium sandy clay loam; moderate medium subangular blocky (fine crumb in hand); weak discontinuous clayskins; moist & slightly firm; common fine tubular pores; few fine & medium roots; few medium hard quartz stones; few flakes of muscovite; old worm casts; HCl negative; gradual, slightly wavy boundary to: [Sample PH003/2 at 20-30]
32 – 56	10YR 4/6 (dark yellowish brown) with medium dark brown mottles; medium sandy clay loam+; medium sub angular blocky but fine crumb in hand; weak discontinuous clayskins; moist and friable; medium fine pores; few medium roots; common medium hard gneiss & quartz stones; few old worm casts; many flakes of muscovite mica; much charcoal; HCl negative; gradual wavy boundary to: [Sample PH003/3 @ 40-50]
56-86	7.5YR 5/6 (strong brown); soft weathering rock (gritty loamy sand); weathering rock angular structure; moist, soft weathering rock; medium tubular pores; few fine roots; abundant hard *in situ* quartz & gneiss stones; HCl negative; diffuse boundary to: [Sample PH003/4 at 65-75]
86 – 127	7.5YR 5/6 (strong brown) with weathering colours but redder than above; weathered rock (medium sandy loam); moist, soft; common fine pores; rare fine roots; HCl negative: [Not sampled]
127 –157+	As above but redder and harder. [Not sampled]
Comment:	This is typical of the shallow and medium residual soils of the hill slopes at Yusipang. Note the crumb structure throughout the solum (to 56 cm). These are mainly macrofaunal but multiple freeze – thaw is probably important in the topsoil.

SPAL analytical results for BSS Profile PH003 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH003/1	0-3	4192	5.8	4.0	1.8	-	14	9.5	0.33	29
/2	20-30	4193	5.8	4.4	1.4	0.02	1	0.7	0.07	10
/3	40-50	4194	5.8	3.9	1.9	-	1	0.5	0.02	25
/4	65-75	4195	6.2	4.1	2.1	-	1	0.2	0.01	20

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH003/1	11.8	2.9	1.0	0.2	15.9	-	29.9	-	53	-
/2	1.3	0.6	0.2	0.1	2.2	-	10.1	-	22	-
/3	1.1	0.7	0.2	0.1	2.1	-	11.5	-	18	-
/4	1.3	0.9	0.4	0.1	2.7	-	9.5	-	28	-

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PH003/1						47.4	9.9	25.4	35.3	17.2	L
/2						38.5	10.6	26.1	36.7	24.9	L
/3						34.3	11.8	27.8	39.6	26.1	L
/4						58.4	10.0	17.1	27.1	14.5	SL

Profile:	PH004	
Map unit:	Vi	
Soil classification:	Provisional Yusipang soil class:	Imperfectly drained valley soil (Vi)
	Soil Taxonomy:	Aquic Ustifluvent
	FAO*:*	Gleyic Fluvisol
Survey area:	Yusipang RNR-RC	
Location:	East of N track, ca 150 m N of Potato Store	
GPS:	27^0 7.98′ N, 89^0 42.46′ E.	
Altitude:	*2820m a.s.l*	
Described & sampled:	1.7.97, HB Tamang.	
Climate:	General:	Cool temperate, P = ca 800 mm p.a.
	Recent weather:	*Showers*
Regional topography:	Lower mountain	
Site position:	Toe slope	
Slope:	28%, ca 200 m long, facing S (193^0)	
Site drainage:	Imperfect	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Fan alluvium.
Land use:	Pasture land	
Vegetation:	*Artimesia*, sedges, and grasses.	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Common medium gneiss
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm

0 – 20	7.5YR3/3 (dark brown); coarse sandy loam; weak fine crumb; few fine hard gneiss stones, common flakes of muscovite; HCl negative; abundant medium and fine roots; moist & friable; few flat worms seen in the side wall of profile; many pores; slightly wavy boundary to: [Sampled PH004/1 @ 0- 10]
20 - 79	7.5YR.3/4 (dark brown) with common fine faint reddish brown mottles; coarse sandy loam; weak medium breaking to fine crumb - subangular blocky; weak discontinuous moisture films; moist, friable; many medium & fine pores; common fine roots; common medium hard quartz and gneiss stones; common flakes of muscovite mica; old worm casts; HCl negative; clear wavy boundary to: [PH004/2 @ 45 –55]
60 - 79	As above but pockets of discontinuous layer as follows: 10YR 3/6 (dark yellowish brown) with medium faint orange & grey mottles; gritty coarse sand; single grain; many medium pores; wet and slightly sticky; few fine roots; common medium hard gneiss & quartz stones; common flakes of muscovite; HCl negative; discontinuous gradual boundary to: [Not sampled]
79 - 100	10YR 5/6 (yellowish brown) with many fine faint grey & orange mottles; medium sandy loam; weak medium subangular blocky; wet and slightly plastic; many medium and fine tubular pores; few fine roots; many medium hard quartz & gneiss stones; few flakes of muscovite; HCl negative; regular slightly wavy boundary to: [Sample PH004/3 at 85- 95]
100- 150+	10Y 4/3 (brown) with reddish brown mottles; medium sand; single grain; wet, and slightly plastic and sticky; common fine pores; few fine roots; many boulders of gneiss and quartz; HCl negative; few flakes of muscovite: [Not sampled]
Comment:	Although at the base of a footslope, much of the parent material of this profile has come down valley as fan alluvium, although the irregular occurrence of the horizon 60 – 79 cm suggests that local lower slope colluviation has also occurred.

SPAL analytical results for BSS Profile PH004 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH004/ 1	0-10	4225	6.2	4.9	1.3	_	13	4.0	0.22	18
/2	45-55	4226	5.9	4.4	1.5	_	4	1.3	0.12	11
/3	85-95	4227	6.7	4.7	2.0	_	1	0.4	0.04	10

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAC	EBS%
PH004 /1	8.0	2.3	1.1	0.2	11.6	-	18.0	-	64	-
/2	3.3	1.3	0.2	0.1	4.9	-	12.0	-	41	-
/3	2.0	1.0	0.3	0.1	3.4	-	10.1	-	34	-

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PH004 /1						56.5	9.6	17.4	27.0	16.4	SL
/2						43.8	11.8	23.0	34.8	21.4	L
/3						64.3	12.5	12.1	24.6	11.2	SL

Profile:	PH005	
Map unit:	Vi	
Soil classification:	Provisional Yusipang soil class:	Imperfectly drained valley floor soil (Vi).
	Soil Taxonomy:	Aquic Ustifluvent
	FAO:	Gleyic Fluvisol
Survey area:	Yusipang RNR-RC	
Location:	North of feeder road, opposite Kunzang apple orchard.	
GPS:	27^0 8.06′ N, 89^0 42.30′ E.	
Altitude:	*2840 m a.s.l*	
Described & sampled:	1.7.97, HB Tamang.	
Climate:	General:	Cool temperate, P = ca 800 mm p.a.
	Recent weather:	Cloudy
Regional topography:	Low mountains	
Site position:	Front edge of mid terrace	
Slope:	10 %, terraced, ca 100 m long facing SW (230^0)	
Site drainage:	Slightly imperfect.	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Alluvium.
Land use:	Edge of one month old vegetable cultivation (cabbage)	
Vegetation:	*Artemisia* ,bracken and *Yushania sp*. on field edge.	
Surface:	Litter:	None
	Outcrops:	None
	Stones:	Common hard round & subangular boulders
	Cracks:	None
	Roots:	None
	Microrelief:	None
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 36	7.5YR3/2 (dark brown) with no mottles; silt loam (high O.M); weak medium breaking to fine crumb; moist & friable; abundant medium & fine tubular pores; abundant medium roots; few fine & medium hard & soft & quartz stones; few flakes of muscovite mica; few earthworm casts; HCl negative; clear irregular boundary to: [Sample PH00 5/1 @ 0-10]
36 - 76	7.5YR.4/3 (brown) with no mottles; coarse sandy clay loam; strong subangular blocky; dry & firm; common medium & fine tubular pores; common medium & fine roots; few medium subrounded gneiss stones; few flakes of muscovite; few old earthworm casts; HCl negative; gradual irregular boundary to: [Sample PH005/2 at 30-40]
76 - 116	10YR 4/3 (brown) with no mottles; coarse sandy clay loam; strong medium subangular blocky; common medium & fine tubular pores; moist & firm; common medium & fine roots; few medium subrounded gneiss stones; common flakes of muscovite; few old earthworm casts; HCl negative; gradual irregular boundary to: [Sample PH005/3 @ 90-100]
116 – 154	7.5YR 3/3 (dark brown) with no mottles; silty loam; weak medium subangular blocky; moist & slightly firm; common medium & fine tubular pores; common medium & fine roots; few boulders & coarse subangular hard quartz & gneiss gravel; few flakes of muscovite; HCl negative; clear regular boundary to: [Sample PH005/4 at 130- 140]
154 - 200	10YR 5/6 (yellowish brown) with few fine & medium distinct reddish brown mottles; loamy medium sand; weak medium subangular blocky; moist, firm in face & friable in hand; few fine tubular pores; few fine roots; common medium subrounded hard quartz & gneiss stones; HCl negative; few flakes of muscovite; clear regular boundary to: [Sample PH005/5 @ 170-180]
200 – 243+	2.5YR 5/3 (weak red) with few fine & medium reddish brown mottles; coarse sand (pockets of silt deposits in places); single grain structure; few pores; moist, firm in face & friable in hand; few fine roots; abundant medium subrounded hard quartz & gneiss gravel; HCl negative; few flakes of muscovite: [Not sampled]
Comment:	This cutting shows clearly the relatively stone – free nature of the upper metre or so (1.54 m here) of the valley floor deposits. The relatively brightly coloured yellowish and red colours below 154 cm are also common in these deposits. They are through to result from depositional variations, not pedogenic orizonation.

SPAL analytical results for BSS Profile PH005 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PH005/ 1	0-10	4228	6.4	4.9	1.5	-	35	4.1	0.21	20
/2	50-60	4229	5.6	4.0	1.6	-	5	3.9	0.18	22
/3	90-100	4230	5.9	4.2	1.7	-	3	0.4	0.07	5.7
/4	130-140	4231	6.2	4.3	1.9	-	2	0.6	0.07	8.5
/5	170-180	4232	5.8	4.1	1.7	-	1	1.4	0.04	35

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PH005 /1	8.3	2.3	1.4	0.1	12.1	-	19.1	-	63	-
/2	13.8	2.4	0.4	0.2	16.8	-	17.1	-	98	-
/3	4.0	1.0	0.2	0.1	5.4	-	11.1	-	48	-
/4	4.2	1.4	0.2	0.1	5.9	-	12.3	-	48	-
/5	0.7	0.7	0.2	0.1	1.6	-	13.1	-	12	-

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PH005 /1						55.4	7.6	20.2	27.8	16.8	SL
/2						27.7	23.4	27.8	51.2	21.2	ZL
/3						53.3	9.8	19.6	29.4	17.3	SL
/4						29.5	8.7	22.5	31.2	19.3	L
/5						51.1	6.2	23.2	29.4	19.5	L

Profile: **PK004**

Map unit: Vf

Soil classification: Provisional Bhutan Soil Series: Freely drained valley soil (Vf)
Soil Taxonomy: Typic Ustrochrept
WRB: Eutric Fluvisol

Survey area: Yusipang RNR-RC
Location: 20 m from North of meteorological station in the Horticulture section

GPS: 27^0 27.66' N, 89^0 42.74' E.
Altitude: 2700 m. a s. l.

Described & sampled: 29.8.97, K Tshering

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers

Regional topography: Low mountains
Site position: Alluvial fan

Slope: 5 %, rectilinear, ca 1 km long +, SE facing (145^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss & quartzite.
Drift: Fan alluvium

Land use: Fodder trial
Vegetation: *Trifolium repens, Rumex nepalensis,* tall fescue, Italian ryegrass, cocks foot and local weeds

Surface: Litter: None
Outcrop: None
Stones: Few medium hard angular gneiss & quartz stones
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 18 7.5YR 4/2 (brown) with few fine faint yellowish orange & reddish brown mottles; fine sandy clay; moderate medium subangular blocky; few discontinuous clay cutans; moist & slightly hard; common medium pores; many medium roots; old earthworm casts; clear straight boundary to: [Sample PK004/1 @ 0 - 10 cm]

18-50 7.5YR 5/6 (strong brown) with common medium reddish brown & orange mottles; fine sandy clay; moderate medium angular blocky; few moderate discontinuous claycutans; moist & firm; common medium & fine pores; few fine roots; few fine hard gneiss & quartz stones; common medium manganese stains; clear slightly wavy boundary to: [Sample PK004/2 @ 30-40 cm]

50-68 10YR 5/6 (yellowish brown) with common medium & fine, faint orange, reddish brown and reddish yellow mottles; gravelly loam +; moderate medium subangular blocky; common moderate discontinuous brown cutans; moist & very firm; due to presence of stones; few medium pores; abundant roots; many hard quartz & soft weathering gneiss stones; clear wavy boundary to: [Not sampled]

68-88 7.5YR 4/6 (strong brown) with no mottles; coarse sandy loam +; massive breaking to moderate medium subangular blocky; common moderate discontinuous brown cutans; moist & very firm; many medium & fine pores; abundant roots; many fine hard quartz stones, common gravel & grits; with common black manganese stains; diffuse boundary to: [Sample PK004/3 @ 73-83 cm]

88-115 Mixed reddish brown, orange, brownish yellow and pale brown; very fine sandy loam; massive breaking to moderate medium subangular blocky; common moderate discontinuous claycutans; moist & very firm; common medium & fine pores; abundant roots; few black manganese stains; clear wavy boundary to [Sample PK004/4 @ 95-105 cm]

115 – 120+ Many slightly hard and hard rounded gneiss and quartz stones: [Not sampled]

Comment: The bright warm colour makes this soil quite distinctive on the valley floor, on the rest of which grey and brownish grey soil colours predominate. The very firm consistence in the lower subsoil horizons tends towards compaction.

SPAL analytical results for BSS Profile PK004 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	PH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK004/ 1	0-10	4209	6.9	5.4	1.5	Nd	35	2.7	0.23	12
/2	30-40	4210	7.0	5.0	2.0	Nd	1	0.1	0.01	Nd
/3	73-83	42 11	6.9	4.7	2.2	Nd	1	0.1	0.01	Nd
/4	95-105	4212	6.7	4.7	2.0	nd	1	0.1	0.01	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK004 /1	11.5	3.1	1.0	0.1	15.6	Nd	15.1	Nd	100	Nd
/2	3.8	1.5	0.6	0.1	6.0	Nd	8.0	Nd	75	Nd
/3	7.3	3.0	0.2	0.2	10.6	Nd	11.0	Nd	97	Nd
/4	7.2	3.1	0.2	0.2	10.7	nd	11.1	nd	96	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK004 /1	Nd	Nd	Nd	Nd	Nd	39.2	11.9	24.6	36.5	24.3	L
/2	Nd	Nd	Nd	Nd	Nd	42.9	10.6	24.1	34.7	22.5	L
/3	Nd	Nd	Nd	Nd	Nd	56.1	9.0	16.4	25.4	18.5	SL
/4	nd	nd	nd	Nd	nd	47.4	12.9	20.6	33.5	19.2	L

Profile: **PK005**

Map unit: Vg

Soil classification: Provisional Bhutan Soil series**:** Poorly drained valley soil (Vg)
Soil Taxonomy: Typic Endoaquept
WRB: Dystric Gleysol

Survey area: Yusipang RNRRC
Location: 200 m from Horticulture Office
GPS: 27^0 27.57' N, 89^0 42.72' E
Altitude: 2710 m a. s l.

Described & sampled: 1.9.97, K Tshering

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers.

Regional topography: Low mountains
Site position: Alluvial fan

Slope: 9% concave, ca 500m long + , ENE facing (71^0)
Site drainage: Very poor

Parent material: Solid: Thimphu gneiss and quartz
Drift: Alluvium

Land use: Marshy waste land
Vegetation: *Artemisia sp.* and sedges

Surface: Litter: None
Outcrop: None
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 56 2.5Y 5/1 (grey) with no mottles; silty loam; massive, moist & friable; abundant pores; common medium & fine roots; abundant muscovite flakes, HCl negative; diffuse boundary to: [Sample PK005/1 @ 0-10 cm]

56 – 80 2.5Y 4/1 (dark grey) with no mottles; loamy coarse sand; weak coarse subangular blocky breaking to medium subangular blocky; moist, friable; common pores; abundant medium & fine roots; abundant muscovite flakes; HCl negative; clear regular boundary to: [Sample PK005/2 @ 60-75 cm]

80 – 90 + 2.5Y 3/1 (very dark grey) with no mottles; silty loam; medium subangular blocky; moist- wet & friable; abundant medium & pores; abundant medium & fine roots; abundant muscovite flakes, HCl negative: [Sample PK005/3 @ 80-90 cm]

Comments: This soil is very dark throughout, due to the slow decomposition of the organic matter. This profile is poorly drained, and is an example class Vg – valley floor gleys, with surface water and distinct marshy vegetation. However it lacks the bluish subsoil colours found in profile PK006. This may be due to masking by the high contents of organic matter.

SPAL analytical results for BSS Profile PK005 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK005/ 1	0-10	4213	5.9	3.9	2.0	Nd	6	1.0	0.04	25
27	60-75	4214	5.4	3.8	1.6	Nd	4	5.9	0.22	
/3	80-90	4215	5.9	4.3	1.6	nd	9	1.9	0.15	13

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK005 /1	0.5	0.3	0.1	0.1	1.0	Nd	5.1	Nd	19	Nd
/2	2.5	0.8	0.3	0.2	3.7	Nd	25.3	Nd	15	Nd
/3	4.3	0.9	0.8	0.1	6.1	nd	15.3	nd	40	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK005 /1	Nd	Nd	Nd	Nd	Nd	78.2	7.0	9.7	16.7	5.2	SL
/2	Nd	Nd	Nd	Nd	Nd	32.5	10.9	31.8	42.7	24.7	L
/3	nd	nd	nd	Nd	nd	52.2	9.5	20.7	30.2	17.6	SL

Profile: **PK006**

Map unit: Vi

Soil classification: Provisional Bhutan Soil series: Valley gley (Vg)
Soil Taxonomy: Typic Endoaquept
WRB: Dystric Gleysol.

Survey area: Yusipang RNRRC
Location: 100 m E of Horticulture Office
GPS: 27^0 27.62' N, 89^0 42.66' E, (PDOP 3.6)
Altitude: ca 2650 m. a. s. l.

Described & sampled: 1.9.97, K Tshering

Climate: General: Cool temperate, P = ca 800mm p.a.
Recent weather: Shower

Regional topography: Low mountains
Site position: Alluvial fan.

Slope: 8 %, rectilinear, ca 500m long +, facing SE (128^0)
Site drainage: Imperfect

Parent material: Solid: Thimphu Formation
Drift: Alluvium

Land use: Orchard
Vegetation: Apple with ground cover of *Rumex nepalensis*, chilies + maize

Surface: Litter: None
Outcrop: None
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 50 10YR 4/2 (dark greyish brown) with common medium fine and red brown mottles; coarse sandy loam +; subangular blocky structures; moist & friable; many medium and fine pores; many fine and medium roots; abundant muscovite flakes; many earthworm and grubs; HCl negative; clear regular boundary to: [Sample PK006/1 @ 0-10 cm]

50 – 60 5PB 5/1 (bluish grey) with many common reddish brown mottles, silty clay; subangular blocky structures; moist & friable; common fine pores; few fine and medium roots; many muscovite flakes; HCl negative; clear regular boundary to: [Sample PK006/2 @ 50-60 cm]

60 – 89 5PB 4/1 (dark bluish grey) with common medium distinct and dark brown mottles; coarse sandy loam; subangular blocky; moist to wet, friable; common fine pores; few fine roots; many muscovite flakes, no stones; HCl negative; diffuse boundary to: [Sample PK006/3 @ 65-75 cm]

89 – 98 + 10B 5/1 (bluish grey) with abundant medium distinct dark brown mottles; silty clay loam; slightly wet, slightly firm; abundant fine pores; few fine roots; HCl negative: [Sample PK006/4 @ 90-100 cm]

Comments: This is a very clear valley floor gley, with distinctive bluish subsoil colours. However it has less surface water than PK005, and is used for crops, and the weeds are docks rather than sedges.

SPAL analytical results for BSS Profile PK006 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK006 /1	0-10	4216	5.9	4.2	1.7	Nd	2	0.7	0.09	7.7
/2	30-50	4217	5.8	3.9	1.9	Nd	3	0.9	0.07	13
/3	60-70	4218	5.4	3.6	1.8	nd	2	1.6	0.12	13

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK006 /1	2.3	0.8	0.3	0.1	3.5	Nd	11.9	Nd	29	Nd
/2	2.0	0.7	0.3	0.1	3.1	Nd	13.1	Nd	23	Nd
/3	4.5	1.0	0.5	0.2	6.2	nd	19.1	nd	32	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK006 /1	Nd	Nd	Nd	Nd	Nd	51.4	10.5	21.1	31.6	16.9	L
/2	Nd	Nd	Nd	Nd	Nd	47.2	10.0	23.0	33.0	19.8	L
/3	Nd	nd	nd	Nd	nd	13.1	10.4	38.5	48.9	37.9	ZICL

Profile: **PK007**

Map unit: Lt

Soil classification
Provisional Bhutan Soil series class: Low terrace soil (Lt)
Soil Taxonomy: Typic Ustifluvent
WRB: Eutric Fluvisol

Survey area: Yusipang RNRRC
Location: 20 m south of Potato Store.
GPS: 27^0 27.87' N, 89^0 42.54' E,
Altitude: 2745 m. a. s. l.

Described & sampled: 2.9.97, K Tshering

Climate:
General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Sunny

Regional topography: Low mountains
Site position: Alluvial fan

Slope: 1%, rectilinear, 1km long +, facing SSE (153 ^{0})
Site drainage: Good

Parent material:
Solid: Thimphu Formation
Drift: Alluvium

Land use: Cabbage
Vegetation: Cabbage, maize, beans, *Cosmos bipinnatus, Artemisia, Rumex* and some grasses

Surface:
Litter: None
Outcrop: None
Stones: Abundant coarse & medium subangular & angular quartz & gneiss stones
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

cm

0-34 2.5Y 3/1 (very dark grey) with no mottles; loamy coarse sand; weak medium & fine crumb; slightly wet &, slightly firm; abundant medium & fine tubular pores; abundant fine & medium grass roots; common coarse & medium, gneiss & quartz boulders; earthworm casts; few charcoal; HCl negative; diffuse boundary to: [Sample PK007/1 @ 0-10 cm]

34-90+ 2.5Y 3/1 (very dark gray) with no mottles; loamy coarse sand; moderate medium & fine crumb; slightly wet & slightly firm; common tubular pores; no roots; common boulders & few fine & medium stones; HCl negative: [Sample PK007/2 @ 40-85 cm]

Comment: This soil is very shallow with many boulders throughout in both horizons.

SPAL analytical results for BSS Profile PK007 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK007/ 1	0-10	4219	6.4	4.9	1.5	Nd	35	2.2	0.14	16
/2	40-85	4220	6.5	4.9	1.6	nd	11	0.9	0.05	18

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK007 /1	3.5	1.0	0.8	0.1	5.5	Nd	11.1	Nd	49	Nd
/2	3.8	0.7	0.3	0.3	5.1	nd	9.4	nd	54	nd

Fine earth granulometric.

BSS No.	**Sand**						**Silt**			Clay	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK007 /1	N d	nd	nd	nd	Nd	75.5	8.6	12.9	21.5	3.0	LS
/2	nd	nd	nd	nd	nd	75.7	7.4	10.9	18.3	6.0	SL

Profile: **PK008**

Map unit: Fi

Soil classification: Provisional Bhutan soil series: Imperfectly drained footslope soil (Fi)
Soil Taxonomy: Aquic Ustorthent
WRB: Gleyic Regosol

Survey area: Yusipang RNRRC
Location: Extreme northwestern boundary
GPS: 27^0 27.89 N, 89^0 42.37' E, PDOP 3.2
Altitude: 2880 m. a. s. l.

Described & sampled: 2.9.97, K Tshering

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Sunny

Regional topography: Low mountains
Site position: Mid footslope

Slope: 50 %, irregular, 1 km long +, facing NNE (25^0)
Site drainage: Imperfect

Parent material: Solid: Thimphu Formation
Drift: Colluvium

Land use: Waste land
Vegetation: *Yushania, Salix, Artemisia,* bracken and few grasses

Surface: Litter: *Yushania* fronds, 1cm, discontinuous
Outcrop: None
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 40 10YR 2/1 (black) with no mottles; coarse sandy loam; medium fine crumb; slightly wet & firm; abundant fine medium tubular pores; abundant coarse, many medium & fine roots; few medium, fine quartz & gneiss stones; HCl negative; clear regular boundary to: [Sample PK008/1 @ 20-30 cm]

40 – 89 10YR 5/4 (yellowish brown) with common medium discontinuous reddish brown mottles; coarse sandy loam; medium subangular blocky; slightly wet & firm; common medium fine tubular pores; common medium & fine roots; common medium hard quartz & gneiss stones; HCl negative; gradual regular boundary to: [Sample PK008/2 @ 50-60 cm]

89 – 120 10YR 5/3 (brown) with common medium distinct reddish brown & orange mottles; fine sandy clay loam; common medium subangular blocky structures; slightly wet, firm; tubular pores; few medium & fine roots; faint manganese stains, HCl negative; gradual regular boundary to: [Sample PK008/3 @ 90-100 cm]

120 – 150 + 10YR 5/6 (yellowish brown) with common medium distinct reddish brown & orange mottles; fine sandy clay loam; common medium subangular blocky; slightly wet & firm, common medium pores; few fine & medium grass roots; HCl negative: [Sample PK008/4 @ 130-140 cm]

Comment: Strong throughflow gives wet topsoil and perched watertable.

SPAL analytical results for BSS Profile PK008 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK008/ 1	0-10	4221	6.3	4.9	1.4	Nd	21	3.8	Tr	Nd
/2	50-60	4222	6.4	4.2	2.2	Nd	1	0.2	Tr	Nd
/3	90-100	4223	6.4	4.1	2.3	Nd	1	0.2	Tr	nd
/4	130-140	4224	6.2	4.6	1.6	nd	2	0.3	Tr	n

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK008 /1	11.1	1.7	0.7	0.1	13.6	Nd	20.2	Nd	68	Nd
/2	2.2	1.2	0.3	0.2	4.2	Nd	11.0	Nd	38	Nd
/3	3.7	1.6	0.3	0.1	5.7	Nd	18.2	Nd	31	Nd
/4	3.3	1.6	0.3	0.2	5.4	nd	19.0	nd	28	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK008 /1	nd	Nd	Nd	Nd	Nd	60.2	24.6	4.8	29.4	10.4	SL
/2	Nd	Nd	Nd	Nd	Nd	63.7	9.9	15.2	25.1	11.2	SL
/3	Nd	Nd	Nd	Nd	Nd	34.6	11.2	29.5	40.7	24.7	L
/4	nd	nd	nd	nd	nd	41.8	18.2	11.7	29.9	28.4	CL

Profile: **PK009**

Map unit: Fi

Soil classification: Provisional Bhutan soil series**:** Imperfectly drained footslope soil (Fi)
Soil Taxonomy: Typic Epiaquept
WRB: Gleyic Regosol

Survey area: Yusipang RNR-RC
Location: Halfway between fertiliser shed and garage.
Altitude: 2740 m. a. s. l.

Described & sampled: 19.9.97, K Tshering

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers

Regional topography: Low mountains
Site position: Footslope

Slope: 15 %, straight, ca 500m+long +, facing ESE (120 ^{0})
Site drainage: Imperfectly drained

Parent material: Solid: Thimphu gneiss
Drift: Footslope colluvium

Land use: Apple orchard
Vegetation: Apples with dense ground cover of *Cosmos bipinnatus, Galinsoga parviflora, Gnaphaline Affine, Chenapodium album, Rumex nepalensis*, & grasses.

Surface: Litter: Discontinuous grass litter, 0.5 cm deep
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: Slightly irregular, old cultivation
Faunal activity: None
Other features: None.

Profile description: (Colours are moist unless indicated)
cm

0 - 30 10YR 3/2 (very dark brown) with no mottles; medium sandy loam +; moderate fine - medium crumb; moist & friable; many fine pores; common fine & medium roots; very fine muscovite flakes; earthworms casts & ant holes; HCl negative; gradual regular boundary to: [Sample PK009/1 @ 0-10 cm]

30–50 10YR 3/1 (very dark grey) with few medium very faint yellowish & reddish brown mottles; loamy medium sand; moderate medium subangular blocky breaking to weak medium crumb; moist & friable; common fine pores; few fine roots; common fine muscovite flakes; gradual regular boundary to: [Sample PK009/2 @ 35 -45 cm]

50-66 10YR 3/2 (very dark greyish brown) with common coarse distinct brown & grey (weathered rock) mottles; gravelly loam; coarse – weak medium angular blocky breaking to fine crumb; moist & friable; & stony; many fine pores; common medium & fine roots; common fine flakes of muscovite; few charcoal near lower boundary; clear regular boundary to: [Sample PK009/3 @ 55-65 cm]

66 –107 10YR 5/3 [brown) with many coarse distinct reddish brown, olive brown, brown & orange mottles coarse sandy clay loam; massive breaking to weak fine subangular blocky; moist; slightly wet & firm; few fine pores; no roots; few fine & medium soft – slightly hard gneiss & quartz stones; many medium muscovite flakes; many charcoal; clear wavy boundary to: [Sample PK009/4 @ 80-90 cm]

107 – 140+ 10YR 4/2 (dark greyish brown) with common prominent reddish brown & orange mottles; very fine sandy clay loam; massive weak very coarse angular blocky breaking to fine crumb; moist & firm, sticky & plastic; few fine pores; no roots; strong moisture films running down block faces; HCl negative: [Sample PK009/5 @ 120-30 cm]

Comment: Typical imperfectly drained footslope soil. There appears to be strong throughflow in the horizon 66-107 cm, giving rise to the moisture films in the horizon beneath.

SPAL analytical results for BSS Profile PK009 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK009/ 1	0-30	4253	5.8	4.5	1.3	0.01	3	0.4	Tr	nd
/2	30-50	4254	6.3	4.7	1.6	0.01	1	0.2	Tr	Nd
/3	50-66	4255	6.4	4.2	2.0	0.01	1	0.1	Tr	Nd
/4	66-107	4256	6.2	3.9	2.3	0.01	1	0.2	Tr	nd
/5	107-140	4257	5.7	4.2	1.5	0.01	1	2.2	Tr	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK009 /1	5.4	1.3	0.6	0.1	7.4	Nd	10.1	Nd	73	Nd
/2	4.3	1.2	0.4	0.2	6.0	Nd	8.1	Nd	75	Nd
/3	2.4	0.9	0.2	0.1	3.7	Nd	4.3	Nd	85	Nd
/4	2.5	1.7	0.5	0.2	4.8	Nd	9.4	Nd	51	Nd
/5	2.2	1.7	0.5	0.1	4.6	nd	10.1	nd	45	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK009 /1	Nd	Nd	Nd	Nd	Nd	59.2	9.4	17.5	96.9	13.9	SL
/2	Nd	Nd	Nd	Nd	Nd	67.8	10.7	12.9	23.6	8.6	LS
/3	Nd	Nd	Nd	Nd	Nd	78.0	8.5	9.1	17.6	4.4	SL
/4	nd	nd	nd	nd	Nd	57.8	8.9	16.3	25.2	17.0	SL
/5	nd	Nd	nd	nd	nd	38.3	11.4	25.3	36.7	25.0	SC

Profile: PH006

Map unit: Ff

Soil classification: Provisional Yusipang soil class: Freely drained footslope soil (Ff)
Soil Taxonomy: Dystric Ustochrept
FAO: Dystric Regosol

Survey area: Yusipang RNR-RC
Location: 100 m away from NW feeder road (close to the end fence)
Altitude: 2810 m a.s.l

Described & sampled: 19.8.97, HB Tamang.

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: *Sunny*

Regional topography: Low mountain
Site position: Toeslope

Slope: 9 %, rectilinear 200 m long, facing SE (190 ^{0})
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Colluvium

Land use: Fallow
Vegetation: A*rtimesia sp*, few pear trees, *Rumex* sp, *Cosmos* & Conyza.

Surface: Litter: 5 cm thick discontinuous grass
Outcrops: None
Stones: Common hard round - subangular boulders
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
Cm

0 – 14 7.5YR 3/2 (dark brown); fine few reddish brown mottles; medium sandy loam +; moderate medium breaking to fine crumb & subangular blocky; moist & friable; few fine & medium hard quartz stones; abundant fine pores; few active earthworms; few charcoal; HCl negative; abundant fine roots; clear slightly wavy boundary to: [Sample PH00 6/1 @ 0-10]

14 – 27 7.5YR.3/3 (dark brown) with common medium distinct reddish brown & yellow mottles; fine sandy clay loam; weak medium subangular blocky; moist & friable; common fine tubular pores; many fine roots; few fine hard quartz stones; earthworm casts in places; HCl negative; clear regular boundary; [Sample PH006/2 @ 15-20]

27 - 34 7.5YR 3/2 (brown) with common fine distinct reddish brown & orange mottles; fine sandy clay loam; weak medium subangular blocky; common fine tubular pores; moist & friable; few fine roots; earthworm casts in places; HCl negative; clear slightly wavy boundary to: [Sample PH006/3 @ 27-34]

34 – 41 Mixed colors (reddish brown, orange and grey) medium sandy clay loam; weak medium subangular blocky; with weak moist & friable; discontinuous clayskins; common fine tubular pores; few fine roots; HCl negative; clear regular boundary to: [Not sampled]

*4*1 - 65 7.5YR 3/2 (dark brown) with many medium distinct grey brown & orange mottles; medium sandy loam+; weak medium subangular blocky breaking to fine crumb weak discontinuous clayskins; moist, slightly firm; common fine tubular pores; few fine roots; few fine hard quartz; HCl negative; clear regular boundary to: [Sample PH006/4 @ 30-60]

65 - 84 7.5YR 3/2 (dark brown) with few fine faint orange and grey mottles medium sandy loam+; weak medium subangular blocky breaking to fine crumb structure; weak discontinuous clayskins; common fine tubular pores; moist and slightly firm; few fine roots; few fine hard quartzite stones; HCl negative; clear regular boundary to [Not sampled]

84 - 96 7.5YR 3/2 (dark brown) with no mottles; medium sandy clay loam; weak medium subangular blocky structure; weak discontinuous clayskins; common fine pores; moist and slightly firm; few fine roots; HCl negative; clear regular boundary to; [Sample PH006/5 at 85-95]

96-112 10YR 3/6 (yellowish brown) with many patches of weathering rock of black, reddish brown+, grey and orange colours; coarse sandy loam+; moderate medium subangular blocky; weak discontinuous moisture films; common fine tubular pores; moist and slightly firm; common medium quartz and gneiss stones; HCl

negative; few fine muscovite flakes; diffuse boundary to: [Not sampled]

112-135 7.5YR 4/6 (strong brown) with common medium distinct black yellow & orange mottles; medium sandy loam+; moderate medium subangular blocky; strong discontinuous clayskins; common pores; moist and very firm; HCl negative; abundant flakes of muscovite: [Not sampled]

Continued by auger; (no sample)

135-150 As (112-135)

150-165 10YR 5/3 (brown) few fine faint orange & dark brown mottles; medium sandy loam+; moist and firm.

165-185 Mixed distinct black and dark brown weatherd rock colours; medium sandy loam-; friable.

185-210 7.5YR 4/4 (brown) with many fine faint orange & grey mottles; medium sandy loam+; slightly firm, common quartz stones:

210-235 10YR 4/4 (brown) common fine distinct reddish brown & orange mottles; fine sandy clay loam; moist & friable; common medium gneiss stones:

Comment: The very complex layering in this profile (13 horizons) is mostly due to the variable deposition by the colluvial / alluvial processes in the toeslope position at the base of the hill.

SPAL analytical results for BSS Profile PH006 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
Ph006 /1	0-10	4258	5.4	4.7	0.7	-	1	2.0	0.14	14
/2	15-20	4259	5.3	4.1	1.2	-	2	1.7	0.12	14
/3	27-34	4260	5.3	4.0	1.3	-	10	0.5	0.12	4
/4	50-60	4261	5.8	4.0	1.8	-	1	0.5	0.03	17
/5	85-95	4262	6.2	4.4	1.8	-	1	0.5	0.03	17

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Ph006 /1	2.9	0.7	0.3	0.2	4.1	-	10.3	-	40	-
/2	2.0	0.6	0.2	0.2	2.9	-	9.1	-	32	-
/3	2.0	0.4	0.2	0.4	3.0	-	8.0	-	37	-
/4	3.0	0.7	0.2	0.2	4.1	-	11.2	-	37	-
/5	5.1	1.6	0.5	0.3	7.5	-	10.1	-	74	-

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
Ph006 /1						48.5	11.3	22.5	33.8	17.7	L
/2						46.8	13.2	23.0	36.2	17.0	L
/3						50.1	10.3	22.2	32.5	17.4	L
/4						44.3	9.5	22.9	32.4	23.3	L
/5						43.2	8.7	23.8	32.5	24.3	L

Profile:	PK001	
Map unit:	Hd	
Soil classification:	Provisional Bhutan Soil Series:	Deep hill soil (Hd)
	Soil Taxonomy:	Dystric Ustochrept.
	FAO:	Dystric Cambisol.
Survey area:	Yusipang RNR-RC	
Location:	150 m W of fertiliser shed	
GPS:	27^0 27. 64' N 89^0 42. 54' E	
Altitude:	2740 m. a. s. l.	
Described & sampled:	19.6.97, K Tshering	
Climate:	General:	Cool temperate, P = ca 800 mm pa
	Recent weather:	Fine
Regional topography:	Low mountains	
Site position:	Lower slope	
Slope:	44%, convex, ca 1 km long, ENE facing (75^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Colluvium
Land use:	Abandoned orchard	
Vegetation:	Apples with dense ground cover of bracken, *Cosmos bipinnatus, Galinsoga parviflora, Gnaphaline affine, Chenapodium album, Rumex nepalensis,* and local grasses.	
Surface:	Litter:	Continuous bracken frond litter 6-8 cm deep
	Outcrops:	None
	Stones:	Few fine gneiss
	Cracks:	None
	Roots:	None
	Microrelief:	Abandoned terraces
	Faunal activity:	None
Other features:	None	

Profile description: (Colours are moist unless indicated)

cm	
0-12	7.5YR 4/3 (dark brown) with no mottles; medium sandy loam; moderate medium subangular blocky breaking to moderate medium–coarse crumb; moist & friable; many fine pores; abundant fine & medium (bracken) roots; few medium hard gneiss stones, & few very fine muscovite flakes; HCl negative; earthworms, ants & spider seen whilst digging, earthworm casts, ant holes; clear slightly wavy boundary to: [Sample PK001/1 @ 0-10 cm]
12-25	7.5YR 4x/4 (dark grey) with many coarse fine dark brown & reddish brown mottles; medium sandy loam; many medium subangular blocky breaking to moderate medium crumb; moist & slightly firm; many fine & medium tubular pores; many few fine & medium common fine pores; few fine roots; few medium & fine hard quartz and gneiss stones; HCl negative; earthworm cast; abundant muscovite flakes; clear wavy boundary to: [Sample PK001/2 @ 15-25 cm]
25-40	7.5 YR 3/2 (dark brown) many medium coarse & reddish brown mottles; medium sandy loam +; moderate medium subangular blocky breaking to moderate medium crumb; moist & slightly firm; many fine tubular pores; many fine roots; few fine hard gneiss; few flakes of charcoal; few earthworm casts; HCl negative; clear wavy boundary to: [Sample PK001/3 @t27-37 cm]
40-76	7.5YR 4/6 [strong brown) with few fine faint slightly darker mottles; medium sandy clay loam; moderate medium breaking to moderate fine subangular blocky; moderate discontinuous clayskins on channel walls; moist & firm; many fine tubular pores; few medium & fine bracken roots; common coarse soft to slightly hard weathering gneiss quartz stones; few muscovite flakes; few charcoal; flatworm seen & few earthworm casts; HCl negative; gradual regular boundary to: [Sample PK001/4 @ 55-85 cm]
76-96	7.5YR 5/6 [strong brown) with few fine faint slightly darker mottles; medium sandy clay loam; moderate medium breaking to moderate fine subangular blocky; weak discontinuous clayskins and organic matter cutans on Ped faces; moist or firm; many fine & medium tubular pores; common medium & fine bracken roots; few fine hard quartz stones; few muscovite flakes; few charcoal; few wormcasts and one rat hole seen; HCl negative; gradual irregular boundary to: [Not sampled]
96-114	10YR 4/4 [dark yellowish brown) with many medium & distinct greyish; reddish & yellowish brown mottles; medium sandy clay; moderate medium breaking to moderate fine subangular blocky; weak discontinuous

clayskins and organic matter cutans on ped faces; moist & slightly firm; many fine & medium tubular pores; many fine roots; common fine soft & hard weathered gneiss & quartz stones; few muscovite flakes; few charcoal; few wormcasts; HCl negative; clear & slightly wavy boundary to:
[Sample PK001/5 @ 100-110 cm]

114-140 7.5YR 5/8 (strong brown) with common fine faint yellow & reddish yellow mottles; clay loam; strong medium subangular blocky; moderate discontinuous clayskins; moist firm; many fine tubular pores; common fine roots; common medium soft to hard weathering gneiss & quartz stones, few muscovite flakes; few charcoal; few worm casts; HCl negative; gradual and regular boundary to:
[Sample PK001/6 @ 125-135 cm]

140-64+ 7.5YR 5/6 (strong brown) with common medium faint yellowish red mottles; clay loam; moderate medium breaking to fine subangular blocky; moderate discontinuous clayskins; moist & slightly firm; many fine tubular pores; few fine roots; few fine hard gneiss stones, and few muscovite flakes; few insects; HCl negative; [Not sampled]

Comments: This profile appears to have two buried topsoils. The upper, at 25 – 40 cm, was probably buried when the cultivation terraces were formed. The lower, at 96 – 114 cm, may be natural and due to episodic hillwash deposition on this lower slope site, even though it now has a convex slope profile and is probably a net loser of colluvium.

SPAL analytical results for BSS Profile PK001 Survey area: Yusipang RNR-RC

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PK001/ 1	0-10	4203	6.1	3.9	2.2	Nd	3	1.7	0.01	Nd
/2	15-25	4204	6.2	4.6	1.6	Tr	1	1.7	0.01	nd
/3	27-37	4205	6.1	4.8	1.3	Nd	1	1.5	0.16	9.3
/4	55-65	4206	6.5	4.4	2.1	Nd	1	0.6	0.02	30
/5	100-110	4207	nd	4.7	nd	Nd	10	0.8	0.05	1 6
/6	125-135	4208	6.5	4.1	2.4	nd	2	0.3	0.03	10

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK001 /1	3.5	1.3	0.5	Tr	5.4	Nd	13.3	Nd	40	Nd
/2	3.5	1 .0	0.2	Tr	4.7	Nd	10.2	Nd	46	Nd
/3	7.0	1.4	0.1	0.1	8.6	Nd	11.9	Nd	72	Nd
/4	2.2	1.8	0.2	0.1	4.2	Nd	9.2	Nd	46	Nd
/5	2.5	1.9	0.2	0.1	4.6	Nd	12.8	Nd	36	Nd
/6	2.0	2.1	0.2	0.1	4.4	nd	10.0	nd	44	nd

Fine earth granulometric.

BSS No.	Sand						Silt			**Clay**	**Texture class**
	>1000 micron	425-1000	212-425	106-212	50-106	**Total sand**	20-50 micron	2-20	**Total silt**		
PK001 /1	Nd	Nd	Nd	Nd	Nd	55.5	10.5	18.0	28.5	16.6	SL
/2	Nd	Nd	Nd	Nd	Nd	56.0	10.8	15.8	26.6	17.3	SL
/3	Nd	Nd	Nd	Nd	Nd	55.7	10.0	18.2	28.2	16.0	SL
/4	Nd	Nd	Nd	Nd	Nd	49.2	11.3	18.9	30.2	20.5	L
/5	Nd	Nd	Nd	Nd	Nd	34.2	3.3	39.8	43.1	20.7	ZL
/6	nd	nd	nd	nd	nd	27.1	14.7	34.7	49.4	23.5	ZL

Profile: **Pd002**

Map unit: Not mapped

Soil classification: Provisional Yusipang class: Fi – Imperfectly drained footslope soil
Soil Taxonomy: Aquic Ustorthent.
FAO: Gleyic Regosol

Survey area: Yusipang RNR-RC
Location: Cutting on Lama track, just outside northern boundary of survey area.
GPS: 27^0 28.06' N. 89^0 42.32' E. PDOP = 6
Altitude: 2830 m a.s.l.

Described & sampled: 2.7.97, T Dorji

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers

Regional topography: Low mountains
Site position: Edge of terrace in upper section of valley floor

Slope: 53 %, convex, ca 400m + long, NNW facing (330^0)
Site drainage: Imperfect.

Parent material: Solid: Thimphu gneiss
Drift: Fan alluvium

Land use: Forest land, formerly cleared for arable

Vegetation: *Juglans regia, Cosmos bipinnatus, Pteridium aquilinum, Trifolium repens, Galinsoga parviflora, Artemisia sp, Quercus glauca, Gnaphaline affine, Plantago erosa, Persicaria nepalensis, Chenapodium album, Rumex nepalensis*, and few grasses.

Surface: Litter: Discontinuous *Quercus* leaves, 2 - 3 cm deep.
Outcrops: None.
Stone: Common boulders & medium hard subangular stones of gneiss & quartz
Cracks: None
Roots: None
Microrelief: Slight stepping, 5 cm high and 25 cm wide, fairly regular.
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)

cm	
0 – 5	7.5YR 3/3 (dark brown) with no mottles; medium sandy loam; moderate fine crumb; moist, friable, abundant tubular pores; abundant roots; few medium hard subrounded quartz stones; common charcoal; HCl negative; clear regular boundary to: [Not sampled]
5 –28	7.5YR 4/3 (brown) with no mottles; coarse sandy loam; moderate medium crumb; moist, friable, abundant medium tubular pores; common fine & medium roots; common medium hard to soft subangular gneiss & quartz stones & few fine flakes of muscovite; earthworm and grub seen; HCl negative; gradual and slightly wavy boundary to: [Not sampled]
28 –48	10YR 4/3 (brown) but lighter than above horizon with common medium distinct reddish brown mottles; coarse sandy loam; moderate medium subangular blocky; moist & friable; common medium & fine tubular pores; common medium & fine roots; common medium hard subangular gneiss & quartz stones; few flakes of muscovite; earthworm seen; HCl negative; clear and slightly wavy boundary to: [Not sampled]
48 –76/92	10YR 4/6 (dark yellowish brown) with few fine weak reddish brown & orange mottles; loamy coarse sand; single grain; moist & slightly friable; common pores; few medium & fine roots; few medium hard gneiss & quartz stones; HCl negative; clear & very wavy boundary to: [Not sampled]
76/92 –120	2.5Y 5/3 (light olive brown) with common medium distinct reddish brown & orange mottles; loamy coarse sand; moderate medium subangular blocky; moderate discontinuous clayskins; moist & firm; common tubular pores; few medium roots; common, medium, hard gneiss & quartz stones; HCl negative; clear regular boundary to: [Not sampled]
120 –196	10YR 4/2 (dark greyish brown) with abundant medium distinct reddish brown & orange mottles; medium sandy clay; strong medium subangular blocky; weak discontinuous clayskins; moist & firm; few fine tubular pores; few medium & fine roots; common medium hard subrounded gneiss & quartz stones; few flakes of muscovite; few charcoal; HCl negative; clear regular boundary to: [Not sampled]

196 –227+ 10YR 4/6 (dark yellowish brown) with abundant medium distinct reddish brown & orange mottles; coarse sandy clay; moderate medium subangular blocky; faint discontinuous clayskins; moist, firm; few fine tubular pores; few fine roots; abundant medium hard subrounded, platy gneiss & quartz stones; few flakes of muscovite, few charcoal; HCl negative; [Not sampled]

Comments: This profile was not sampled as it is just outside the soil survey area. The pale subsoil matrix colour and bright mottling indicate imperfect drainage. This soil is distinctly layered but the steep slope and non-angular stones suggest local movement. The profile is therefore assigned to class Fi, imperfectly drained footslopes.

Profile:	PH001	
Map unit:	Vi	
Soil classification:	Provisional Yusipang soil class:	Imperfectly drained valley soil (Vi)
	Soil Taxonomy:	Humaqueptic Epiaquent.
	FAO:	Dystric Gleysol.
Survey area:	Yusipang RNR-RC	
Location:	Western horticulture block.	
GPS:	27^0 7.62′ N. 89^0 42.69′ E.	
Altitude:	2630m	
Described & sampled:	18.6.97, HB Tamang.	
Climate:	General:	Cool temperate, P = ca 800 mm p.a.
	Recent weather:	Cloudy
Regional topography:	Low mountains	
Site position:	Centre of valley floor	
Slope:	10 %, straight, ca 1km long, ESE facing (119^0)	
Site drainage:	Imperfectly drained	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Alluvium
Land use:	Horticulture trial	
Vegetation:	Strawberries and weeds, *Rumex, Amaranthus, & Galinsoga.*	
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 - 15	7.5YR 4/1 (dark grey) moist, 10YR 6/4 (light yellowish brown) dry; medium sandy clay loam; strong medium crumb; moist, friable; many tubular pores; abundant fine roots; few fine hard quartz stones & many muscovite flakes; clear wavy boundary to: [Not sampled]
15 –40	10YR 4/2 (dark greyish brown) with many fine faint dark brown mottles; coarse sandy clay loam; moderate coarse breaking to fine subangular blocky; moist, firm; common fine & medium tubular pores; common fine roots; few fine hard quartz stones & common flakes of muscovite; HCl negative; gradual slightly wavy boundary to: [Not sampled]
40 –53	10YR 4/2 (dark greyish brown) with medium fine faint dark brown mottles; coarse sandy clay loam; moderate coarse breaking to fine subangular blocky structures; moist and firm; common medium & fine tubular pores; common fine roots; few fine hard gneiss & quartz stones; few flakes of muscovite; HCl negative; clear slightly wavy boundary to: [Not sampled]
53 –72	10YR 3/2 (very dark greyish brown) with rare fine faint brown mottles; silty loam; weak medium subangular blocky structures; weak discontinuous clayskins; wet - moist, friable & slightly sticky; common fine tubular pores; rare medium soft gneiss stones; HCl negative; gradual wavy boundary to: [Not sampled]
72 –84	7.5YR 2.5/1 (black) with few fine faint reddish brown & yellow mottles; silty clay loam; weak medium subangular blocky; with continuous clayskins; moist - wet, friable; medium few tubular pores; common fine roots; common fine hard gneiss & quartz stones; HCl negative; clear slightly wavy boundary to: [Not sampled]
84 -104	10YR 5/1 (grey) with few medium distinct orange mottles; coarse sandy clay loam; massive; wet, sticky & plastic; common medium tubular pores; rare very fine roots; common fine hard quartz stones; common flakes of muscovite; HCl negative; [Not sampled]

Comment: This is a highly stratified and poor-imperfectly drained valley floor soil. The black horizon at 72-84 cm appears to be a buried topsoil, as it runs downslope at a angle more or less parallel to the ruling slope, and is oblique to the flat top of the artificial terrace. The burial may be natural or may have occurred during terrace construction.

Profile:	PK002	
Map unit:	Hs	
Soil classification:	Provisional Bhutan Soil Series: **Yusipang series**	Shallow hill soil (Hs)
	Soil Taxonomy:	Dystric Ustrochrept
	FAO:	Dystric Cambisol
Survey area:	Yusipang RNR-RC	
Location:	Yusipang track across north end of RNRC	
GPS:	27^0 28.13' N; 89^0 47.31' E.	
Altitude:	2840 m a.s.l	
Described & sampled:	2 .7.97, K Tshering	
Climate:	General:	Cool temperate, P = ca 800 mm pa
	Recent weather:	Heavy showers within last 72 hours
Regional topography:	Low mountains	
Site position:	Lower slope	
Slope:	65 %, concave, ca 400- 500 m long, SSE facing (160 ^{0})	
Site drainage:	good	
Parent material:	Solid:	Thimphu gneiss
	Drift:	Residual
Land use:	Uncultivated land with scrub and bushes	
Vegetation:	Blue pine, *Artemisia, Rosa sericea*, chokashing, wangkashing and apple.	
Surface:	Litter:	Discontinuous grass litter 0.5 cm deep
	Outcrops:	None
	Stones:	Few fine & medium hard platy gneiss stones
	Cracks:	None
	Roots:	None
	Microrelief:	Slight stepping due to hillwash arrested by vegetation
	Faunal activity:	None
	Other features:	None

Profile description: (Colours are moist unless indicated)

cm	
0 – 7	7.5YR 3/3 (dark brown) with no mottles; loam; moderate fine crumb; moist, friable; many fine pores; abandoned fine roots; few fine hard gneiss stones, common charcoal; earthworms casts & few ants present, HCl negative; clear regular boundary to: [Not sampled]
7–24	10YR 4/4 (dark yellowish brown) with no mottles; moderate fine medium crumb; sandy clay loam; medium fine orange brown; fare few discontinuous moisture films few fine pores; moist & hard -moderately friable; few fine grass root; few & medium hard quartz & gneiss stones; HCl negative; few wormcasts; common charcoal & decayed roots; clear regular boundary to: [Not sampled]
24-48	10YR 5/6 (yellowish brown) with mixed reddish yellow & brown weathering rocks colours; coarse sandy clay + (weathered rock), medium angular blocky breaking to fine crumb; few fine discontinuous moisture films; many pores; slightly dry & moderate friable; few fine grass roots; medium hard common & soft gneiss stones; HCl negative; some wormcasts & dry decayed roots; muscovite flakes; gradual regular boundary to: [Not sampled]
48 -73	10YR 5/4 (dry yellowish brown); with mixed weathered rocks colours; medium sandy clay; moderate medium angular to fine subangular blocky; common continuous moisture films; medium & fine pores; slightly dry, hard & firm; few fine grass roots; few hard & soft quartz & gneiss stones; muscovite flakes; gradual regular boundary to: [Not sampled]
73 – 124	7.5YR 4/4 (brown) with mixed weathered rock colours; medium sandy clay; medium angular to fine subangular blocky; few fine continuous moisture films; medium & fine pores; moist, very hard – moderate friable; very fine roots; medium hard & soft quartz & gneiss stones; muscovite & biotite flakes; clear slightly wavy boundary to: [Not sampled]
124 – 150+	10YR 4/6 (m) strong brown & mixed weathered rock colours, & black manganese spots; loam - sandy clay & discontinuous weathered rock; medium subangular blocky; fine clayskins; few fine pores; slightly moist & slightly friable; no roots; few fine pores; HCl negative; few fine muscovite & biotite flakes; [Not sampled]

Comment: Typical shallow residual hill soil, even through at very base of slope. The reddish appearance is due to the rubefaction weathering mottles, not the matrix colours.

Profile: **PK003**

Map unit: Vi

Soil classification: Provisional Bhutan Soil Series: Imperfectly drained valley soil (Vi)
Soil Taxonomy: Aquic Ustifluvent.
FAO: Gleyic Fluvisol.

Survey area: Yusipang RNRRC
Location: 325 m North of Potato Store on feeder road.
GPS: 27^0 27.97' N, 89^0 42.40' E, PDOP 4.4
Altitude: 2839 m a.s.l

Described & sampled: 30.7.97, K Tshering

Climate: General: Cool temperate, P = ca 800 mm p.a.
Recent weather: Showers

Regional topography: Low mountains
Site position: Connecting slope, from alluvial fan down to low terrace/ floodplain

Slope: 44 %, rectilinear, ca 50 m long, SSW facing (204 ^{0})
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Alluvium

Land use: Waste land
Vegetation: *Cosmos bipinnatus* and other weeds.

Surface:
Litter: Thin discontinuous twigs
Outcrop: None
Stones: Few gneiss boulders upslope, up to 1 m diameter
Cracks: None
Roots: None
Microrelief: Slight stepping
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0 - 12 7.5YR 4/2 (brown) with no mottles; coarse sandy loam; moderate coarse crumb; moist, very friable; many tubular pores; common fine *Cosmos* roots; few fine hard gneiss & quartz stones; common earthworm casts & few burrows; gradual regular boundary to: [Not sampled]

12 – 57 7.5YR 4/3 (brown) with no mottles; coarse sandy loam; weak fine subangular blocky breaking to medium crumb; moist, slightly firm; many tubular pores; many fine & medium tree & *Cosmos* roots; common medium hard subangular gneiss & quartz stones, few coarse charcoal; earthworm casts & few worms present; clear regular boundary to: [Not sampled]

57 – 81 10YR 4/3 (brown) with no mottles; coarse sandy loam; moderate medium subangular blocky breaking to moderate medium crumb; slightly moist, friable; many medium, fine & coarse pores; few fine & medium roots; common coarse hard angular gneiss & quartz stones; earth worm casts and ant holes; gradual regular boundary to: [Not sampled]

81 – 118 10YR 6/4 (light yellowish brown) with no mottles; loamy coarse sand; weak medium angular blocky breaking to single grain; slightly moist, brittle; many pores; few fine roots; many fine hard gneiss & quartz stones, few fine charcoal; few insect burrows; clear regular boundary to: [Not sampled]

118 – 141 7.5YR 4/3 (brown) with no mottles; coarse sandy loam; moderate medium subangular blocky; moist, firm; many medium & fine pores; few medium roots; common fine & medium hard & soft gneiss & quartz stones, few fine charcoal; gradual regular boundary to: [Not sampled]

141 – 165 10YR 5/3 (brown) with common very faint reddish brown & brown mottles; medium sandy loam; weak coarse angular blocky; moist, slightly friable; many medium & fine pores; few medium roots; common fine & medium hard & soft gneiss and quartz stones; clear regular boundary to: [Not sampled]

165 – 220+ 10YR 5/4 (yellowish brown) with no mottles; bouldery & stony loamy coarse sand; stony-single grain structure; moist stony consistence with interstitial slightly friable; many pores; few fine roots; abundant gneiss & quartz gravel, stones and boulders: [Not sampled]

Comment: This is typical of the valley floor soils at the upper end of the alluvial fan. Stone contents are high and fine earth textures are lighter than in the soils further down the fan, e.g. compared with Profile PH001. The distinctive yellowish brown subsoil layer is very deep, at 165 + cm.

APPENDIX C: Soil Correlation

App C 1. Soil classification and correlation in Bhutan.

Table 5.3 in the main report summarises the correlation of the Yusipang soil classes with the international soil classifications. This appendix discusses the reasoning behind the correlations assigned. This is necessary because BSSP is at an early stage of its operations and the soil correlations still need to be worked out. Some correlations will undoubtedly be revised in the future, as we learn more about the soils of Bhutan.

The international systems suffer from several problems. The worst is that there are two of them. It is to the discredit of the international pedological community that they have not agreed to a single system. Proponents of the two main systems – the USDA and FAO – feel that the other has too many defects to be acceptable. Nonetheless either system would be improved more quickly if it was accepted by all and was the sole focus of attention.

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

Pedologists working in Nepal have mostly used the Soil Taxonomy but previous consultants in Bhutan have preferred the FAO system. At this stage it is not necessary for Bhutan to choose between the two systems. It is intended that, at present, BSSP will use local soil classes and names within Bhutan, and will correlate them against both of the international systems (AHT 1995).

App C 2. General criteria

Before considering individual soils, there are some environmental characteristics of the area as a whole that need to be determined before the application of Soil Taxonomy.

App C 2.1 Soil moisture regime

This is necessary for the assignment suborders or great groups in Soil Taxonomy. In the absence of soil moisture data, soil moisture regimes are nomally approximated from rainfall totals and distribution. Yusipang has an ustic atmospheric climate, which is defined as having more 90 consecutive dry days per year and having a summer rainfall distribution. All of the soils at Yusipang have ustic soil moisture regimes except for the poorly drained and some of the imperfectly drained soils. These have an aquic moisture regime, which refers to soils that are permanently wet due to their topographic position. Some of the imperfectly drained soils may have udic moisture regimes which are transitional between ustic and aquic, and have less than 90 consecutive dry days per year.

App C 2.2 Soil temperature regime

This is a criterion for classification at family level in Soil Taxonomy. In the absence of soil temperature data, atmospheric temperatures are used. Yusipang has a mesic atmospheric temperature regime, with an annual mean between 8^0 C and 15^0 C and a summer – winter

difference greater than 5^0 C. All of the soils at Yusipang are assumed to have mesic soil temperature regimes.

App C 2.3 Mineralogy class

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

App C 2.4 Particle size class

This varies with stone content and fine earth texture, and therefore varies for the different soil classes at Yusipang, although most are coarse loamy or loamy – skeletal.

App C 3. Correlation of Yusipang soils

App C 3.1 Shallow and medium depth hill soils

Most of these soils appear to be sedentary and quite deeply weathered. Their subsoils have slightly higher clay contents than the topsoil but clayskins are not common. These soil fit well into the Inceptisols of Soil Taxonomy or the Cambisols FAO. Most of them have dark topsoils that are shallow (< 18 cm) so that they qualify by default for the Soil Taxonomy suborder Ochrepts. The soil moisture regime puts them into the Ustochrept group, with subdivision into the lithic (for the shallow hill soils), dystric (for most of the rest, as their base saturations are less than 50%) or typic (all others) subgroups. In the FAO system, similar criteria apply, and these soils mostly qualify as Dystric Cambisols. A few may qualify as Humic Cambisols.

App C 3.2 Deep hill and well drained footslope soils

These soils consist of recent, layered deposits of fairly intensively weathered material. In Soil Taxonomy, the degree of weathering has priority over the layering in keying out, so that most of these soils probably qualify as Dystric or Typic Ustochrepts. A few of these soils have high contents of unweathered minerals, and the soils therefore quality as Typic Ustorthents. In the FAO system, the layering of the deposits keys out before the degree of weathering, and these soils qualify as Regosols, rather than Cambisols.

App C 3.3 Imperfectly drained footslope and valley floor soils

The impeded drainage is the main classification criterion in these soils. In Soil Taxonomy, most of them are considered to be Aquepts, with the less weathered soils probably qualifying as Aquents. Many of these soils are kept wet for long periods by shallow subsurface throughflow. This makes the drainage of their upper layers worse than in the lower subsoils, and the soils therefore qualify as Epiaquepts rather than groundwater – fed Endoaquepts. This distinction is not made in the FAO system, and these soils qualify as mollic (high organic matter and base saturation greater than 50%) Gleysols.

App C 3.4 Poorly drained soils

These soils are probably wet all year and qualify as Aquepts or Aquents in Soil Taxonomy and as Gleysols in FAO. Many of them have slow decomposition rates and have accumulated

mucky topsoils with high contents of organic matter. However none of these appear to be organic or deep enough to qualify as Histosols (same name in both systems at last !). As these soils have ground water tables, and are wet throughout the profile they, qualify for the Endo – rather than Epi – groups in the Aquept and Aquent suborders of Soil Taxonomy. Although insufficient for the Histosols, the organic matter contents are high enough for some of these soils to qualify as humic or mollic subgroups in ST. In the FAO system they qualify as Humic Gleysols.