Royal Government of Bhutan

Bhutan Soil Survey
National Soil Services Centre, Simtokha
Department of Research and Development Services
Ministry of Agriculture

THE DETAILED SOIL SURVEY

OF

DARLA, RNR RESEARCH SUBCENTRE, CHHUKHA

Report No. 13 (a)

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(Recompilation of January 2003)

SUMMARY

This is the technical report of a detailed soil survey of the Darla site for a new subcentre of RNR Research Centre (West). The soil survey fieldwork was done in April 2000. A brief and less detailed general report is also available.

This version of the report was recompiled in January 2003 to include:

- Chapter 8 Physical Land Suitability Evaluation
- Appendix C – a summary of the laboratory data with ratings shown for each of the mapped soils
- Appendix E - A copy of the soil map is included– this map will be digitized in time
- Appendix F – A summary of the results of physical land suitability assessment

The survey area covers 11.75 ha (about 29 acres) and is located in Darla geog in Chhukha Dzongkhag. It is about eight kilometres by road southeast of Jumja town on the Jumja - Darla - Manitar feeder road. There is a track of about 400 metres from Tala Hydro Electric Project power house road to the site.

The area is underlain by the highly metamorphosed rocks of the Thimphu Formation. The main rock type is mica schist and this weathers to give high contents of clay and silt in all of the soils. There are also some mafic rocks. Topographically there two parts to the sites. The southwestern section is on the lower slope of the Damdara ridge. The northeastern section of the site is located on the relatively flat and broad spur crest, with short but fairly steep slopes down to minor streams. The site ranges in altitude from about 1680 up to 1820 m.

The main soils of the flatter section of the site are deep clays. The topsoil is yellowish brown or dark yellowish brown, very fine sandy clay loam - silty clay. It has a friable consistence and crumb structure, which are attributed to vigorous earthworm activity. The subsoil is brown - dark yellowish brown clay loam - clay. The main soils on the steep southwestern slopes are the stony and deep. They are somewhat similar to the deep clay soils in colour and structure but have more variable and sandier subsoil textures. They also have high contents of stones in their subsoils. There are also some shallow – moderately deep (<100 cm to weathered mica schist) clays on the same slope. There are narrow strips of wet and poorly drained soils in minor depressions and streamlines that run down the slope.

The soil classes are grouped in two mapping units. The most extensive is the complex of the mixed shallow and stony soils, which accounts for 63% of the sites. The deep clay is mapped as a consociation, which cover 37 % of the area.

BSS has not seen much of the soils of the Darla area so far. However it is thought that the soils of the site are probably typical of substantial areas on the Thimphu geological formation in the surrounding region. If this is correct, there are no major soil-related reasons why research results on the subcentre cannot be extrapolated to local forests and farms in the region.

ACKNOWLEDGEMENTS

The fieldwork for this survey was done by H.B Tamang, Kado Tshering, Tsheten Dorji and Ian Baillie. The report was drafted by Tsheten Dorji and Ian Baillie and compiled by Ms Pema Wangmo. The soil analyses were done by SPAL. The interim map was prepared by Tsheten Dorji.

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ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometery
a.d.	Air dry
AHT	Agrar - und HydrotechniK, GmbH, (Germany).
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
AvP, AP	Available Phosphate
AWC	Available water capacity (amount of water held in soil at suctions low enough for root uptake, = MC% FC – MC% WP)
asl	Above sea level
BS%	Base saturation percentage
BSS	Bhutan Soil Survey
C	Clay
ca	Approximately
CEC	Cation exchange capacity
Chhu	Stream or river (Dzongkha)
CL	Clay loam
Colluvium	Local hillwash, moved by surface erosion and slow non-glacial creep processes.
Complex	Soil mapping unit with several co-equal soil classes.
Consociation	Soil mapping unit with one soil class dominant but others as minor constituents.
Danida	Danish International Development Assistance.
Declivity	Slightly depressed area running downslope on steep hillside; often a seepage zone, with hydrophilic vegetation, e.g. sedges. *Equisetum*
DEM	Digital elevation model
DRDS	Division of Research and Development Services of MoA (formerly REID)
EBS%	Effective base saturation (= TEB/ECEC)
EC	Electrical conductivity
ECEC	Effective cation exchange capacity (=TEB + Extr Al + Extr H) Nations.
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FAO	Food and Agriculture Organisation of United Nations
FC	Field capacity (MC% at suction of 0.1 atmospheres)
fe	fine earth (particle size < 2mm)
FeMn	Ferri-managaniferous, dark red - reddish brown – black stains and soft concretions with high contents of ferric iron and manganese is horizons with seasonally impeded drainage
Geog	Block or sub district, administrative subdivision of Dzongkhag.
GIS	Geographical information system
Gley	Soil that is permanently wet, poorly aerated and has predominantly grayish colours, due to reduction of free iron to ferrous valency state. May have local oxidising conditions giving rust - coloured mottles, especially around root channels.
GPS	Global positioning system
GR	General report
GSB	Geological Survey of Bhutan
GSI	Geological Survey of India
ha	Hectare
HCl	Hydrochloric acid
Horizon	Soil layer
In situ	In original position or place (Latin)
Kamzhing, Kamshing	Rainfed agriculture
L	Loam
LUPP	(former) Land Use Planning Project, in PPD
LUSS	(current) Land Use and Statistics Section, in PPD
MC%	Moisture content % (w/w)
MCT	Main central thrust
me	milliequivalent (unit of exchangeable cations)
me%	milliequivalents per 100 g fine earth (=cmol / kg)
MoA	Ministry of Agriculture
mS/cm	milliSiemens per centimetre (unit of electrical conductivity)
MTI	Ministry of Trade and Industry.
Nd	No data.
NH_4OAc	Ammonium acetate
$\_OC$	Organic carbon
o.d.	Oven dry

OM	Organic matter
P	Phosphate
pH	Measure of acidity - alkalinity
PM	Parent material
PPD	Planning and Policy Division, MoA
ppm	Parts per million
Profile	Sequence of horizons from surface down to unaltered parent material
REID	(former) Research, Extension and Irrigation Division, of MoA (now DRDS)
RGOB	Royal Government of Bhutan
RNR	Renewable natural resources (includes agriculture, animal husbandry and forestry in RGOB sense)
RNR-RC	RNR Research Centre.
RNR – RSC	RNR Research Subcentre
S	Sand
SMU	Soil mapping unit
SoB	Survey of Bhutan
SoI	Survey of India
sp, spp	Species (singular & plural)
SPAL	Soils and Plant Analysis Laboratory, NSSC, REID, Simtokha.
Spur	Plunging ridge off side of mountain or main ridge down to valley, alternates with re-entrants
ST	Soil Taxonomy (USDA system of soil classification)
Tr	Trace
TEB	Total exchangeable bases (= exchangeable Ca + Mg + Na + K)
THEL	Tala Hydroelectric Project Limited
TN	Total nitrogen
USDA	United States Department of Agriculture
v/v	% by volume
WR	Weathered rock
WRB	World Reference Base for Soil Resources (ISRIC development of FAO system of soil classification)
WT	Water table
w/w	% by weight
X	Exchangeable (for cation)
Z, Zi	Silt

1 INTRODUCTION

This is the technical report of the detailed soil survey of the Darla site for the new subcentre for RNR RC (West). It is intended for those who wish to know about the soils in detail, and includes soil profile descriptions and chemical analyses. A briefer general report (BSS **SS13**, 2000) will be prepared.

1.1 Darla RNR Research Subcentre

The main Renewable Natural Resources Research Centre for the Western Bhutan is located at Yusipang, near Thimphu. It has a national mandate for research in forestry and a regional mandate to coordinate all RNR research and extension work. It spans an altitude range from 2600 to 2900m a.s.l., close to the upper limits for important crops in Bhutan. Its climate is affected by it position close to the Thimphu valley, one of the main dry valleys of Bhutan. With a mean annual rainfall of about 800 mm, it is quite dry, and blue pine is the main forest type in the area.

Fig 1.1 The RNR Site from the NE with Sawmill in the Foreground

A site at Darla in Chhukha Dzongkhag has been acquired as a subcentre, for field research and extension activities in the lower, warmer and more humid parts of the western region. In particular it will be the main centre for research in the subtropical and warm temperate broadleaf forests.

The subcentre will be developed with assistance from Helvetas. The necessary preliminaries for establishing a new research subcentre include surveys of the resources available. Helvetas has requested data on soils, topography and existing infrastructure, so that its architects can start their surveys and designs for the buildings.

As part of this collection of background data, RNR - RC Yusipang commissioned the Survey of Bhutan to do a detailed topographic survey of the site (see Section 4.2 below) in March 2000. BSS used the resultant topo map as the base for a detailed soil survey, the fieldwork for which was done in April 2000.

The area for subcentre was previously private land, most of which the government has bought from the villagers of Darla. The remainder is still used for sawmill. It is anticipated that RGOB will buy or transfer the sawmill, and that its land will be incorporated into subcentre.

1.2 Aims of the soil survey of Darla RNR Research Subcentre

The detailed soil survey of the site of the subcentre was undertaken with objectives of:

- Providing detailed information on the nature and distribution of soils.
- Facilitating the development of the infrastructure for the new subcentre.
- Indicating the typicality of the soils for research trials and the extent to which the findings can be extrapolated to other parts of the region.
- Providing BSS with data for the development of a national soil classification, and for national and regional soil maps.

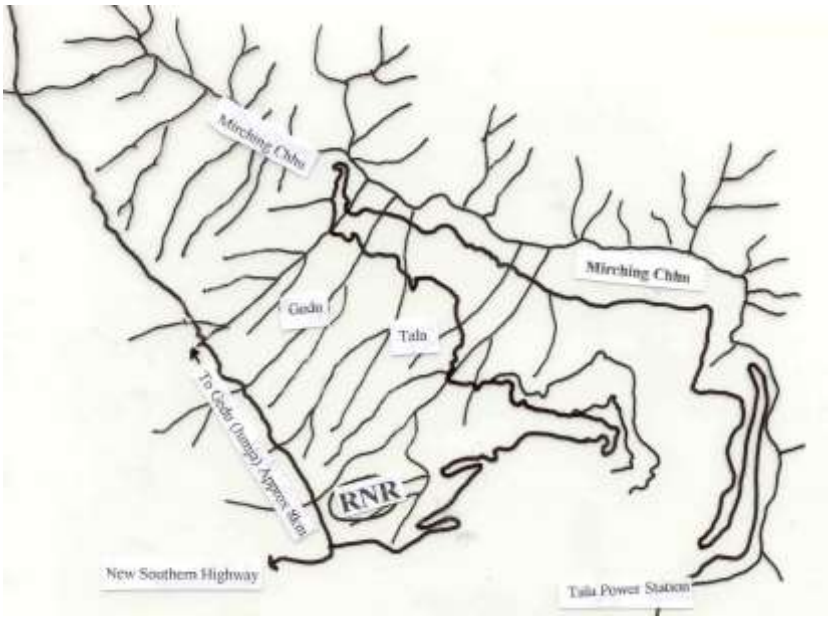
2 THE SURVEY AREA

2.1 Location and extent

The Darla subcentre is located in Darla (previously called Gengu) geog in Chhukha Dzongkhag. It is about 8 kilometres by road southeast of Jumja town, on the northeastern side of the Jumja – Darla – Manitar feeder road. This road is being extended westwards from Manitar to Phuntsholing, and will eventually link the present Thimphu – Sorchen - Phuntsholing highway with Phuntsholing - Kalikhola road in Sarpang Dzongkhag, and will become part of the national highway system. There is a 400 metres access spur road to the site from the Tala Hydro Electric Project (THEL) powerhouse road.

The subcentre is located at 26° 52' N and 89° 34' E. The soil survey includes the sawmill area and covers about 11.75 ha (29.02 acres).

Figure 2.1 Location of the RNR Sub-Centre



2.2 Climate

There are no meteorological data for Darla. However it is hoped that a full meteorological station, complete with soil temperature recorders, will be one of the first priorities for the new subcentre. For the present the climatic data from Gedu town have been taken as being equivalent, as it is close (about 8 km), and the altitude difference is only ca 300 m.

The survey area stretches from altitude of about 1680 to about 1820m a.s.l, and is in the warm temperate climatic zone, with warm temperate forest as the dominant natural vegetation. The survey area has a predominantly northwesterly aspect.

Table 2.1 summarises the main features of the climate of Gedu for the period 1985 - 1998, and shows that the mean minimum temperatures drop to about 2^0 C in January, and rise to about 14^0 C in July. The mean maximum rises from about 11^0 C in January to 28^0 C during July. The absolute maximum recorded is 32^0 C on days in June and July and the absolute minimum recorded is 0^0 C for a day in December. The mean air temperature is just over 14^0 C and the difference between winter and summer means is greater than 6^0 C, so the soil temperature regime is almost certainly mesic in Gedu. However LUPP study of Bongo and Gengu (1997) estimates that air temperature in Darla is about 1^0 C higher than at Gedu. Therefore the soil temperature in Darla probably qualifies as thermic by USDA Soil Taxonomy terms.

Table 2.1 Climatic summary for Gedu 1985 - 1995

Months	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year mean or total**
Temperature (^{0}C)													
n (number of complete records)	*9*	*9*	*8*	*8*	*8*	*9*	*8*	*8*	*9*	*7*	*8*	*8*	***7**** *(Years with complete data**)***
Mean (Average of monthly mean minimum & mean maximum)	6.6	9.5	12.0	15.9	15.5	21.1	21.8	20.1	18.5	16.4	12.0	8.9	**14.5** (Average of monthly means**)**
Mean minimum (Average of daily minima for month)	2.0	3.4	6.9	10.8	10.7	15.9	15.6	16.9	16.0	13.3	8.4	5.4	**11.0** (Average of monthly minima**)**
Absolute minimum (Coldest daily minimum on record for month)	1	1	3	5	7	14	12	11	14	8	5.5	**0**	**0** (Coldest daily minimum on record)
Mean maximum (Average of daily maxima for month)	11.2	15.5	17.2	21.0	20.4	26.3	28.1	23.2	21.0	19.5	5.5	12.3	**21.0** (Average of monthly maxima)
Absolute maximum (Hottest daily maximum on record for month)	19	19	21	28	30	**32**	**32**	29	27	25	20	16	**32** (Hottest daily maximum on record)
Rainfall (mm)													
n (number of complete records)	*10*	*9*	*9*	*9*	*10*	*10*	*11*	*9*	*9*	*10*	*9*	*10*	***9**** *(No. of years with complete data)*
Mean of monthly totals	80	98	156	255	449	539	755	673	465	196	60	24	**3560** (Mean annual total for years with complete data)
Monthly maximum (Highest total on record for month)	159	137	275	366	680	833	911	1055	726	320	120	48	**3940** (Highest annual total for years with complete data)
Monthly minimum (Lowest total on record for month)	0	58	37	143	217	217	598	290	203	71	0	0	**3180** (Lowest annual total for years with complete data)
Highest daily rainfall (Wettest day on record for month)	65	31	70	116	**292**	180	260	232	109	186	37	22	**292** (Wettest day on record)

***** Source: Data from MTI

Table 2.1 shows that the mean annual rainfall at Gedu is about 3600 mm, of which about 2800 mm (77%) falls in the monsoon months of May - September. Humidities and cloud cover are high during the monsoon but clear skies and dry winds prevail in the winter months. As discussed in Appendix D, the soil moisture regime appears to be udic by USDA Soil Taxonomy terms. The precipitation can be very intense, with a highest daily rainfall of 299 mm recorded during May.

2.3 Geology and soil parent materials

According to the report and map of Chatterjee and Khorana (1987), the survey area is underlain by the high grade metamorphic rocks of the Thimphu Formation. Within the Thimphu they differentiate between augen gneiss and pelitic schist with quartzite, and the boundary between them is close to the subcentre. However the outcrops and stones seen during the fieldwork confirm the LUPP (1997) finding that this area is on the schists. As well as quartzites, the schist contains subordinate beds of a metabasic rock, which is greenish in colour. Chatterjee & Khorana mention subordinate limestone but none was seen during our fieldwork. The predominant schist is greenish grey when fresh, and contains much biotite as well as muscovite. The iron contents appear to be quite high and the reddish brown weathering colours predominate.

There are a few shallow residual soils on the steeper slopes, but most of the soils are formed in colluvium (hillwash). The gently sloping spur crest on the lower part of the site appears to be completely covered with colluvium.

2.3 Topography and drainage

Topographically there are two parts to the site.

The southwestern section is on the lower slopes of the Damdara ridge. Slopes are irregularly rectilinear with gradients in the range 40 - 80 %. There are three minor streams running down this slope.

There is a marked break of slope at the base of the hills and the northeastern section of the site is located on the relatively flat and broad crest of a spur, with short but fairly steep slopes down to minor streams on either side

2.4 Land use and vegetation

The steep southwestern section is mainly under forest. This was originally warm temperate forest dominated by the *Castanopsis*, especially *Castanopsis indica*. Other tree species include *Nyssa javanica, Daphniphyllum chortaccum, Schima wallichii, Alnus nepalensis, Symplocos* spp and *Eurya* spp. The ground vegetation includes *Gleichenia* spp, *Daphne* spp, *Dichoria* spp, *Eupatorium adhenophorum*, *Sellaginella* spp and *Viburnum* spp. This forest has been greatly disturbed by cutting for firewood and other uses, and by the construction and upgrading of the road. Cardamom may have been cropped in the area, but none was seen during the soil survey fieldwork.

The flatter areas on the spur crest and slopes have been cleared of forest and cultivated. The lower sections were irrigated from minor channels and wetland rice was grown. The spur crest was cultivated for rainfed maize. It is not known when cultivation was stopped. Since then the open areas have been used for unimproved pasture for cattle. Part of the area is now occupied by a small sawmill, and its timber log and saw timber yards. The steep side slopes of the spur are mostly under highly disturbed *Castanopsis* forest and the scrub derived from its over-exploitation. There are small patches of open grassland in the slope forest, grazed by cattle and goats.

3. PREVIOUS SOILS INFORMATION

3.1 Bongo and Gengu study (LUPP 1997)

The study of Bongo and Gengu by LUPP (1997) covered the whole Darla (formerly Gengu) geog. Our survey is in the Souremi – Darla section of their area. They distinguished the soils of this section as somewhat different from the rest of them, as mainly derived from mica schist. These soils are deeper, finer textured and generally have better physical characteristics than the soils derived from the augen and granitic gneisses of the Thimphu Formation further north. They are much more stable and deeper than the landslip prone soils derived from the phyllites and quartzites of the Shumar and Phuntsholing formations to the southwest. However the mica schist soils are about a pH unit more acid than the gneiss soils and have poor base status.

4 METHODS

4.1 Field

The fieldwork for this survey was done over two days in April 2000.

The soils were examined on a routine basis at 21 sites, mainly with a 1.2 m Edelman auger, fitted with a 7 cm combination head where possible, but switching to a 7 cm stony soil head where necessary. Duplicate augerings were done at 2 of the sites, where the first attempt was stopped by stones at less than 50 cm. Most of the routine observations were sited by free survey, using the features shown on the detailed topographic base map. A few were located at 25 m intervals with a measuring tape along compass traverses aligned more or less up and down slope.

For routine soil observations the following site data were collected:

Location, GPS; general topography and site position; the angle (in %), aspect, length and form of the slope; solid geology and drift parent material; general land use and current crops/vegetation; irrigation type; artificial land shaping features; fertiliser use, if present and 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 eight sites. Two of the detailed descriptions were done in purpose-dug profile pits, and the rest in freshly cut-back cuttings.

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, and capping.

The soils were described by horizons according to international conventions (FAO 1990). 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); consistence in situ and in hand; number size and type of roots; reaction to HCl (to test for presence of free carbonate minerals); concretions of iron, manganese or other secondary formations; presence and effects of animals (wormcasts etc.); any other features (e.g. charcoal); clarity and shape of lower boundaries.

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

The overall observation density exceeds 2/ha, which makes this a very detailed survey by international standards.

4.2 Mapping

The site is located on Survey of Bhutan/Survey of India 1:50 000 topo sheet No. 78 F/9. This dates from the 1960's and has contours at 40m vertical intervals. This is inadequate for detailed site planning and as a base map for detailed soil mapping.

RNR-RC (West) therefore commissioned a detailed topographic survey of the site by the Survey of Bhutan. The topographic fieldwork was done in March 2000 and the map produced in April. The map is at scale 1:1000 and the contours are at 2m vertical intervals. The map is not tied in to the national x-y grid. The contours are not tied into the national vertical control points, and are taken from an arbitrary base of 1000m for the lowest point in the area. The map therefore has altitudes that are about 680 m below the real values.

The map is a satisfactory base for detailed soil survey. Identifiable ground features are well shown and enabled soil observations to be sited on a free survey basis, and avoided the need for many traverses.

The SoB topo maps were used as field sheets and are the bases of the attached interim soil map. This is at scales of approximately 1:1800. It was produced by photocopying the SoB map adjusting to fit an A3 sheet. It will be digitised into the GIS and finalised as a GIS map at a later stage, when x-y and vertical controls are available.

4.3 Laboratory

The 25 soil samples collected from the main horizons of the eight 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 Simtokha. 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 and hydrogen. This is known as the 'effective cation exchange capacity' (ECEC). SPAL does not measure extractable Al and H in soils with pH (water) greater than 5.5, but several Darla soils are sufficiently acid for the Al and H to be determined.

5 SOIL CLASSIFICATION, CHARACTERISTICS, AND CORRELATION

5.1 Soil classification

The soils of the Darla RNR Research subcentre are mostly derived from mica schist, and have a limited range of colours and textures. They are grouped into four main classes, on depth, stones and natural drainage as summarised in Table 5.1. In the descriptions of each soil class in section 5.2, the main features of the profiles are described. More details of the morphologies for individual profiles are given in Appendix B. The 'D' prefix for the class codes indicates that the classes are specific to Darla. It is intended that they will be integrated into a national soil series classification in the near future.

Table 5.1 Summary of soil classes at Darla RNR Research subcentre, Chhukha.

SOIL CLASS		Brief description	Profiles & analyses (see Appendix B)
Code	Name		
DDC	Deep clay	Dark yellowish brown fine sandy clay loam - silty clay topsoil; over brown - dark yellowish brown deep clay with few or no stones within top metre; Flat spur crest	Pd113 PH072 PH075
DDS	Stony deep sandy clay	Brown fine sandy loam topsoil; over yellowish brown sandy clay subsoil with many stones within 100 cm; Mostly on steep slopes	PH073 PH074 PH076 PK126
DSM	Shallow - moderately deep clay	Brown silty clay loam topsoil; over strong brown silty clay with hard quartz stones; over soft highly weathered schist bedrock in top 100 cm. Steep slopes	Pd112
DHG	Hill gley	Dark greyish brown silty loam topsoil; over dark yellowish brown - dark greyish brown silty loam - sandy loam + with distinct brown & orange mottles; Small areas in declivities & stream lines	No profile

5.2 Characteristics of soil classes at Darla RNR Research subcentre.

5.2.1 Deep clay (DDC)

These are the dominant soils on the gently sloping spur crest. They have been used for rainfed cultivation in the past. Part of the area is now occupied by sawmill, and rest is pasture. These soils are predominantly deep with few or no stones within a top metre. There are three fully described and sampled profiles (see Pd113, PH072 & PH075 in the Appendix B).

The topsoil is yellowish brown or dark yellowish brown, very fine sandy clay loam to silty clay in texture, with weak fine subangular blocky breaking to crumb structure, and has good porosity. The porosity, friability and crumb structures are attributed to vigourous earthworm activity, and many worms were seen. The subsoil is brown - dark yellowish brown clay loam - clay, which has a friable consistence throughout. The structures of this horizon are mostly very weak subangular blocky. In two of the described profiles there are clay coatings on the subsoil ped faces.

The analyses show that topsoil contents of organic carbon are moderate – high, and of total nitrogen are moderate, giving good C:N ratios (9 - 10). The contents of available P are generally very low in the described

profiles. These soils have very low - moderate exchangeable bases (> than 15 me %) with low base saturations, all less than 45 %). Two of the profiles are slightly acid, with pH values in the range 5.5-6.5. However the third profile (PH075) is very acid, with pH values around 5, and Al as the dominant cation. Topsoil contents of available K are very low - moderate and are very low in the subsoils. Exchangeable K contents are variable.

5.2.2 Stony deep clay (DDS)

These soils are common on the steep upper section of the site. They also occur on the side slopes of the lower spur. The area is under broadleaf forest, with *Gleichenia* spp and grasses as the main ground cover. There are four fully described and sampled profiles. (see PH073, PH074, PH076 & PK126 in the Appendix B).

They are somewhat similar to the deep clay soils in colour, and structures but have more variable and slightly sandier subsoil textures. By definition they have high content of stones in their subsoils.

The topsoils are brown - dark yellowish brown and fine sandy loam to sandy loam + in texture. They have very weak medium subangular blocky and crumb structures with good porosity. Where these soils have many - abundant roots the topsoils tend to have root-bound crumb structures. The subsoil is dark yellowish brown - yellowish brown with fine sandy clay loam to very fine sandy clay textures, except for profile PH076 which has sandy loam texture. Their structures are mainly weak - very weak medium subangular blocky, breaking to fine crumb, and the consistence is generally friable or stony. Stone contents vary from few to many. The stones vary in hardness and types from mainly hard quartz and gneiss to softer fragments of weathered schist. One of the described profiles (see PK126 in Appendix B) has a stone line about 10 cm thick of slightly hard - hard subangular quartzitic schist and gneiss. This is probably due to earthworm sorting.

Topsoil contents of organic carbon and total nitrogen are moderate – high, with reasonable C:N ratios. Contents of available P are very low.

Three of the profiles are very acid, with a pH values of about 5. These soils have very low total exchangeable bases and a very poor base status. One of profiles (PK126) is moderately acid, but its base saturations are also low. In the described profiles both topsoil and subsoil have low - moderate contents of exchangeable K, but available K levels are very low throughout.

5.2.3 Shallow & moderately deep clay (DSM)

These soils are extensive on the steep rectilinear slopes of southwestern section of the subcentre. Most of them are under forest or pasture. There is one fully described and sampled profile (see Pd112 in the Appendix B).

By definition these soils are shallow - moderately deep, and are underlain by bedrock at less than 100 cm. In the described profile the topsoil is brown with reasonable porosity. It is silty clay loam in texture and has a moderate medium subangular structure. It has a few hard quartz stones and soft weathered schist. The subsoil is dark yellowish brown - strong brown silty clay, underlain directly by the highly weathered schist at 55/64 cm. The structure is weak medium, breaking to fine, subangular blocky.

In the single analysed profile the topsoil has high organic carbon (3.5 %), and moderate total nitrogen, and the C:N ratio is reasonably good. This profile has very poor base saturation (<35 %), with exchangeable bases totaling between 0.9 and 2.4 me%. It is an acid soil, with pH values in the range 5.3 - 5.6. Exchangeable K contents are moderate in the topsoil but low in the subsoil. Available P and K contents are very low throughout.

5.2.4 Hill gley (DHG)

These soils are not extensive. They are found as narrow strips in the declivities and on the stream line of spur slopes. They are distinguished from the other soils in being seasonally wet. Despite their wet appearance the auger description lacks the predominantly grey colours normally associated with gleys.

There are no described and analysed profiles, but augering shows that the topsoil is dark greyish brown. silty loam with no stones. The subsoil colour varies from dark yellowish brown - dark greyish brown with many

fine distinct brown and orange mottles. It has silty loam - very fine sandy loam + texture with moderate contents of predominantly quartz stones.

5.2.5 Chemical characteristics

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

Table 5.2 Ranges of chemical analyses, by soil classes, of Darla RNR Research subcentre.

SOIL CLASS (number of profiles analysed)	TOPSOIL ONLY				TOPSOIL AND SUBSOIL (T/S)				
	Org. C (%)	Total N (%)	C:N	AvP (ppm)	pH	TEB (me %)	BS (%)	Exch K (me %)	AvK (ppm)
DDC (3)	3.0 - 3.2	0.31 - 0.36	9 - 10	1 - 3	5.0 - 5.9/ 5.1 - 5.8	1.0 - 7.5/ 1..2 - 3.5	6 - 42/ 8 - 22	0.3 - 1.1/ 0.2 - 0.8	7 - 118/ 19 - 98
DDS (4)	1.7 - 6.7	0.33 - 0.75	5 - 10	1 - 3	4.6 - 5.4/ 4.6 - 5.6	0.8 - 5.3/ 0.7 - 2.6	3 - 24/ 4 - 13	0.2 - 0.4/ 0.1 - 0.3	11 - 54/ 4 - 26
DSM (1)	3.5	0.39	9	1	5.3/ 5.6	2.4/ 0.9	19/ 8	0.3/ 0.1	32/ 7

See Table A.1 in Appendix A for interpretation of these values and Appendix C for further analyses of the data.

The data show that there is little variation in organic matter and nitrogen status between the classes. Topsoil contents of both organic carbon and total nitrogen are moderate - high, and C:N ratios are good, with value ranging from 5 – 10. Available P contents are very low. Base saturations are low in all the classes, all less than 45 %, with many TEB values less than 5. The low base saturations are associated with acid pH values (all less than 6). Contents of available K are generally very low.

5.3 Soil correlation

5.3.1 General

The local soil classes are given simple descriptive names that are only applicable for the Darla site. In order to see how the Darla soils fit into a wider context, it is necessary to correlate them with soils elsewhere in Bhutan and also with the international systems of soil classification.

5.3.2 Bongo and Gengu profiles (LUPP 1997)

BSS has not yet done any surveys in high rainfall areas similar to Darla.

The only previous soils data relevant to this survey are the those from the LUPP study of Bongo and Gengu (1997). This study did not classify or map the soils of the area but includes detailed descriptions and analyses of 59 profiles. As noted above (see Chapter 3), their soils can be divided into three main groups according to parent material:

Gneiss-derived soils in the northern part of their survey area
Soils derived from phyllites and quartzite in the southwestern part of their area
Soils derived from mica schist in the Souremi - Dhamdar area

Only the third group, the mica schist soils, are relevant to the Darla RNR-RSC .

The correlation between our soil classes and their mica schist profiles are summarised in Table 5.3.

5.3.3 Correlation with international soil classifications.

The local names given to classes and soil mapping units are too generalised to be useful to soil scientists outside Bhutan. For them it is necessary to give the equivalents in the international systems of soil

classification. At present BSS correlates its soil classes with the systems of FAO and the US Department of Agriculture. Table 5.4 correlates the Darla soil classes with the 1998 version of the FEO World Reference Base for Soil Resources, and with the 2nd edition (1999) of the USDA Soil Taxonomy.

Because full and definite correlations require some laboratory and environmental data, which are not available for the Darla soils, the correlations in Table 5.4 are approximate. The basis of the correlations is discussed further in Appendix C.

5.3.4 Correlation with geotechnical classification of soils.

Stability of soil terraces and water conveyance systems are important for irrigated agriculture in Bhutan. The Irrigation Section of DRDS, MoA has developed a geotechnical classification of soil and land types for irrigation purpose. Even if land is not irrigated, their classification is useful, as it give an indication of general land and soil stability. Table 5.5 correlates the soil classes of Darla with their classification.

The soils all appear qualify for the same category of lean clays, and the rock group is schist. Lean clays are moderately strong when dry, moderately sticky and plastic when wet, but are rated as having poor erosion resistance. Illitic and kaolinitic clay minerals are thought to co-dominate in the Darla and these minerals generally conform to the lean type. However the soils on the site do not look particularly erodible.

Table 5.3 Correlations between Darla RNR-RSC soils classes and LUPP (1997) mica schist profiles

Darla RNR-RSC soil class	Equivalent LUPP profiles	Notes
DDC	BP 17	Subsoil BS higher (ca 90%) than in Darla soils
	BP 22	Similar pH & BS% as Darla soils
	BP 31	
	BP 32	
	GP 1	
	GP 2	
	GP 3	Subsoil similar in pH & BS% as Darla soils, but topsoil is less leached
	GP 4	Subsoil similar in pH & BS% as Darla soils, but topsoil is less leached
	GP 5	Transitional to DDS
	GP 6	Similar pH & BS% as Darla soils
	GP 7	Transitional to DDS
	GP 8	Similar pH & BS% as Darla soils
DDS	BP 19	Transitional gneiss-schist, with pH and BS higher than in Darla soils
	PB 23	
	PB 24	pH and BS slightly higher than in Darla soils
	PB 25	
	GP 9	Not sampled
	GP 11	Coarse textured f.e. in subsoil & topsoil is less leached
	GP 12	Similar pH & BS% as Darla soils, f.e. & texture is silty clay loam
	GP 15	Similar pH & BS% as Darla soils
DSM	BP 18	Transitional gneiss-schist, with pH and BS higher than in Darla soils
	PB 26	pH and BS slightly higher than in Darla soils

DHG	No gleyed soils described or sampled in LUPP study

Table 5.4 International correlations of soil classes at Darla RNR-RSC.

Darla soil class		Subunit in FAO World Reference Base for Soil Resources (FAO 1998)	Great group in USDA Soil Taxonomy (Soil Survey Staff 1999) [Family in italics]
Code	**Name**		
DDC	Deep clay	Haplic Acrisol; Dystric Cambisol	Typic Hapludult; Dystric Hapludept *[thermic, clay, mixed]*
DDS	Stony deep soil	Dystric Cambisol; Haplic Acrisol	Dystric Hapludept; Typic Hapludult *[thermic, fine loamy , clay & skeletal, mixed]*
DSM	Shallow & moderately deep soil	Dystric Cambisol	Dystric & Typic Hapludept *[thermic, clay, mixed]*
DHG	Hill gley	Dystric Gleysol	Typic Endoaquept. *[thermic, fine loamy & clay, mixed]*

Table 5.5 Geotechnical correlation of soils of Darla RNR-RSC.

Darla soil class	DRDS Irrigation Section Geotechnical Soil Classification	
	Land unit	Soil group
DDC	3A/B	CL- lean clay low plasticity
DDS	2	
DSM		
DHG	2 & 3A/B	

* Source for class criteria: CIP (1993)

6. SOIL DISTRIBUTION AND MAPPING

6.1 Soil distribution.

Since the soils are classified on the basis of soil depth, stone content and natural drainage, the distribution of the soil classes is only moderately related to topographic position. The deep clay soils predominate the flat spur crest of the main subcentre site. The dominant soils on the upper steep slope of the main site are the stony deep clays. The shallow - moderately deep soils are mostly extensive soils in the southwestern rectilinear slope and the side slope of the spur crest. The hill gleys occur in narrow strips in the declivities and streamline on the spur slope.

6.2 Soil mapping units.

The deep clay soils are mapped as DDC consociation. Consociations have one class of soil predominant but also contain impurities of other classes. The upper steep slope and the southwestern lower rectilinear section of the main site is mapped as the SX complex (with classes DSM and DDS). Complexes are mapping units with two or more soil classes in roughly equal proportions, but also contain small areas of other classes.

The compositions of the mapping units are summarised in Table 6.1. Their areas are summarised in Table 6.2. The 1:1800 soil map of the main sub station site is located in the end pocket of this report.

Table 6.1. Composition of soil mapping units at Darla RNR Research subcentre, Chhukha.

Mapping unit	Type	Main soil classes	Minor soil classes
DC	Consociation	DDC	DHG DDS
SX	Complex	DSM DDS	DDC DHG

Table 6.2 Area of soil mapping units, Darla RNR Research subcentre, Chhukha.

Soil mapping unit	**Area**		
	Ha	**acres**	**% survey area.**
DC	4.31	10.65	36.7
SX	7.44	18.37	63.3
Total	**11.75**	**29.02**	**100**

7 OVERVIEW AND IMPLICATIONS

7.1 Overview of soils.

The Darla RNR-RSC contains a limited range of soils, on account of its small size and homogeneous geology. All of the soils are acid and highly leached. Their contents of Ca and Mg are low, and many crops will benefit from liming.

The main differences between the soils of the subcentre relate to their physical properties. The soils with the best balance of good drainage and sufficient depth to give substantial water holding capacity are the deep clays (mapping unit DC).

The stony sandy clay soils (part of mapping unit SX) appear to be moderately satisfactory. They have more limited water holding, and are more liable to runoff and erosion because of their steep slopes.

The shallow - moderately deep soils (also mapped as part of SX) may experience moisture stress during the drier season, despite their heavy textures (silty clay). Rooting depth for tree crops in these soils is probably not a major problem, as these soils are underlain by soft weathered mica schist.

The hill gleys have severe drainage constraints especially during monsoon months. However they are of very limited extent.

7.2 Implications of results

The subcentre will undertake a range of activities, including on-station trials, the coordination of off-station trials, and the integration and dissemination of the technical information for extension staff in the subregion.

Central location and good transport links are critical for the off-station activities. However the suitability of the site for on-station research trials is partly affected by the characteristics of the soils. In particular the results of the soil survey of the site can contribute to the following issues:

Are the soils suitable for forest and fodder research?
Are the soils typical of large areas of forest and agricultural land in the region, so that on-station research findings can be extrapolated?
Are the soils likely to create major difficulties for the development of the RNR-RSC infrastructure?

The first two points can be taken together. For useful research it is not required that the site should have highly suitable soils for the enterprise. In fact this is a disadvantage, as the researchers may achieve production levels that cannot be reached off the station. They may also under-estimate some of the management problems encountered by foresters and farmers on less favourable soils in the area. Soils that are typical, rather than excellent, are required for useful research. BSS has so far not surveyed soils elsewhere in southwestern Bhutan. However comparison with the LUPP study of Bongo and Gengu Geogs suggests that the soil conditions on the RNR-RSC are similar to parts of the subregion, so that on-station research results should be practicable and applicable.

8 PHYSICAL LAND SUITABILITY EVALUATION

8.1 Background

One of the purposes of soil survey is to allow land to be evaluated or classified as to its physical suitability for specific crops or enterprises and the present survey was requested to allow detailed planning to be done. During 1999 and 2000 BSS developed a provisional system for the physical evaluation of land (BSS Working Paper WP9c, 2000). The system works on the principle of limiting factors, with land assessed according to its worst features. However, the specific crops under consideration by the RNR-RC were not advised to BSS and it has been assumed that tree crops will be planted and land suitability classification has been done accordingly.

The process adopted by BSS is to consider the physical factors that, by and large, have the most effect on the growth of the crop in question. The farmer or land user cannot change some of these features or factors whilst others, such as fertility, can be altered. All the factors considered are detailed in Table 8.1 below where it is noted if the feature can be altered or not. Consideration of all these factors, singly and in combination, is used to assess if the land is generally suitable or unsuitable for the intended purpose from a physical point of view.

It should be noted that the BSS system assesses only the physical attributes of the soil and site; no consideration is given to social or economic factors as this is beyond the ability or brief of BSS. Socio and agro-economists would be expected to incorporate the BSS findings in any assessment they might make of the situation or locality.

Table 8.1 Factors Considered for Land Evaluation

Factor	Limitation Code	Permanent Feature or Not	Notes
Altitude	c	Permanent, can not be altered or influenced	Too high and we get frosts or temperatures too low for economic growth. Too low and some plants suffer heat stress. Use of different varieties can overcome some of the effects of altitude.
Aspect	c	Permanent, can not be altered or influenced	With the wrong aspect crops can be subjected to too little sunshine (radiation) and infections such as moulds etc can develop. Similarly, some crops do not like too much sunshine.
Slope	t	Can be altered if landshaping carried out	An expensive intervention
Existing erosion	t	In theory a non-permanent condition but in many situations very difficult to stop or control	Best solution is to install anti-erosion measures and stay off such land and not even cultivate close to such land
Potential erosion	t	Semi-permanent as amelioration is possible	Best solution is to avoid using land with moderate or high potential for erosion
Flood hazard	f	Semi-permanent as amelioration is possible	Flood protection measures usually involve earth moving or civil engineering interventions and are expensive to install. The best policy is to avoid cultivation and use of land perceived to be at risk
Surface stones	w	Non-permanent and can be cleared	Surface stones make the soil more difficult to work and can damage agricultural implements and machinery, planting or transplanting of some crops can become very difficult.
Topsoil stones	w	Semi-permanent and can be cleared or re-arranged to some extent.	Surface stones – within 25cm depth – can be removed by sieving or hand clearance but this is a very expensive / time consuming intervention. For wetland use, the situation can be ameliorated by puddling – that is ploughing the field whilst flooded and the stones selectively sink to the bottom of the plough layer

Factor	Limitation Code	Permanent Feature or Not	Notes
Precipitation	m	Permanent, but the situation can be influenced and ameliorated	Use of supplementary irrigation or water harvesting techniques can be used to ameliorate the situation when rainfall is too low. If rainfall is too high or too intense we can get fungal infections with crops rotting in the field and physical crop damage respectively.
Soil depth – rooting depth	m	Permanent, can not be altered or influenced unless landshaping is done and extra soil is deposited on the site	The reserves of moisture and nutrients in a shallow soil can be boosted by ameliorative measures such as application of FYM and use of water-harvesting techniques or supplementary irrigation.
Subsoil texture	m	Permanent, can not be altered or influenced	This is usually taken as 25cm and deeper and is normally the main moisture and nutrient uptake zone by most crops.
Subsoil stones	m	Permanent, can not be altered or influenced	Subsoil stones – 25cm and deeper – dilute the nutrient content and water holding capacity of the soil since stones are inert inclusions
Slope form	m	Non-permanent and can be changed by landshaping – expensive intervention	Concave sites collect extra water from run-off as it flows into the site, whilst convex shaped sites suffer more run-off.
Profile (soil) drainage	d	Non-permanent and can be changed by installation of soil drains – expensive intervention	Different crops have different tolerance and requirement for well drained or poorly drained soils.
Cation Exchange Capacity (CEC)	y	Non-permanent feature and can be altered by addition of various amendments – normally FYM	A measure of fertility potential and the ability of the soil to retain added nutrients.
Base Saturation (BS)	y	Non-permanent feature and can be improved by addition of FYM and or fertilisers	A measure of inherent fertility and a measure of the nutrients readily available to the crop
Soil Reaction (pH)	y	Non-permanent feature and can be altered by addition of amendments such as lime or FYM	Some crops are very tolerant to soil acidity whilst others require a narrow range of pH. Liming not normally feasible in Bhutan.
Aluminium Saturation (ASP)	y	Non-permanent feature and can be altered by addition of amendments such as lime, gypsum or FYM	A relationship exists between ASP and pH and some crops are sensitive to aluminium. Addition of chemicals not normally feasible in Bhutan.

8.2 Crop Criteria and Physical Suitability Classification

Based on information supplied by the crop specialists at the RNR centres, personal knowledge of staff of BSS and the other sections of NSSC plus a literature search, criteria have been compiled for 32 various crops currently cultivated in Bhutan. No attempt has been made to establish criteria for all crops grown in the country – only the most prominent.

The criteria include the upper and lower altitudes at which the crop will grow and gives the range for optimum growth. Ranges are given for all the factors detailed in Table 7.1. Finally, intermediate ranges between the optimum and totally unsuitable are given and the end result is that four classes are defined. The classes are as shown in Table 8.2.

An example of the criteria compiled and currently used for physical land suitability classification for apples is presented in Table 8.3. Data on the criteria of all the other crops considered are in a similar format.

Table 8.2 Suitability Classes

Suitability Class	Description	Input Level Required for Acceptable Yields / Crops
Class S1	Highly suitable	Low
Class S2	Moderately suitable	Moderate inputs of landshaping, anti-erosion measures husbandry, nutrients, ameliorants or water required
Class S3	Marginally suitable	High levels of landshaping, anti-erosion measures, husbandry, nutrients, ameliorants or water required
Class N	Not suitable	The crop would not grow in a satisfactory manner or the Inputs required would cost more than the returns from the crop.
Class SC3	Conditionally suitable	A more lax category applied to land already in use by the farmer – if new land this would be classified as unsuitable (Class N)

Table 7.3 Criteria for Apple Cultivation

			NEW LAND				EXISTING LAND		
		Class Suitability	S1 High	S2 Moderate	S3 Marginal	N Unsuitable	S1 & S2 High/Mod	SC3 Marginal	N Unsuitable
Parameter		Unit							
Altitude	c	masl	2200 - 2400	2401 – 2500 2199 - 2000	2501 – 2600 1999 - 1800	>2600 <1800	As new land	2501 – 2800 1999 - 1700	>2800 <1700
Aspect	c	Compass	E to SSE or SSW to W	NNE to E , W to NNW, SSE to SSW	NNW to NNE	N/A	As new land	NNE - NNW	N/A
Slope	t	%	<30	31 - 50	51 - 60	>60	As new land	51 - 70	>70
Erosion	t	Class	Nil	Nil - Slight	Slight - Moderate	Severe	As new land	Slight - Moderate	Severe
Erodibility	t	Class	Low	Low - Slight	Slight - Moderate	High	As new land	Slight - Moderate	High
Flood hazard	f	m above river bed	>20	20 – 10	9 - 5	<5	As new land	10 – 4.5	<4.5
Surface stones	w	% or class	Nil – Com 0 – 20%	Com – Many 20 – 35%	Many >35%	Abundant >50%	As new land	Many Abundant 35 – 60%	>60%
Topsoil stones	w	% or class	Nil – Few 0 – 5%	Few – Com 5.1 – 20%	Com – Many 20 – 35%	Abundant >35%	As new land	Com – Many 20 – 40%	>40%
Rainfall	m	mm / yr	1200 -900	899 – 800 1201 - 1300	799 – 600 1301-1500	<600 >1500	As new land	799 - 500	<500
Rooting Depth	m	cm	>100	99 - 75	74 - 50	<50	As new land	74 - 45	<45
Subsoil texture	m	texture	L, SL, ZL	SCl, ZCl, Cl, LvfS	C, SC, ZC, CL(h), LfS	LmS, mS, and coarser	As new land	LmS and finer	mS, LcS, LvcS, cS, vcS
Subsoil stones	m	% or Class	Nil – Few 0 – 5%	Few – Com 5.1 – 20%	Com – Many 20 – 35%	Abundant >35%	As new land	Com – Many 20 – 40%	>40%
Slope form	m	Shape	Concave or Rectilinear	NA	NA	NA	As new land	NA	NA
Soil drainage	d	Class	Well	Moderate	Imperfect or S/What Exs	Poor,Very Poor or Excessive	As new land	Poor or S/What Excessive	Very Poor or Excessive
CEC	y	me/100g	>15	15 - 5	NA	NA	As new land	NA	NA
BS	y	%	>80	80 - 35	<35	NA	As new land	NA	NA
pH	y		7.0 – 6.0	5.9 – 5.7 7.1 – 7.3	5.6 - 5.5 7.3 - 7.5	<5.5 >7.5	As new land	>5.0 <8.0	<5.0 >8.0
ASP	y		<20	21 - 30	31 - 40	>40	As new land	31 - 45	>45

Notes 1 ***c*** *= climate;* ***t*** *= topography;* ***m*** *= soil moisture;* ***w*** *= workability;* ***d*** *= soil drainage;* ***y*** *= soil chemistry*

2 For wetland rice rainfall is not used but some measure of the reliability of the water supply is required

3 Criteria Not Applied to this crop

8.3 Application of the System

The relevant data (altitude, aspect, slope etc) for each site or each map unit under study are stored in the BSS soil database – BHUSOD. These data are extracted from BHUSOD and can be used in two ways:

(a) manually
(b) automatically

In most cases of new survey the planned land use might be known before the survey is executed and, if so, only the physical land suitability classification for the planned crop would be done and this can easily be done manually. However, in some cases it be required to try and establish which would be the crop most suited to the land; in this case the suitability classification for all crops may have to be checked. If the latter is the case then the automatic application of the system is essential.

8.3.1 Manual Application

In the manual application the user refers to the table of criteria (eg Table8.3) and matches the data to the class for each factor – one starts at the top of the table and works down through the rows. As soon as any data item falls into a class below Class S1 the classification cannot return to Class S1, but it may fall further if any data item then falls in Class S3 or Class N. When one reaches the bottom of the form the worst class or classes are taken as the suitability classification of the site or map unit in question.

Normally up to three limitation codes are given. That is a final classification might be, for example;

- Class S1 (everything falls in the Class S1 column)
- Class S2c (perhaps the altitude falls in the Class S2 column)
- Class S3cmy (perhaps aspect, subsoil texture and pH fall in the Class S3 column)
- Class Nctw (perhaps the altitude, slope and surface stone cover all fall in the Class N column).

8.3.2 Automatic Application

BSS has developed a series of spreadsheets incorporating "look-up tables" where all one has to do is insert the relevant data on altitude, aspect, slope etc. into the spreadsheet table and classification is done automatically. This process removes the possible effects of operator error – however it is dependent on the data being correct and the criteria being accurate. As time progresses and knowledge of crops and crop requirements grows the criteria can and will be updated.

8.4 Land Utilisation Types

When dealing with more than one crop the volume of data can become vast and confusing. To help simplify the situation the crops have provisionally been placed into the following broad groups or categories known as Land Utilisation Types (LUTs):

Table 8.4 Land Utilisation Types

LUT No.	Name	Inclusions
1	Chhusing	Wetland rice
2	Staple food crops	Potatoes, maize, buckwheat, barley, wheat, sorghum, millet, cassava
3	Cash crops - trees	Apples, citrus, stone fruits, walnut, cashew, betel nut, mango, papaya
4	Cash crops - vegetables	Asparagus, chili, eggplant, tomato, cucumber, onion, brassicas, pulses
5	Cash crops - other	Mustard, groundnut, soybean, ginger, banana, sugarcane, strawberry

As knowledge grows and the system develops it may be possible to re-define the Land Use Types (LUTs) where the crops in each LUT have basically the same requirements and criteria for growth.

The BSS spreadsheets designed for automatic assessment of the physical suitability of the land for the various crops have been set up with one sheet for each of the above LUTs.

8.5 Physical Land Suitability Classification for the Demonstration Plot

8.5.1 Basic Data

The basic data, extracted from the database, and used for physical land suitability classification in the Demonstration Plot at Yusipang are presented in Table 7.5. These data were inserted into the BSS look-up tables and the summary of the output from this operation is presented in Section 8.5.2.

For the present situation variants of the data have been entered for each map unit. These variants have been called "upper" and "lower". The "upper " figures represent the higher altitudes, better drainage or better texture found in the unit. Conversely, "lower" covers the lower altitudes, poorer drainage or other risk factors. These variants were used rather than an overall average figure for the unit.

Table 8.5 Basic Data for Physical Land Suitability Classification of Darla Map Units

	Basic Data																	
Map Unit	Altitude - m asl	Aspect - compass direction	Slope - %	Erosion - degree or class	Erodibility - degree or cclass	Flooding - m above river	Surface Stones - %	Topsoil Stones - %	Rainfall - mm / year	Soil Depth - cm	Dominant Subsoil Texture	Subsoil Stones - %	Slope Form - shape	Drainage - class	CEC - me/100g	BS - %	pH	ASP - %
H upper	2530	E	55	Low	Low	20	2	2	800	125	CL	2	CVX	WD	8.3	23	5.4	ND
H lower	2490	SE	30	Low	Low	20	2	2	800	90	SCL	2	CVX	WD	8.3	23	5.4	ND
VH upper	2523	E	57	Low	Low	20	2	2	800	125	CL	2	CCV	MWD	*8.3*	23	5.4	ND
VH lower	2495	SE	27	Low	Low	10	2	2	800	90	SCL	2	CCV	MWD	*8.3*	23	5.4	ND
LV upper	2510	SE	40	Low	Low	15	2	2	800	125	SCL	2	CCV	WD	*8.3*	23	5.4	ND
LV lower	2489	SE	30	Low	Low	10	2	2	800	100	SL	2	CCV	MWD	*8.3*	23	5.4	ND
V upper	2530	SE	30	Low	Low	5	2	2	800	125	SCL	2	CCV	PD	6.7	46	6.0	ND
V lower	2497	SSE	25	Low	Low	2	2	2	800	100	SCL	2	CCV	PD	6.7	46	6.0	ND
X upper	2518	SE	30	Low	Low	10	10	5	800	100	CL	15	IRR	MWD	*6.7*	46	6.0	ND
X lower	2497	ESE	25	Low	Low	5	20	10	800	75	SCL	15	IRR	ID	*6.7*	46	6.0	ND

For Map Units names refer Table 5.1, Chapter 5
Units VH, LV and X– no laboratory data, assume similar to nearby units
"upper and lower" – the higher altitude, better drainage class etc that exists for the unit

Drainage classes	*WD*	*Well drained*
	MWD	*Moderately well drained*
	ID	*Imperfectly drained*
	PD	*Poorly drained*

8.5.2 Output from Automatic Classification

The summary information from the LUT spreadsheet for tree crops is given below in Table 8.6 –the full data are not shown due to excessive volume and size. The order of presentation in the following sections is the same for each LUT to aid correlation with the names of the units as shown in Table 8.5 above.

As can be seen from the summary, based on the crop criteria presently used by BSS in the classification system and the available data for the land in question, there is very little suitability for any of the crops considered on any of the map units.

Physical suitability for all the tree crops assessed, apart from Walnut, is classed as unsuitable (Class N). Walnut is assessed as Class N (unsuitable) in the poorly drained valley unit "V" and marginally suitable (Class S3) in all the other units. Unless walnut is a very tolerant tree crop these results suggest that perhaps the crop criteria for walnut are too lax, and should be re-assessed, or that the criteria for all the other crops are too harsh, and re-assessment for all should be done.

On the basis of the present assessment the main limiting factors are as shown in Table 8.7.

Table 8.6 Land Classification for Tree Crops (LUT 3) - Summary

Summary LUT 3	Apples	Citrus	Stone Fruit	Walnut	Cashew	Mango	Papaya	Betel Nut
Map Unit / Series	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION
H upper	Nty	Ncmt	Ncmt	S3cty	Nmt	Nmty	Nmt	Nmt
H lower	Nty	Ncmt	Nmt	S3cy	Nmt	Nmy	Nm	Nm
VH upper	Nty	Ncmt	Ncmt	S3cty	Nmt	Nmty	Nmt	Nmt
VH lower	Nty	Ncmt	Nmt	S3y	Nm	Nmy	Nm	Nm
LV upper	Nty	Ncmt	Ncmt	S3cy	Nmt	Nmty	Nmt	Nmt
LV lower	Nty	Ncmt	Nmt	Sc3y	Nmt	Nmy	Nm	Nm
V upper	Ntd	Ncdmt	Ncmt	Nd	Ndt	Ndf	Ndm	Ndm
V lower	Ntd	Ncdmt	Ndmt	Nd	Ndf	Ndf	Ndm	Ndfm
X upper	Nt	Ncmt	Ncmt	S3cy	Nmt	Nm	Nm	Nm
X lower	Nt	Ncmt	Nmt	S3cdwy	Nm	Nm	Nm	Nm

Limitation code		
	c	Climate – generally too high altitude
	d	Drainage – poorly drained soils in parts
	f	Flood – risk of flood as site is not very high above stream line
	m	Soil moisture limitation – mainly through limited rainfall
	t	Steepness of slope
	y	Soil fertility problem – mainly acidic soils

Table 8.7 Limiting Factors in Physical Land Suitability in Demonstration Plot

Subscript Code	Factor	Major / Minor	Cause / Limitation	Remedial Actions
c	Climate	Major – can not be altered	Low temperatures due to higher than optimum altitude	This feature cannot be altered
d	Drainage	Minor	High water table and poor drainage in Unit "V"	Installation of soil drains can ameliorate the situation
f	Flood	Minor – one unit only	Some risk of flooding in Unit V near the existing stream line	Flood protection could be installed

Subscript Code	Factor	Major / Minor	Cause / Limitation	Remedial Actions
m	Soil moisture	Major	Soil moisture reserves would be on the low side due to less than adequate rainfall	This situation can be changed by supplementary irrigation and / or water harvesting techniques.
t	Topography	Major – can be altered	Most of the slopes are too steep for cultivation	Situation can be changed by landshaping and terrace or basin construction – but the stability of the soil would require checking.
w	Workability	Minor – one unit only	Some restriction by surface rock and stones in Unit X	Surface stones can be cleared but rock outcrops present a more major problem – but overall there is not a large amount of rock or stone in the area concerned
y	Fertility	Major	Soil pH is generally rather acid and there is the possibility of relatively high exchangeable aluminium in the soils – though this has not been determined.	This limitation can be removed through the application of lime and / or Farm Yard Manure, both of which reduce acidity. If limestone were to be applied dolomite should be sued to help address the noted magnesium deficiency

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APPENDIX A METHODS OF SOIL ANALYSIS USED AT SPAL, SIMTOKHA

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

The SPAL methods vary according to soil pH. The methods summarized below are only those for soils with pH (water) > 7, as no non-acid samples were collected during this survey. Some of the samples have pH (water) < 5.5, and the determinations for very acid soils (i.e. the of extractable Al and H) are also given.

Sample preparation.

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

pH.

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

Soil extracts.

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

- Total N is extracted and converted into ammonium form by micro-Kjeldahl digestion with H_2SO_4 and a Se-based catalyst.
- Ammonium – N and nitrate – N are extracted by shaking with 0.01 M $CaCl_2$ for two hours.
- For soils with pH (water) < 7, available P is extracted by shaking 5 g of fine earth with 35 ml of the Bray and Kurtz extractant of 0.5 M HCl and 1 M NH_4F for 1 minute.

- Available K is extracted by shaking 5 g of fine earth with 50 ml of 0.01 M $CaCl_2$ for 2 hours.
- Exchangeable Ca, Mg, K and Na are extracted by leaching 5 g of fine earth with 100 ml of 1M ammonium acetate (NH_4OAc).
- For the soils with pH (water) < 7.5, the ammonium is extracted by leaching the soil with excess 1 M KCl, and measured to give the Cation Exchange Capacity.
- Extractable Al and H are extracted from 5 g fine earth with 100 ml of 1 M acidified KCl.

Assays of extracts.

- The NH_4 in the extracts from the Total N digestion, the KCl leaching for CEC determination, and from NH_4 – N; NO_3 – N; available P; available K; and exchangeable K and Na in the different extracts are measured with the Skalar Segmented Flow Analyser system, which includes colorimeters for NH_4, NO_3 and P, and a flame spectrophotometer for K and Na.
- Exchangeable Ca and Mg in the NH_4OAc leachate are measured with a Unicam Atomic Adsorption Spectrophotometer.

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.

TEB, BS and C:N.

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

- TEB = Exchangeable Ca + Mg + K + Na.

- BS (NH_4OAc) = TEB / CEC (NH_4OAc).
- C:N = Organic C / Total N.

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

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

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

Source: AHT 1995.

APPENDIX B SOIL PROFILE DESCRIPTIONS AND ANALYSES

This appendix includes the detailed descriptions and analyses of the soil profiles, in the order summarised in Table B.1

Table B.1 Summary of Darla RNR-RSC soil profiles.

Profile Number	Darla soil class	Number of horizons analysed.
Pd112	DSM	2
Pd113	DDC	5
PH072	DDC	4
PH073	DDS	3
PH074	DDS	2
PH075	DDC	3
PH076	DDS	2
PK126	DDS	4
TOTAL	**8**	**25**

Profile: Pd112

Map unit: DSM

Soil Classification: Darla RNR Research subcentre soil class: Shallow & moderately deep clay (DSM)
Soil Taxonomy: Dystric Hapludept *[thermic, clay, mixed]*
WRB: Dystric Cambisol

Survey area: Darla RNR Research subcentre
Location: Upper side W slope, NW corner
GPS: Not done
Altitude: 1740 m asl.

Described & sampled: 26.04.2000, Tsheten Dorji

Climate: *General:* *Warm temperate*, *P = ca 3600 mm p.a*
Recent weather: Misty with some showers

Regional topography: Lower mountains
Site position: Upper side slope of main spur

Slope: 21%, ca 100 m + to stream, rectilinear, aspect NNw (335^0)
Site drainage: Good

Parent material: Solid: Thimphu
Drift: Colluvium

Land use: *Rough grazing*
Vegetation: *Rubia cordifolia, Epitorium adhenophorum, Gleichenia* spp*, Daphne* spp *& Fragaria* spp*.*

Surface: Litter: None
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: 2-3 cm irregular cattle poaching
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
cm

0-20/29 10YR 4/3 (brown) with many medium distinct reddish brown & brown mottles; silty clay loam; moderate medium breaking to fine subangular blocky; many fine & few medium pores; moist & firm; abundant fine & few medium grass roots; few fine soft weathered schist & few fine hard angular quartz & gneiss stones; HCl negative; common earthworms; rare manganese stains; clear slightly wavy boundary to:
[Sample Pd112/1 @ 0 -10 cm]

20/29-55/64 10YR 4/6 (dark yellowish brown) with no mottles; silty clay; weak medium breaking to fine subangular blocky; very weak discontinuous clayskins & moderate discontinuous organic cutans; many fine & few medium pores; moist & firm; rare fine roots; common medium & coarse soft schist & few fine hard angular quartz & gneiss stones; HCl negative; clear broken boundary to:
[Sample Pd112/2 @ 35-45 cm]

55/64-81+ Mixed 10YR 5/6 (yellowish brown) & 7.5YR 5/6 (strong brown) with weathering rock colours of red, grey & white; silty clay; interstitial weak medium breaking to fine subangular blocky; many fine & few medium & coarse pores; moist, stony & firm; abundant highly weathered schist & common fine & medium hard angular quartz & gneiss stones; HCl negative: [Not sampled]

SPAL analytical results for BSS Profile Pd112 Survey area: Darla

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					
Pd112 /1	0 - 10	7706	5.3	3.9	1.4	0.01	1	3.5	0.39	9
Pd112 /2	35 - 45	7707	5.6	3.8	1.7	0.01	1	0.9	0.37	2

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pd112 /1	1.6	0.4	0.3	0.1	2.4	nd	12.7	nd	19	nd
Pd112 /2	0.6	0.1	0.1	0.1	0.9	nd	10.6	nd	8	nd

Overall Physical Suitability for Crops / LUTs

Wetland

Site	Chhusing
PD112	S3cdy

Dryland Staples

	Potato	Maize	Buckwheat	Barley	Wheat	Sorghum	Millet	Cassava
PD112	Nm	SC3/Nc	Nm	Nm	SC3/Ny	Ncy	S3cty	Nc

Tree Crops

	Apples	Citrus	Stone Fruit	Walnut	Cashew	Mango	Papaya	Betel Nut
PD112	Nm	Nc	Nm	Nm	Ncm	SC3/Nmy	Nc	Nc

Vegetables

	Asparagus	Chili	Egg Plant	Tomato	Cucumber	Onion	Brassicas	Pulses (beans)
PD112	Nm	Nm	SC3/Ncy	SC3/Ny	Ny	Nmy	SC3/Ny	Nm

Other Crops

	Mustard	Groundnuts	Soybean	Ginger	Banana	Pineapple	Sugarcane	Strawberry
PD112	S3cy	Nc	Nm	Nc	S3cty	SC3/Nc	Nc	Ncm

For an explanation of the Suitability Codings Refer BSS Working Paper 9c

Profile: Pd113

Map unit: DDC

Soil Classification: Darla RNR Research subcentre soil class: Deep clay (DDC)
Soil Taxonomy: Typic Hapludult *[thermic, clay, mixed]*
WRB: Haplic Acrisol

Survey area: Darla RNR Research subcentre
Location: Ca 170 m+ NE of sawmill/ca 100 m WNW of electric pole on northern slope.
GPS: Not done
Altitude: 1744 m asl.

Described & sampled: 26.04.2000, Tsheten Dorji

Climate: General: Warm temperate, P = ca 3600 mm p.a
Recent weather: Misty with showers half an hour back

Regional topography: Lower mountains
Site position: Lower end of spur flat

Slope: 11%, ca 150 m + to stream, terraced rectilinear, aspect NNW (343^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Residual or colluvium

Land use: Abandoned dry land presently under pasture
Vegetation: Fragaria spp, Gleichenia spp, Epitorium adhenophorum & grasses

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

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

10YR 4/4 (dark yellowish brown) with common fine & medium distinct reddish brown mottles in top 5 cm; silty clay; weak medium breaking to fine subangular blocky & fine crumb; weak discontinuous organic cutans on pore walls & Ped faces; many fine pores; moist & firm; many fine & few medium roots; few quartz gravel; HCl negative; common earthworms & few grubs; diffuse boundary to:
[Sample Pd113/1 @ 0-10 cm]

28-62 7.5YR 4/3 (brown) with no mottles; clay; very weak medium breaking to fine subangular blocky; weak discontinuous clayskins; many fine & few medium pores; moist & firm; few fine roots; HCl negative; lens shaped red 15-20 cm thick highly weathered rock; diffuse boundary to:
[Sample Pd0113/2 @ 40-50 cm]

62-91 7.5YR 5/4 (brown) with no mottles; clay; weak coarse breaking to medium & fine subangular blocky; weak - moderate discontinuous clayskins; many fine & common medium roots; moist & firm; rare fine roots; HCl negative; rare black manganese; diffuse boundary to: [Sample Pd113/3 @ 70-80 cm]

91-139 10YR 4/6 (dark yellowish brown) with no mottles; clay; moderate medium breaking to fine subangular blocky; moderate discontinuous clayskins; common fine & medium pores; moist & slightly friable in face but very friable in hand; rare very fine roots; HCl negative; diffuse boundary to: [Sample Pd113/4 @ 110-120 cm]

139-154+ 7.5YR 5/6 (strong brown) with no mottles; clay; weak medium breaking to very fine subangular blocky; very weak discontinuous clayskins; common fine & few medium pores; moist & slightly firm; no roots; rare soft black manganese concretions; HCl negative: [Sample Pd113/5 @ 140-150 cm]

SPAL analytical results for BSS **Profile Pd113** **Survey area: Darla**

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					
Pd0113 /1	0 - 10	7708	5.2	3.7	1.5	0.01	1	3.0	0.31	10
Pd0113 /2	40 - 50	7709	5.6	3.8	1.8	0.01	1	0.8	0.12	7
Pd0113 /3	70 - 80	7710	5.6	3.7	1.9	0.01	1	6.0	0.97	6
Pd0113 /4	110 - 120	7711	5.6	3.8	1.8	0.01	1	0.4	nd	nd
Pd0113 /5	140 - 150	7712	5.6	3.7	1.9	0.01	1	0.4	nd	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
Pd0113 /1	0.8	0.1	0.3	0.1	1.3	nd	17.5	nd	7	nd
Pd0113 /2	0.8	0.2	0.3	0.1	1.4	nd	18.8	nd	8	nd
Pd0113 /3	0.8	0.2	0.3	0.1	1.4	nd	17.2	nd	8	nd
Pd0113 /4	0.6	0.2	0.2	0.1	1.2	nd	17.8	nd	6	nd
Pd0113 /5	0.4	0.1	0.2	0.1	0.8	nd	13.3	nd	6	nd

Comments: Although pH are mostly just >5.5, BS % are very low, and the soil may have substantial contents of extractable Al & H. Assumed to be Hapludult in Soil Taxonomy, but the high topsoil silt may be aeolian.

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PD113	**S3cdy**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PD113	Nm	SC3/Nc	Nm	Nm	SC3/Ny	Ncy	SC3/Nm	Nc

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PD113	**Nm**	**Ncm**	**Nm**	**Nm**	**Ncm**	**SC3/Ny**	**Nc**	**Nc**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PD113	Nm	Nm	SC3/Ncy	SC3/Nmy	Ny	Nmy	SC3/Ny	Nm

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PD113	S3cmy	Ncm	Nm	Ncm	S3cmy	Nm	Nc	Ncm

Profile: PH072

Map unit: DDC

Soil Classification: Darla RNR Research subcentre soil class: Deep clay (DDC)
Soil Taxonomy: Typic Hapludult *[thermic, clay, mixed]*
WRB: Haplic Acrisol

Survey area: Darla RNR Research subcentre
Location: 30m north east of sawmill
GPS: Not recorded
Altitude: *1750m a.s.l*

Described & sampled: 26.4.2000, H B Tamang

Climate: *General:* *Warm temperate, P = ca 3600 mm p.a*
Recent weather: Cloudy

Regional topography: Low mountains
Site position: Flat top

Slope: 3%, 250m+long, rectilinear, aspect SW (200^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Residual

Land use: *Abandoned improved pasture*
Vegetation: Kikiyu grass, *Trifolium repens* & Rye grass

Surface: Litter: Few patches of tree bark & cow dung
Outcrops: Rare coarse hard angular gneiss
Stones: None
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
Cm

0-9 10YR 5/4 (yellowish brown) with many medium distinct greyish brown mottles; very fine sandy clay loam; weak medium subangular blocky; weak discontinuous clayskins; few medium & many fine pores; moist & friable; few coarse & many medium & fine roots; HCl negative; clear regular boundary to: [SamplePH072/1 @ 0-9cm]

9-71 10YR 4/3 (brown) with no mottles; clay loam; very weak fine subangular blocky breaking to weak medium crumb; weak discontinuous clayskins; few medium & many fine pores; moist & friable; common fine roots; HCl negative; common worm holes & casts; clear regular boundary to: [Sample PH072/2 @ 40-50cm]

71-83 10YR 4/6 (dark yellowish brown) with no mottles; clay loam; very weak fine subangular blocky breaking to fine crumb; moderate discontinuous clayskins; common coarse & many fine pores; moist & friable; rare fine roots; clear regular boundary to: [Sample PH072/3 @ 72-82cm]

83-150 10YR 5/8 (yellowish brown) with no mottles; silty clay loam; very weak fine subangular blocky breaking to fine crumbs; weak discontinuous clayskins; common medium & many fine pores; moist - wet & slightly sticky & friable; no roots; rare medium highly weathered mica-schist & quartz stones; HCl negative: [Sample PH072/4 @ 100-110cm]

150-190+ Continued by auger, 5YR 4/6 (yellowish red) with no mottles; silty clay; moist - moist & sticky; few fine hard quartz stones; hit moderately weathered mica schist rock: [Not sampled]

Comments: In 0-71cm depth (first & second horizons), the soil structures are crumby and friable because of active faunal activities. Mica schist appeared to be dominant parent material for high content of clay. 150cm onwards soils are red, which could be the segregation of iron from underlying rocks

SPAL analytical results for BSS Profile PH072 Survey area: Darla

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					
PH072 /1	0 - 9	7715	5.9	4.0	1.9	0.02	3	3.1	0.31	10
PH072 /2	40 - 50	7716	6.1	4.0	2.1	0.02	1	0.8	0.13	6
PH072 /3	72 - 82	7717	5.8	3.9	1.9	0.01	1	0.7	0.11	3
PH072 /4	100 - 110	7718	5.6	3.8	1.8	0.01	1	0.3	0.06	5

Exchangeable base status

BSS No.	Exchangeable					Extr Al	Extr H	CEC		BS%	
	Ca	Mg	K	Na	TEB			AmOAc	ECEC	AmOAc	EBS%
PH072 /1	5.4	0.9	1.1	0.1	7.5	nd	nd	17.7	nd	42	nd
PH072 /2	3.5	0.9	1.2	0.1	5.8	nd	nd	18.8	nd	30	nd
PH072 /3	2.1	0.5	0.8	0.1	3.5	nd	nd	15.8	nd	22	nd
PH072 /4	1.9	0.4	0.6	0.1	3.0	nd	nd	10.0	nd	30	nd

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PH72	**S3d**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PH72	Nm	S2fmy	Nm	Nm	S3my	Nc	S3cy	Nc

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PH72	**Nm**	**S3c**	**Nm**	**Nm**	**Nm**	**S3c**	**Nc**	**Nc**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PH72	Nm	Nm	SC3/Nc	S3m	Ny	Nm	S2my	Nm

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PH72	S3y	Nc	Nm	Nc	S3c	S3cm	Nc	Ncm

Profile: PH073

Map unit: DDS

Soil Classification: Darla RNR Research subcentre soil class: Stony deep soil (DDS)
Soil Taxonomy: Typic Hapludult *[thermic, clay, mixed]*
WRB: Haplic Acrisol

Survey area: Darla RNR Research subcentre
Location: 20m below Tala-Pasakha road & 40m NW of PWD store
GPS: Not recorded
Altitude: *1770m a.s.l*

Described & sampled: 26.4.2000, H B Tamang

Climate: *General:* *Warm temperate, P = ca 3600 mm p.a*
Recent weather: Rain

Regional topography: Low mountains
Site position: Middle of hill slope

Slope: 30%, 1km+long, rectilinear, aspect ENE (65^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Colluvium

Land use: *Natural broad leaf forest*
Vegetation: Bracken, *Schima wallichii* & lichen

Surface: Litter: 1-2cm continuous leaves & twigs
Outcrops: None
Stones: None
Cracks: None
Roots: None
Microrelief: Hummock
Faunal activity: None
Other features: None

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

0-30 10YR 4/2 (dark greyish brown) with no mottles; very fine sandy loam; very weak fine crumb; common fine pores; moist & friable; few coarse & many medium & fine roots; rare coarse schistose gneiss stones; HCl negative; clear wavy boundary to:
[Sample PH073/1 @ 0-10 cm]

30-125 10YR 5/4 (yellowish brown) with no mottles; clay loam; very weak fine crumbs; many fine pores; moist & friable; few medium & fine pores; few fine hard quartz & soft gneiss gravel; gradual wavy boundary to:
[Sample PH073/2 @ 80-90 cm]

125-175 10YR 4/4 (dark yellowish brown) with no mottles; stony very fine sandy clay loam; very weak fine crumbs; many medium pores; moist & friable; no roots; abundant medium, fine & few coarse quartzitc gneiss stones; HCl negative:
[Sample PH073/3 @ 140-150 cm]

Comments: This is a moderately deep hill soil. Though, this cutting is from natural forest there is hardly any faunal activities. Few coarse surficial tree roots netting over cutting areas.

SPAL analytical results for BSS **Profile PH073** **Survey area: Darla**

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					
PH073 /1	0 - 10	7719	4.6	3.5	1.1	0.01	1	1.7	0.35	5
PH073 /2	80 - 90	7720	5.2	3.8	1.4	0.01	1	1.5	0.17	9
PH073 /3	140 - 150	7721	4.6	3.8	0.8	0.01	1	1.0	0.09	11

Exchangeable base status

bb	Exchangeable				TEB	Extr Al	Extr H	CEC		BS%	
PH073 /1	0.2	0.4	0.3	0.1	0.9	7.9	0.2	23.1	9	3	10
PH073 /2	0.5	0.3	0.1	0.1	0.9	4.7	0.4	17.0	6	4	15
PH073 /3	0.5	0.3	0.1	0.1	0.9	3.9	0.3	9.4	5	8	11

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PH73	**S3dmy**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PH73	Nm	SC3/Ny	Nm	Nmy	Ny	Ncy	SC3/Ny	Nc

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PH73	**Nmy**	**SC3/Ny**	**Nm**	**Nm**	**Nm**	**Ncy**	**Nc**	**Nc**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PH73	Nm	Nm	Ny	Ny	Ny	Nmy	Ny	Nmy

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PH73	S3y	Nc	Nm	Nc	S3cty	SC3/Ny	Nc	Ncm

Profile: PH074

Map unit: DDS

Soil Classification: Darla Research subcentre soil class: Stony deep soil (DDS)
Soil Taxonomy: Dystric Hapludept *[thermic, clay, mixed]*
WRB: Dystric Cambisol

Survey area: Darla RNR Research subcentre
Location: 50m below PWD store
GPS: Not recorded
Altitude: *1760m a.s.l*

Described & sampled: 26.4.2000, H B Tamang

Climate: *General:* *Warm temperate, P = ca 3600 mm p.a*
Recent weather: Rain

Regional topography: Low mountains
Site position: Middle of spur

Slope: 40%, 200m+long, rectilinear, aspect NE (55^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Colluvium

Land use: *Clearing in natural broad leaved forest*
Vegetation: Bracken, & *Artimesia* spp

Surface: Litter: 1-2 cm continuous decayed leaves & twigs
Outcrops: None
Stones: Abundant medium & fine hard angular gneiss & phyllites
Cracks: None
Roots: None
Microrelief: Hummock
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
Cm

10YR 4/4 (dark yellowish brown) with no mottles; fine sandy loam+; root bound fine crumb; few fine pores; moist & very friable; few coarse & many medium & fine roots; few medium hard angular gneiss & quartz stones; HCl negative; few ants; clear regular boundary to: [Sample PH074/1 @ 0-10 cm]

22-54 10YR 6/6 (brownish yellow) with no mottles; fine sandy clay; very weak fine subangular blocky breaking to crumb; many fine & few medium pores; moist & friable; few coarse & many medium roots; few coarse & common medium hard quartz & gneiss stones; HCl negative; clear regular boundary to: [Sample PH074/2 @ 30-40 cm]

54-81 10YR 5/4 (yellowish brown) with no mottles; fine sandy clay; very weak fine subangular blocky breaking to crumb; weak discontinuous clayskins; many fine & few medium pores; moist & friable; few medium roots; many medium & few coarse hard gneiss, quartz & phyllite stones; HCl negative; clear regular boundary to: [Not sampled]

81-140+ 10YR 5/3 (brown) with no mottles; fine sandy clay; very weak fine subangular blocky breaking to crumb; weak discontinuous clayskins; few fine pores; slightly dry & slightly hard; rare medium & common fine roots; abundant medium, fine & common coarse phyllite, gneiss & quartz gravel; HCl negative: [Not sampled]

SPAL analytical results for BSS Profile PH074 Survey area: Darla

Reaction, P & organic matter

BSS No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			b	KCl	Diff					
PH074 /1	0 - 10	7722	4.8	3.8	1.0	0.01	1	6.7	0.69	10
PH074 /2	30 - 40	7723	5.1	3.8	1.3	0.01	1	2.8	0.29	10

Exchangeable base status

bb	Exchangeable				TEB	Extr Al	Extr H	CEC		BS%	
	Ca	Mg	K	Na				AmOAc	ECEC	AmOAc	EBS%
PH074 /1	1.4	0.2	0.3	0.1	2.0	4.4	0.8	23.0	7	9	29
PH074 /2	0.9	0.1	0.2	0.1	1.3	6.4	0.2	20.4	8	6	16

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PH74	**Nw**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PH74	Nmw	Nw	Nm	Nmwy	Nwy	Ncy	SC3/Nwy	Nc

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PH74	**Nmy**	**SC3/Nwy**	**Nm**	**Nm**	**Nm**	**Ncy**	**Nc**	**Nc**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PH74	Nmw	Nm	Ncy	Ntwy	Nwy	Nmwy	Ny	Nmwy

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PH74	Nw	Ncw	Nm	Ncm	SC3/Ntw	SC3/Nmwy	Nc	Ncmw

Profile: PH075

Map unit: DDC

Soil Classification: Darla RNR Research sub centre soil class: Deep clay (DDC)
Soil Taxonomy: Typic Hapludult *[thermic, fine loamy, mixed]*
WRB: Haplic Acrisol

Survey area: Darla RNR Research subcentre
Location: 35^0 (NE) & ca 150m away from sawmill
GPS: Not recorded
Altitude: *1750m a.s.l*

Described & sampled: 26.4.2000, H B Tamang

Climate: *General:* *Warm temperate, P = ca 3600 mm p.a*
Recent weather: Rain

Regional topography: Low mountains
Site position: Lower part of steep slope

Slope: 35%, 200m+long, convex, aspect ENE (83^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Colluvium

Land use: *Abandoned dry land*
Vegetation: Bracken & Kikiyu grass

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

0–18 10YR 5/4 (yellowish brown) with common medium faint greyish brown mottles; fine sandy clay loam; weak fine subangular blocky breaking to crumb; few medium & many fine pores; moist & friable; common coarse & many medium & fine grass roots; few fine hard angular quartz gravel; HCl slightly positive; few pieces of charcoal; clear regular boundary to: [Sample PH075/1 @ 0-10 cm]

18-62 10YR 4/3 (brown) with no mottles; fine sandy loam+; very weak medium subangular blocky breaking to fine crumb; few medium & many fine pores; moist & friable; few coarse, medium & many fine roots; HCl slightly positive; few pieces of charcoal; clear regular boundary to:
[Sample PH075/2 @ 35-45 cm]

62-92 10YR 4/2 (dark greyish brown) with common coarse & many medium distinct reddish brown & greyish brown mottles; very fine sandy clay loam; very weak medium subangular blocky breaking to fine crumb; few coarse & many fine pores; moist & very friable; rare coarse & many fine roots; HCl slightly positive; few pieces of charcoal; clear regular boundary to: [Sample PH075/3 @ 75-85 cm]

92-142+ 10YR 6/4 (light yellowish brown) with common coarse distinct red & orange mottles; silty clay; very weak medium subangular blocky breaking to fine crumb; weak discontinuous clayskins; few medium & many fine pores; moist & very friable; many medium & few fine roots; HCl negative: [Not sampled]

SPAL analytical results for BSS Profile PH075 Survey area: Darla

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					
PH075 /1	0 - 10	7724	5.0	3.8	1.2	0.01	1	3.2	0.4	9
PH075 /2	35 - 45	7725	5.1	3.8	1.3	0.01	1	3.2	0.3	9
PH075										

/3	75 - 85	7726	4.9	3.7	1.2	0.01	1	3.1	0.4	7

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	Extr H	CEC		BS%	
	Ca	Mg	K	Na				AmOAc	ECEC	AmOAc	EBS%
PH075 /1	0.6	0.1	0.1	0.2	1.0	4.7	0.2	17.2	5.9	6	17
PH075 /2	0.8	0.1	0.2	0.1	1.2	4.7	0.1	13.7	6.0	8	20
PH075 /3	0.8	0.1	0.1	0.1	1.1	5.9	0.2	20.7	7.2	5	16

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PH75	**S3dmty**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PH75	Nm	S3mty	Nm	Nm	SC3/Ny	Ncy	S3cmty	Nc

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PH75	**Nm**	**S3cty**	**Nm**	**Nm**	**Nm**	**SC3/Ny**	**Nc**	**Nc**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PH75	Nm	Nm	SC3/Ncy	Nt	Ny	Nmy	SC3/Ny	Nm

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PH75	S3my	Nc	Nm	Nc	SC3/Nt	S3cmty	Nc	Ncm

Profile: PH076

Map unit: DDS

Soil Classification: Darla RNR Research subcentre soil class: Stony deep soil (DDS)
Soil Taxonomy: Dystric Hapludept *[thermic, loamy - skeletal, mixed]*
WRB: Dystric Cambisol

Survey area: Darla RNR Research subcentre
Location: 500m west of sawmill
GPS: Not recorded
Altitude: *1770m a.s.l*

Described & sampled: 26.4.2000, H B Tamang

Climate: *General:* *Warm temperate, P = ca 3600 mm p.a*
Recent weather: Cloudy

Regional topography Low mountains
Site position: Midslope of steep section

Slope: 89%, 100m+long, regular, aspect ENE (63^0)
Site drainage: Good

Parent material: Solid: Thimphu gneiss
Drift: Colluvium

Land use: *Natural broadleaf forest*
Vegetation: Bracken & *Castanopsis* spp

Surface: Litter: 0-4cm continuous decayed leaves & twigs
Outcrops: None
Stones: Few medium & fine angular quartz
Cracks: None
Roots: None
Microrelief: None
Faunal activity: None
Other features: None

Profile description: (Colours are moist unless indicated)
Cm

0-20 7.5 YR 5/4 (brown) with no mottles; gravelly sandy loam; weak fine crumb; no pores; moist & friable; many coarse & abundant medium & fine roots; abundant medium hard quartz & gneiss stones; HCl negative; few medium dead roots; clear wavy boundary to: [Sample PH076/1 @ 0-10c m]

20-50 7.5YR 4/2 (brown) with no mottles; medium sandy loam; very weak fine subangular blocky breaking to very fine crumb; interstitial pores; moist & friable; common coarse & many medium & fine roots; few coarse & medium & many fine hard angular gneiss gravel; HCl negative; clear wavy boundary to: [Sample PH075/2 @ 35-45 cm]

50-90 10YR 5/4 (yellowish brown) with no mottles; coarse sandy loam+; very weak fine subangular blocky breaking to crumb; interstitial pores; moist, stony & friable; few coarse & many medium & fine roots; rare coarse & many medium & fine hard angular quartz gravel; HCl negative; clear wavy boundary to: [Not sampled]

10YR5/4 (light olive brown) with no mottles; gravelly sandy loam+; very weak fine crumb; no pores; moist stony & friable; common medium & few fine roots; abundant medium & many coarse hard angular gneiss & quartz stones; HCl negative: [Not sampled]

130-183+ 10YR 5/6 (yellowish brown) with no mottles; gravelly sandy loam; very weak fine crumb; no pores; moist & friable; few medium & fine roots; abundant medium & many coarse hard angular gneiss & quartz gravel; HCl negative:
[Not sampled]

Comment: Soils are loose and crumby structure throughout. These are attributed to faunal activities and the presence of dense and deep tree roots. This is confirmed by high contents of organic matter in top 50 cm. Weak soil horizon developments are due to high rate of colluviation.

SPAL analytical results for BSS Profile PH076 Survey area: Darla

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					
PH076 /1	0 - 10	7727	5.0	3.7	1.3	0.01	3	6.4	0.8	9
PH076										

/2	30 - 40	7728	4.6	3.6	1.0	0.01	1	6.2	0.7	9

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	Extr H	CEC		BS%	
	Ca	Mg	K	Na				AmOAc	ECEC	AmOAc	EBS%
PH076 /1	4.4	0.6	0.4	0.1	5.5	3.8	0.4	9.6	9.7	24	57
PH076 /2	0.6	0.3	0.3	0.1	1.4	7.2	0.6	9.2	9.2	5	15

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PH76	**Nt**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PH76	Nmt	Nt	Nmt	Nmt	Nt	Ncty	Nt	Nct

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PH76	**Nmt**	**Nt**	**Nmt**	**Nm**	**Nmt**	**Nct**	**Nct**	**Nct**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PH76	Nmt	Nmt	Nt	Nt	Nty	Nmty	Nt	Nmt

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PH76	Nt	Nct	Nmt	Nct	Nt	Nt	Nct	Ncmt

Profile: PK126

Map unit	DDS	
Soil classification	Provisional Bhutan soil series: **Yusipang**	
Stony deep soil (DDS)		
	Soil Taxonomy:	Dystric Hapludept *[thermic, loamy - skeletal mixed*]
	WRB:	Dystric Cambisol
Survey area:	**Darla RNR Research subcentre**	
Location:	Ca 25 m south of saw mill	
GPS:	Not done	
Altitude:	Not done	
Described & sampled	25.4.2000, Kado Tshering	
Climate:	General:	Subtropical, P = 3600 mm p.a.
	Recent weather:	Partly cloudy
Regional topography	Low mountains	
Site position	Flat land on spur	
Slope:	20%, convex; 2 k m long +, aspect ESE (120^0)	
Site drainage:	Good	
Parent material:	Solid:	Thimphu Formation
	Drift:	Colluvium
Land use	Abandoned improve pasture land	
Vegetation:	*Trifolium repens; Festruca arundinesia & Lolium multiflorum*	
Surface:	Litter:	None
Outcrops:	None	
Stones:	Many medium & fine angular quartz & schistose gneiss	
	Cracks:	None
Roots:	None	
Microrelief:	Undulant surface	
Faunal activity:	None	
	Other features:	None

Profile description: (colours are moist unless indicated)
cm

0-4 10YR 4/4 (dark yellowish brown) with no mottles; fine sandy loam; root bound crumb; interstitial pores; moist & friable; few medium & abundant grass roots; HCl negative; clear regular boundary to: [Sample PK126/1 @ 0 - 10 cm]

4-20 10YR 4/4 (dark yellowish brown) with common medium distinct reddish brown mottles; very fine sandy clay loam; weak medium - fine subangular blocky breaking to fine crumb; many fine & few medium pores; moist & friable; many fine & medium grass roots; few earthworms; HCl negative; clear regular boundary to: [Not sampled]

20-48 7.5YR 4/6 (strong brown) with no mottles; very fine sandy clay; weak medium - fine subangular breaking to fine crumb; weak discontinuous clayskins; many fine pores; moist &friable; many fine grass roots; few fine quartz gravel; HCl negative; clear regular boundary to: [Sample PK126/ 2 @ 30 - 40 cm]

48-60 Stone line of medium slightly hard & hard subangular quartz, granite & schistose gneiss; interstitial pores; moist & stony; no roots; abundant hard & soft gneiss, schist & granite stones; HCl negative; clear regular boundary to: [Not sampled]

60-88 7.5YR 6/8 (reddish yellow) with no mottles; fine sandy clay loam; weak medium breaking to fine subangular blocky; many fine & common pores; moist & friable; few fine grass roots; few medium & fine quartz gravel; few ants & insects; HCl negative: clear regular boundary to: [Sample PK126/ 3 @ 70 - 80 cm]

88-116 7.5YR 5/8 (strong brown) with no mottles; stony very fine sandy clay loam - fine sandy clay loam; few fine pores; moist & stony; rare fine grass roots; abundant coarse quartz & medium soft gneiss stones; many coarse hard & slightly hard iron & manganese concretions; HCl negative; clear regular boundary to: [Sample PK126/ 4 @ 95 -105 cm]

116-155+ Mixed colour of brown, reddish yellow & grey; stony gravelly sandy clay loam; no pores seen; moist & stony; no roots; abundant hard & soft gneiss, schist & quartzite stones; few coarse & slightly hard iron & manganese concretions; HCl negative: [Not sampled]

Comment**:** Well-weathered rock and multiple colluviation. Soil P.H is liable to be 5.5 and base saturation supposes to have been moderate to high

SPAL analytical results for BSS **Profile PK126** **Survey area: RNRC Darla**

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					
PK126 /1	0 - 10	7729	5.4	3.8	1.6	0.01	1	3.4	0.3	10
/2	30 - 40	7730	5.6	4.0	1.6	0.01	1	1.4	0.2	9
/3	70 - 80	7731	5.8	4.0	1.8	0.01	1	0.4	nd	nd
/4	95 - 105	7732	5.5	3.9	1.6	0.01	1	0.7	nd	nd

Exchangeable base status

BSS No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PK126 /1	2.9	0.1	0.2	0.2	3.3	nd	17.3	nd	19	nd
/2	2.2	0.1	0.2	0.2	2.6	Nd	18.8	nd	14	nd
/3	1.3	0.1	0.1	0.2	1.7	nd	4.3	nd	39	nd
/4	1.5	0.1	0.1	0.2	1.9	nd	6.6	nd	29	nd

Overall Physical Suitability for Crops within Land Utiliisation Types

Wetland

	Chhusing
PK126	**SC3/Nw**

Dryland Staples

	Potato	**Maize**	**Buckwheat**	**Barley**	**Wheat**	**Sorghum**	**Millet**	**Cassava**
PK126	Nm	SC3/Nw	Nm	Nm	SC3/Nwy	Ny	SC3/Nw	SC3/Nm

Tree Crops

	Apples	**Citrus**	**Stone Fruit**	**Walnut**	**Cashew**	**Mango**	**Papaya**	**Betel Nut**
PK126	**Nm**	**S3mwy**	**Nm**	**Nm**	**Nm**	**SC3/Ny**	**S3mwy**	**S3mwy**

Vegetables

	Asparagus	**Chili**	**Egg Plant**	**Tomato**	**Cucumber**	**Onion**	**Brassicas**	**Pulses (beans)**
PK126	Nm	Nm	SC3/Ny	SC3/Nmwy	Ny	Nmy	SC3/Nwy	Nm

Other Crops

	Mustard	**Groundnuts**	**Soybean**	**Ginger**	**Banana**	**Pineapple**	**Sugarcane**	**Strawberry**
PK126	SC3/Nw	SC3/Nmw	Nm	Nm	S3mwy	SC3/Nm	Nc	Nm

Appendix C

Table C.1 Chemical Characteristics of Darla Topsoils

										Exchangeables									Cation Ratios		Cation Ratios			Tonnes / Hectare CaCO3 equivalent		
Series	Site No.	Depth	pH	pH	pH	Avail P	Org C	Total N	C:N	meq / 100g							BS						Depth	Lime Requirement to achieve ASP		
			H2O	KCl	diff	ppm	%	%		Ca	Mg	K	Na	TEB	Al	CEC	ASP	%	C/Mg	Rating	Mg/K	Rating		5%	10%	20%
DDS	PH073	0 - 10	4.60	3.50	1.10	1.00	1.70	0.35	5	0.20	0.40	0.30	0.10	1.00	7.90	23.10	34	4	0.50	Ca deficient	1.33	Mg deficient	0 - 10	13.455	12.69	11.16
		Mean	**4.60**	**3.50**	**1.10**	**1.00**	**1.70**	**0.35**	**5**	**0.20**	**0.40**	**0.30**	**0.10**	**1.00**	**7.90**	**23.10**	**34**	**4**	**0.50**	**Ca deficient**	**1.33**	**Mg deficient**	**Mean**	**13.46**	**12.69**	**11.16**
	PH074	0 -10	4.80	3.80	1.00	1.00	6.70	0.69	10	1.40	0.20	0.30	0.10	2.00	4.40	23.00	19	9	7.00	Mg deficient with P inhibition	0.67	Mg deficient	0 -10	7.38	6.84	5.76
		Mean	**4.80**	**3.80**	**1.00**	**1.00**	**6.70**	**0.69**	**10**	**1.40**	**0.20**	**0.30**	**0.10**	**2.00**	**4.40**	**23.00**	**19**	**9**	**7.00**	**Mg deficient with P inhibition**	**0.67**	**Mg deficient**	**Mean**	**7.38**	**6.84**	**5.76**
	PH076	0 - 10	5.00	3.70	1.30	3.00	6.40	0.80	8	4.40	0.60	0.40	0.10	5.50	3.80	9.60	40	57	7.33	Mg deficient with P inhibition	1.50	Mg deficient	0 - 10	6.048	5.256	3.672
		Mean	**5.00**	**3.70**	**1.30**	**3.00**	**6.40**	**0.80**	**8**	**4.40**	**0.60**	**0.40**	**0.10**	**5.50**	**3.80**	**9.60**	**40**	**57**	**7.33**	**Mg deficient with P inhibition**	**1.50**	**Mg deficient**	**Mean**	**6.05**	**5.26**	**3.67**
	PK126	0 - 10	5.40	3.80	1.60	1.00	3.40	0.30	11	2.90	0.10	0.20	0.20	3.40		17.30		20	29.00	Mg deficient with P inhibition	0.50	Mg deficient	0 - 10			
		\																					\			
		Mean	**5.40**	**3.80**	**1.60**	**1.00**	**3.40**	**0.30**	**11**	**2.90**	**0.10**	**0.20**	**0.20**	**3.40**		**17.30**		**20**	**29.00**	**Mg deficient with P inhibition**	**0.50**	**Mg deficient**	**Mean**			
	Series Mean		**4.95**	**3.70**	**1.25**	**1.50**	**4.55**	**0.54**	**8**	**2.23**	**0.33**	**0.30**	**0.13**	**2.98**	**5.37**	**18.25**	**31**	**22**	**10.96**	**Mg deficient with P inhibition**	**1.00**	**Mg deficient**	**Series**	**6.72**	**6.20**	**5.15**
	Series Rating		**Low**			**VL**	**H**	**H**	**VG**	**L**	**VL**	**M**	**L**	**VL**	**H**	**M**	**VH**	**VL**								
DSM	Pd112	0 - 10	5.30	3.90	1.40	1.00	3.50	0.39	9	1.60	0.40	0.30	0.10	2.40		12.70		19	4.00	OK	1.33	Mg deficient	0 - 10			
		Mean	**5.30**	**3.90**	**1.40**	**1.00**	**3.50**	**0.39**	**9**	**1.60**	**0.40**	**0.30**	**0.10**	**2.40**		**12.70**		**19**	**4.00**	**OK**	**1.33**	**Mg deficient**	**Mean**			
	Series Mean		**5.30**	**3.90**	**1.40**	**1.00**	**3.50**	**0.39**	**9**	**1.60**	**0.35**	**0.20**	**0.10**	**2.40**		**12.70**		**19**	**4.00**	**OK**	**1.33**	**Mg deficient**				
	Series Rating		**Low**			**VL**	**H**	**M**	**VG**	**VL**	**VL**	**L**	**L**	**VL**		**L**		**VL**								
DDC	Pd113	0 - 10	5.20	3.70	1.50	1.00	3.00	0.31	10	0.80	0.10	0.30	0.10	1.30		17.50		7	8.00	Mg deficient with P inhibition	0.33	Mg deficient	0 - 10			
		Mean	**5.20**	**3.70**	**1.50**	**1.00**	**3.00**	**0.31**	**10**	**0.80**	**0.10**	**0.30**	**0.10**	**1.30**		**17.50**		**7**	**8.00**	**Mg deficient with P inhibition**	**0.33**	**Mg deficient**	**Mean**			
	PH072	0 - 9	5.90	4.00	1.90	3.00	3.10	0.31	10	5.40	0.90	1.10	0.10	7.50		17.70		42	6.00	Mg slightly deficient	0.82	Mg deficient	0 - 9			
		Mean	**5.90**	**4.00**	**1.90**	**3.00**	**3.10**	**0.31**	**10**	**5.40**	**0.90**	**1.10**	**0.10**	**7.50**		**17.70**		**42**	**6.00**	**Mg slightly deficient**	**0.82**	**Mg deficient**	**Mean**			
	PH075	0 - 10	5.00	3.80	1.20	1.00	3.20	0.40	8	0.60	0.10	0.10	0.20	1.00	4.70	17.20	27	6	6.00	Mg slightly deficient	1.00	Mg deficient	0 - 10	7.974	7.488	6.516
		Mean	**5.00**	**3.80**	**1.20**	**1.00**	**3.20**	**0.40**	**8**	**0.60**	**0.10**	**0.10**	**0.20**	**1.00**	**4.70**	**17.20**	**27**	**6**	**6.00**	**Mg slightly deficient**	**1.00**	**Mg deficient**	**Mean**	**7.97**	**7.49**	**6.52**
	Series Mean		**5.37**	**3.83**	**1.53**	**1.67**	**3.10**	**0.34**	**9**	**2.27**	**0.37**	**0.50**	**0.13**	**3.27**	**4.70**	**17.47**	**27**	**19**	**6.67**	**Mg slightly deficient**	**0.72**	**Mg deficient**	**Series**	**7.97**	**7.49**	**6.52**
	Series Rating		**Low**			**VL**	**H**	**M**	**VG**	**L**	**VL**	**M**	**L**	**L**	**M**	**M**	**H**	**VL**								
Overall mean for topsoils			**5.15**	**3.78**	**1.38**	**1.50**	**3.88**	**0.44**	**9**	**2.16**	**0.34**	**0.36**	**0.13**	**3.01**	**4.45**	**17.26**	**26**	**21**	**8.48**	**Mg deficient with P inhibition**	**0.94**	**Mg deficient**	**Topsoil**	**6.35**	**5.91**	**5.02**
Overall ratings for topsoils			**Low**			**VL**	**H**	**M**	**VG**	**L**	**VL**	**M**	**L**	**L**	**M**	**M**	**H**	**VL**								

Table C.2 Chemical Characteristics of Darla Subsoils

										Exchangeables									Cation Ratios		Cation Ratios			Tonnes / Hectare CaCO3 equivalent		
Series	Site No.	Depth	pH	pH	pH	Avail P	Org C	Total N	C:N	meq / 100g							BS						Depth	Lime Requirement to achieve ASP		
			H2O	KCl	Diff	ppm	%	%		Ca	Mg	K	Na	TEB	Al	CEC	ASP	%	C/Mg	Rating	Mg/K	Rating		5%	10%	20%
DDS	PH073	80 - 90	5.20	3.80	1.40	1.00	1.50	0.17	9	0.50	0.30	0.10	0.10	1.00	4.70	17.00	28	6	1.67	Ca slightly deficient	3.00	Mg slightly deficient	80 - 90	7.965	7.47	6.48
		140 - 150	4.60	3.80	0.80	1.00	1.00	0.09	11	0.50	0.30	0.10	0.10	1.00	3.90	9.40	41	11	1.67	Ca slightly deficient	3.00	Mg slightly deficient	140 - 150	6.597	6.174	5.328
		Mean	**4.90**	**3.80**	**1.10**	**1.00**	**1.25**	**0.13**	**10**	**0.50**	**0.30**	**0.10**	**0.10**	**1.00**	**4.30**	**13.20**	**35**	**8**	**1.67**	**Ca slightly deficient**	**3.00**	**Mg slightly deficient**	**Mean**	**7.28**	**6.82**	**5.90**
	PH074	30 - 40	5.10	3.80	1.30	1.00	2.80	0.29	10	0.90	0.10	0.20	0.10	1.30	6.40	20.40	31	6	9.00	Mg deficient with P inhibition	0.50	Mg deficient	30 - 40	10.854	10.188	8.856
		Mean	**5.10**	**3.80**	**1.30**	**1.00**	**2.80**	**0.29**	**10**	**0.90**	**0.10**	**0.20**	**0.10**	**1.30**	**6.40**	**20.40**	**31**	**6**	**9.00**	**Mg deficient with P inhibition**	**0.50**	**Mg deficient**	**Mean**	**10.85**	**10.19**	**8.86**
	PH076	30 - 40	4.60	3.60	1.00	1.00	6.20	0.70	9	0.60	0.30	0.30	0.10	1.30	7.20	9.20	78	14	2.00	Ca slightly deficient	1.00	Mg deficient	30 - 40	12.231	11.502	10.044
		Mean	**4.60**	**3.60**	**1.00**	**1.00**	**6.20**	**0.70**	**9**	**0.60**	**0.30**	**0.30**	**0.10**	**1.30**	**7.20**	**9.20**	**78**	**14**	**2.00**	**Ca slightly deficient**	**1.00**	**Mg deficient**	**Mean**	**12.23**	**11.50**	**10.04**
	PK126	30 - 40	5.60	4.00	1.60	1.00	1.40	0.20	7	2.20	0.10	0.20	0.20	2.70		18.80		14	22.00	Mg deficient with P inhibition	0.50	Mg deficient	30 - 40			
		70 - 80	5.80	4.00	1.80	1.00	0.40			1.30	0.10	0.10	0.20	1.70		4.30		40	13.00	Mg deficient with P inhibition	1.00	Mg deficient	70 - 80			
		95 - 105	5.50	3.90	1.60	1.00	0.70			1.50	0.10	0.10	0.20	1.90		6.60		29	15.00	Mg deficient with P inhibition	1.00	Mg deficient	95 - 105			
		Mean	**5.63**	**3.97**	**1.67**	**1.00**	**0.83**	**0.20**	**7**	**1.67**	**0.10**	**0.13**	**0.20**	**2.10**		**9.90**		**28**	**16.67**	**Mg deficient with P inhibition**	**0.83**	**Mg deficient**	**Mean**			
	Series Mean		**5.06**	**3.79**	**1.27**	**1.00**	**2.77**	**0.33**	**9**	**0.92**	**0.20**	**0.18**	**0.13**	**1.43**	**5.97**	**13.18**	**48**	**14**	**7.33**	**Mg deficient with P inhibition**	**1.33**	**Mg deficient**	**Series**	**10.12**	**9.50**	**8.27**
	Series Rating		**Low**			**VL**	**M**	**M**	**VG**	**VL**	**VL**	**L**	**L**	**VL**	**H**	**L**	**VH**	**VL**								
DSM	Pd112	35 - 45	5.60	3.80	1.70	1.00	0.90	0.37	2	0.60	0.10	0.10	0.10	0.90		10.60		8	6.00	Mg slightly deficient	1.00	Mg deficient	35 - 45			
		Mean	**5.60**	**3.80**	**1.70**	**1.00**	**0.90**	**0.37**	**2**	**0.60**	**0.10**	**0.10**	**0.10**	**0.90**		**10.60**		**8**	**6.00**	Mg slightly deficient	**1.00**	**Mg deficient**	**Mean**			
	Series Mean		**5.60**	**3.80**	**1.70**	**1.00**	**0.90**	**0.37**	**2**	**0.60**	**0.10**	**0.10**	**0.10**	**0.90**		**10.60**		**8**	**6.00**	**Mg slightly deficient**	**1.00**	**Mg deficient**				
	Series Rating		**Mod**			**VL**	**L**	**M**	**VG**	**VL**	**VL**	**L**	**L**	**VL**		**L**		**VL**								
DDC	Pd113	40 -50	5.60	3.80	1.80	1.00	0.80	0.12	7	0.80	0.20	0.30	0.10	1.40		18.80		7	4.00	OK	0.67	Mg deficient	40 -50			
		70 - 80	5.60	3.70	1.90	1.00	6.00	0.97	6	0.80	0.20	0.30	0.10	1.40		17.20		8	4.00	OK	0.67	Mg deficient	70 - 80			
		110 - 120	5.60	3.80	1.80	1.00	0.40			0.60	0.20	0.20	0.10	1.10		18.80		6	3.00	OK	1.00	Mg deficient	110 - 120			
		140 - 150	5.60	3.70	1.90	1.00	0.40			0.40	0.10	0.20	0.10	0.80		13.30		6	4.00	OK	0.50	Mg deficient	140 - 150			
		Mean	**5.60**	**3.75**	**1.85**	**1.00**	**1.90**	**0.55**	**6**	**0.65**	**0.18**	**0.25**	**0.10**	**1.18**		**17.03**		**7**	**3.75**	**OK**	**0.71**	**Mg deficient**	**Mean**			
	PH072	40 - 50	6.10	4.00	2.10	1.00	0.80	0.13	6	3.50	0.90	1.20	0.10	5.70		18.80		30	3.89	OK	0.75	Mg deficient	40 - 50			
		72 -82	5.80	3.90	1.90	1.00	0.70	0.11	6	2.10	0.50	0.80	0.10	3.50		15.80		22	4.20	OK	0.63	Mg deficient	72 -82			
		100 - 110	5.60	3.80	1.80	1.00	0.30	0.06	5	1.90	0.40	0.60	0.10	3.00		10.00		30	4.75	OK	0.67	Mg deficient	100 - 110			
		Mean	**5.83**	**3.90**	**1.93**	**1.00**	**0.60**	**0.10**	**6**	**2.50**	**0.60**	**0.87**	**0.10**	**4.07**		**14.87**		**27**	**4.15**	**OK**	**0.69**	**Mg deficient**	**Mean**			
	PH075	35 - 45	5.10	3.80	1.30	1.00	3.20	0.30	11	0.80	0.10	0.20	0.10	1.20	4.70	13.70	34	9	8.00	Mg deficient with P inhibition	0.50	Mg deficient	35 - 45	7.956	7.452	6.444
		75 - 85	4.90	3.70	1.20	1.00	3.10	0.40	8	0.80	0.10	0.10	0.10	1.10	5.90	20.70	29	5	8.00	Mg deficient with P inhibition	1.00	Mg deficient	75 - 85	10.008	9.396	8.172
		Mean	**5.00**	**3.75**	**1.25**	**1.00**	**3.15**	**0.35**	**9**	**0.80**	**0.10**	**0.15**	**0.10**	**1.15**	**5.30**	**17.20**	**31**	**7**	**8.00**	**Mg deficient with P inhibition**	**0.75**	**Mg deficient**	**Mean**	**8.98**	**8.42**	**7.31**
	Series Mean		**5.48**	**3.80**	**1.68**	**1.00**	**1.88**	**0.33**	**7**	**1.32**	**0.29**	**0.42**	**0.10**	**2.13**	**5.30**	**16.36**	**31**	**14**	**5.30**	**Mg slightly deficient**	**0.72**	**Mg deficient**	**Series**	**8.98**	**8.42**	**7.31**
	Series Rating		**Low**			**VL**	**M**	**M**	**VG**	**VL**	**VL**	**M**	**L**	**VL**	**H**	**M**	**VH**	**VL**								
Overall mean for subsoils			**5.28**	**3.80**	**1.48**	**1.00**	**2.20**	**0.34**	**7**	**1.03**	**0.22**	**0.26**	**0.11**	**1.62**	**4.97**	**14.05**	**44**	**13**	**6.40**	**Mg slightly deficient**	**1.06**	**Mg deficient**	**Subsoils**	**9.84**	**9.23**	**8.03**
Overall ratings for subsoils			**Low**			**VL**	**M**	**M**	**VG**	**VL**	**VL**	**L**	**L**	**VL**	**H**	**L**	**VH**	**VL**								

Rating Codes:	**VH**	**H**	**M**	**L**	**VL**	
	Very high	High	Modera	Low	Very low	
Ratings source:	Soil Survey Handbook for Bhutan., BSS, NSSC Semtokha, Ministry of Agriculture, Bhutan, November 2000					

APPENDIX D CORRELATION WITH INTERNATIONAL CLASSIFICATION

D.1 Soil classification and correlation in Bhutan.

Table 5.4 in the main report summarises the correlation of the Darla soil classes with the international soil classifications. This appendix discusses the reasons for the correlations assigned.

D.2 General criteria

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

D.2.1 Soil moisture regime.

This is necessary for the assignment to suborders or great groups in Soil Taxonomy. In the absence of soil moisture data, soil moisture regimes are normally approximated from rainfall totals and distribution. The Gedu climatic data indicate that Darla has an atmospheric climate that is likely to give an udic soil moisture regime, which is defined as having less than 90 consecutive dry days per year and having a summer rainfall distribution. All of the soils at Darla are assigned udic soil moisture regimes, except for the poorly drained soils (DHG). These have an aquic moisture regime, which refers to soils that are permanently wet for most of the year, due to their topographic position.

D.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. The atmospheric temperature regime at Gedu appears to be on the margin between mesic and thermic. As Darla is 200-300 m lower in altitude, the soils at Darla are assigned thermic soil temperature regimes, i.e. annual means between 15 and 22^{o} C, and summer-winter difference of monthly means greater than 5^{o} C.

D.2.3 Mineralogy class

Although mica is a visible component in all of the soils at Darla, 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.

D.2.4 Particle size class.

This varies with stone content and fine earth texture. The deep clays (DDC) and many of the of other soils at Darla are clay PSC. The stony soils (DDS and DSM) are in the clay-skeletal or loamy – skeletal classes.

D.3 International correlations of Darla RNR-RSC soil classes

D.3.1 Deep clay (DDC)

Most of the soils in this class have increases in clay content with depth and also some clay skins on the surfaces of subsoil peds, and can probably therefore be correlated with international classes that require argillic horizons. However the textural profiles of these soils may have been influenced by the addition of substantial quantities of windblown dust. This is almost entirely comprised of coarse silt and very fine sand, and dilutes the clay content of the upper horizons. The proportion of clay

therefore increases with depth, away from the aeolian influence, and gives a false impression of argilluviation. Nonetheless these soils are correlated with Acrisols in WRB and Hapludults in ST. They probably mostly qualify for the typical classes (known as haplic in WRB and typic in ST).

Those soils without argillic horizons are highly weathered, and qualify as Cambisols in WRB and Hapludepts in ST (in the dystric subclasses in both systems).

D.3.2 Deep stony soils (DDS)

Most of these soils are correlated with the Cambisols in WRB and the Hapludepts in ST. Because their base saturations are below 50%, they qualify for the dystric subclasses. A few have sufficient increases in clay content and visible clayskins to qualify as Haplic Acrisols in WRB and Typic Hapludults in ST.

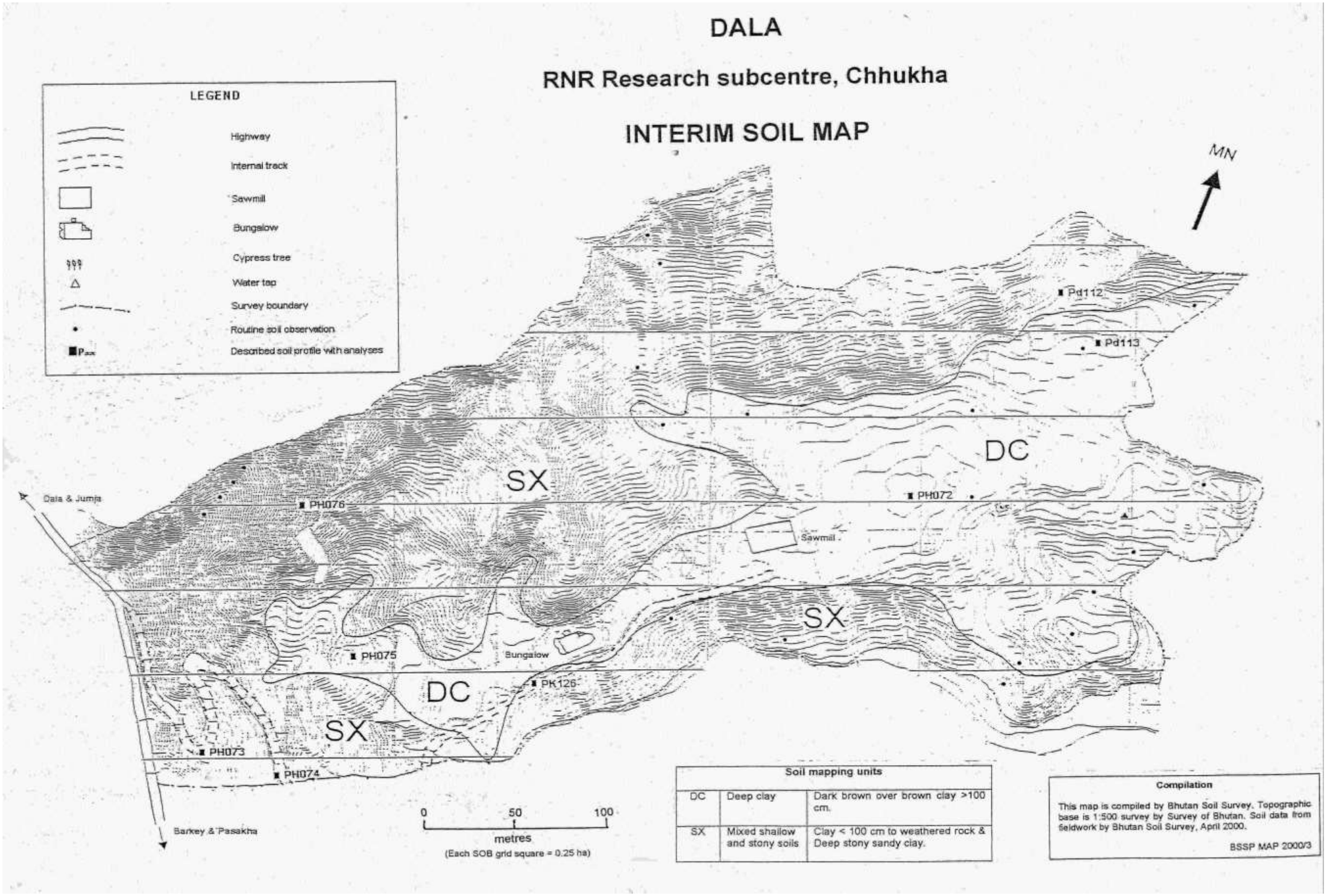
D.3.3 Shallow and moderately deep soils (DSM)

All of these soils are correlated with Dystric Cambisols in WRB and Dystric Hapludepts in ST.

D.3.4 Hill gley (DHG)

The moderately impeded drainage is the main criterion in these soils. They lack well developed gley colours and do not qualify as Gleysols in WRB or Aquepts in ST. They are best correlated with the Gleyic Acrisols in WRB and the Aquic Hapudults in ST.

APPENDIX E Interim Soil Map



APPENDIX F Physical Land Suitability

Table F.1 Summary of Ratings for Chhusing

Map Unit / SeriesSites, Soil Series or Map Unit names or numbers	Chhusing
	OVERALL CLASSIFICATION
(Sample data)	Ndm
PD112	S3cdy
PD113	S3cdy
PH72	S3d
PH73	S3dmy
PH74	Nw
PH75	S3dmty
PH76	Nt
PK126	SC3/Nw

Notes:

Class	Description
S1	Highly suitable, no limitations
S2	Moderately suitable
S3	Marginally suitable
SC3	Conditionally suitable
N	Not suitable

Suffix Code	Limitation
c	CLIMATE: Altitude & aspect
d	DRAINAGE: Soil drainage class
f	FLOOD RISK
m	MOISTURE: Rainfall, soil depth, soil texture, water supply
t	TOPOGRAPHY: gradient, erosion, erodability
w	WORKABILITY: stone and rock contents
y	FERTILITY: Cation Exchange, Base Saturation, Ph, Aluminium Saturation

Table F.2 Summary of Ratings for Dryland Staples

	Summary LUT 2							
	Potato	Maize	Buckwheat	Barley	Wheat	Sorghum	Millet	Cassava
Map Unit / Series	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION
Bhur	Ncm	S3cmwy	S3cmwy	Ncm	SC3/Nc	SC3/Ny	S3cmwy	S3cmwy
PD112	Nm	SC3/Nc	Nm	Nm	SC3/Ny	Ncy	S3cty	Nc
PD113	Nm	SC3/Nc	Nm	Nm	SC3/Ny	Ncy	SC3/Nm	Nc
PH72	Nm	S2fmy	Nm	Nm	S3my	Nc	S3cy	Nc
PH73	Nm	SC3/Ny	Nm	Nmy	Ny	Ncy	SC3/Ny	Nc
PH74	Nmw	Nw	Nm	Nmwy	Nwy	Ncy	SC3/Nwy	Nc
PH75	Nm	S3mty	Nm	Nm	SC3/Ny	Ncy	S3cmty	Nc
PH76	Nmt	Nt	Nmt	Nmt	Nt	Ncty	Nt	Nct
PK126	Nm	SC3/Nw	Nm	Nm	SC3/Nwy	Ny	SC3/Nw	SC3/Nm

Table F.3 Summary of Ratings for Tree Crops

Summary LUT 3	Apples	Citrus	Stone Fruit	Walnut	Cashew	Mango	Papaya	Betel Nut
Map Unit / Series	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION
Bhur (Sample)	**Ncm**	**S3mwy**	**Ncm**	**Ncm**	**Ncm**	**S3fmwy**	**S3cmy**	**S3mwy**
PD112	**Nm**	**Nc**	**Nm**	**Nm**	**Ncm**	**SC3/Nmy**	**Nc**	**Nc**
PD113	**Nm**	**Ncm**	**Nm**	**Nm**	**Ncm**	**SC3/Ny**	**Nc**	**Nc**
PH72	**Nm**	**S3c**	**Nm**	**Nm**	**Nm**	**S3c**	**Nc**	**Nc**
PH73	**Nmy**	**SC3/Ny**	**Nm**	**Nm**	**Nm**	**Ncy**	**Nc**	**Nc**
PH74	**Nmy**	**SC3/Nwy**	**Nm**	**Nm**	**Nm**	**Ncy**	**Nc**	**Nc**
PH75	**Nm**	**S3cty**	**Nm**	**Nm**	**Nm**	**SC3/Ny**	**Nc**	**Nc**
PH76	**Nmt**	**Nt**	**Nmt**	**Nm**	**Nmt**	**Nct**	**Nct**	**Nct**
PK126	**Nm**	**S3mwy**	**Nm**	**Nm**	**Nm**	**SC3/Ny**	**S3mwy**	**S3mwy**

Table F.4 Summary of Ratings for Vegetables

Summary LUT 4	Asparagus	Chili	Egg Plant	Tomato	Cucumber	Onion	Brassicas	Pulses (beans)
Map Unit / Series	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION
Bhur sample data	**Ncm**	**S3wmy**	**S3mwy**	**S3cmwy**	**Ny**	**Nm**	**SC3/Nw**	**S3cmwy**
PD112	Nm	Nm	SC3/Ncy	SC3/Ny	Ny	Nmy	SC3/Ny	Nm
PD113	Nm	Nm	SC3/Ncy	SC3/Nmy	Ny	Nmy	SC3/Ny	Nm
PH72	Nm	Nm	SC3/Nc	S3m	Ny	Nm	S2my	Nm
PH73	Nm	Nm	Ny	Ny	Ny	Nmy	Ny	Nmy
PH74	Nmw	Nm	Ncy	Ntwy	Nwy	Nmwy	Ny	Nmwy
PH75	Nm	Nm	SC3/Ncy	Nt	Ny	Nmy	SC3/Ny	Nm
PH76	Nmt	Nmt	Nt	Nt	Nty	Nmty	Nt	Nmt
PK126	Nm	Nm	SC3/Ny	SC3/Nmwy	Ny	Nmy	SC3/Nwy	Nm

0

Table F.5 Summary of Ratings for Other Crops

Summary LUT 5	Mustard	Groundnuts	Soybean	Ginger	Banana	Pineapple	Sugarcane	Strawberry
Map Unit / Series	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION	OVERALL CLASSIFICATION
Bhur	S3wmy	SC3/Mw	Ncm	S3cmwy	S3mwy	S3cmwy	S3cmwy	Ncm
PD112	S3cy	Nc	Nm	Nc	S3cty	SC3/Nc	Nc	Ncm
PD113	S3cmy	Ncm	Nm	Ncm	S3cmy	Nm	Nc	Ncm
PH72	S3y	Nc	Nm	Nc	S3c	S3cm	Nc	Ncm
PH73	S3y	Nc	Nm	Nc	S3cty	SC3/Ny	Nc	Ncm
PH74	Nw	Ncw	Nm	Ncm	SC3/Ntw	SC3/Nmwy	Nc	Ncmw
PH75	S3my	Nc	Nm	Nc	SC3/Nt	S3cmty	Nc	Ncm
PH76	Nt	Nct	Nmt	Nct	Nt	Nt	Nct	Ncmt
PK126	SC3/Nw	SC3/Nmw	Nm	Nm	S3mwy	SC3/Nm	Nc	Nm

For a full explanation of the ratings system please refer to BSS Working Paper 9c, Physical Land Suitability.