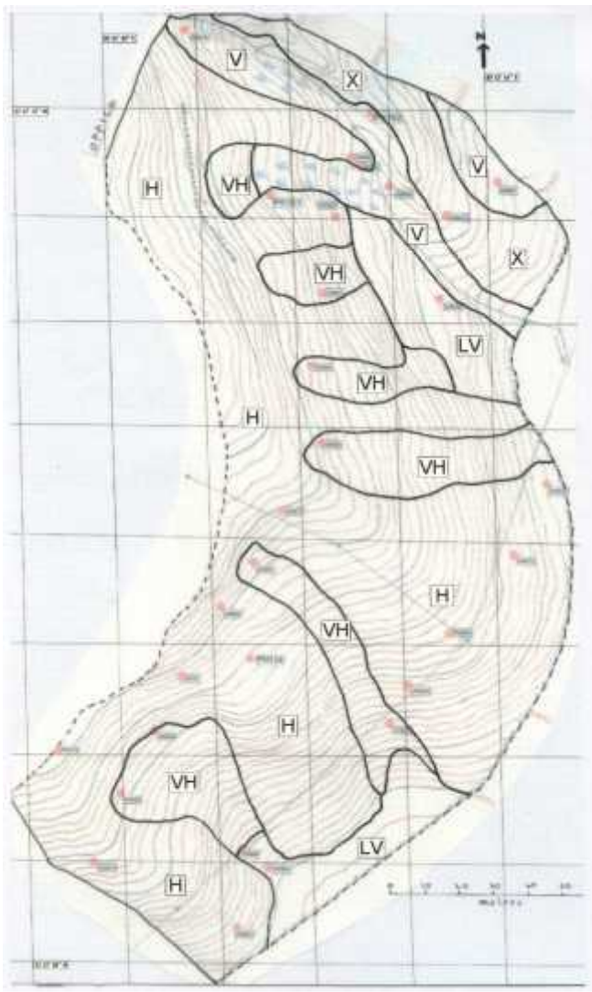
Royal Government of Bhutan
Bhutan Soil Survey
National Soil Services Centre, Semtokha
Department of Research and Development Services
Ministry of Agriculture

YUSIPANG DEMONSTRATION PLOT



Soil Survey Report SS16

February 2002 / Update of 30 May 2003

SUMMARY

S.1 Background

This is the Technical Report of a very detailed soil survey of part of the Yusipang, RNR Sub-centre. In the past BSS has also produced a report of the detailed survey of the whole station – BSS Report No 1a, August 1998.

The survey was requested by RNR-RC Yusipang to allow planning and development of the lower part of the station since the original survey and map did not supply quite enough information due to the scale of the original study.

The survey was completed over three days in November 2001. A draft map of the surveyed area was issued in early December 2001 to allow initial planning to start. The publication of this report has been delayed awaiting completion of analytical studies by the Soil and Plant Analytical Laboratory (SPAL). All data from the field survey were entered into the BSS database – BHUSOD, Bhutan Soil Databank.

This should be looked upon as an addendum to the original report and contains no, or little, repetition of information contained in that original report. For data on geology etc reference should be made to BSS Report 1a, 1998.

A further addendum was done in May 2003 when the results for available moisture holding capacity (AWHC) became available. Samples for AWHC were taken when "Soil Monoliths" were collected for the RNR-Expo held during March 2003.

S.2 Location and Environment

The RNR-RC farm is located about 8 kilometres by road northeast of the Simtokha junction on the main Thimphu – Chhuzom east-west highway. The whole RNR-RC centre covers about 95 ha (235 acres). The present soil survey covers 2.32 ha (5.73 acres) and is located between 27^{o} 27' 28" to 27^{o} 27' 37" N and 89^{o} 42' 40" to 89^{o} 42' 44" E.

The survey area has a predominantly south easterly to south-south easterly aspect, lies between 2,480m and 2,530m with annual precipitation of around 800mm and is in the provisionally defined cold temperate climatic zone. Information on temperatures and rainfall can be obtained form the original survey report.

The area surveyed is generally moderately steep to very steep, with most of the area very steep on convex to concave slopes of 30 – 57% gradient, though on the footslopes and in valleys gradients are less.

Most of the area comprises degraded dryland terraces carrying scrub grassland and abandoned orchard trees.

S.3 Soils

The Demonstration Plot contains a limited range of soils, on account of the small size of the area and homogeneous geology. All of the soils are virtually gravel free, slightly acid (pH 6.3) to very acid (pH 4.85) with most of the topsoils of the well-drained soils being slightly acid (average pH 5.8) whilst the subsoils are very acidic (average pH 5.38). The topsoils of the poorly drained unit are very acid (average pH 5.33) whilst the subsoils here are slightly acidic (average pH 6.04) – this is to be expected in flooded soil as pH always increases to near neutral in such situations. Contents of organic carbon are moderate in topsoils (1.3%) and low (0.9%) in subsoils whilst total nitrogen is low (0.10%) to very low (0.08%) in top and subsoils respectively. Overall fertility potential and inherent fertility can be classified as poor and there is an indicated deficiency of magnesium.

Inherent, or existing, fertility is measured by the levels of exchangeable cations, total exchangeable bases, base saturation and levels of organic carbon, total nitrogen and available phosphate. Overall, both topsoils and subsoils are rated as having low to very low inherent fertility.

Fertility potential, or the ability of the soil to retain any added nutrients rather than allow them to be leached out, is assessed by the cation exchange capacity (CEC) of the soil. Overall the soils in this area all have low

fertility potential in that CEC is rated low in both top and subsoils with overall average values of 9.3 and 7.7 me/100g in topsoil and subsoil respectively. Fertility potential could be improved by the application and incorporation by ploughing-in of FYM.

Overall, application of FYM would improve the existing fertility status, improve the fertility potential and would, most likely, also assist with the reduction of soil reaction / acidity (pH).

AWHC values are acceptable and the soils apparently could hold sufficient moisture for normal plant growth. However, the moisture release curves show that the subsoils generally tend to hold the stored moisture quite strongly and plant could have difficulty accessing and using this moisture – the plants would then suffer moisture stress. Similarly, many of the soils have high bulk density (BD) in the subsoil and this indicates compaction and poor porosity – features which do not favour plant growth.

The problems of BD, porosity and moisture release could be ameliorated by digging very deep planting holes and refilling with soil which has more favourable characteristics.

S.4 Physical Land Suitability

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. 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.

BSS has developed a series of spreadsheets incorporating “look-up tables” where all one has to do is insert the relevant physical data on altitude, aspect, slope etc. (these data being held in BHUSOD and easily extracted) into the spreadsheet table and classification is done automatically. This process removes the possible effects of operator error – however it is dependent on the physical 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. The suitability classes used are as below.

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 S.1 Suitability Classes

Suitability Class	Description	Input Level Required for Acceptable Yields / Crops
Class S1	Highly suitable	Low
Class S2	Moderately suitable	Moderate inputs of land shaping, anti-erosion measures husbandry, nutrients, ameliorants or water required
Class S3	Marginally suitable	High levels of land shaping, 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)

The present survey was requested to allow detailed planning for planting of unspecified tree crops to be done. Since the specific crops under consideration by the RNR-RC were not advised to BSS the physical land suitability classification has been done only for use of the land under LUT 3.

Table S.3 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

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. Otherwise, without some major inputs in the form of land shaping, water supply and addition of soil amendments, such as FYM and liming materials , much of this area remains classified as unsuitable under the BSS system.

S.5 Implications of results

The RNR-RC will develop this area further with external help and the present assessment of physical land suitability may help in the selection of crops and inputs required to overcome the risk factors identified during this survey.

Necessary inputs could well include:

- Land shaping or forming to overcome the problems of steep slopes
- Use of supplementary irrigation or water harvesting techniques to help overcome the effects of limited rainfall
- Installation of soil drains to remove the excess groundwater in the valley unit, if this unit is to be used
- Installation of flood protection measures if areas close to the existing stream line are used
- Application of FYM and or liming materials to increase soil reaction (pH) to create a more suitable root zone
- Application of FYM to increase the fertility and fertility potential, some of the FYM should be applied at depth to help improve the main uptake zone of tree roots – if trees are to be planted
- Application of dolomite to address the apparent deficiency of magnesium

This is one the first attempts that BSS has made to produce physical land evaluation or land suitability based on survey data and it must be understood that this is a test of the BSS system as much as a report on the soils of the area. If the criteria used in the BSS evaluations are incorrect in any way then they will not give a true reflection of the suitability of the site. However, it is already known that several ventures on the site have been less than successful, or sustainable, suggesting that perhaps the BSS ratings are not totally incorrect.

BSS will welcome any feedback and constructive criticism this report and mapping may generate since feedback will allow BSS to refine and develop the assessment system.

ABBREVIATIONS and GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic absorption spectrophotometery
Acre	Area of measurement, = 0.405 ha
aeolian	Windblown deposit. Usually high in coarse silt and very fine sand, i.e. 20-100 microns, stone-free, and sometimes ultraporous
Alluvial fan	Poorly stratified and sorted material deposited on floor of side valley
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
asl	Above sea level
ASP	Aluminium Saturation Percentage
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)
AWP	Army Welfare Project
BHUSOD	Bhutan Soil Databank
BSS	Bhutan Soil Survey
BS%	Base saturation percentage
C	Clay (finest mineral particles in soils, > 2um in diameter, important store for some nutrients and water, make soils sticky & heavy to work)
ca	Approximately
CEC	Cation exchange capacity
Chhuzhing, chhushing	Terrace Irrigated paddy rice land
CL	Clay loam
cm	Centimetre
Colluvium	Local hillwash, moved by surface erosion and slow non-glacial creep processes.
Complex	Soil mapping unit with several co-equal soil classes.
Concave	Slope form of dip on slope, with steep gradient upslope and gentle gradient downslope. Tends to accumulate water & be imperfectly or poorly drained.
Consociation	Soil mapping unit with one soil class dominant but others as minor constituents.
Convex	Slope form of protuberance on slope, with gentle gradient upslope and steep gradient downslope. Tends to shed water & be droughty.
Creep	Slow gravitational mass movement of colluvium downslope.
Crotovina	see 'krotovina'
CV	*Curriculum vitae* (= biodata)
Ccv	Concave
Cvx	Convex
Danida	Danish International Development Assistance.
dbms	Database management system (Database)
DRDS	Department of Research and Development Services of MoA (formerly REID)
DSC	Druk Seed Company
EBS%	Effective base saturation (= TEB/ECEC)
EC	Electrical conductivity
ECEC	Effective cation exchange capacity (=TEB + Extr Al + Extr H)
Eluvial	Soil horizon formed by the washing out of some components
ET	Evapotranspiration
Evapotranspiration	Sum of evaporation from soil and other surfaces, and transpiration from leaves
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
FC	Field capacity (MC% at suction of 0.1 atmospheres)
Fine earth	Soil particle size < 2mm
FeMn	Ferri-managaniferous, dark red - reddish brown - black stains and soft concretions with high contents of ferric iron and manganese in horizons with seasonally impeded drainage
Freely drained	Soils in which most large pores drain their water soon after rain or irrigation at all times of the year. Identified by moist or dry feel, and warm brown, reddish or yellowish colours and absence or grey, rust or orange mottles
FYM	Farmyard manure

GIS	Geographical information system
Gley	Soil that is permanently wet, poorly aerated and has predominantly greyish colours, due to reduction of free iron to ferrous valency state. May have local oxidising conditions giving rust - coloured mottles, especially around root channels.
GLCE	General land capability evaluation
GPS	Global positioning system
GSI	Geological Survey of India
ha	Hectare
HCl	Hydrochloric acid
Horizon	Soil layer
Illuvial	Soil horizon formed by enrichment of some components washed in from eluvial horizon(s) above
ID	Imperfectly drained (soil)
Imperfectly drained	Soils in which most large pores drain their water soon after rain or irrigation for much of the year, but remain filled for long spells in summer Identified by moist or wet feel, and grey or brown colours and many grey, rust or orange mottles.
In situ	In original position or place (Latin)
Interfluve	Land between two rivers, include halves of two valleys and ridge between them, (from Latin *inter* = between, *fluvius* = river)
Kamzhing, Kamshing	Rainfed agriculture
Knickpoint	Steep section in long profile of river bed, separating 2 concave sections
L	Loam (Mixed soil with substantial quantities of all three particle size classes, i.e. clay, silt and sand)
Lamella (pl. = –ae)	Discontinuous horizontal subsoil layer or lens of deposited silt or clay (usually from deposition of parent material, not argilluviation)
LC	Land conversion (from wetland rice to other uses)
LS	Land Suitability
LUSS	(current) Land Use and Statistics Section, in PPD
MD / MWD	Moderately well drained (soil)
Mag	Magnetic (for bearings)
MC%	Moisture content % (w/w)
MLT	Miscellaneous Land Type
Munsell	System of standard soil colour notation, operated by matching soil against standard charts. Colour described by 'hue' (Spectral composition, red, yellow, blue, green); 'value' (dilution with white), & 'chroma' (darkness)
NA	Not applicable / Not applied
ND	No data / Not Determined
NPM	National Project Manager
NS	Not sampled (in soil profile descriptions)
NSSC	National Soil Services Centre, DRDS, Semtokha
OC	Organic carbon
OM	Organic matter
Panzhing, Panshing	Rotational cultivation with heaping and burning of high OM topsoils
P	Phosphate
PD	Poorly drained (soil)
PM	(Soil) Parent Material
Pptn	Precipitation, rainfall
pH	Measure of acidity - alkalinity
Profile	Sequence of horizons from surface down to unaltered parent material
Rectilinear	Straight slope with more or less similar gradients up- and downslope
Ri	Stream or river (Sharchop)
RNR-RC	Renewable Natural Resource – Research Centre
SCB	Soil classification of Bhutan
Series	Main group of soil classes in Bhutan. Also sixth highest level of subdivision in USDA Soil Taxonomy.
Shrub	Broad-leaved plant with short woody stem, generally < 8 m high
Si / Z	Silt (intermediate sized mineral particles in soils, 2 - 50 um in diameter, important store for plant available water, make soils slippery & vulnerable to surface erosion and capping, aka Z, Zi)
SK	Sinclair Knight (authors of first known soil survey in Bhutan)
SMR	Soil Moisture Regime, defined in Soil Taxonomy
SMU	Soil mapping unit

SoB	Survey of Bhutan
Sokshing	Forest from which needle or leaf litter is collected for livestock bedding and FYM.
Solifluction	Summer movement of saturated thawed surface material over top of permanently frozen subsoil. Occurs in periglacial conditions
Solum	True soil, in which soil processes have removed many traces of parent material structures.
sp, spp	Species (singular & plural)
SPAL	Soils and Plant Analysis Laboratory, NSSC, DRDS, Semtokha.
Spur	Plunging ridge off side of mountain or main ridge down to valley, alternates with re-entrants
SS	Soil Surveyor
SSS	Senior Soil Surveyor
SSF& PNMP	Sustainable Soil Fertility & Plant Nutrition Management Project, NSSC, DRDS.
SS&LRP	Soil Survey and Land Resources Project (now BSS)
ST	Soil Taxonomy (USDA system of soil classification)
STR	Soil temperature regime, defined in Soil Taxonomy
Surface wash	Movement of individual surface soil particles by running surface water.
SWXD / SXD	Somewhat excessively well drained (soil)
Tr	Trace
TEB	Total exchangeable bases (= exchangeable Ca + Mg + Na + K)
Terrace, river	Bench along side of river valley where old alluvium has been left by downcutting of river bed
Terrace	Flat field created by leveling sloping land. Used for wetland rice, & enclosed by bund to retain irrigation water.
TN	Total nitrogen
USDA	United States Department of Agriculture
VPD	Very poorly drained (soil)
WD	Well drained (soil)
WT	Water table
XD / XWD	Excessively well drained (soil)
Z, Zi	Silt (intermediate sized mineral particles in soils, 2 - 50 um in diameter, important store for plant available water, make soils feel slippery & vulnerable to surface erosion and capping, aka Si)

1 INTRODUCTION

This is the technical report of the very detailed soil survey of the lower part, Demonstration Plot, of the Yusipang RNR-RC farm. It is intended for those who wish to know about the soils in detail, and includes soil profile descriptions and chemical analyses.

1.1 Background

Bhutan Soil Survey (BSS) carried out a detailed soil survey of the whole farm area in 1998 and that survey is reported in BSS Report 1a, August 1998. In November 2001 BSS was requested to look at the area of the demonstration plat in more detail to allow detailed planning and development of the area.

1.2 Aims of the soil survey of Demonstration Plot

The very detailed soil survey covered only a minor part of the RNR-RC area and was undertaken with the objectives of:

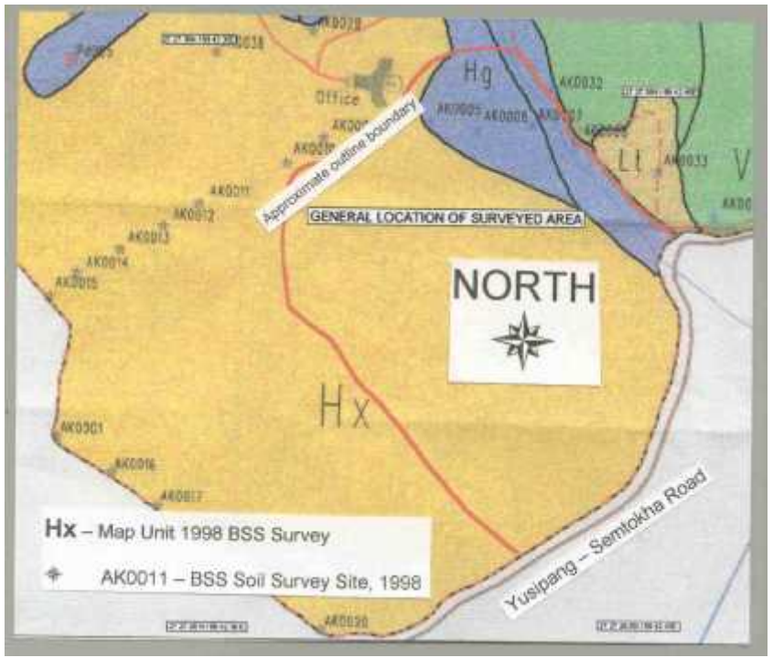
- Providing detailed information on the nature and distribution of soils.
- Providing BSS with further data for the development of national soil classification, and to build up a base of national and regional soil maps.
- Provide a soil map of about 1:1,000 scale
- Provide a provisional physical land suitability assessment to enable the station to plan their usage of the farm

2 THE SURVEY AREA

2.1 Location and extent

The Yusipang RNR-RC is located about 8 kilometres by road north east of the Semtokha Junction on the Thimphu to Chhuzom main east west highway. The location of the present survey site is on the lower edge of the original survey area, just above the highway and is shown in Figure 2.1. Figure 2.1 is compiled on an extraction of the 1998 BSS soil map and the area surveyed lies southeastwards of the offices marked in Figure 2.1.

Figure 2.1 Location



The whole RNR-RC centre covers about 95 ha (235 acres). The present soil survey covers 2.32 ha (5.73 acres) and is located between 27^{o} 27’ 28” to 27^{o} 27’ 37” N and 89^{o} 42’ 40” to 89^{o} 42’ 44” E.

The survey area has a predominantly south easterly to south-south easterly aspect, lies between 2,480m and 2,530m and is in the provisionally defined cold temperate climatic zone.

The area surveyed is generally moderately steep to steep with convex to concave slopes of 30 – 50% gradient, though on the footslopes and in valleys gradients are less. The steepness of the area can be seen in Figure 2.2 which presents a copy of the topographic map produced for the study – note this figure is not to scale.

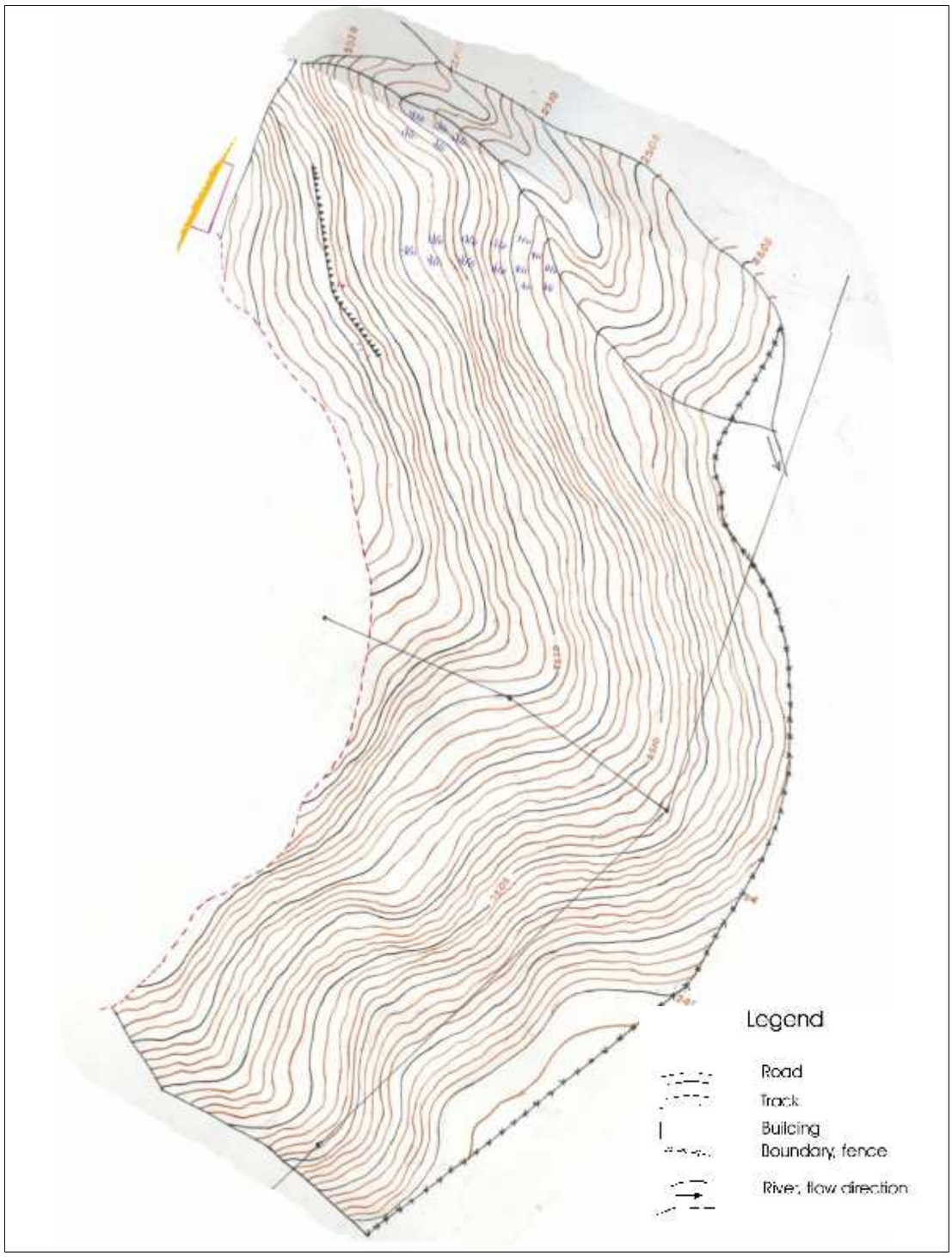
2.2 Climate

Information on temperatures and rainfall can be obtained form the original survey report but annual precipitation is in the order of 800mm and the site is classified as falling in the cold temperate climatic zone.

2.3 Geology and soil parent materials

The survey area is noted as lying on the Thimphu Gneiss formation and a fuller description can be found in the original report. Parent materials of the area studied were largely comprised of unconsolidated deposits of a colluvial nature.

Figure 2.2 Demonstration Area Contour Map



2.4 Topography and drainage

Most of the survey area comprises mid and lower slopes of hill spurs; with convex to rectilinear form whist the minor valleys and valley heads are concave in shape. Slopes on the convex areas are moderately steep

to steep with gradients of 30 – 55% whilst in the concave areas slopes are less steep – apart from the upper valley heads.

Drainage lines are generally not incised and are mapped as valley heads, or areas where surface water gathers at the upper reaches of incipient streamlines. The valley heads drain south eastwards. There is one clear streamline in the north part of the area and that also drains south eastwards.

2.5 Land use and vegetation

Almost all of the area had been planted to fruit trees but the trees were being cleared at the time of the survey. There was a relatively dense coverage of various grasses that offered protection to the soil surface and helped prevent excessive run-off and erosion of the site.

Some of the land, in the northern section, has been cultivated but appears to have been abandoned.

3. PREVIOUS SOILS INFORMATION

As stated previously, the whole of the RNR-RC was surveyed at detailed level in 1998 by the BSS and reference should be made to the report for more detailed information about the site in general.

Only three sites from the original survey fell within the boundary of the very detailed survey area. All previous sites were auger observations and contributed little to immediate knowledge of the area.

4. METHODS

4.1 Pre-field Work

After receiving the request for the study BSS undertook the following actions:

- Discussions were held with RNR-RC staff to determine the extent and requirements of the study
- The original soil map was studied and the area of the Demonstration Plot delineated.
- A survey plan was drawn up based on the extent of the area and to meet FAO very detailed survey limits.
- A provisional base map was compiled at around 1:1,000 scale by enlargement (via GPS/GIS software) of the original soil map.
- Profile and Auger forms were made available along with other field consumable supplies.

For the detailed planning and mapping of the survey it was necessary to have a topographic base map. On checking with the RNR – RC Yusipang it was discovered that the RNR-RC had commissioned the compilation of a topographic map at a suitable scale and with contours at 1m intervals. A copy of this map was passed to BSS and was used for the fieldwork and mapping. A copy of the map can be seen in Figure 2.2, Chapter 2.

The above contour map was re-compiled in GPS mapping software (Ozi Explorer) to enable geographic registration of the map and to allow incorporation of coordinates collected by GPS devices during the survey.

4.2 Field

The fieldwork for this survey was done over three days in November 2001.

The soils were examined on a routine basis at 27 sites comprising 24 auger observations and three soil profile pits. Augering was mainly with a 1.2 m Edelman auger, fitted with a 7 cm stony soil head since the soils were very dry and hard. A 7 cm combination head was used in some of the more moist soils, particularly in the valley heads and streamlines. The distribution of the soil survey sites can be seen in Figure 4.1. Including the previous sites some 29 sites are found within the area.

For routine auger bores and profile pit soil observations the following site data were collected:

- Location, GPS; general topographic and site position;
- Previous erosion; the angle (in %), aspect, length and form of the slope;
- Solid geology and drift parent material;
- General present and previous land use and current crops / vegetation;
- Relief; irrigation type; artificial land shaping features;
- Microrelief, rock outcrops; stones, litter, cracks, faunal activity, and capping.
- Fertiliser use, if present and if known; site drainage and surface stones.

The soils in auger samples 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 (dry and in field moisture condition when possible);
- Number, size, contrast and colour of mottles;
- Field texture;
- Number, size, form, type and colour of concentrations;
- Number, size and type of stones;
- Moisture condition and consistence.

The soils were described in more detail at three sites. All the detailed descriptions were done in purpose-dug profile pits. 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 dry, moist and wet;
- Number, size, type and orientation of roots;
- Reaction to HCl (to test for presence of free carbonate minerals);
- Presence of concretions of iron, manganese or other secondary formations;
- Presence and effects of animals (wormcasts etc.);
- Any other features (e.g. charcoal); and clarity and shape of lower boundaries.

All data were collected on purpose designed proforma.

Figure 4.1 Distribution of Soil Survey Sites

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

4.3 Mapping

As stated in the previous BSS report the RNR-RC is sited ion the Survey of Bhutan 1:50,000 scale topographic sheet number 78 E /11. This scale is inadequate for detailed site planning and as a base map for detailed soil mapping at the planned presentation scale of 1:1,000

As stated in Chapter 4 it was discovered that the RNR-RC had commissioned the compilation of a topographic map at a suitable scale and with contours at 1m intervals. A copy of this map was passed to BSS and was used for the fieldwork and mapping. A copy of the original contour map can be seen in Figure 2.2, Chapter 2.

The above contour map was re-compiled in GPS mapping software (Ozi Explorer) to enable geographic registration of the map and to allow incorporation of coordinates collected by GPS devices during the survey. Although the map is geographically registered to the best of the ability of BSS it should not be taken as authoritative documentation of the exact location.

4.4 Laboratory

Ten soil samples were collected from the main horizons of the three detailed profiles and were analysed by the Soil and Plant Analytical Laboratory (SPAL) of the national Soil Services Centre (NSSC) of the Ministry of Agriculture at Semtokha. The methods of analysis used by SPAL are summarised in Appendix A of the original 1998 BSS report.

The only chemical methodological point that needs to be mentioned here concern the measurement of soil pH and the presence of exchangeable aluminium. Recent experience of BSS is that when soil pH falls to less than 6.0 there is every possibility of exchangeable aluminium in the soil. In fact SPAL normally automatically determines exchangeable aluminium when pH falls to 6.0 or 5.5, but in this case they failed to so ands there is no documented proof for the presence of aluminium in the exchange complex – though it is more than likely since some pH values are noted at 5 or less.

4.5 Data Storage

All field data were collected on the above-mentioned proforma and these proforma have, until the present, been the main data storage medium. All the data have now been entered into the Bhutan Soil Databank (BHUSOD) database system.

5 SOIL DISTRIBUTION AND MAPPING

5.1 Soil distribution and mapping.

The distribution of the soils is shown in the map attached to this report.

There are five map units covering the entire survey area and each map unit is relatively pure in that the soils are quite uniform within each unit. However, only an extremely detailed survey could ensure map units do not include much in the way of soils other than those presented in this report.

The map units were defined in the field and office on noted correlations between topography and soil observations. The features on the topographic map were used to draw the boundaries of the map units – normally boundaries would be drawn with the aid of aerial photographs but no photographs or photographs of suitable scale were located.

5.2 Soil mapping units

All of the soils have been mapped as either pure units, pure units have one dominant series or soil type, or complexes, which contain a mixture of soils. Only Map Unit X is considered a complex mainly due to the presence of rock outcrops which give rise to soils of various depths. All of the mapping units are presented below in terms of type, land use, land shaping, topography, etc. and summarised in Table 5.1 and chemical laboratory analytical results are presented in Appendix B.

Table 5.1 Composition and Extent of Soil Mapping Units

Map unit	Type	Main features	Soil	Extents		
				Ha	Acre	%
H	Pure	Steep to very steep convex hill slopes (30 – 55%) with easterly aspect and generally rock and gravel free. Mostly with degraded dryland terraces carrying abandoned apple orchard or scrubland.	Deep to moderately deep reddish and yellowish brown well-drained sandy loam to clay loams sometimes with gravel derived from weathered schist. Topsoils are slightly acid (pH H_20 5.8) with low inherent fertility, indicated slight magnesium deficiency and low fertility potential (CEC 10.7me/100g). Subsoils are very acid (pH H_20 5.38) with very low inherent fertility, indicated slight magnesium deficiency and low fertility potential (CEC 8.3 me/100g).	1.44	3.57	62.3
VH	Pure	Valley heads and upper sections of minor valleys with concave slopes of 27 – 57% and east to southeast aspect. Generally gravel and rock free surface and with degraded dryland terraces carrying abandoned apple orchard or scrubland.	Deep to moderately deep brown to yellowish-brown moderately well drained sandy clay loam to clay loam with minor mottling. Fertility and fertility potential likely to be similar to Map Unit H but lower sections should benefit from inflow of groundwater.	0.35	0.86	14.9
LV	Pure	Lower sections of minor valleys occurring within unit H with concave slopes of less than 35% and easterly aspect. Normally with degraded dryland terraces.	Deep well to moderately well drained dark brown to dark yellowish brown (due to organic staining) sandy loam to sandy clay loam often with few to common gravels of quartz, gneiss and schist. Fertility and fertility potential likely to be not unlike Map Units H & V.	0.19	0.46	8.1

V	Pure	Marshy areas and wet valleys.	Deep, poorly drained pale coloured mottled sandy clay loam normally with water table within 100cm depth. Topsoils are very acid (pH H_20 5.33) with very low inherent fertility, indicated deficiency of magnesium and low fertility potential (CEC 6.6 me/100g). Subsoils are slightly acid (pH H_20 6.04) with low to very low inherent fertility, indicated magnesium deficiency with possible phosphate inhibition and low fertility potential (CEC 6.7me/100g).	0.20	0.49	8.6
X	Complex	Lower toe slopes and ridges sometimes with rock outcrops on the surface	Deep to moderately deep, imperfectly to moderately well drained sandy clay loam to clay loam, sometimes over paralithic bedrock	0.14	0.35	6.1
			Totals	**2.32**	**5.73**	**100**

5.2.1 "H" map unit

The "H" map unit occurs throughout the survey area apart from along the northern boundary and in the northeast corner. It is mapped as a pure unit and covers 1.44 ha (3.57 acres) or 62.3% of the area. The unit comprises minor crests, hill slopes and spurs generally with steep to very steep (30 – 55% gradient) slopes with an average gradient of 43% and aspect SE to SSE. There is very little surface gravel cover and rock outcrops normally non-existent. The unit is presently covered in grass on degraded dryland terraces that have, in the past been planted to apple or other tree crop – but the trees have been neglected and are presently being removed.

Soils are generally deep to moderately deep, reddish and yellowish brown well drained sandy loam to sandy clay loam or clay loam, sometimes with gravel derived from weathered schist. Topsoils are slightly acid (pH water 5.8) with low inherent fertility as reflected by Avail-P rated very low at 3.43 ppm, Organic Carbon rated medium at 1.83%, Total-N rated low at 0.13%, Total Exchangeable Bases [TEB] rated low at 3.93 me/100g and Base Saturation [BS] low at 39%. Fertility potential, or the ability to retain added nutrients, reflected by Cation Exchange Capacity [CEC] rated low at 10.7 me/100g. Cation ratios Ca:Mg and Mg:K of 6.6 and 1.25 respectively indicate slight to moderate magnesium deficiency.

Subsoils are very acid (pH water 5.38) with very low inherent fertility as reflected by Avail-P rated very low at 2.28 ppm, Organic Carbon rated low at 1.05%, Total-N rated very low at 0.09%, Total Exchangeable Bases [TEB] rated very low at 1.42 me/100g and Base Saturation [BS] very low at 23%. Fertility potential, or the ability to retain added nutrients, reflected by Cation Exchange Capacity [CEC] rated low at 8.3 me/100g. Cation ratios Ca:Mg and Mg:K of 6.3 and 2.42 respectively indicate slight magnesium deficiency.

5.2.2 "VH" map unit

The "VH" map unit occurs throughout the area and comprises concave valley heads and the upper reaches of the minor valleys that dissect the area, draining in an east to southeasterly direction. The map unit is located on strongly sloping to very steep slopes with gradients ranging from 27 – 57% and 38% on average. It is a pure map unit and covers 0.35 ha (0.86 acre) or 14.9 % of the area. The occurrences generally have very few to no surface stones and gravel. No rock outcrops were seen. The unit is presently under dryland cultivation with degraded dryland terraces and scrubland grass or old apple trees.

Soils are deep to moderately deep brown to yellowish-brown moderately well drained sandy clay loam to clay loam with minor mottling. No profile pit and hence no soil analysis exist at present for the soil on this map unit. However, characteristics are most likely very similar to the soils in Unit "H" but he moisture resources in this unit should be better than in "H" due to inflow and seepage from the surrounding convex areas.

5.2.3 "LV" map unit

The "LV" map unit is found as two very small occurrences, one in the southeast corner and the other on the eastern boundary in the middle of the area. It is a pure map unit and covers 0.19 ha (0.46 acre) or 8.1 %

area of the area. The map unit comprises lower sections of minor valleys that drain the area and is located on steep slopes of 35 - 40 % and has southeasterly or easterly aspect. The occurrences generally have stone and gravel free surfaces. No rock outcrops were seen. The unit is presently under degraded dryland terraces covered in scrub grassland and trees.

Deep well to moderately well drained dark brown to dark yellowish brown (due to organic staining) sandy loam to sandy clay loam often with few to common gravels of quartz, gneiss and schist.

Very minor unit and no profile pit dug or sampled. Fertility and fertility potential likely to be not unlike Map Units VH but possibly with higher inherent fertility due to the indicated higher content of organic matter.

5.2.4 "V" map unit

The "V" map unit occurs in the north part of the area as a single small area and is mapped as a pure map unit and covers 0.2 ha (0.49 acre) or 8.6 % of the survey area. The map unit comprises marshy areas and a wet valley that drains the northern area and is located below the offices with gently to strongly sloping gradients and southeasterly aspect. Little traversing was done through this area as it has little obvious potential, no surface stones or rock outcrops were seen. The unit is presently not cultivated due to the generally high water table.

Soils are deep, poorly drained pale coloured mottled sandy clay loam normally with water table within 100cm depth. Topsoils are very acid (pH water 5.33) with low to very low inherent fertility as reflected by Avail-P rated low at 6.13 ppm, Organic Carbon rated very low at 0.35%, Total-N rated very low at 0.06%, Total Exchangeable Bases [TEB] rated very low at 1.12 me/100g and Base Saturation [BS] very low at 19%. Fertility potential, or the ability to retain added nutrients, reflected by Cation Exchange Capacity [CEC] rated low at 6.63 me/100g. Cation ratios Ca:Mg and Mg:K of 5.63 and 1.17 respectively indicate slight to moderate magnesium deficiency.

Subsoils are slightly acid (pH water 6.04l) with low to very low inherent fertility as reflected by Avail-P rated very low at 3.49 ppm, Organic Carbon rated low at 0.67%, Total-N rated very low at 0.06%, Total Exchangeable Bases [TEB] rated low at 3.28 me/100g and Base Saturation [BS] low at 46%. Fertility potential, or the ability to retain added nutrients, reflected by Cation Exchange Capacity [CEC] rated low at 86.7 me/100g. Cation ratios Ca:Mg and Mg:K of 6.83 and 1.96 respectively indicate slight to moderate magnesium deficiency.

5.2.5 "X" map unit

The "X" map unit occurs as a continuous small strip parallel to the northern boundary on the western half of the farm. It is a complex map unit and covers 0.14 ha (0.35 acre) or 6.1 % of the area. The map unit comprises lower toe slopes of spurs and ridges and has strongly sloping to steep slopes of 25 - 30 % and has predominant southwesterly aspect. The occurrences have few to common surface stones or gravel and a few rock outcrops were noted. The unit has undergone land shaping with degraded dryland terraces partly under scrub vegetation or abandoned apple trees.

Soils are deep to moderately deep, imperfectly to moderately well drained sandy clay loam to clay loam, sometimes over paralithic bedrock – no profile pit was dug and few observations made since this area seemed to have relatively low potential.

6 SOIL CLASSIFICATION, CHARACTERISTICS AND CORRELATION

6.1 Soil classification

The soils of the Demonstration Plot have not, at this time, been classified into the BSS soil series nor correlated with the international systems – as is normally done. These classifications and correlations will be done in due course but will add little to the information supplied in this report.

The soils of the Demonstration Plot are derived from colluvial deposits derived from rocks of the Thimphu formation – mainly gneiss and schists. The soils have a limited range of colours and range from reddish browns to yellowish brown apart from the poorly drained soils in the poorly drained valley. The soils will be grouped into soil series, on criteria of particle size class, drainage etc as defined in the BSS Soil Series 2001 document – but this has not yet been done due to pressure of time. In the descriptions of each map unit in Section 5.2, the main features of the soils of the site are described, these basic description will form part of the soil series descriptions in due course. More details of the individual typical profiles are given in Appendix B.

The table below summarises the soils of the survey area and shows the land use, soil characteristics plus the typical profile.

Table 6.1 Summary of Soils of the Demonstration Plot, Yusipang.

Map Unit	Land Use	Brief soil description	No of Sites	Typical profiles
H	Abandoned orchard and scrubland	Deep to moderately deep reddish and yellowish brown well-drained sandy loam to clay loams sometimes with gravel derived from weathered schist. Topsoils are slightly acid (pH H_20 5.8) with low inherent fertility, indicated slight magnesium deficiency and low fertility potential (CEC 10.7me/100g). Subsoils are very acid (pH H_20 5.38) with very low inherent fertility, indicated slight magnesium deficiency and low fertility potential (CEC 8.3 me/100g).	15	PH124
VH	Abandoned orchard and scrubland	Deep to moderately deep brown to yellowish-brown moderately well drained sandy clay loam to clay loam with minor mottling. Fertility and fertility potential likely to be similar to Map Unit H but lower sections should benefit from inflow of groundwater.	7	AA005
LV	Abandoned orchard and scrubland	Deep well to moderately well drained dark brown to dark yellowish brown (due to organic staining) sandy loam to sandy clay loam often with few to common gravels of quartz, gneiss and schist. Fertility and fertility potential likely to be not unlike Map Units H & V.	3	AK868
V	Abandoned orchard and scrubland	Deep, poorly drained pale coloured mottled sandy clay loam normally with water table within 100cm depth. Topsoils are very acid (pH H_20 5.33) with very low inherent fertility, indicated deficiency of magnesium and low fertility potential (CEC 6.6 me/100g). Subsoils are slightly acid (pH H_20 6.04) with low to very low inherent fertility, indicated magnesium deficiency with possible phosphate inhibition and low fertility potential (CEC 6.7me/100g).	3	PK162
X	Abandoned orchard and scrubland	Deep to moderately deep, imperfectly to moderately well drained sandy clay loam to clay loam, sometimes over paralithic bedrock	1	AH677
		Total Sites	**29**	

6.2 Fertility of the Soils of the Demonstration Plot

The fertility and analytical characteristics of the individual soils have been presented in Section 5.2 whilst this section aims to present an overall picture of the soils studied in this survey area.

6.2.1 Soil Reaction

Overall the topsoils are slightly acid with an average pH of 5.64, a figure that should indicate that exchangeable aluminium and an aluminium saturation percentage should not be a major problem. However, the topsoil of the soil in the valley – V – unit are rated as very acid with topsoil pH values between 5.03 and 5.62 giving an average of 5.33 – indicating that these soils could have an exchangeable aluminium problem.

Subsoils in the valley unit are classified as slightly acid with pH values ranging from 5.62 to 6.37 giving an average of 6.04. The increased pH in these wet soils would be expected since pH normally alters to around 7, or neutral, when soils are flooded (Refer BSS WP10, Soil Acidity and Aluminium, July 2001). Subsoils on the hill units are in the range of 4.85 – 6.04 with an average of 5.38 and classified as very acid. Some liming might be in order for very sensitive crops but no calculations have been done as to liming rate due to lack of sufficient data. Application of farmyard manure (FYM) would be beneficial in reducing acidity. If other liming materials were to be considered then dolomite should be used as this would help ameliorate the apparent deficiency of magnesium.

6.2.2 Inherent Fertility

Inherent, or existing, fertility is measured by the levels of exchangeable cations, total exchangeable bases, base saturation and levels of organic carbon, total nitrogen and available phosphate. Overall, both topsoils and subsoils are rated as having low to very low inherent fertility – refer Appendix A.

Topsoils are rated as having moderate level of organic carbon overall and C:N ratios are rated as good. The subsoils have low levels of organic carbon but the C:N ratios are rated as very good. Values determined for available phosphate are variable but overall the data to hand indicate that levels are very low in top and subsoils. Study of the various ratios of Ca:Mg and Mg:K indicate that there are some imbalances ands possible deficiencies of nutrients – in particular Ca in the topsoil of some hillslope soils and Mg in the topsoil and subsoil throughout. The low to very low levels of total exchangeable bases plus the cation ratios indicate the need for addition of fertiliser or FYM.

6.2.3 Fertility Potential

Fertility potential, or the ability of the soil to retain any added nutrients rather than allow them to be leached out, is assessed by the cation exchange capacity (CEC) of the soil. Overall the soils in this area all have low fertility potential in that CEC is rated low in both top and subsoils with overall average values of 9.3 and 7.7 me/100g in topsoil and subsoil respectively. Fertility potential could be approved by the application and incorporation by ploughing-in of FYM.

Overall, application of FYM would improve the existing fertility status, improve the fertility potential and would, most likely, also assist with the immobilization of exchangeable aluminium and reduction of soil reaction / acidity (pH).

7 PHYSICAL LAND EVALUATION and CLASSIFICATION

7.1 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 7.1 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 7.1 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.

7.2 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 7.2.

An example of the criteria compiled and currently used for physical land suitability classification for apples is presented in Table 7.3. Data on the criteria of all the other crops considered are in a similar format.

Table 7.2 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

7.3 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.

7.3.1 Manual Application

In the manual application the user refers to the table of criteria (eg Table7.3) 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).

7.3.2 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.

7.4 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 7.4 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.

7.5 Physical Land Suitability Classification for the Demonstration Plot

7.5.1 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 7.5.2.

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 7.5 Basic Data for Physical Land Suitability Classification of Yusipang 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*

7.5.2 Output from Automatic Classification

The summary information from the LUT spreadsheet for tree crops is given below in Table 7.6 –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 7.5 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 7.7.

Table 7.6 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 7.7 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

8. AVAILABLE SOIL MOISTURE

8.1 Introduction

Recent investigations (Refer BSS Working paper WP 20 – Soil Moisture) by BSS indicated some strange features in some Bhutanese soils that resulted in the soil having rather low or poor ability to retain and store soil moisture. Accordingly samples were taken for laboratory determination of the available soil water (moisture) holding capacity (AWHC) to ensure that this problem did not exist in Yusipang RNR-RC demonstration plot.

8.2 AWHC

Every soil holds specific amounts of moisture and the water holding capacity (AWHC) of any soil is defined as the difference between the amount of moisture held at field capacity and at the permanent wilting point. Simplified versions of the various definitions are given below. Normally the various amounts of moisture held by the soil are determined in the laboratory.

Field capacity (FC) is the amount of moisture that the soil holds when it has been saturated (by rainfall or irrigation) and all moisture that drains under the effects of gravity has drained out of the soil.

Permanent wilting point (PWP) is the amount of moisture that remains in the soil when plants can no longer extract that moisture.

Available water (moisture) holding capacity AWHC is the amount of moisture available for uptake by plants and is the moisture that is held by the soil between Field Capacity (FC) and Permanent Wilting Point (PWP).

However, not all the available moisture held in the soil can and is taken up by plants and it is normal to base all calculations on the **readily available moisture holding capacity** (RAWHC). The readily available water holding capacity (RAWHC) is normally taken as 75% of the total AWHC.

Bulk density (BD) is the weight of a unit volume of soil and is expressed as g / cc (grams / cubic centimetre). Bulk density is required when the calculations of the AWHC is done. In Bhutan it has been discovered that many soils have very low BD values, giving the soils Andic properties, and the normal correlations between soil texture and AWHC do not hold. However, from the field studies BSS did not expect low BD values to be found.

8.3 Samples for AWHC – Yusipang RNR-RC

AT the time of the survey none of the soils described and sampled appeared to have the “indicators” that BSS has started to recognise in connection with soils having AWHC problems. Though subsequent observations when soil monoliths were taken suggested that the hill slope soil (PH124) might fall into the category with high bulk density and one of the lower horizons of the wet soil (PK162) almost seemed to be thixotropic and warranted study.

One undisturbed core sample was taken from each horizon, in theory three samples should be taken from each horizon but time and availability of sampling rings excluded normal practice in this instance. Duplicate samples should be taken to allow any sample that turns out to contain stones or gravel or is damaged in any way to be rejected.

The samples were taken to the SPAL laboratory and the analyses done there with the data being recorded in proforma designed by BSS.

8.4 Findings

All the relevant data in connection with the AWHC studies is to be found in Appendix D and a summary is presented in Table 8.1.

Table 8.1 AWHC of Yusipang RNR-RC Soils

Profile	Sample No	% Coarse Material Gravel in sample	Texture of fine earth of sample	BD	AWHC Wt %	AWHC Vol %	RAWHC Vol %	*BD Norms for sample texture*	*AWHC (Estimated) Norms for sample texture*	*Vol % Moisture at PWP (15bar) Norms for sample texture*
Unit	*Unit*			*g/cc*	*Wt %*	*Vol%*	*Vol%*	*g/cc*	*Vol%*	*Vol%*
PH124	PH124/1	5	Sl	1.26	21.09	26.59	19.94	*1.50*	*12.00*	*6.00*
			Mean	1.26	21.09	26.59	19.94			
PH124	PH124/2	5	Cl	1.72	7.89	13.54	10.15	*1.35*	*19.00*	*15.00*
			Mean	1.72	7.89	13.54	10.15			
PH124	PH124/3	3	Cl	1.66	9.47	15.72	11.79	*1.35*	*19.00*	*15.00*
			Mean	1.66	9.47	15.72	11.79			
PH124	PH124/4	3	Cl	1.67	9.00	15.06	11.29	*1.35*	*19.00*	*15.00*
			Mean	1.67	9.00	15.06	11.29			
PK162	PK162/1	5	SCl	0.91	25.28	23.10	17.33	*1.40*	*18.00*	*12.00*
			Mean	0.91	25.28	23.10	17.33			
PK162	PK162/2	15	CsCl	1.26	19.83	24.94	18.71	*1.45*	*17.00*	*11.00*
			Mean	1.26	19.83	24.94	18.71			
PK162	PK162/3	30	CsCl	1.44	18.66	26.91	20.19	*1.45*	*17.00*	*11.00*
			Mean	1.44	18.66	26.91	20.19			
PK162	PK162/4	25	CsCl	1.46	20.43	29.87	22.40	*1.45*	*17.00*	*11.00*
			Mean	1.46	20.43	29.87	22.40			

8.4.1 BD – Bulk Density

In the above table column 5 presents the BD of the sample whilst column 8 presents what BD one would expect based on the soil texture. In this case of PH124 the bulk densities, apart from the surface layer (PH124/1) are all considerably higher (1.66 – 1.72) than what would be expected (1.35). Such BDs can cause problems for soils as they indicate a lack of soil porosity – poor soil porosity reduces the ability of the soil to absorb and transmit moisture and air. In addition the soils can be so dense that roots have difficulty passing through or penetrating the soil in their search for moisture and nutrients. However, the surface horizon of PH124 actually has slightly lower BD than expected, but at 1.26 not significantly lower than the norm of 1.5.

The BD values found in PK162 are not vastly different from the expected values apart from the surface layer, which at <1 is much lower then the expected 1.4). The lower horizons range from 1.26 – 1.46 as compared the expected value of 1.45 and show no great abnormality.

8.4.2 AWHC

The AWHC, given as volume %, is shown in column 7 for the samples whilst the RAWHC is given in column 8. Comparison with the “norms” in column 10 shows that:

- the AWHC of PH124 / 1 is about twice what would be expected with value of 26.6% as compared to norms of 12%
- AWHC for the lower horizons of PH124 is not very much different from what would have been expected at 13.5 – 15.7% as compared to the expected 19% for the texture recorded

- The surface horizon of PK162 has a bit (about 5%) higher AWHC (23.1%) than would be expected (18%) for the texture. However the surface horizon would only be exploited by the trees when they were very young
- The subsoil horizons of PK162 have about 8 - 12% higher AWHC (25 – 30%) than would be expected (17%) for the textures of coarse sandy clay loam recorded.

The conclusion is that, overall, these soils appear to have little problem with the amount of soil moisture that would be available to trees – especially since trees exploit the lower or subsoil horizons.

However, the total amount of moisture that the soil can hold does not give the complete picture, how the moisture is released (for uptake by plants) is of great importance:

- If the soil is very porous, that is if it has many large or very large pores, the soil water can largely drain out under gravity – at low tensions. If this happens the water is lost in the drainage and not available to the plant
- If the soil has most of its pores as very fine to micro sizes any moisture that does enter the soil can be held at such high tension by the soil that the moisture is not available to plants. In other words if the soil has most of its pores as very small sizes then the water remains longer in the soil and cannot be lost due to the effects of gravity but the plants cannot access and use that moisture for growth.

To establish just how the moisture is lost from the soil one has to construct moisture release curves. A moisture release curve basically plots the amount of moisture in the soil at any given suction or tension - a saturated soil is under low or nil suction / tension (0 bar or pF 0) whilst a soil at permanent wilting point is under high suction / tension (15 bar or pF 4.2).

Curves have been drawn for the Yusipang RNR-RC samples and are shown in Appendix C along with a bar diagrams showing the pore size distribution.

In the figures the perpendicular axis (Soil Moisture Content) shows how much moisture (expressed as volume %) is in the soil. The horizontal axis (pF) shows the tensions/ suctions increasing from left to right – the conversion from pF to atmospheric suction (bar) is as follows:

Table 8.2 Conversions from pF to Bar (Atmospheric pressure / Suction)

Conversions						
pF	2.0	2.3	2.5	2.7	3.0	4.2
bar	0.1	0.2	0.3	0.5	1.0	15.0
kPa	10	20	30	50	100	1500

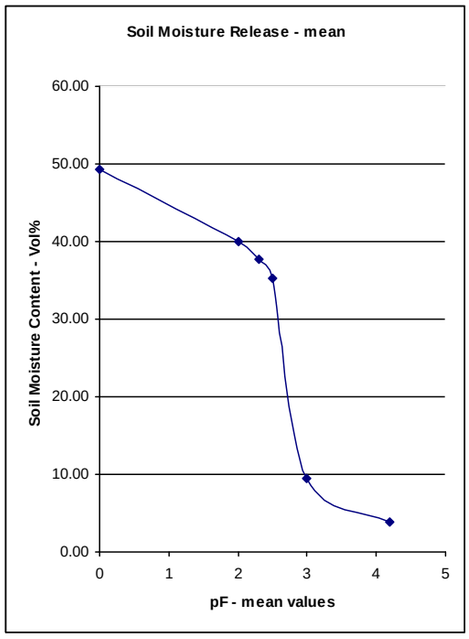
8.4.2.1 Moisture Release from PH124

The curve drawn through the points gives an indication that at low tensions (pF 0 – 2.5) the soil, both samples, contains a significant volume of moisture (35 to 50 volume%).

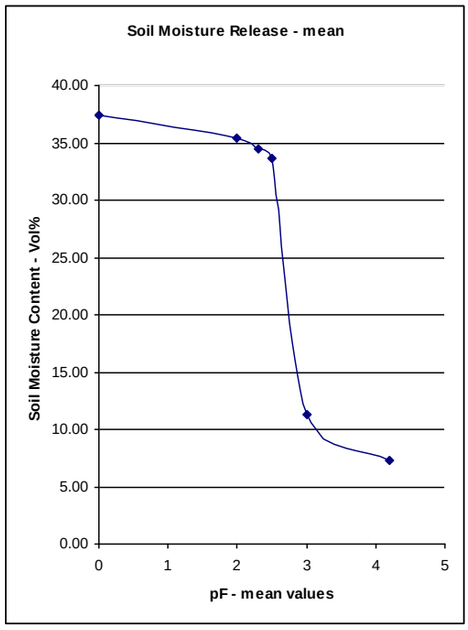
With the surface soil the content starts to reduce rapidly from pF2.5 to pF3.0 and at pF3 the content has fallen to about 10% and this curve appears perfectly normal suggesting no problems.

However, with the subsoil, the shape of the release curve is totally different and this indicates that the soil tends to hold the soil moisture quite strongly and does not start to release it till close to pF 3.0 – this could indicate that plants could have difficulty in gaining access to the moisture. This soil is within the main rooting depth of trees and the soil below this layer (110 – 140 cm) holds the moisture more strongly still (Refer Appendix C, Figure c.2).

Figure 8.1 Moisture Release Curve PH124



Topsoil (0 – 22cm)



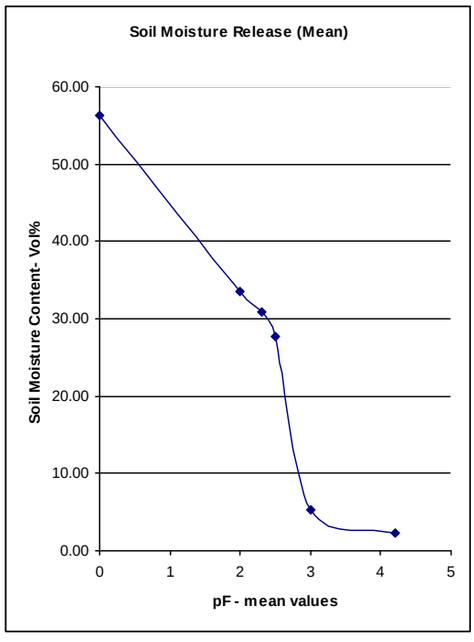
Subsoil (43 –110cm)

In summary, this soil holds moisture so strongly in the subsoil that trees planted could suffer moisture stress even though there is moisture still held within the soil.

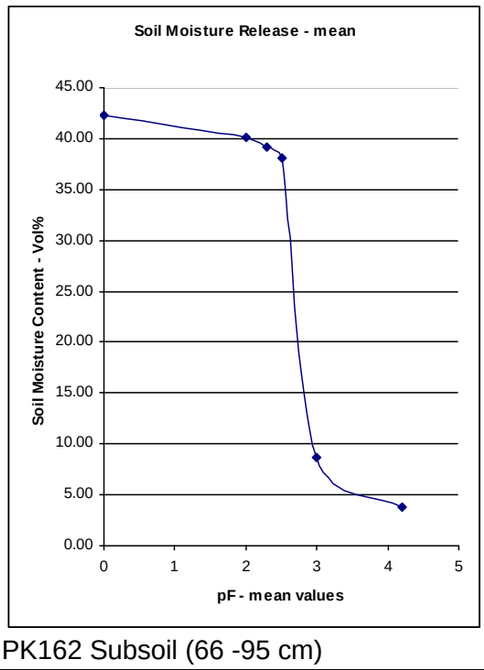
8.4.2.2 Moisture Release from PK162

The curves for the topsoil and subsoil are totally different for PK162. As can be seen in Figure 8.2 the topsoil curve falls rapidly from very low tension whilst the subsoil curve hardly falls at all.

Figure 8.2 Moisture Release Curve PK162



PK162 Topsoil (0 – 15 cm)



PK162 Subsoil (66 -95 cm)

The topsoil holds around 57% moisture at saturation (pF 0), this has fallen to about 30% by pF 2.5 and to 5% by pF3. This curve suggests that the soil loses moisture rapidly under the effect of gravity and soil moisture would be lost to drainage rapidly and possibly before the plants could use it.

The curve for the subsoil of PK162 is not that different from that of PH124 subsoil in that the soil holds the moisture quite strongly till almost pF3 then the curve falls rapidly and by pF 3 less than 10% moisture remains. This curve shows that the subsoil hold moisture so strongly that plants could have difficulty using it and the plants could suffer moisture stress.

Only the curve for the lower top soil (15 – 31 cm) of PK162 shows a normal release pattern (Refer Appendix C, Figure C.2)

8.4.3 Soil Porosity

Soils absorb and transmit moisture and air via the pores in the soil. As noted above – Section 8.4.1 – some of the soils sampled had higher than expected bulk density (BD) and this indicates poor soil porosity. From the laboratory data pore size distributions have been calculated, the findings are presented in Appendix D and some explanation is offered below.

For porosity measurements and presentations the following sizes of pores are used.

Table 8.3 Types and Sizes of Soil Pores

	Size Of Pores	
Type of Pores	m	mm
Micropores	0.2 - 9	0.0002 - 0.009
Micro- extremely fine	9 - 30	0.009 - 0.03
Visible	>30	> 0.03

If “Total Porosity” lies between 30 – 40% this indicates that the soil is compacted to some extent and root development will be hampered. The total porosity of the various soil samples are shown in Table 8.4.

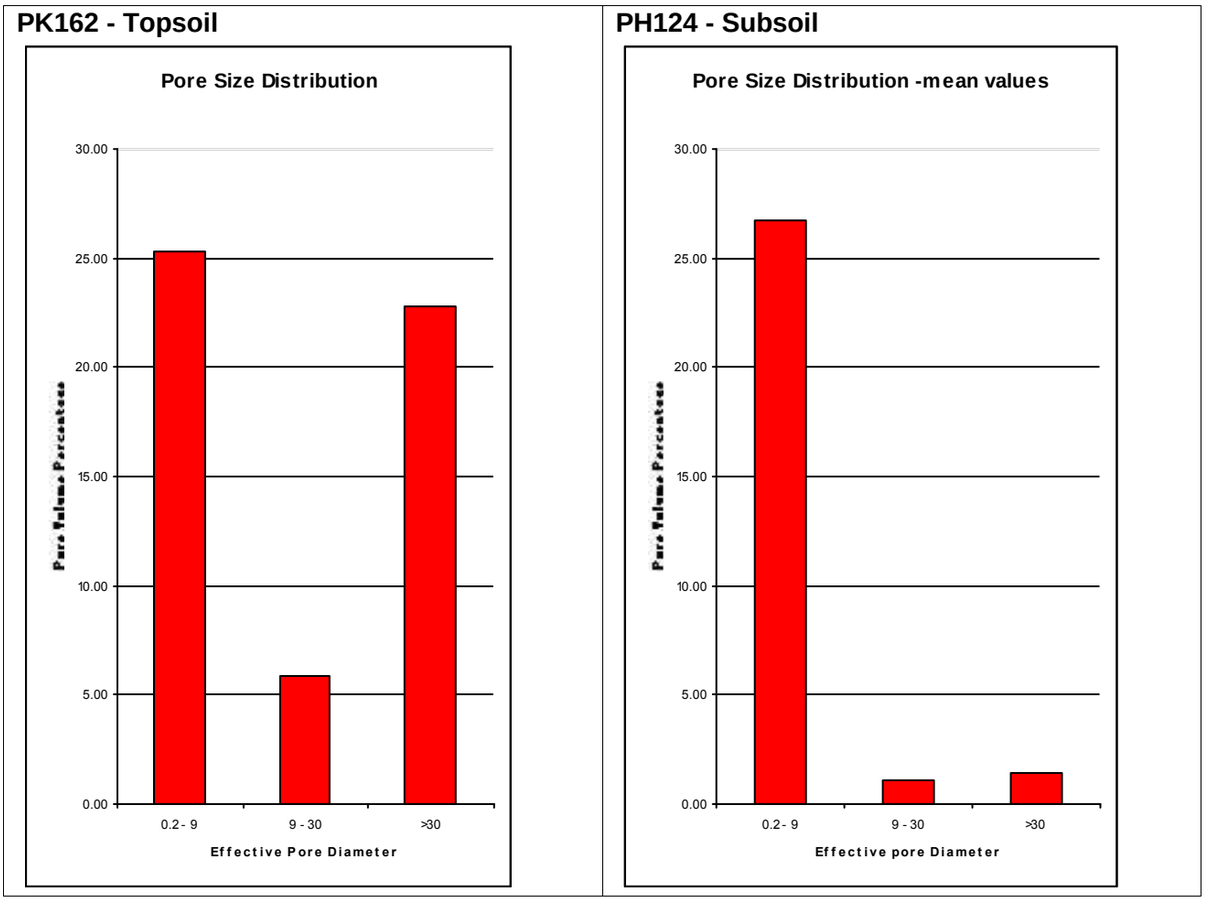
Table 8.4 Total Porosity of Yusipang RNR-RC Soils

Sample Number	**Horizon Type**	**Total Porosity %**	**Micro** Pore size distribution (0.2 - 9 μm)	**Extremely Fine** Pore size distribution (9 - 30 μm)	**Fine** Aeration porosity (>30 μm)
PH124/ 1	Topsoil	52.43	31.56	4.72	9.17
PH124/ 2	Lower top soil	35.25	23.11	2.42	4.11
PH124/ 3	Subsoil	37.32	26.42	1.73	2.03
PH124/ 4	Subsoil	36.84	26.72	1.05	1.39
PK162/ 1	Topsoil	65.61	25.33	5.83	22.77
PK162/ 2	Lower topsoil	52.53	28.39	5.46	12.48
PK162/ 3	Subsoil	45.56	31.60	3.73	3.73
PK162/ 4	Subsoil	44.83	34.24	2.02	2.12

As can be seen the total porosity of the various soils lies between 35 and 65, this is in agreement with what is normal – norms are quoted as lying between 30 – 70%. However, it can also be seen that several of the total porosities lie within or close to the range (30 – 40%) which indicates soil compaction and restrictions to root growth.

In addition it can also be seen that some of the soils have a preponderance of micro pores and hardly any of the “Fine” size (>0.03mm), two extremes are shown in Figure 8.5.

Figure 8.5 Extremes of Pore Size Distribution



PK162 topsoil has a relatively normal distribution of pores in the various sizes, though the middle size is slightly low. Soil with this type of distribution pattern would be considered, more or less, normal with no great problems, apart from possibly rather rapid drainage due to a large number of larger pores (>30).

On the other hand PH124 subsoil virtually has all its pores as the micro size with virtually none in the middle and larger size. Soils with this distribution pattern do present major problems in that they will have extremely slow rates of transmission of soil moisture and air and will be compact enough to hinder root development.

8.5 Conclusions on AWHC, BD and Porosity

It is concluded that the soils of the Yusipang RNR-RC demonstration plot have properties that are less than favourable for the growth of crops. The soils tend to have acceptable capacity for storage of soil moisture (AWHC) but the rates of release of the moisture in the subsoils is lower than would be desired – the soil tends to retain the moisture and not release it to plants. Bulk densities (BD) in some cases are generally higher than would be expected or desired and the high BD is associated with less than favourable porosity and, in some cases, very poor content of larger pores.

9 OVERVIEW AND IMPLICATIONS

9.1 Overview of soils.

The Demonstration Plot contains a limited range of soils, on account of the small size of the area and homogeneous geology. All of the soils are virtually gravel free, slightly acid to very acid with most of the topsoils of the well-drained soils being slightly acid whilst the subsoils are very acidic. The topsoils of the poorly drained unit are very acid whilst the subsoils here are slightly acidic – this is to be expected in flooded soil as pH always increases to near neutral in such situations. Contents of organic carbon are moderate in topsoils and low in subsoils whilst total nitrogen is low to very low in top and subsoils respectively. Overall fertility potential and inherent fertility can be classified as poor and there is an indicated deficiency of magnesium.

9.2 Overview of the Topography and Location

The dominating features of the area, from a physical suitability viewpoint, are:

- steep slopes – giving rapid run off of rainfall, increase risk of erosion if there is run-off and difficulties cultivation
- higher than optimum altitude giving low temperatures
- less than optimal rainfall for dryland agriculture, and
- less than favourable aspect (SE to SSE) which could lead to some areas getting less sunshine than required for the crops that might be under consideration.

9.2 Implications of results

The RNR-RC will develop this area further with external help and the present assessment of physical land suitability may help in the selection of crops and inputs required to overcome the risk factors identified during this survey.

Necessary inputs could well include:

- Land shaping or forming to overcome the problems of steep slopes
- Use of supplementary irrigation or water harvesting techniques to help overcome the effects of limited rainfall
- Installation of soil drains to remove the excess groundwater in the valley unit, if this unit is to be used
- Installation of flood protection measures if areas close to the existing stream line are used
- Application of FYM and or liming materials to increase soil reaction (pH) to create a more suitable root zone
- Application of FYM to increase the fertility and fertility potential, some of the FYM should be applied at depth to help improve the main uptake zone of trees – if trees are to be planted
- Application of dolomite to address the apparent deficiency of magnesium

This is one the first attempts that BSS has made to produce physical land evaluation or land suitability based on survey data and it must be understood that this is a test of the BSS system as much as a report on the soils of the area. If the criteria used in the BSS evaluations are incorrect in any way then they will not give a true reflection of the physical suitability of the site. However, it is already known that several ventures on the site have been less than successful, or sustainable, suggesting that perhaps the BSS ratings are not totally incorrect.

BSS will welcome any feedback and constructive criticism this report and mapping may generate since feedback will allow BSS to refine and develop the assessment system.

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APPENDIX A Chemical Characteristics of the Demonstration Plot Yusipang RNR-RC

Table A.1 Characteristics of Topsoils of Demonstration Plot, Yusipang RNR-RC

											Exch Cations Me / 100g								Cation Ratios		Cation Ratios
Map Unit	**Site No.**	**Depth**	**pH** H2O	**pH** KCl	**pH** diff	**Avail P** ppm	**Avail K** ppm	**Org C** %	**Total N** %	**C:N**	**Ca**	**Mg**	**K**	**Na**	**TEB**	**CEC**	**BS** %	**Ca/Mg**	**Rating**	**Mg/K**	**Rating**
H	PH124	0 - 12	6.52	4.98	1.54	1.20	171.86	2.30	0.14	16	5.89	1.13	1.18	0.07	8.27	11.44	72	5.21	Mg slightly deficient	0.96	Mg deficient
		12 - 25	6.04	4.12	1.92	0.04	64.95	0.40	0.04	10	1.25	0.59	0.43	0.07	2.34	7.00	33	2.12	Ca slightly deficient	1.37	Mg slightly deficient
		Mean	**6.28**	**4.55**	**1.73**	**0.62**	**118.41**	**1.35**	**0.09**	**13**	**3.57**	**0.86**	**0.81**	**0.07**	**5.31**	**9.22**	**58**	**3.67**	**OK**	**1.16**	**Mg deficient**
H	PK161	0 - 15	5.03	3.57	1.46	5.68	31.29	2.80	0.20	14	3.00	0.38	0.20	0.10	3.68	14.37	26	7.89	Mg deficient with P inhibition	1.90	Mg deficient
		15 - 25	5.62	3.66	1.96	6.80	19.91	1.80	0.13	14	1.10	0.10	0.13	0.08	1.41	10.00	14	11.00	Mg deficient with P inhibition	0.77	Mg deficient
		Mean	**5.33**	**3.62**	**1.71**	**6.24**	**25.60**	**2.30**	**0.17**	**14**	**2.05**	**0.24**	**0.17**	**0.09**	**2.55**	**12.19**	**21**	**9.45**	**Mg deficient with P inhibition**	**1.33**	**Mg deficient**
	Map unit mean		**5.80**	**4.08**	**1.72**	**3.43**	**72.00**	**1.83**	**0.13**	**14**	**2.81**	**0.55**	**0.49**	**0.08**	**3.93**	**10.70**	**39**	**6.56**	**Mg slightly deficient**	**1.25**	**Mg deficient**
	Rating		**SA**	**ND**	**ND**	**VL**	**ND**	**M**	**L**	**G**	**L**	**L**	**M**	**VL**	**L**	**L**	**L**				
V	PK162	0 - 15	5.03	3.57	1.46	5.68	19.92	0.60	0.06	10	0.59	0.13	0.13	0.10	0.95	8.26	12	4.54	OK	1.00	Mg deficient
		15 - 25	5.62	3.66	1.96	6.58	36.27	0.10	0.05	2	0.70	0.23	0.22	0.13	1.28	4.99	26	3.04	OK	1.05	Mg deficient
		Mean	**5.33**	**3.62**	**1.71**	**6.13**	**28.10**	**0.35**	**0.06**	**6**	**0.65**	**0.18**	**0.18**	**0.12**	**1.12**	**6.63**	**19**	**3.79**	**OK**	**1.02**	**Mg deficient**
	Map unit mean		**5.33**	**3.62**	**1.71**	**6.13**	**28.10**	**0.35**	**0.06**	**6**	**0.65**	**0.18**	**0.18**	**0.12**	**1.12**	**6.63**	**19**	**3.79**	**OK**	**1.02**	**Mg deficient**
	Rating		**VA**	**ND**	**ND**	**L**	**ND**	**VL**	**VL**	**VG**	**VL**	**VL**	**L**	**L**	**VL**	**L**	**VL**				
	Overall mean	**topsoils**	**5.64**	**3.93**	**1.72**	**4.33**	**57.37**	**1.33**	**0.10**	**11**	**2.09**	**0.43**	**0.38**	**0.09**	**2.99**	**9.34**	**32**	**5.63**	**Mg slightly deficient**	**1.17**	**Mg deficient**
	Overall ratings	**topsoils**	**SA**	**ND**	**ND**	**VL**	**ND**	**M**	**L**	**G**	**L**	**VL**	**M**	**VL**	**VL**	**L**	**VL**				

Ratings:

A	**EA**	**G**	**H**	**L**	**M**	**N**	**ND**	**SA**	**VA**	**VG**	**VH**	**VL**	**VP**
Alkaline	Ext Acid	Good	High	Low	Mod	Neutral	Not Determined	Sli Acid	Very Acid	Very Good	Very high	Very low	Very Poor

Source: Soil Survey Handbook for Bhutan., BSS, NSSC Semtokha, Ministry of Agriculture, Bhutan, November 2000

Table A.2 Characteristics of Subsoils of Demonstration Plot, Yusipang RNR-RC

											Exch Cations Me / 100g										
Map Unit	**Site No.**	**Depth**	**pH** H2O	**pH** KCl	**pH** Diff	**Avail P** ppm	**Avail K** ppm	**Org C** %	**Total N** %	**C:N**	**Ca**	**Mg**	**K**	**Na**	**TEB**	**CEC**	**BS** %	**Ca/Mg**	**Rating**	**Mg/K**	**Rating**
H	PH124	25 - 43	6.04	4.12	1.92	0.04	64.95	0.40	0.04	10	1.25	0.59	0.43	0.07	2.34	7.00	33	2.12	Ca slightly deficient	1.37	Mg deficient
		43 - 110	5.79	3.97	1.82	1.42	15.60	0.20	0.04	5	0.87	0.88	0.13	0.08	1.96	6.07	32	0.99	Ca deficient	6.77	OK
															0.00						
		Mean	**5.92**	**4.05**	**1.87**	**0.73**	**40.28**	**0.30**	**0.04**	**8**	**1.06**	**0.74**	**0.28**	**0.08**	**1.43**	**6.54**	**33**	**1.55**	**Ca slightly deficient**	**4.07**	**OK**
	PK161	25 - 33	4.85	3.47	1.38	3.82	19.91	1.80	0.13	14	1.10	0.10	0.13	0.08	1.41	10.00	14	11.00	Mg deficient with P inhibition	0.77	Mg deficient
		Mean	**4.85**	**3.47**	**1.38**	**3.82**	**19.91**	**1.80**	**0.13**	**14**	**1.10**	**0.10**	**0.13**	**0.08**	**1.41**	**10.00**	**14**	**11.00**	**Mg deficient with P inhibition**	**0.77**	**Mg deficient**
	Map unit mean		**5.38**	**3.76**	**1.63**	**2.28**	**30.09**	**1.05**	**0.09**	**11**	**1.08**	**0.42**	**0.21**	**0.08**	**1.42**	**8.27**	**23**	**6.28**	**Mg slightly deficient**	**2.42**	**Mg slightly deficient**
	Rating		**VA**	**ND**	**ND**	**VL**	**ND**	**L**	**VL**	**G**	**VL**	**VL**	**L**	**VL**	**VL**	**L**	**VL**				
V	PK162	25 - 31	5.62	3.66	1.96	6.58	36.27	0.10	0.05	2	0.70	0.13	0.22	0.13	1.18	4.99	24	5.38	Mg slightly deficient	0.59	Mg deficient
		31 - 66	6.37	4.73	1.64	2.80	211.27	1.50	0.10	15	3.92	0.23	1.46	0.06	5.67	8.96	63	17.04	Mg deficient with P inhibition	0.16	Mg deficient
		66 - 95	6.12	4.20	1.92	1.08	110.47	0.40	0.02	20	1.34	0.94	0.64	0.07	2.99	6.03	50	1.43	Ca slightly deficient	1.47	Mg deficient
		Mean	**6.04**	**4.20**	**1.84**	**3.49**	**119.34**	**0.67**	**0.06**	**12**	**1.99**	**0.43**	**0.77**	**0.09**	**3.28**	**6.66**	**46**	**7.95**	**Mg deficient with P inhibition**	**1.03**	**Mg deficient**
	Map unit mean		**6.04**	**4.20**	**1.84**	**3.49**	**119.34**	**0.67**	**0.06**	**12**	**1.99**	**0.43**	**0.77**	**0.09**	**3.28**	**6.66**	**46**	**7.95**	**Mg deficient with P inhibition**	**1.03**	**Mg deficient**
	Rating		**SA**	**ND**	**ND**	**VL**	**ND**	**L**	**VL**	**G**	**VL**	**VL**	**H**	**VL**	**L**	**L**	**L**				
	Overall mean	Subsoils	**5.60**	**3.90**	**1.70**	**2.68**	**59.84**	**0.92**	**0.08**	**11**	**1.38**	**0.42**	**0.39**	**0.08**	**2.04**	**7.73**	**31**	**6.83**	**Mg slightly deficient**	**1.96**	**Mg deficient**
	Overall rating	Subsoils	**SA**	**ND**	**ND**	**VL**	**ND**	**L**	**VL**	**G**	**VL**	**VL**	**M**	**VL**	**VL**	**L**	**VL**				

Ratings:

A	**EA**	**G**	**H**	**L**	**M**	**N**	**ND**	**SA**	**VA**	**VG**	**VH**	**VL**	**VP**
Alkaline	Ext Acid	Good	High	Low	Mod	Neutral	Not Determined	Sli Acid	Very Acid	Very Good	Very high	Very low	Very Poor

Source: Soil Survey Handbook for Bhutan., BSS, NSSC Semtokha, Ministry of Agriculture, Bhutan, November 2000

APPENDIX B Soil Profiles

Profile: **PH124**

Described & sampled:	H.B. Tamang 16 Nov 2001
Survey area:	Yusipang RNR-RC
Map unit:	H
Soil Classification:	
BSS Soil Series:	ND
Soil Taxonomy:	ND
WRB:	ND
Coordinates:	27^0 27' 30.9" **N** and 89^0 42' 41.4" **E** GPS
Topographic Map:	No.: ND Scale: 1:1,500 Date: Nov 2001
Location:	Upper portion of Demonstration Plot within RNR-RC Yusipang
Altitude:	2680 masl GPS
Climate:	
General:	Cool temperate
Recent weather:	Cloudy
Parent material:	
Solid:	Thimphu Formation – Gneiss
Drift:	Colluvium
Topography:	
Landform:	Mid mountain
Site position:	Mid slope of spur
Aspect:	SE
Slope:	40 %
Erosion:	None
Run-off:	Rapid
Site drainage:	Good
Microrelief:	100 –200 cm from terraces
Surface:	
Surface Condition:	Dry hard
Surface cracks:	None
Surface capping:	Nor recorded
Lichen/Algae:	Yes
Surface litter:	Dense cover of raw leaf litter of about 1cm depth
Surface outcrops:	None
Surface stones:	Few subangular hard quartz fine gravels
Vegetation category:	Dryland
Landuse:	Horticulture – apple and pear
Soil Depth Limit:	None
Soil Drainage Class:	Well drained
Water Table Depth:	None

Notes / Comments:

Profile description: (Colours are moist unless indicated)

Layer	cm	Type	Description
I	0 – 12	Ap	Light brownish gray (10YR 6/2) dry and dark yellowish brown (10YR 4/4) moist weak coarse subangular blocky breaking to moderate fine subangular blocky sandy loam with muscovite flakes; few subangular hard medium quartz gravel; very hard dry, friable moist and slightly sticky plus non-plastic wet consistency; few fine and coarse tubular pores; many fine irregular fibrous roots; no reaction to dilute HCl and clear smooth boundary to: [Sample No. PH124 /1
I	12 – 43	B1	Very pale brown (10YR 7/4) dry and yellowish brown (10YR 5/6) moist weak coarse subangular blocky breaking to moderate medium subangular blocky structured clay loam; muscovite flakes; few hard medium quartz gravels; common medium round black and orange ferromagnesian concentrations; friable moist, slightly sticky plus moderately plastic wet consistency; weak thin discontinuous clay skin coatings on peds; many fine tubular pores; few fine irregular fibrous roots; no reaction to dilute HCl and gradual smooth boundary to: [Sample No.PH124/2
I	43 – 110	Bw	Brownish yellow (10YR 6/6) moist moderate coarse subangular blocky structured clay loam; muscovite flakes; few fine hard angular quartz gravels; common medium slightly hard rounded ferromagnesian concentrations; friable moist, slightly sticky plus moderately plastic wet consistency; weak thin discontinuous clay skin coatings on peds; few fine tubular pores; few fine irregular fibrous roots; no reaction to dilute HCL and gradual smooth boundary to: [Sample No.PH124 /3]
I	110 - 140	Bw2	Reddish brown (5YR 5/4) moist strong medium subangular blocky structured clay loam; few soft medium gravels; many medium soft black ferromagnesian concentrations; very friable moist, moderately sticky plus moderately plastic wet consistency; moderate discontinuous medium clay coatings on peds; few fine interstitial pores; no reaction to dilute HCl. [Sample No.PH124/4]
	Notes:		Clay coatings but not recognised as an argillic horizon

Analytical Results for Profile: PH124 **Survey Area: Yusipang RNR-RC**

Reaction + nutrients

BSS No.	Depth Cm	SPAL Lab No.	pH Water	pH KCl	pH Diff	EC mS/cm	Avail-P ppm	Avail-K ppm	OC %	Total-N %	C:N Ratio
PH124/1	0 – 12	.	6.52	4.98	1.54		1.20	171.86	2.30	0.14	16
PH124/2	12- 43		6.04	4.12	1.92		0.04	64.95	0.40	0.04	10
PH124/3	43 - 110		5.79	3.97	1.82		1.42	15.60	0.20	0.04	5

Exchangeables

BSS No.	Exch Ca Me/100g	Exch Mg Me/100g	Exch K Me/100g	Exch Na Me/100g	TEB Me/100g	Exch Al Me/100g	Extr H Me/100g	CEC AmOAc Me/100g	ECEC Me/100g	BS %	ASP %
PH124/1	5.89	1.13	1.18	0.07	8.27			11.44		72	
PH124/2	1.25	0.59	0.43	0.07	2.34			7.00		33	
PH124/3	0.87	0.88	0.13	0.08	1.96			6.07		32	

Particle Size Distribution

	SAND %						SILT %			CLAY %		
BSS No.	>1000 micron	1000-425 micron	425-212 micron	212-106 micron	106-50 micron	Total Sand	50-20 micron	20-2 micron	Total silt	Total clay	Texture	USDA PSC
		.										

Available Moisture and Emerson Stability Class

	SOIL WATER CONTENT						Soil Water Holding Capacity		Emerson Test
BSS No.	BD g/cm	0.1 bar vol%	0.2 bar vol%	0.3 bar vol%	0.4 bar vol%	5 bar vol%	15 bar vol%	AWHC vol%	RAWHC vol%	Stability Class

Photographs etc.

Profile: **AA005**

Described & sampled:	A..A. Hutcheon 28 Nov 2001
Survey area:	Yusipang RNR-RC
Map unit:	VH
Soil Classification:	
BSS Soil Series:	ND
Soil Taxonomy:	ND
WRB:	ND
Coordinates:	27^0 27' 29.6"**N** and 89^0 42' 40" **E**
Topographic Map:	No.: ND Scale:1:5000 Date: November 2001
Location:	Below footpath on line one of auger holes in Yusipang Demo Plot
Altitude:	2682 masl - GPS
Climate:	
General:	Cool temperate
Recent weather:	Fair and sunny
Parent material:	
Solid:	Thimphu Formation – Gneiss and Schist
Drift:	Colluvium
Topography:	
Landform:	Mid mountains
Site position:	Valley head
Aspect:	E
Slope:	30%
Erosion:	Nil
Run-off:	Moderate to rapid
Site drainage:	Good
Microrelief:	100 – 200 cm from land shaping terraces
Surface:	
Surface Condition:	Slightly moist and moderately hard
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	No
Surface litter:	No
Surface outcrops:	None
Surface stones:	None
Vegetation category:	Tree crops
Landuse:	Abandoned orchard
Soil Depth Limit:	None
Soil Drainage Class:	Well drained
Water Table Depth:	None
Notes / Comments:	Relatively high in very steep valley head

Profile description: (Colours are moist unless indicated)

Layer	cm	Type	Description
I	0 – 2	Ap	Very dark grayish brown (10YR 3/2) moist mottle and gravel free loam with slightly moist friable, non-sticky and slightly plastic wet consistency. Few muscovite flakes and no reaction to dilute HCl. [Not Sampled]
I	2 – 15		Dark yellowish brown (10YR 4/4) moist mottle and gravel free loam with few fine round ferromagnesian concentrations and friable moist, non-sticky and slightly plastic wet consistency. Few muscovite flakes and no reaction to dilute HCl. [Not Sampled]
II	15 – 20		Dark brown (7.5YR 4/4) moist mottle and gravel free sandy clay loam with few fine round ferromagnesian concentrations and friable moist, slightly sticky and slightly plastic wet consistency. Few muscovite flakes and no reaction to dilute HCl. [Not Sampled]
II	20 – 70		Reddish brown (5YR 4/4) mottle and gravel free sandy clay loam with few medium round ferromagnesian concentrations and friable moist, slightly sticky and slightly plastic wet consistency. Few muscovite flakes and no reaction to dilute HCl. [Not Sampled]
II	70 – 100		Strong brown (7.5YR 5/6) mottle and gravel free loam with few to common medium round ferromagnesian concentrations and friable moist, non-sticky and slightly plastic wet consistency. Few muscovite flakes and no reaction to dilute HCl. [Not Sampled]
	Notes:		Auger sample only so no laboratory analyses. Narrow dark Organic Matter stained top horizon and quite red middle horizons.

Profile: **AK0868**

Described & sampled:	Kado Tshering 30 Nov 2001
Survey area:	Yusipang RNR-RC
Map unit:	LV
Soil Classification:	
BSS Soil Series:	ND
Soil Taxonomy:	ND
WRB:	ND
Coordinates:	27^0 27' 29.5" **N** and 89^0 42' 41.5" **E**
Topographic Map:	No.: ND Scale:1:1,500 Date: Nov 2001
Location:	Yusipang Demonstration Plot
Altitude:	2640 masl
Climate:	
General:	Cool temperate
Recent weather:	Clear sunny
Parent material:	
Solid:	Thimphu Formation
Drift:	Colluvium
Topography:	
Landform:	Mid mountains
Site position:	Minor valley bottom
Aspect:	150^0
Slope:	35%
Erosion:	Severe, gully
Run-off:	Very rapid
Site drainage:	Good
Microrelief:	50 – 100cm undifferentiated
Surface:	
Surface Condition:	Dry slightly hard
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	Not recorded
Surface litter:	Not recorded
Surface outcrops:	None
Surface stones:	None
Vegetation category:	Fallow
Landuse:	Tsesa
Soil Depth Limit:	None
Soil Drainage Class:	Well drained
Water Table Depth:	None
Notes / Comments:	Deep well drained medium textured dark coloured soil

Profile description: (Colours are moist unless indicated)

Layer	cm	Type	Description
I	0 –25	Ap	Brown (10YR 5/3) dry dark grayish brown (10YR 4/2) moist mottle free fine sandy loam with common fine subrounded hard gravel. Dry hard consistence and no reaction to dilute HCl. [Not Sampled]
I	25 - 100	B	Dark yellowish brown (10YR 4/4) moist mottle free medium sandy clay loam with common medium gneiss and quartz gravel. Moist firm consistency and no reaction to dilute HCl. [Not Sampled]
	Notes:		Auger sample so not sampled for lab analysis

Profile: **PK162**

Described & sampled:	Kado Tshering 30 Nov 2001
Survey area:	Yusipang RNR-RC
Map unit:	V
Soil Classification:	
BSS Soil Series:	ND
Soil Taxonomy:	ND
WRB:	ND
Coordinates:	27^0 27' 36" **N** and 89^0 42' 42.8" **E**
Topographic Map:	No.: nd Scale: 1:1,500 Date: Nov 2001
Location:	Demonstration plot, below horticulture office
Altitude:	2672 masl GPS
Climate:	
General:	Cool temperate
Recent weather:	Sunny
Parent material:	
Solid:	Thimphu Formation – gneiss
Drift:	Colluvium
Topography:	
Landform:	Mid mountains
Site position:	Lower slope in minor valley
Aspect:	SE
Slope:	25 %
Erosion:	Slight rilling
Run-off:	Slow
Site drainage:	Poor
Microrelief:	50 – 100cm from terraces
Surface:	
Surface Condition:	Dry slightly hard
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	None
Surface litter:	Scattered partially decomposed grass litter of 1cm depth
Surface outcrops:	None
Surface stones:	None
Vegetation category:	Dryland
Landuse:	Horticulture
Soil Depth Limit:	None
Soil Drainage Class:	Poor
Water Table Depth:	66 cm
Notes / Comments:	Abundant mica in horizon 2 and site has fluctuating water table

Profile description: (Colours are moist unless indicated)

Layer	cm	Type	Description
I	0 – 15	Ap	Light gray (10YR 7/2) dry and very dark grayish brown (10YR 3/2) moist mottle free weak fine crumb structured sandy clay loam with few fine angular slightly hard medium sized quartz gravels. Moist friable, non-sticky and non-plastic wet consistency. Many fine vesicular pores and abundant irregular fine fibrous roots. No reaction to dilute HCl and clear smooth boundary to: [Sample No. PK162 /1]
I	15 – 31	AB	Grayish brown (2.5Y 5/2) moist coarse sandy clay loam with weak fine sub-angular blocky structure and many coarse distinct dark yellowish brown mottles. Common hard angular medium quartz gravel and many mica flakes. Slightly firm moist and moderately sticky plus moderately plastic wet consistency; few fine interstitial pores and many irregular medium fibrous roots. No reaction to dilute HCl and clear smooth boundary to: [Sample No. PK162/2]
II	31 – 66	BW	Dark grayish brown (10YR 4/2) moist gravelly fine sandy clay loam with moderate medium breaking to strong fine sub-angular blocky structure and abundant coarse distinct and few medium faint reddish brown mottles; many hard medium angular quartz gravels; many medium interstitial medium pores; few 1.0 – 5.0 mm cracks and common medium woody roots; No reaction to dilute HCl and clear wavy boundary to: [Sample No. PK162/3]
II	66 - 95	BC	Gray (2.5Y 5/1) moist strong coarse angular blocky structured gravelly coarse sandy clay loam with abundant coarse distinct yellowish brown mottles; moist slightly firm, wet slightly sticky and slightly plastic consistency; many medium angular quartz and quartzite medium gravels; charcoal; few fine interstitial pores and no roots; No reaction to dilute HCl. [Sample No PK162 /4]

Notes:

Analytical Results for Profile: PK162 **Survey Area: Yusipang RNR-RC**

Reaction + nutrients

BSS No.	Depth Cm	SPAL Lab No.	pH Water	pH KCl	pH Diff	EC mS/cm	Avail-P ppm	Avail-K ppm	OC %	Total-N %	C:N Ratio
PK162/1	0 – 15	.	5.03	3.57	1.46		5.68	19.92	0.60	0.06	10
PK162 2	15 – 31		5.62	3.66	1.96		6.58	36.27	0.10	0.05	2
PK162/3	31 – 66		6.37	4.73	1.64		2.80	211.27	1.50	0.10	15
PK162/4	66 - 95		6.12	4.2	1.92		1.08	110.47	0.40	0.02	20

Exchangeables

BSS No.	Exch Ca Me/100g	Exch Mg Me/100g	Exch K Me/100g	Exch Na Me/100g	TEB Me/100g	Exch Al Me/100g	Extr H Me/100g	CEC AmOAc Me/100g	ECEC Me/100g	BS %	ASP %
PK162/1	0.59	0.13	0.13	0.10	0.95			8.26		12	
PK162 2	0.70	0.23	0.22	0.13	1.28			4.99		26	
PK162/3	3.92	0.23	1.46	0.06	5.67			8.96		63	
PK162/4	1.34	0.94	0.64	0.07	2.99			6.03		50	

Particle Size Distribution

	SAND %						SILT %			CLAY %		
BSS No.	>1000 micron	1000-425 micron	425-212 micron	212-106 micron	106-50 micron	Total Sand	50-20 micron	20-2 micron	Total silt	Total clay	Texture	USDA PSC
PK162/1		.										
PK162 2												
PK162/3												
PK162/4												

Available Moisture and Emerson Stability Class

		SOIL WATER CONTENT						Soil Water Holding Capacity		Emerson Test
BSS No.	BD g/cm	0.5 bar vol%	0.6 bar vol%	0.7 bar vol%	0.8 bar vol%	5 bar vol%	15 bar vol%	AWHC vol%	RAWHC vol%	Stability Class
PK162/1										
PK162 2										
PK162/3										
PK162/4										

Photographs etc.

Profile: **AH0677**

Described & sampled:	H.B. Tamang 29 Nov 2001
Survey area:	Yusipang RNR-RC
Map unit:	X
Soil Classification:	
BSS Soil Series:	ND
Soil Taxonomy:	ND
WRB:	ND
Coordinates:	**N** and **E** Not Recorded
Topographic Map:	No.: ND Scale: 1:1,500 Date: Nov 2001
Location:	Demonstration Plot
Altitude:	2640 masl Altimeter
Climate:	
General:	Cool temperate
Recent weather:	Sunny
Parent material:	
Solid:	Thimphu Formation
Drift:	Colluvium
Topography:	
Landform:	Mid mountains
Site position:	Edge of terrace, near marshy area close to drainage line
Aspect:	SE
Slope:	25%
Erosion:	Slight undifferentiated
Run-off:	Slow
Site drainage:	Poor
Microrelief:	100 – 200cm from land shaping terrace
Surface:	
Surface Condition:	Moist soft
Surface cracks:	Not recorded
Surface capping:	Not recorded
Lichen/Algae:	None
Surface litter:	None
Surface outcrops:	None
Surface stones:	None
Vegetation category:	Horticulture
Landuse:	Kamshing
Soil Depth Limit:	None
Soil Drainage Class:	Moderately well drained
Water Table Depth:	None

Notes / Comments:

Profile description: (Colours are moist unless indicated)

Layer	cm	Type	Description
nr	0 – 25	nr	Dark grayish brown (10YR 4/2) moist mottle free medium sandy loam with common slightly hard rounded medium gravel. Moist very friable consistency. [Not Sampled]
nr	25 – 65	nr	Dark gray (10YR 4/1) moist gravel and mottle free fine sandy loam with moist firm consistency. [Not Sampled]
nr	65 - 100	nr	Yellowish brown (10YR 5/4) mottle free sandy clay loam with common fine subrounded undifferentiated gravel and moist very firm consistency. [Not Sampled]
	Notes:		Auger sample, no sample for laboratory analysis

APPENDIX C AWHC Data

C.1 Profile PH124

Table C.1 Percentages of Moisture at Various Tensions PH124

Site	Sample No	% Coarse Material Gravel in sample	Texture of fine earth of sample	BD	% Moisture Volume % held at Saturation	% Moisture Volume % held at 0.1 bar	% Moisture Volume % held at 0.2 bar	% Moisture Volume % held at 0.3 bar	% Moisture Volume % held at 1.0 bar	% Moisture Volume % held at 15 bar	AWHC
			Unit	g/cc	Vol %	Vol %	Vol %	Vol %	Vol %	Vol %	Vol %
PH124	PH124/1	5	Sl	1.26	**49.23**	**40.06**	**37.73**	**35.34**	**27.40**	**11.14**	**26.59**
			Mean	1.26	49.23	40.06	37.73	35.34	27.40	11.14	26.59
PH124	PH124/2	5	Cl	1.72	**35.29**	**31.18**	**29.81**	**28.76**	**26.81**	**16.27**	**13.54**
			Mean	1.72	35.29	31.18	29.81	28.76	26.81	16.27	13.54
PH124	PH124/3	3	Cl	1.66	**37.42**	**35.39**	**34.50**	**33.66**	**28.83**	**18.78**	**15.72**
			Mean	1.66	37.42	35.39	34.50	33.66	28.83	18.78	15.72
PH124	PH124/4	3	Cl	1.67	**38.27**	**36.88**	**36.31**	**35.83**	**28.12**	**21.25**	**15.06**
			Mean	1.67	38.27	36.88	36.31	35.83	28.12	21.25	15.06

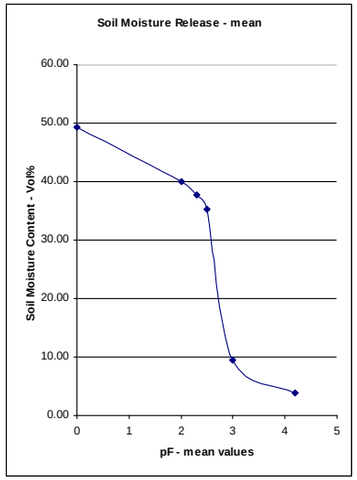
Table C.2 Adjusted Values plus Comparison with Norms PH124

Profile	Sample No	% Coarse Material Gravel in sample	Texture of fine earth of sample	BD	% Moisture Wt to Wt held at FC (0.2bar)	% Moisture Wt to Wt held at PWP (15.0 bar)	AWHC Wt %	Adjusted AWHC Wt %	AWHC Vol %	Adjusted AWHC Vol %	RAWHC Vol %	Adjusted RAWHC Vol %	*BD Norms for sample texture*	*AWHC (Estimated) Norms for sample texture*	*Vol % Moisture at PWP (15bar) Norms for sample texture*
Unit	*Unit*			*g/cc*	*Wt %*	*Wt %*	*Wt %*	*Wt %*	*Vol%*	*Vol%*	*Vol%*	*Vol%*	*g/cc*	*Vol%*	*Vol%*
PH124	PH124/1	5	Sl	1.26	29.93	8.84	21.09	20.04	26.59	25.26	19.94	18.94	*1.50*	*12.00*	*6.00*
			Mean	1.26	29.93	8.84	21.09	20.04	26.59	25.26	19.94	18.94			
PH124	PH124/2	5	Cl	1.72	17.37	9.49	7.89	7.49	13.54	12.86	10.15	9.64	*1.35*	*19.00*	*15.00*
			Mean	1.72	17.37	9.49	7.89	7.49	13.54	12.86	10.15	9.64			
PH124	PH124/3	3	Cl	1.66	20.77	11.30	9.47	9.18	15.72	15.25	11.79	11.44	*1.35*	*19.00*	*15.00*
			Mean	1.66	20.77	11.30	9.47	9.18	15.72	15.25	11.79	11.44			
PH124	PH124/4	3	Cl	1.67	21.69	12.70	9.00	8.73	15.06	14.61	11.29	10.95	*1.35*	*19.00*	*15.00*
			Mean	1.67	21.69	12.70	9.00	8.73	15.06	14.61	11.29	10.95			

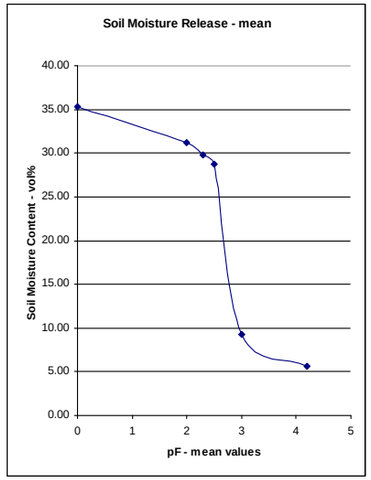
Notes: "Adjusted" value is a reduced value to allow for dilution effect of gravel
RAWHC (Readily Available Water Holding Capacity) is 75% of full AWHC to allow for moisture plants may not be able to access and use

Figure C.1 Moisture Release Curves PH124

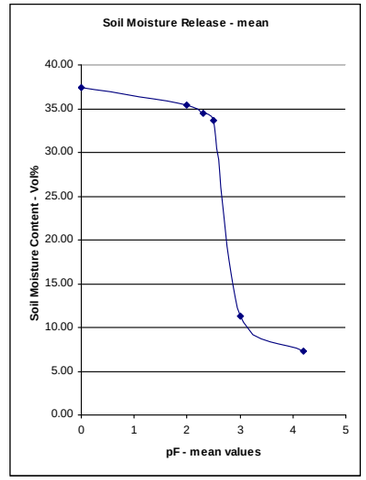
PH124 /1



PH124 /2



PH124 /3



PH 124/4

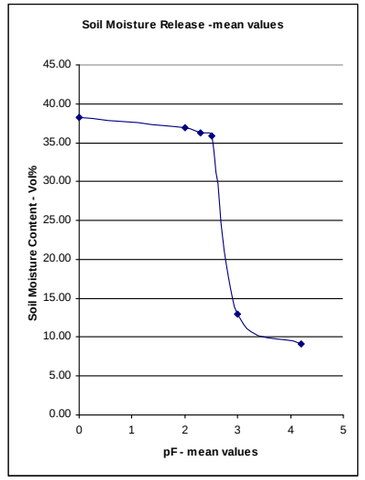
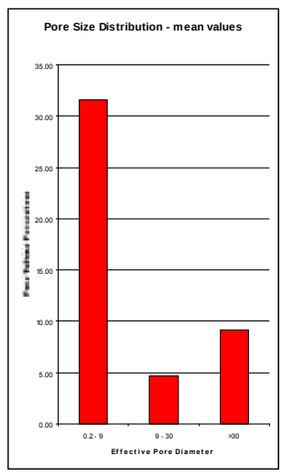
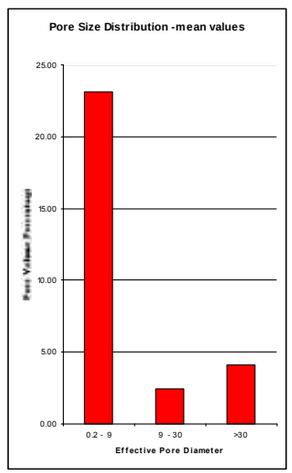
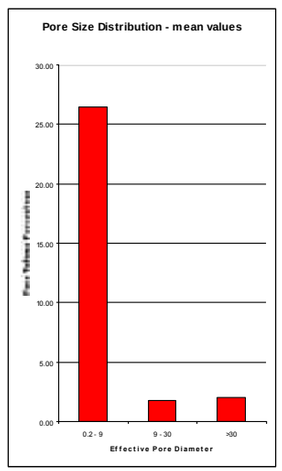
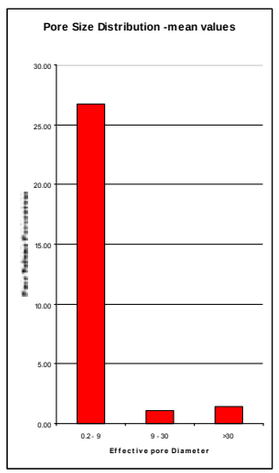


Figure C.2 Pore Size Distribution PH124









C.2 Profile PK162

Table C.3 Percentages of Moisture at Various Tensions PK162

Site	Sample No	% Coarse Material Gravel in sample	Texture of fine earth of sample	BD	% Moisture Volume % held at Saturation	% Moisture Volume % held at 0.1 bar	% Moisture Volume % held at 0.2 bar	% Moisture Volume % held at 0.3 bar	% Moisture Volume % held at 1.0 bar	% Moisture Volume % held at 15 bar	AWHC
			Unit	g/cc	Vol %	Vol %	Vol %	Vol %	Vol %	Vol %	Vol %
PK162	PK162/1	5	SCl	0.91	**56.23**	**33.46**	**30.81**	**27.63**	**17.52**	**7.71**	**23.10**
			Mean	0.91	56.23	33.46	30.81	27.63	17.52	7.71	23.10
PK162	PK162/2	15	CsCl	1.26	**50.29**	**37.81**	**34.58**	**32.35**	**23.20**	**9.64**	**24.94**
			Mean	1.26	50.29	37.81	34.58	32.35	23.20	9.64	24.94
PK162	PK162/3	30	CsCl	1.44	**42.30**	**38.57**	**36.43**	**34.84**	**21.69**	**9.52**	**26.91**
			Mean	1.44	42.30	38.57	36.43	34.84	21.69	9.52	26.91
PK162	PK162/4	25	CsCl	1.46	**42.23**	**40.11**	**39.11**	**38.09**	**19.26**	**9.24**	**29.87**
			Mean	1.46	42.23	40.11	39.11	38.09	19.26	9.24	29.87

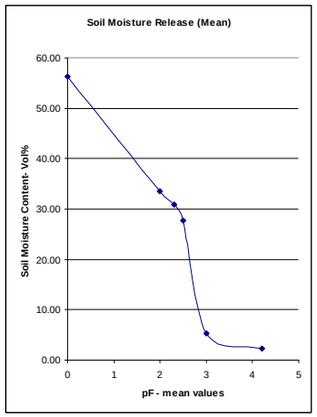
Table C.4 Adjusted Values plus Comparison with Norms PK162

Profile	Sample No	% Coarse Material Gravel in sample	Texture of fine earth of sample	BD	% Moisture Wt to Wt held at FC (0.2bar)	% Moisture Wt to Wt held at PWP (15.0 bar)	AWHC Wt %	Adjusted AWHC Wt %	AWHC Vol %	Adjusted AWHC Vol %	RAWHC Vol %	Adjusted RAWHC Vol %	*BD Norms for sample texture*	*AWHC (Estimated) Norms for sample texture*	*Vol % Moisture at PWP (15bar) Norms for sample texture*
Unit	Unit			g/cc	Wt %	Wt %	Wt %	Wt %	Vol%	Vol%	Vol%	Vol%	*g/cc*	*Vol%*	*Vol%*
PK162	PK162/1	5	SCl	0.91	33.71	8.43	25.28	24.01	23.10	21.95	17.33	16.46	*1.40*	*18.00*	*12.00*
			Mean	0.91	33.71	8.43	25.28	24.01	23.10	21.95	17.33	16.46			
PK162	PK162/2	15	CsCl	1.26	27.49	7.66	19.83	16.85	24.94	21.20	18.71	15.90	*1.45*	*17.00*	*11.00*
			Mean	1.26	27.49	7.66	19.83	16.85	24.94	21.20	18.71	15.90			
PK162	PK162/3	30	CsCl	1.44	25.25	6.60	18.66	13.06	26.91	18.84	20.19	14.13	*1.45*	*17.00*	*11.00*
			Mean	1.44	25.25	6.60	18.66	13.06	26.91	18.84	20.19	14.13			
PK162	PK162/4	25	CsCl	1.46	26.75	6.32	20.43	15.32	29.87	22.40	22.40	16.80	*1.45*	*17.00*	*11.00*
			Mean	1.46	26.75	6.32	20.43	15.32	29.87	22.40	22.40	16.80			

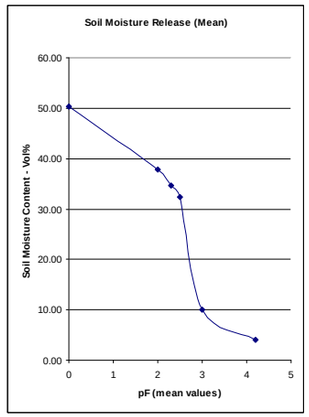
Notes: "Adjusted" value is a reduced value to allow for dilution effect of gravel
RAWHC (Readily Available Water Holding Capacity) is 75% of full AWHC to allow for moisture plants may not be able to access and use

Figure C.3 Moisture Release Curves PK162

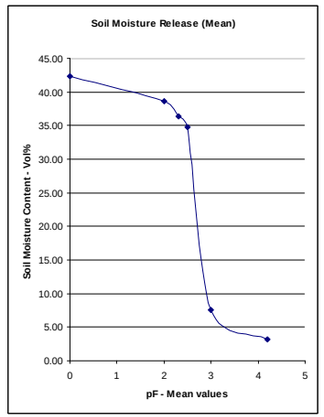
PK162 / 1



PK162 / 2



PK162 / 3



PK162 / 4

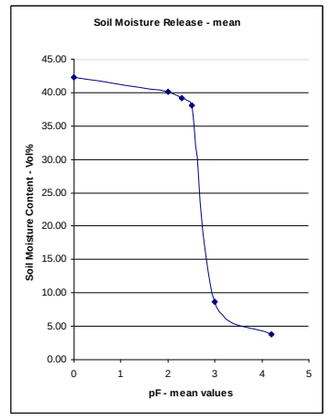
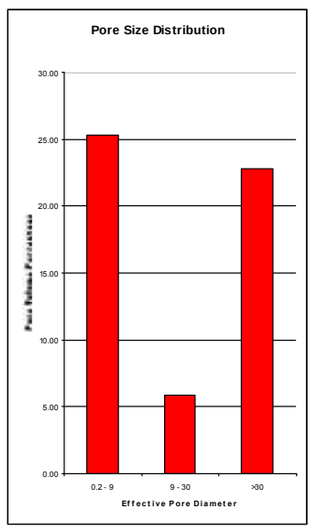
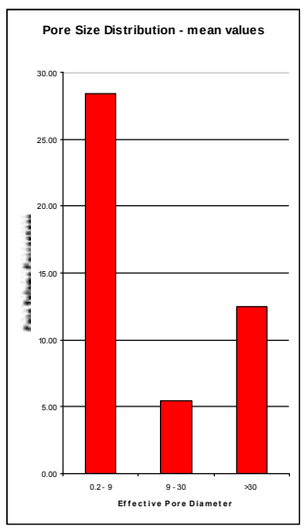
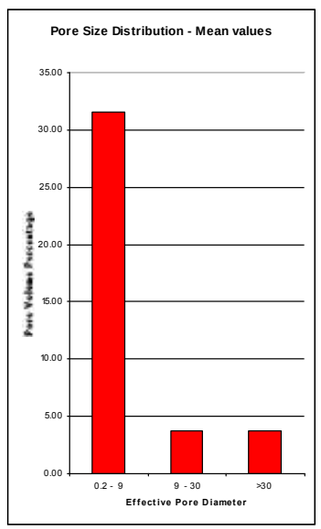


Figure C.2 Pore Size Distribution PK162







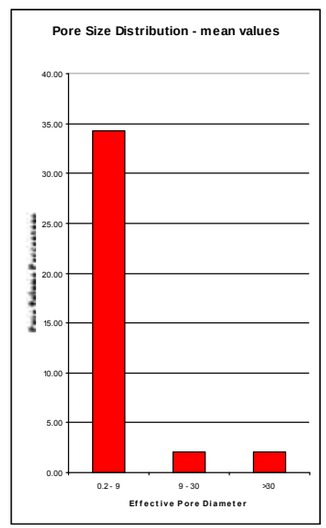


Table C.5 Porosity

POROSITY	PH124/ 1	PH124/ 2	PH124/ 3	PH124 / 4	PK162 / 1	PK162 / 2	PK162 / 3	PK162 / 4
Total porosity	52.43	35.25	37.32	36.84	65.51	52.53	45.56	44.83
Pore size distribution (0.2 - 9 μm)	31.56	23.11	26.42	26.72	25.33	28.39	31.60	34.24
Pore size distribution (9 - 30 μm)	4.72	2.42	1.73	1.05	5.83	5.46	3.73	2.02
Aeration porosity (>30 μm)	9.17	4.11	2.03	1.39	22.77	12.48	3.73	2.12