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Department of Agriculture (DoA)
Ministry of Agriculture and Forests (MoAF)**

**TECHNICAL REPORT ON THE DETAILED SOIL SURVEY OF
THE ROYAL BOTANICAL & RECREATIONAL PARK AT LAMPERI; PUNAKHA**



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SUMMARY

S.1 Background

This is the technical report of the detailed soil survey conducted at the Royal Botanical and Recreational Park at Lamperi under Punakha Dzongkhag. The survey was done to generate soil information for park management and educational purpose for its visitors. The survey was conducted from 4th January to 31st January 2010.

S.2 Location and Environment

The Park is located at Lamperi in Toeb Geog under Punakha Dzongkhag, and is located about 35 km east from Semtokha. The Thimphu-Wangduephodrang National Highway passes along the edges of the survey area. The complete survey area is about 94 acres (Barigang - 64 acres and Wasabi area – 30 acres) and the area extends between 27° 30' 3.84" to 27° 29' 52.70" N latitude and 89° 45' 5.90" to 89° 45' 44.04" E longitude. The survey area lies under colluvium deposit.

The survey area has predominantly N to SE aspect with average slope gradient of about 18°. The area lies between 2634 to 2769 m and falls within the cool temperate climatic zone. Although there is no rainfall data for Lamperi, the climatic data of Dochula has been taken as near equivalent, since the area lies few kms further down the ridge. The annual rainfall is 1470 mm.

S.3 Soils

The Royal Botanical and Recreational Park has limited range of soils, on account of its small size and homogenous landform and geology. All the soils are developed from colluvial deposit which is characterized by unsorted stones and gravels in the solum. The soils are generally very deep and acid in the subsoil (pH of 5.09). The organic carbon is very high (averaging 9.59%) in the topsoil and moderate in the subsoil (averaging 2.23%). The total nitrogen content is moderate (averaging 0.49%) in the topsoil and low (averaging 0.15%) in the subsoil. The normal yardsticks for inherent fertility (both TEB & BS) are very low in the subsoil TEB averaging 1.30 me/100g and BS 4.66%. Available subsoil phosphorus is very low (averaging 1.88 ppm). The individual nutrient elements in the subsoils are rated as "very low" for calcium and magnesium and "moderate" for potassium & sodium. The fertility potential of the soil (the ability of the soil to retain added nutrients) as reflected by the Cation Exchange Capacity (CEC) is very high in the topsoil (averaging 52 me/100g) and high in subsoil (34.04 me/100g).

There is no difference in the soils of the two sites relating from their physical and chemical properties. Therefore a single soil series has been formed considering other parameters such as soil colour, texture, soil drainage, particle size class and gravel contents. The soils are deep and have good water holding capacity. The figure 5.1a and 5.1b shows the distribution of soil types at the park.

ABBREVIATIONS and GLOSSARY

(Simple metric units and chemical element symbols not included)

Acre	Area of measurement, = 0.405 ha
AvP	Available Phosphate
BHUSOD	Bhutan Soil Databank
BS%	Base saturation percentage
CEC	Cation exchange capacity
cm	Centimetre
Colluvium	Local hill wash moved by surface erosion and slow non-glacial creep processes.
DoE	Department of Energy
DoFPS	Department of Forest and Park Services
GPS	Global positioning system
GRF	Government Reserve Forest
FAO	Food and Agriculture Organization of the United Nations
ha	Hectare
HCl	Hydrochloric acid
Horizon	Soil layer
Geog	Block or sub district, administrative subdivision of Dzongkhag
MoAF	Ministry of Agriculture & Forests
MoEA	Ministry of Economic Affairs
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)
NSSC	National Soil Services Centre, DoA, Semtokha
OC	Organic carbon
P	Phosphate
pH	Measure of acidity - alkalinity
PSC	Particle size class
Rectilinear	Straight slope with more or less similar gradients up- and downslope
RBRP	Royal Botanical and Recreational Park
RNRRC	Renewable Natural Resources Research Centre
SL	Sandy loam
SPAL	Soils and Plant Analytical Laboratory, NSSC, DoA, Semtokha.
SS	Soil Surveyor
SSU	Soil Survey Unit
SMR	Soil moisture regime
STR	Soil temperature regime
TEB	Total Exchangeable Bases (= exchangeable Ca + Mg + Na + K)
WD	Well drained (soil)
MSUS	Moderately steep upper slope
MSLS	Moderately steep lower slope
GLS	Gentle lower slope
US	Upper slope
MS	Mid slope
LS	Lower slope
Spp	Species
USDA	United States Department of Agriculture
WRB	World Reference Base

1. INTRODUCTION

The Royal Botanical & Recreational Park (RBRP) at Lamperi was inaugurated on 22nd October 2008 to provide nature based recreational opportunities with networks of walking trails through mixed oak conifer forest beside eco-camping sites. Since the Park does not have any soil information, the National Soil Services Centre (NSSC) was called upon to conduct a detailed soil survey for the area.

Since there was not any soil survey conducted previously, this would be the first technical report of the detailed soil survey of the RBRP at Lamperi under Punakha Dzongkhag. It is intended for the park staff and visitors who wish to know about the soils in detail including soil profile descriptions and its fertility status.

1.1 Aims of the soil survey

The survey was undertaken with the objectives to:

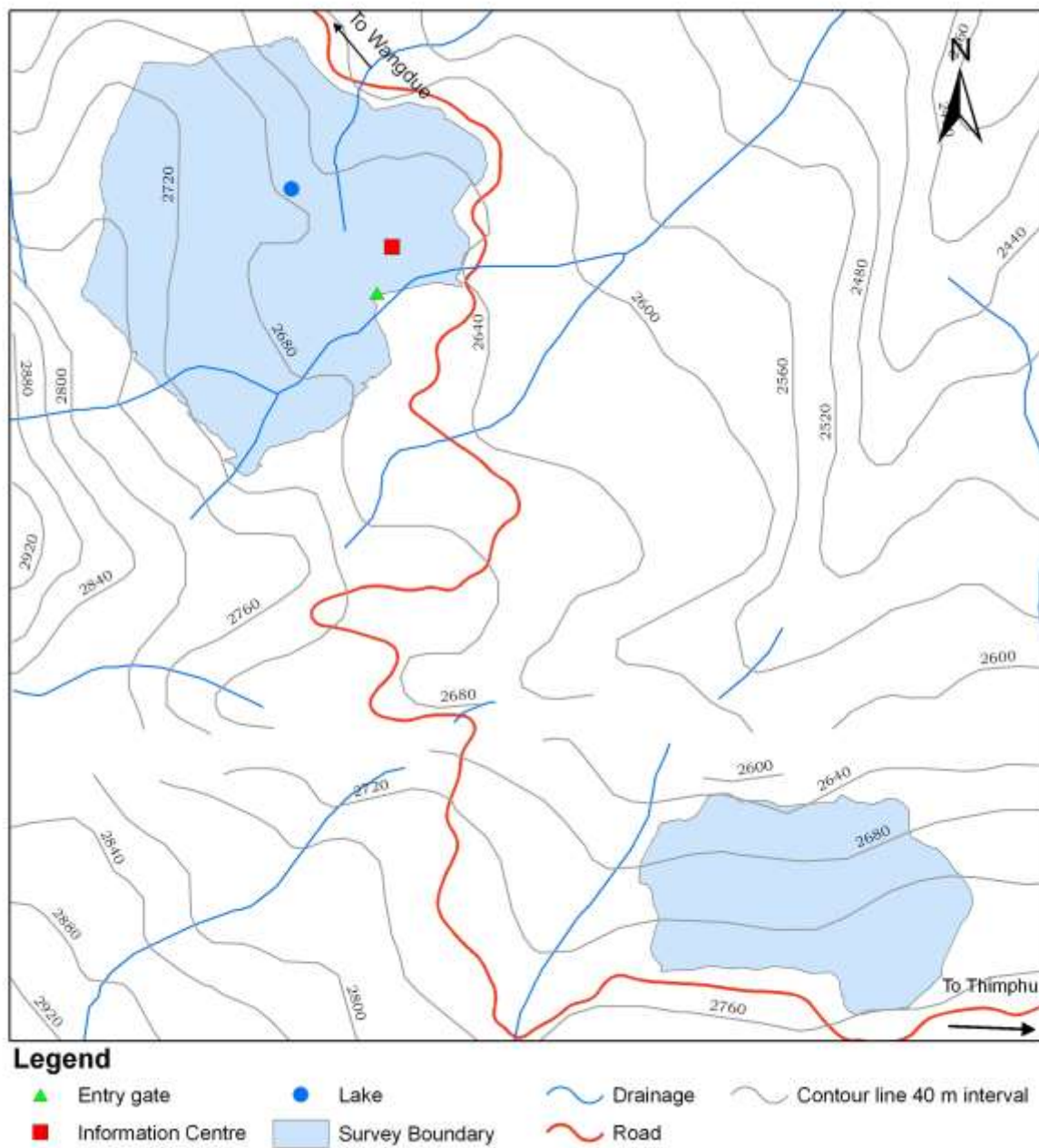
- Provide detailed information on the nature and spatial distribution of the soils for better park management & educational purposes.
- Provide on the job training on soil survey techniques for the Soil Survey Unit (SSU) staff.
- Gather more soil data to further develop the Bhutan Soil Databank (BHUSOD)

2. THE SURVEY AREA

2.1 Location and extent

The Royal Botanical and Recreational Park in Toeb Geog under Punakha Dzongkhag is located about 35 km east (E) from Semtokha. The survey was carried out in two different locations i.e. the main recreational Park at Barigang and the extended Park under Wasabi area. The complete area extends between $27^{\circ} 30' 3.84''$ to $27^{\circ} 29' 52.70''$ N and $89^{\circ} 45' 5.90''$ to $89^{\circ} 45' 44.04''$ E. The location of the survey sites is shown in Figures 2.1. The survey area has a total area of about 93.92 acres (GPS boundaries download onto topographic map and then digitized).

Figure 2.1 Location map of RBRP at Lamperi



2.2 *Climate*

The survey area stretches from an altitude between 2634 m to 2769 masl with predominantly North (N) to Southeast (SE) aspect and falls under the cool temperate climatic zone. *Symplocos* spp. and *Rhododendron* spp. are the dominant vegetation around the survey area but there are other species such as *Oak* spp, *Daphne* spp and *Bamboo* spp.

Since, there is no rainfall data for Lamperi, the climatic data of Dochula has been taken as near equivalent. Table 2.2 summarises the main conditions of the climate of Lamperi for the period 1995 – 2006.

The summation of monthly mean rainfall in Table 2.2 indicates that the annual rainfall around Lamperi was about 1470 mm. The highest monthly rainfall was 489 mm recorded in August month. The highest temperature recorded was 23°C in the month of July and the minimum of -6 in November and January months. The soil moisture regime falls under *ustic* by USDA Soil Taxonomy terms.

Table 2.2 Climatic summary of Dochula 1995 - 2006

Months	J	F	M	A	M	J	J	A	S	O	N	D	Total no. of years
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Temperature °C

<i>n (number of complete records)</i>	11	11	11	11	11	11	11	11	11	11	11	11	11
Mean	3.5	5.5	11	10.5	13.5	15	16	15.5	13.5	12	2	1	11
Mean minimum	-6	-3	1	3	6	8	9	9	5	3	-6	-5	11
Mean maximum	13	14	21	18	21	22	23	22	22	21	10	7	11

Rainfall (mm)

<i>n (number of complete records)</i>	11	11	11	11	11	11	11	11	11	11	11	11	11
Mean	15.1	20.5	28	37.4	104	245	370	348	201	78.4	14.4	8.09	11
Monthly maximum	40	33.4	79.2	85.8	179	360	488	489	357	155	92.8	24.2	11
Monthly minimum	0	0	0	0	0	1	1	0	0	0	0	0	11

Source data from Meteorological Section, DoE, MoEA

2.3 *Geology and Soil parent materials*

The survey area falls within the Thimphu formation with gneiss as the dominant rock type. It is mainly characterized by alternating light and dark bands differing in mineral composition and having coarse grains than those of schist. The light bands of gneiss are generally composed of quartz and feldspar. Hornblende, biotite mica, garnet, or graphite commonly forms the dark bands. The drift parent materials of the soils are mainly colluvial deposits as evidenced by angular and subangular stones found in the described profile pits. Soils on colluvial deposits are usually deep to very deep with coarse to fine textures.

2.4 *Topography and drainage*

Topographically, the survey area is located on a single colluvial slope and the landform mapping was therefore generalized under the same landform unit. Slope shapes are variable i.e. rectilinear, convex, concave etc. Landform unit is shown in figure 2.4a & 2.4b and defined in Table 2.4.

The survey area in general faces north to southeast aspect. The soils are well drained with very low surface runoff due to thick ground cover by local grasses and weeds. There are 3 natural drainage lines at the survey site which finally drains into Toeb Rongchu.

Figure 2.4a *Land Unit Map of Barigang*

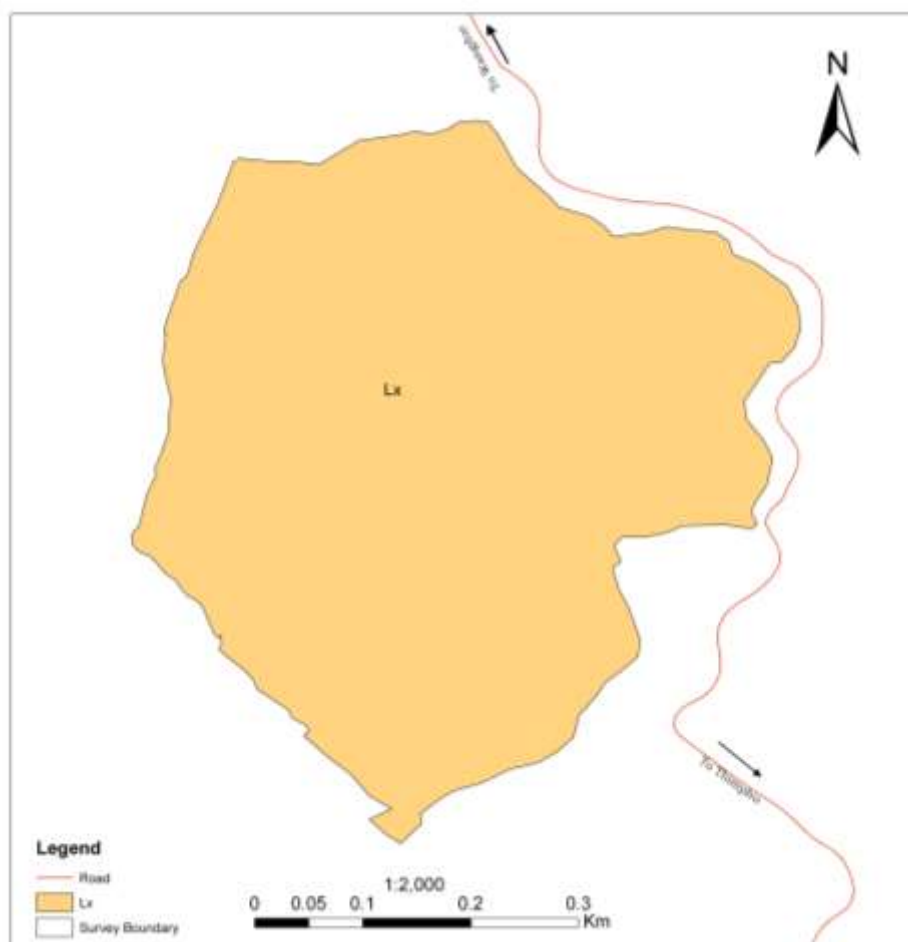


Figure 2.4b Land Unit Map of Wasabi

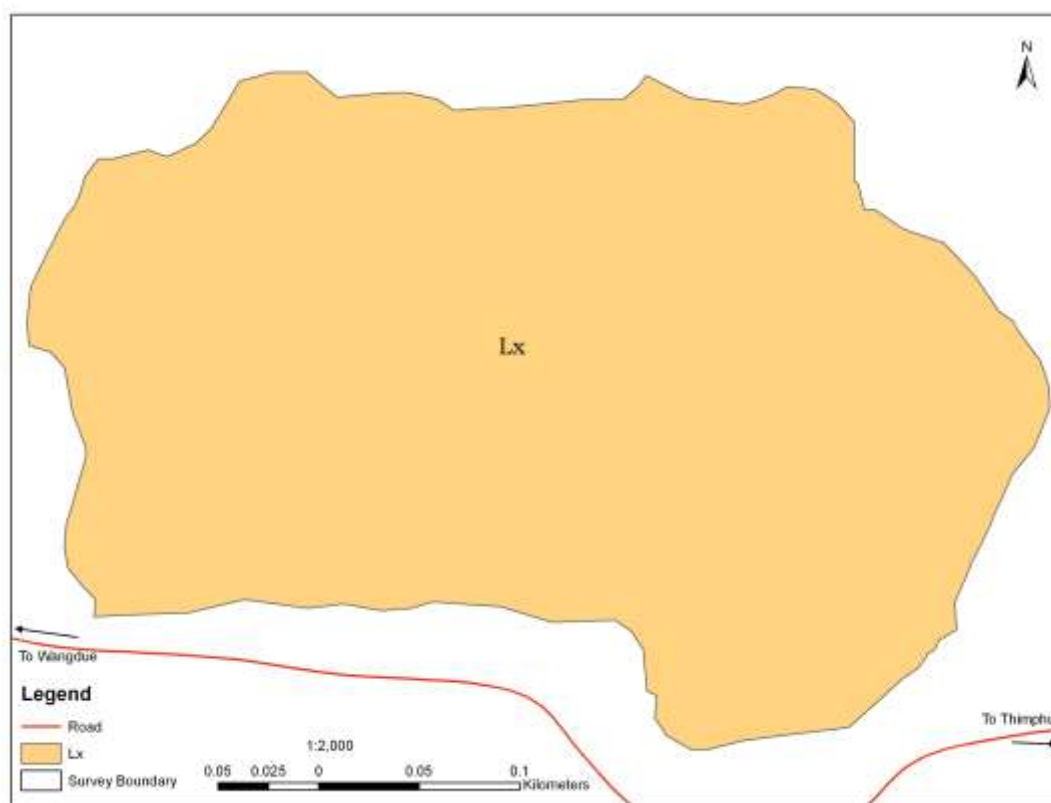


Table 2.4 Description of the land units of Lamperi Park

Map units	Position	Slope (°)	Altitude (m)	Aspect	Rock (%)	Extent		
						Ha	Ac	%
Lx	Mid slope of the high mountain	9 to 33	2661-2758	N	3	38.02	93.92	100
						38.02	93.92	100

2.5 Land use and vegetation

Before the survey area was developed into RBRP in October 2008, it was under Government Forest Reserve land (GRF) and the local communities used it as grazing area for the livestock animals, particularly cattle. Having noticed the scenic beauty and the richness of biodiversity in the area, the Department of Forest and Park Services (DoFPS) developed the site into a park in October 2008.

According to a survey conducted by the DoFPS, in less than an acre land at 2500 m asl revealed that 40 families and 72 species of plants are found excluding fern and grasses. But within the total Park area, 65 families and 179 species of plants have been recorded along with identified 28 rhododendron species. However, *Symplocos*, *Daphne* and Bamboo species dominate the vegetation with Himalayan fir, Juniper and Maple around the survey area.

Currently, the survey area serves as one of the main recreational centre in the capital. The park has a natural lake called Baritsho and another created artificially to make the place more beautiful and attractive.

3. METHODS

3.1 *Pre-field Work*

Prior to the fieldwork, following preparatory works were carried out:

- Prepared the base map by downloading and printing google maps
- Requested Park Division for necessary support during the field work
- Arranged vehicle for the field work
- Arranged field equipments and plastic bags for sample collection
- Printed soil profile and auger forms, etc

3.2 *Field*

The fieldwork for this survey was executed in the month of January 2010. The soils were examined by taking 11 short auger transects. Auger observations were done at 50 m interval along the pre-defined auger transects. On completion of auger observations, the profile pits were located based on the soil information gathered from the auger descriptions. The profile pits were dug and detailed descriptions were done accordingly. Furthermore, soil samples from each horizon were collected for laboratory analysis.

3.2.1 *Site & Soil Data*

All data were collected on the SSU field description cards (both profile and auger). The card consists of two pages; the front page (site data), which is designed to collect the location and site information. The reverse side of the card is for the collection and noting of the soil data. There are nineteen attributes of data to be collected from each soil horizon. The field card has been specifically designed to enable uniform data collection and also for easy entry into the BHUSOD system.

The following site data were collected and noted along with several other features:

- Site number, survey area name, topographic map and date of description
- Location of profile sites, GPS coordinates, and altitude
- Solid, or mapped geology and drift cover or parent material
- The gradient (%), aspect and form of the slope with estimated run-off and site drainage
- Signs of previous soil erosions and risk of flooding
- Micro-relief, hardness of the surface, presence of capping or cracks
- Estimates of rock outcrops (%) plus stones and gravels and any surface litter
- General land use and current crops/vegetation and any known previous land uses, and
- Presence of artificial land shaping features, irrigation type, fertiliser use, if known

The soil data were collected on the following parameters:

- Horizon – the number of the horizons and lithological layers
- The shape and clarity of the boundary between the various soil horizons
- Soil colour
- Texture of the soil in each horizon
- Presence of mottles– frequency, type and colour
- Presence of coarse materials such as gravels, stones and boulders
- Dilute Hydrochloric Acid (HCL) tests to determine if there is any carbonate present
- Moisture and consistence of the soil
- Soil structure - strength, size and shape or type of ped
- Presence of coatings and cutans on natural soil peds, roots, pores and cracks
- Presence of voids and pores – frequency, size and type
- Presence of cracks
- Presence of roots – frequency, size and type
- Presence of faunal activity
- Soil depth limit, and
- Other diagnostic soil features etc

(a) Auger sites

A total of 53 auger observations were made during the fieldwork. During auger description, soils were described at every 20 cm depth until it reached 100 cm (until it was stopped by stones or boulders). The following data were collected during auger description:

- Horizon number, depth and type
- Soil colour by Munsell colour chart
- Number, size, contrast and colour of mottles
- Field texture including coarse material and particle size class (PSC)
- Number, size, shape, hardness and type of stones
- Reaction to HCL: to test for the presence of free carbonates
- Number, size, shape, form type, hardness and colour of concentrations or concretions
- Field moisture status of the soil, consistency and plasticity of each horizon in dry, moist and wet condition.

Composite soil samples were also collected from auger sites to determine the general fertility status of soils.

(b) Profile pit sites

The soils were studied in more detailed by describing 7 profile pits. All the detailed descriptions were done in a purpose dug profile pits (1x1x1.5m³). The nature of site data collected for both auger and profile were maintained exactly the same. However the soils were described in much detailed than auger descriptions, even though the data collected for each horizon was similar as in the auger descriptions, with inclusion of the following:

- Whether the horizons were sampled for analyses
- Lithological layers if recognizable
- Clarity and shape of horizon boundaries
- Presence of any minerals
- Strength, size and type of soil structure
- Development of coatings and cutans (shiny coatings on the surfaces of soil structural units)

All together, 76 samples (including core and composite samples) were collected for laboratory analyses.

3.3 Mapping

The survey area falls within the Survey of Bhutan/Survey of India 1:50000 topographic sheet No. 78 E 14 dated 1998 with contours at 40 m intervals. This scale is inadequate for detailed site planning and to use as a base map for the detailed soil survey. Therefore, to supplement it the survey team printed out Google maps which were then used for use in the field to identify different landforms and other features. GPS tracks were taken along the actual boundary to come up with more accurate boundary of the survey area. After the field survey, the tracks were downloaded onto the topographic map for preparing the final base map at 1:2000.

3.3.1 Maps Produced and Used During the Survey

The following maps were prepared using the topographic map with 40 m contour intervals by the GIS staff at the Centre and then were used to compile other necessary maps for the survey area.

Table 3.3.1 Maps either used or produced during the survey

Map	Scale	Content and Use
Base	-	Google image at 2.5 m resolution with other geographic features such as highway, land use, infrastructural details, etc.
Land Units	1:2,000	Land, or geomorphic units, as seen in the field with all boundaries determined and drawn. Used for locating the auger transects and as a basis for drawing the draft soil map.
Soil Survey Sites	1:2,000	Location of all the observation sites (both auger and profile) plotted on the map by downloading the coordinates from the GPS, using GIS software.
Soil Map	1:2,000	Shows the boundaries between the various soil mapping units defined and mapped.

3.3.2 Final Map Presentations

Once all the draft maps were compiled and checked then they were digitized using GIS tools. The following information and map layers were appended:

- Base map
- Land units
- Survey sites
- Soil map

The final maps were produced at 1:2,000 and copies are appended to this report.

Figure 3.3.2a Distribution of soil augers and profiles for Barigang

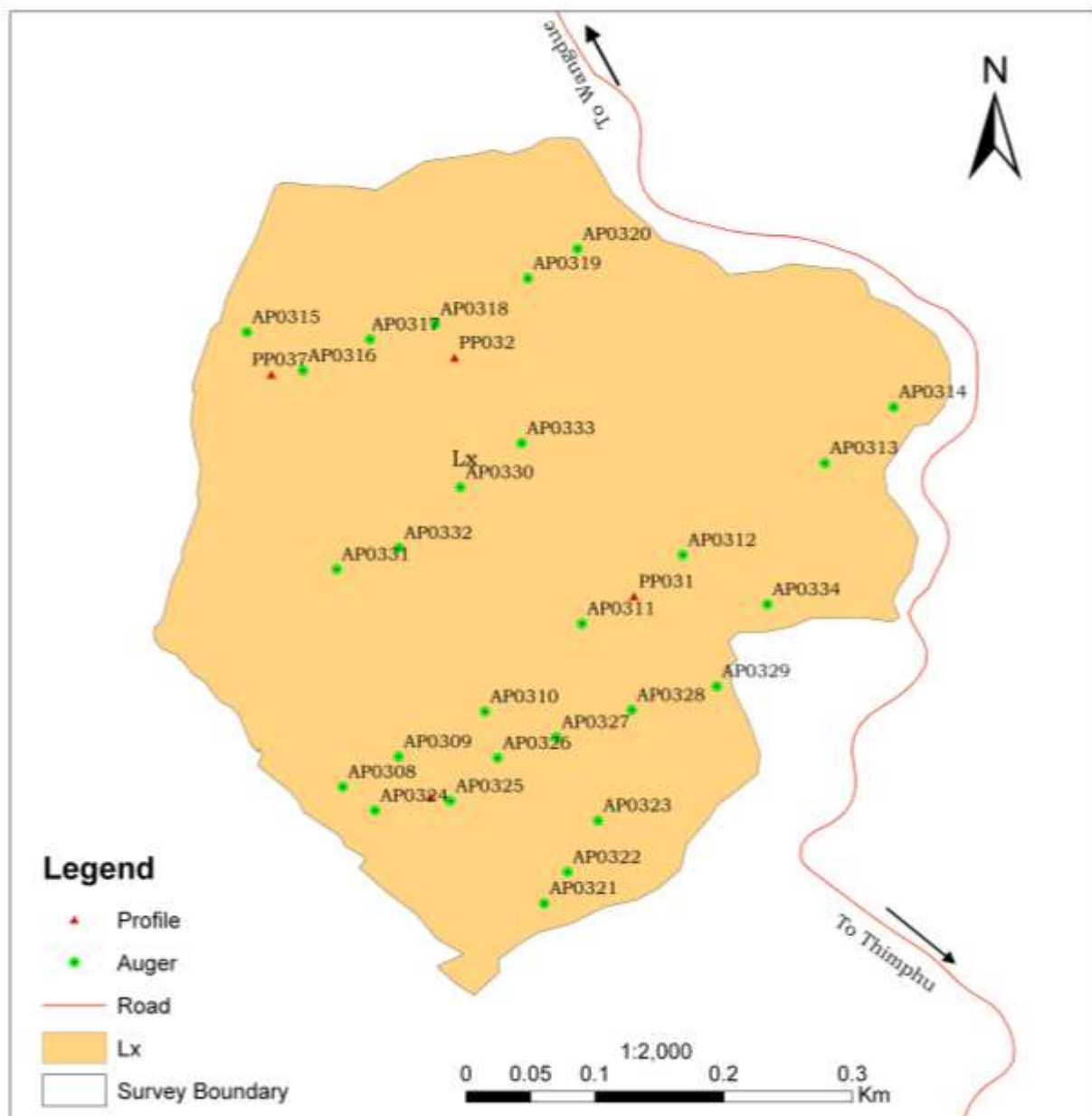


Figure 3.3.2b Distribution of soil augers and profiles for Wasabi

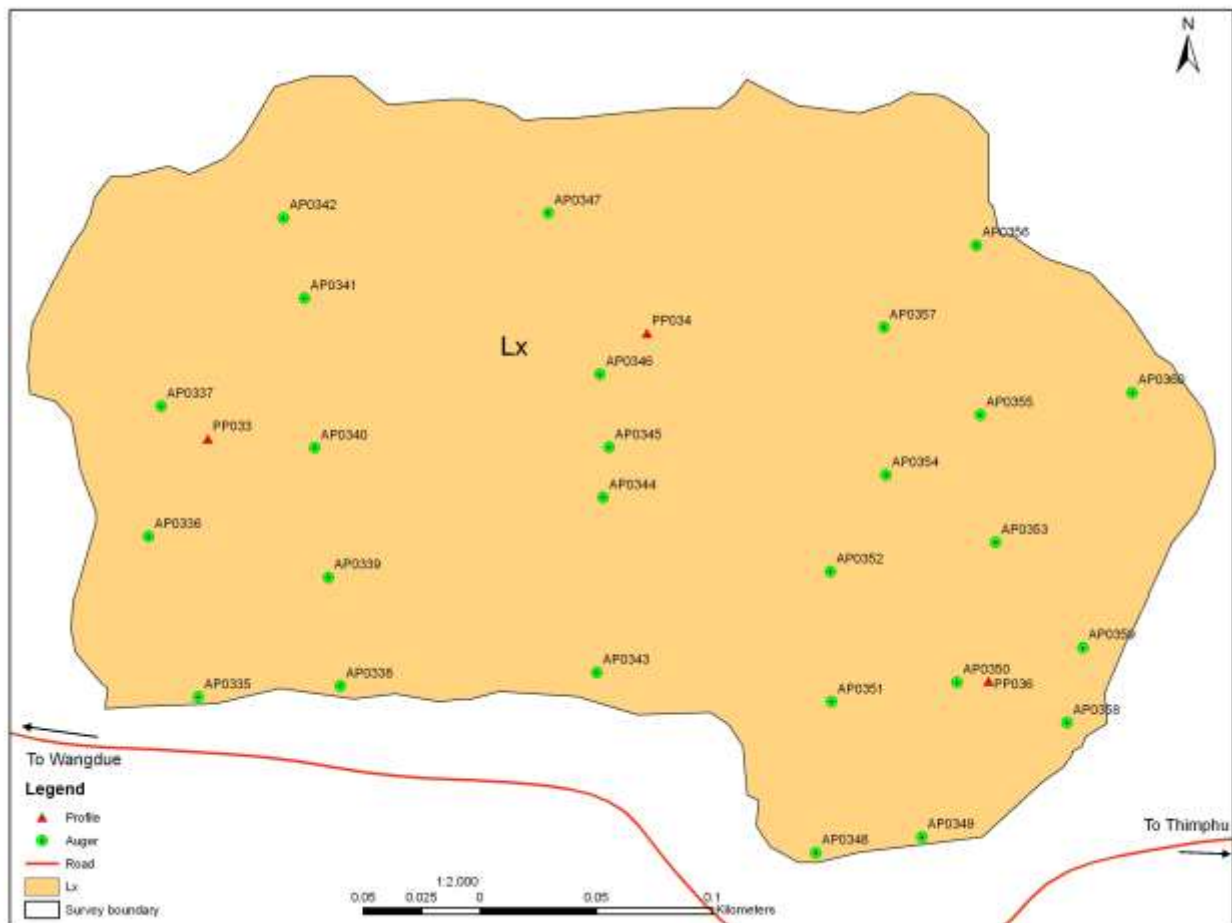


Table 3.3.2 Description of the soil auger and profile

Legends	Description
Lx	Is the general land unit prevailing throughout the survey area
Profile	The detailed soil description is made on profile cards within the survey boundary. Normally it is denoted by symbol such as PP031 which indicates P – Profile, P- referring to surname of the surveyor who made the description (in the current case-Penjor) and then followed by three digit number
Auger	The spatial distribution of the soil is done through auger description. Normally it is denoted by symbol such as AP0031 which indicates A – Auger, P – referring to surname of the surveyor who made the description (in the current case-Penjor) and then followed by four digit number

Soil samples from each horizon from the soil profile pits were collected for analysis. The overall observation density is 12 sites per hectare, which does exceed the FAO minimum number of sites per hectare for mapping at this scale and makes this a very detailed survey by international standards.

3.4 Laboratory

Twenty six soil profile samples and twenty six core samples were collected from the main horizons of the five detailed profiles and were analysed by the Soil and Plant Analytical Laboratory (SPAL) of the NSSC of the Ministry of Agriculture and Forests (MoAF) at Semtokha. Besides, twenty four composite soil samples were also collected and analysed to correlate with the profile soil sample data. The laboratory analysis depicts that the soils are acidic with averaging pH value 5.09.). The organic carbon is very high (averaging 9.59%) in the topsoil and moderate in the subsoil (averaging 2.23%). The total nitrogen content is moderate (averaging 0.49%) in the topsoil and low (averaging 0.15%) in the subsoil. The normal yardsticks for inherent fertility as reflected by TEB & BS are very low averaging 1.30 me/100g and BS 4.66% in both topsoil and subsoil. The fertility potential of this soil as reflected by the CEC is very high in the topsoil (averaging 52 me/100g) and high in subsoil (34.04 me/100g).

Later on, the data collected during the survey will be entered into BHUSOD database system for data storage, sorting and manipulation for reporting in future.

4. SOIL CLASSIFICATION, CHARACTERISTICS & CORRELATION

4.1 Soil classification

The soils of the two survey sites at Lamperi Park are derived from colluvial deposit. The soils do not have wide range of colours. Therefore, it is grouped as one series based on criteria such as stone contents, particle size class, soil depth, soil drainage and chemical characteristics as summarised in Table 4.1.1. While describing soil classes (see Table 4.1.2), the main features of the profiles are described. More details of the morphologies for individual profiles are given in Table 4.1.3.

Table 4.1.1 (below) summarizes the soil series with the map unit. The table is intended to show the map unit, soil characteristics and the typical profiles.

Basic soil fertility data are shown in table 4.1.4 and the general fertility data in Appendix I.

Table 4.1.1 Summary of Soil Series

Map Unit	Soil series	Brief description	Representative profiles	No. of samples
Lx	Lamperi	Deep to very deep soil with dark brown to very dark yellowish brown loam to sandy loam topsoil, underlain by dark yellowish brown sandy clay loam to clay loam subsoil; moderate coarse sub angular blocky structure; common coarse schist & quartzite gravels and stones with pH of 4.53 in the topsoil and pH of 5.09 in the subsoil; nil reaction to HCl; CEC 34.04 me/100g & BS 4.66% in the subsoil.	PP031, PP032, PP033, PP034, PP035, PP036, and PP037	26

Table 4.1.2 Characteristics of soil classes

Soil Series	Process / Drift PM	Landuse	Formation	Climate Class	Depth (cm)	Avg. depth (cm)	PSC	Colour Group	Drainage Class	HCl	Mineralogy Class	Temp Class	Moisture Class
Lamperi	Colluvium	Park	Thimphu	Cool temperate	0-150	123	H	10YR4/6	WD	-ve	Mixed	Mesic	Ustic

Note: PSC – Particle Size Class (Refer SSU WP No. 15)

Drainage Class WD – Well drained, EWD – Excessively Well Drained (Refer SSU WP No. 23)

Table 4.1.3 Description of Soil Series

Soil series	Topsoil Description	Subsoil Description	pH	CEC me/110g	BS %
Lamperi	About 20 cm deep topsoil with dark brown loam to sandy loam texture; few fine sub angular schist and gneiss gravels; weak to moderate, medium & coarse sub angular structure; common fine to many tubular pores; many very fine fibrous roots and no reaction to HCL.	About 20-150 very deep dark yellowish brown sandy clay loam to clay loam subsoil; moderate coarse sub angular blocky structure; common coarse schist & quartzite gravels and stones; many fine tubular pores; few to many fine fibrous roots; no reaction to HCL.	5.09	34.04	4.66

Table 4.1.4 Description of soil chemistry / fertility

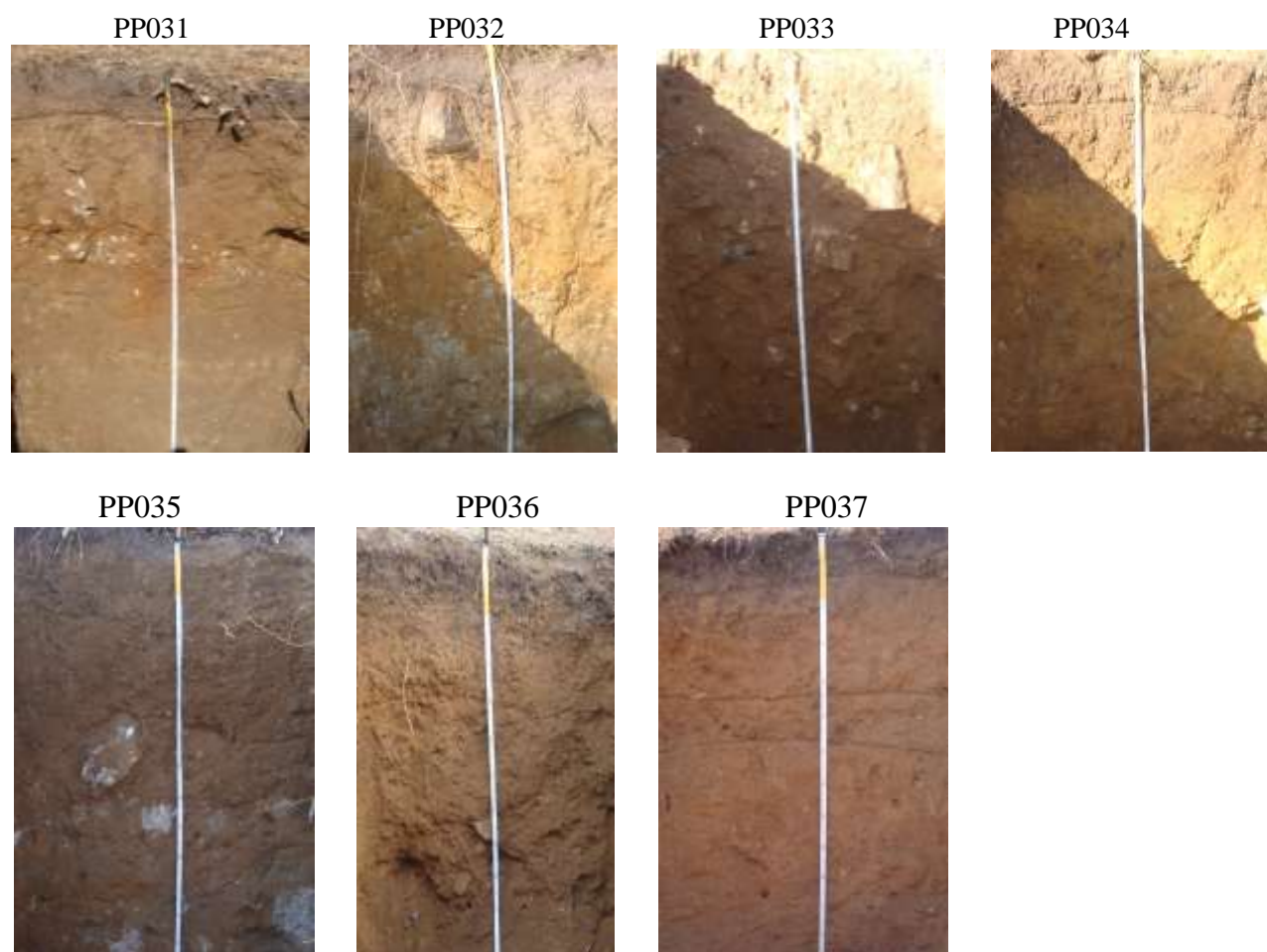
Series	pH (H ₂ O)		CEC		BS		Deficiencies		Ameliorative inputs
	Value *	Class	Me/100g	Rating	%	Class	Topsoil	Subsoil	
Lamperi	4.85 5.09	Ext. Acid and Very acid	34.04	High	4.66	Very low	Slight Ca & Mg deficient	Slight Ca & Mg deficient	Apply dolomite to address the apparent Mg and Ca deficiency and/or limestone to increase the soil pH and Ca deficiency.

* 4.85 – 5.09 (Topsoil and Subsoil pH respectively)

4.2 Description of Soil Series

4.2.1 Lamperi Series (PP031/PP032/PP033/PP034/PP035/PP036 and PP037)

All the profiles are situated on mid slopes with slope gradient ranging from 20% to 59% with north to northeast aspect. The soils are deep to very deep with dark brown to very dark yellowish brown coarse loamy to coarse sandy loam underlain by dark yellowish brown sandy clay loam to clay loam subsoil; moderate coarse sub angular blocky structure; common coarse schist & gneiss gravels and stones.



The fertility potential of this soil as reflected by the CEC is very high in the topsoil (52 me/100g) and high in subsoil (34.04 me/100g) which indicates the ability to fully retain the mineral fertilisers when applied to the soil.

However, there is slight deficiency of Mg and Ca which could be ameliorated by adding dolomite. It should also be remembered that the acid soil could be corrected by adding lime.

The soil stability test indicates that the first horizons are usually stable. However the lower horizons are moderately stable to slightly unstable due to increase in gravel content and coarser soil texture. Not only the soils slake, but also it disperses when a small soil lump is immersed in the water. This indicates that the site is susceptible to soil erosion if exposed to rainwater or active water flow. However, this will not pose any risk for landslide as long as the topsoil is kept intact (refer Appendix II).

4.3 Soil correlation

4.3.1 Previous Survey

In order to see how the Lamperi soils fit into a wider context, it is necessary to correlate them with soils elsewhere in Bhutan and also with the international systems of soil classification. SSU has done a detailed soil survey for the RNRRC at Yusipang which is situated at much lower altitude than Lamperi Park.

Both the survey areas fall under same geological formation (i.e. Thimphu formation), which is mainly characterized by alternating light and dark bands differing in mineral composition and having coarse grains than those of schist. The drift parent materials are also similar which is derived from colluvial deposits.

The difference in soils is mainly attributed by altitude and vegetation cover as Lamperi Park is situated at much higher altitude with thick vegetation cover than Yusipang. The soils at Lamperi are generally very deep, well drained with dominant subsoil texture as sandy loam to clay loam. But the soils of Yusipang are generally deep with clay loam as the dominant subsoil texture. Table 4.3.1 & 4.3.2 gives the description of the different soil types of Lamperi and Yusipang for correlation.

4.3.2 International Correlations

The series names are not useful to soil scientists outside Bhutan. For them it is necessary to give the equivalents in the international systems of soil classification. At present SSU correlates its soil series with the World Reference Base (WRB) and the United States Department of Agriculture (USDA). Table 4.3.3 correlates the Lamperi soil series with the 2006 version of the FAO World Reference Base for Soil Resources, and with the ninth edition (2003) of the USDA Soil Taxonomy.

Full and definite correlations require somewhat detailed and extensive laboratory and environmental data. However, the details are not available for the soils of Lamperi. Therefore, the correlations in Table 4.3.3 are an approximate. The Soil Moisture Regime (SMR) is assigned as *ustic* and the Soil Temperature Regimes (STR) is *mesic*.

Lamperi soils have been classified as Cambisols (WRB) and Inceptisols (USDA) since it is considered that the development of soil structure, often also associated with colour changes, qualify as Cambic horizons horizon due to high organic matter content. Similarly, the parent materials have all been described as consisting of colluvial deposits on the foot slopes.

Table 4.3.1 Soils of Lamperi

Soil series	Brief description
Lamperi	Deep to very deep soil with dark brown to very dark yellowish brown loam to sandy loam topsoil underlain by dark yellowish brown sandy clay loam to clay loam subsoil; moderate coarse sub angular blocky structure; common coarse schist & quartzite gravels and stones, with pH of 4.53 in the topsoil and 5.09 in the subsoil; nil reaction to HCl ; CEC 34.04 me/100g & BS 4.66% in the subsoil

Table 4.3.2 Soils of Yusipang

Map Unit	Land Use	Brief soil description
H	Abandoned orchard and scrubland	<p>Deep to moderately deep reddish and yellowish brown well-drained sandy loam to clay loams sometimes with gravel derived from weathered schist.</p> <p>Topsoils are slightly acid (pH H₂O 5.8) with low inherent fertility, indicated slight magnesium deficiency and low fertility potential (CEC 10.7me/100g).</p> <p>Subsoils are very acid (pH H₂O 5.38) with very low inherent fertility, indicated slight magnesium deficiency and low fertility potential (CEC 8.3 me/100g).</p>
VH	Abandoned orchard and scrubland	<p>Deep to moderately deep brown to yellowish-brown moderately well drained sandy clay loam to clay loam with minor mottling.</p> <p>Fertility and fertility potential likely to be similar to Map Unit H but lower sections should benefit from inflow of groundwater.</p>
LV	Abandoned orchard and scrubland	<p>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.</p> <p>Fertility and fertility potential likely to be not unlike Map Units H & V.</p>
V	Abandoned orchard and scrubland	<p>Deep, poorly drained pale coloured mottled sandy clay loam normally with water table within 100cm depth. Topsoils are very acid (pH H₂O 5.33) with very low inherent fertility, indicated deficiency of magnesium and low fertility potential (CEC 6.6 me/100g).</p> <p>Subsoils are slightly acid (pH H₂O 6.04) with low to very low inherent fertility, indicated magnesium deficiency with possible phosphate inhibition and low fertility potential (CEC 6.7me/100g).</p>
X	Abandoned orchard and scrubland	Deep to moderately deep, imperfectly to moderately well drained sandy clay loam to clay loam, sometimes over paralithic bedrock.

Table 4.3.3 Correlation with International Systems of Soil Classification

Soil Series	Brief series description	Subunit in FAO World Reference Base for Soil Resources (FAO 2006)	Subgroup in USDA Soil Taxonomy (Soil Survey Staff 2003)
Lamperi	Deep to very deep soil; dark brown to very dark yellowish brown loam to sandy loam topsoil, underlain by dark yellowish brown sandy clay loam to clay loam subsoil; moderate coarse sub angular blocky structure; common coarse schist & quartzite gravels and stones with pH of 4.53 in the topsoil and 5.09 in the subsoil; nil reaction to HCl ; CEC 34.04me/100g & BS 4.66%	Haplic Cambisol (Ruptic)	Typic Drystrustepts

5. SOIL DISTRIBUTION AND MAPPING

5.1 Soil distribution.

Throughout the survey area, soils are similar and grouped as one soil type based on criteria like soil colour, stone contents, particle size class, soil depth, soil drainage and chemical characteristics.

The distribution of the soils of Lamperi Park is shown below (see figure 5.1a & 5.1b) and it's descriptions in table 5.1.

Figure 5.1a Barigang soil

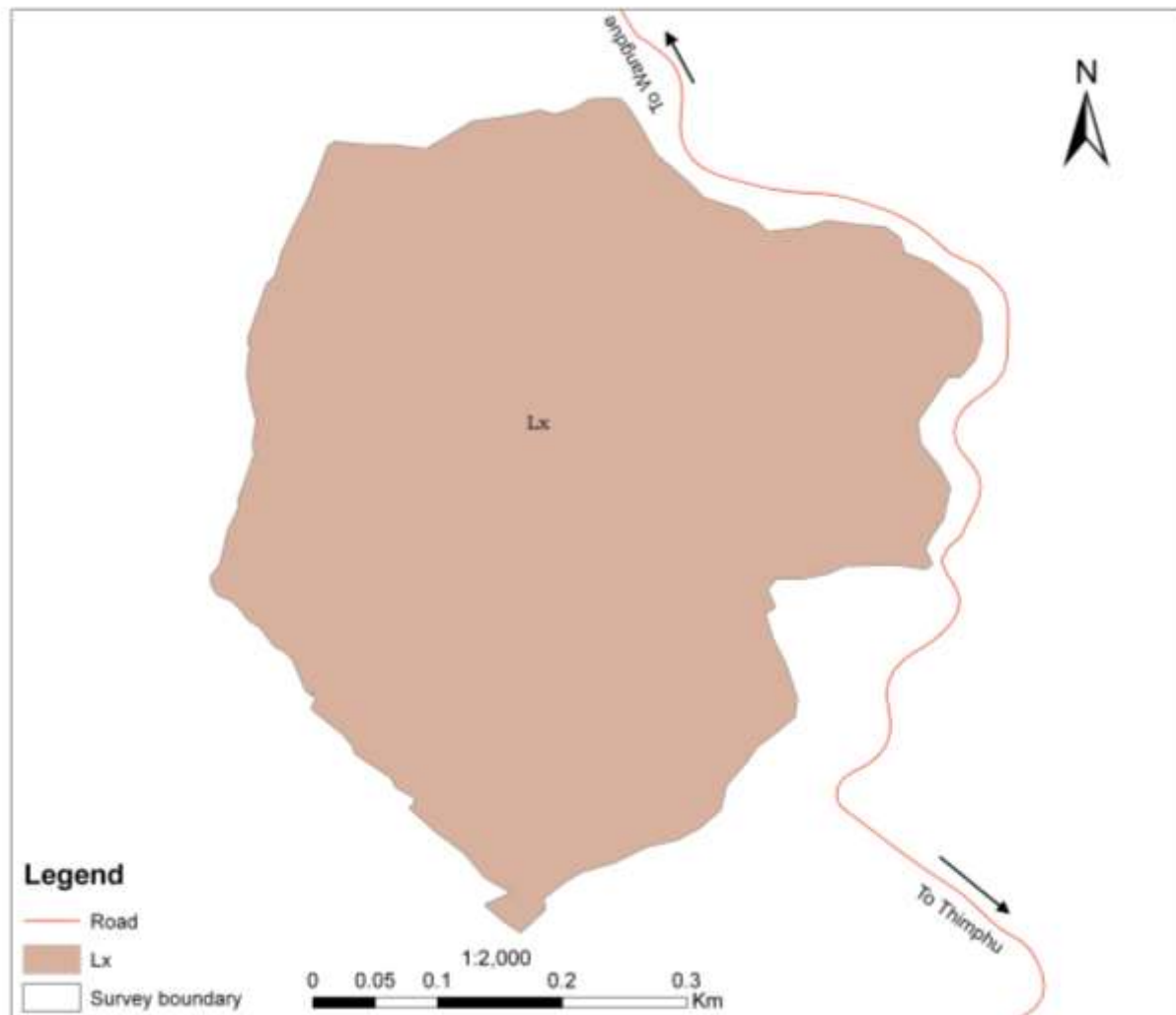


Figure 5.1b Wasabi soil

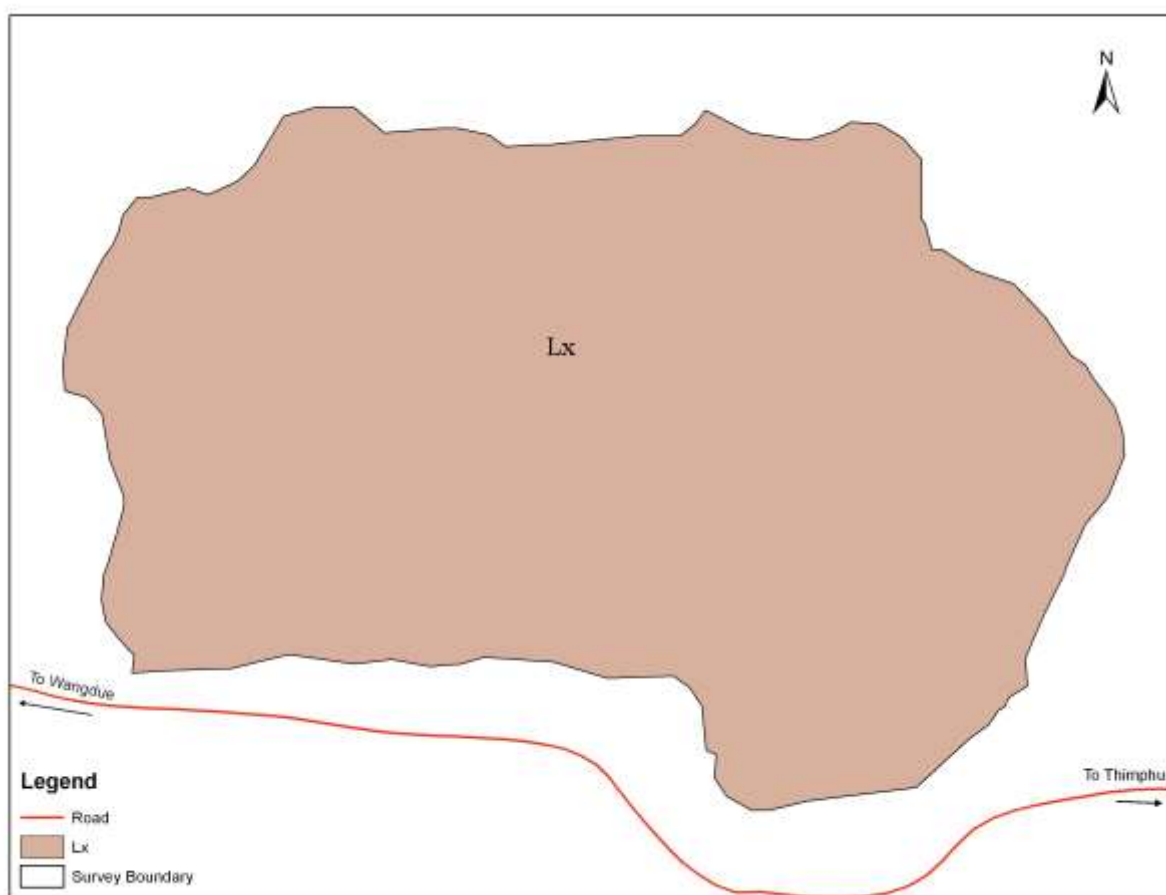


Table 5.1 Brief descriptions of the soils

Map unit	Soil Series	Land Use	Brief Description	Ha
Lx	Lamperi	Recreational park	Deep to very deep soil; dark brown to very dark yellowish brown loam to sandy loam topsoil, underlain by dark yellowish brown sandy clay loam to clay loam subsoil; moderate coarse sub angular blocky structure; common coarse schist & quartzite gravels and stones with pH of 4.53 in the topsoil and 5.09 in the subsoil; nil reaction to HCl; CEC 34.04 me/100g & BS 4.66%	38.02
Total				38.02

6. CONCLUSION

Lamperi has a limited range of soils, on account of the small size and homogenous landform and geology. Total of 53 auger observations and 7 detailed profile descriptions were done. Therefore, there is no difference between the soils of Barigang and Wasabi in relation to their physical properties. The soils are developed from colluvial deposits and the soils are generally deep, acid (pH averaging 5.09 in the subsoil). More than 50% of the whole survey indeed has dominant subsoil texture under sandy loam to clay loam. The organic carbon is very high in the topsoil and moderate in the subsoil. The total nitrogen content is moderate in the topsoil and low in the subsoil. The laboratory analyses also indicated that the inherent fertility of topsoil as reflected by the TEB & BS is low in both the topsoil and subsoil. The fertility potential of the soil (as reflected by the CEC is very high in the topsoil and high in subsoil).

The soils have been classified as Cambisols (WRB) and Inceptisols (USDA) since it is considered that the development of soil structure, often also associated with colour changes, qualify as Cambic horizons horizon due to high organic matter content. Similarly, the parent materials have all been described as consisting of colluvial deposits.

APPENDIX I: CHEMICAL CHARACTERISTICS

Table		Chemical Characteristics of - Topsoils																										
Topsoils																	(Element/CEC) x 100			Cation Ratios			Cation Ratios					
Soil Series	Site No.	Depth	pH H2O	pH KCl	pH Diff	Avail P ppm	Avail K ppm	Org C %	Total N %	C:N	Exchangeables meq / 100g					Mg Sat%	K Sat%	BS %	C/Mg	Rating	Mg/K	Rating						
										Ca	Mg	K	Na	TEB	Al	CEC												
Lamperi	PP033/1	0-20	4.56	4.03	0.53	1.93	48.89	8.30	0.49	17	0.57	0.30	1.52	0.49	2.88	50.70	1	3	6	1.90	Ca sli deficient	0.20	Mg deficient					
	PP034/1	0-20	4.85	4.21	0.64	4.39	38.26	10.80	0.53	20	3.04	0.56	1.20	0.81	5.61	46.42	1	3	12	5.43	Mg sli deficient	0.47	Mg deficient					
	PP037/1	0-20	4.09	3.85	0.24	0.84	65.60	12.70	0.61	21	0.01	0.01	0.42	0.34	0.78	59.74	3	1	2	1.00	Ca sli deficient	0.02	Mg deficient					
	PP031/1	0-20	4.72	4.09	0.63	4.62	24.83	8.50	0.46	18	3.77	0.56	0.54	0.09	4.96	46.71	1	1	11	6.73	Mg sli deficient	1.04	Mg deficient					
	PP032/1	0-20	4.28	3.97	0.31	0.93	26.37	7.60	0.36	21	0.01	0.04	0.70	0.18	0.93	44.85	0	2	2	0.25	Ca deficient	0.06	Mg deficient					
	PP035/1	0-20	4.72	4.29	0.43	1.37	15.30	5.90	0.28	21	0.14	0.03	0.48	0.68	1.33	100.00	0	0	1	4.67	OK	0.06	Mg deficient					
	PP036/1	0-20	4.89	4.16	0.73	0.92	29.66	10.20	0.58	18	2.21	0.24	1.30	0.95	4.70	47.84	1	3	10	9.21	Mg deficient with P inhibition	0.18	Mg deficient					
	PP037/1	0-20	4.09	3.85	0.24	0.84	65.60	12.70	0.61	21	0.22	0.13	0.42	0.34	1.11	39.74	0	1	3	1.69	Ca sli deficient	0.31	Mg deficient					
		Mean		4.53	4.06	0.47	1.98	39.31	9.89	0.49	19.65	1.25	0.23	0.82	0.49	2.79	52.00	0.87	1.70	5.80	3.86	OK	0.18	Mg deficient				
		Series Mean		4.53	4.06	0.47	1.98	39.31	9.59	0.49	19.65	1.25	0.23	0.82	0.49	2.79	52.00	0.87	1.70	5.80	3.86	OK	0.18	Mg deficient				
		Series Rating		Ext Acid	Ext Acid	Ext Acid	V Low	V Low	V High	Mod	Mod	V Low	V Low	High	Mod	V Low	V High	V Low	High	V Low								

Table		Chemical Characteristics of - Subsoils																										
Subsoils																	(Element/CEC) x 100			Cation Ratios			Cation Ratios					
Soil Series	Site No.	Depth	pH H2O	pH KCl	pH Diff	Avail P ppm	Avail K ppm	Org C %	Total N %	C:N	Exchangeables meq / 100g					Mg Sat%	K Sat%	BS %	C/Mg	Rating	Mg/K	Rating						
										Ca	Mg	K	Na	TEB	Al	CEC												
Lamperi	PP033/2	20-60	4.74	4.23	0.51	0.37	13.31	3.90	0.30	13	0.21	0.02	0.53	0.66	1.42	47.22	0	1	3	10.30	Mg deficient with P inhibition	0.04	Mg deficient					
	PP033/3	60-120	4.88	4.45	0.43	0.08	7.53	3.00	0.18	17	0.21	0.08	0.35	0.40	1.04	43.33	0	1	2	2.63	Ca sli deficient	0.23	Mg deficient					
	PP034/2	20-35	5.02	4.37	0.65	0.60	14.90	4.70	0.37	13	0.07	0.01	0.47	0.60	1.15	46.15	0	1	2	7.00	Mg sli deficient	0.02	Mg deficient					
	PP034/3	35-70	5.12	4.51	0.61	0.81	6.36	2.50	0.19	13	0.07	0.06	0.53	0.70	1.36	41.75	0	1	3	1.17	Ca sli deficient	0.11	Mg deficient					
	PP034/4	70-120	5.55	4.52	1.03	12.04	26.67	0.50	0.05	10	0.14	0.13	1.55	0.49	2.31	26.29	0	6	9	1.08	Ca sli deficient	0.08	Mg deficient					
	PP037/2	20-40	4.67	4.32	0.35	0.43	11.54	4.10	0.35	12	0.01	0.16	0.70	0.95	1.82	42.10	41	2	4	0.06	Ca deficient	0.23	Mg deficient					
	PP037/3	40-55	5.01	4.60	0.41	0.11	2.40	1.90	0.15	13	0.01	0.01	0.34	0.76	0.68	40.93	11	1	2	1.00	Ca sli deficient	0.03	Mg deficient					
	PP037/4	55-130	5.28	4.69	0.59	0.01	0.01	1.00	0.10	10	0.01	0.01	0.59	0.08	0.69	11.37	0	5	6	1.00	Ca sli deficient	0.02	Mg deficient					
	PP031/2	20-50	4.88	4.42	0.46	0.44	5.05	3.10	0.14	22	0.14	0.05	0.30	0.08	0.57	44.66	0	1	1	2.80	Ca sli deficient	0.17	Mg deficient					
	PP031/3	50-80	5.29	4.66	0.63	0.19	3.72	1.90	0.07	27	0.21	0.12	0.35	0.02	0.70	38.96	0	1	2	1.75	Ca sli deficient	0.34	Mg deficient					
	PP031/4	80-150	5.36	4.62	0.74	4.37	4.44	0.50	0.05	10	0.20	0.12	0.55	0.38	1.25	21.08	1	3	6	1.67	Ca sli deficient	0.22	Mg deficient					
	PP032/2	20-85	4.81	4.47	0.34	0.09	0.09	2.30	0.13	18	0.21	0.13	0.17	0.25	0.76	40.63	0	0	2	1.62	Ca sli deficient	0.76	Mg deficient					
	PP032/3	85-140	5.31	4.48	0.83	18.79	2.32	0.10	0.05	2	0.01	0.12	0.23	0.33	0.69	15.15	1	2	5	0.08	Ca deficient	0.52	Mg deficient					
	PP035/2	20-45	5.07	4.65	0.42	0.22	5.00	4.40	0.26	17	0.22	0.13	0.17	0.48	1.00	36.15	0	0	3	1.69	Ca sli deficient	0.76	Mg deficient					
	PP035/3	45-70	5.20	4.75	0.45	0.05	1.14	1.70	0.11	15	0.21	0.13	0.08	0.74	1.16	30.35	0	0	4	1.62	Ca sli deficient	1.63	Mg deficient					
	PP035/4	70-90	5.45	4.81	0.64	0.67	1.43	0.60	0.05	12	0.21	0.14	0.72	0.77	1.84	19.99	1	4	9	1.50	Ca sli deficient	0.19	Mg deficient					
	PP035/5	90-130	5.35	4.78	0.57	1.09	4.37	0.60	0.05	12	0.21	0.13	0.95	0.64	1.93	19.31	1	5	10	1.62	Ca sli deficient	0.14	Mg deficient					
	PP036/2	20-40	4.85	4.29	0.56	0.27	10.09	3.30	0.12	28	0.14	0.08	0.47	0.62	1.31	45.46	0	1	3	1.75	Ca sli deficient	0.17	Mg deficient					
	PP036/3	40-110	5.20	4.63	0.57	0.20	4.33	1.90	0.05	38	0.21	0.14	0.54	0.91	1.80	43.59	0	1	4	1.50	Ca sli deficient	0.26	Mg deficient					
	PP037/2	15-40	4.67	4.32	0.35	0.43	11.54	4.10	0.35	12	0.21	0.16	0.70	0.95	2.02	42.10	0	2	5	1.31	Ca sli deficient	0.23	Mg deficient					
	PP037/3	40-55	5.01	4.60	0.41	0.11	2.40	1.90	0.15	13	0.21	0.11	0.34	0.76	1.42	40.93	0	1	3	1.91	Ca sli deficient	0.32	Mg deficient					
	PP037/4	55-130	5.28	4.69	0.59	0.00	0.00	1.00	0.10	10	0.20	0.12	0.59	0.68	1.59	11.37	1	5	14	1.67	Ca sli deficient	0.20	Mg deficient					
		Mean		5.09	4.54	0.55	1.88	6.30	2.23	0.15	18.23	0.15	0.10	0.51	0.56	1.30	34.04	2.72	1.96	4.66	2.13	Ca sli deficient	0.21	Mg deficient				
		Series Mean		5.09	4.54	0.55	1.88	6.30	2.23	0.15	18.23	0.15	0.10	0.51	0.56	1.30	34.04	2.72	1.96	4.66	2.13	Ca sli deficient	0.21	Mg deficient				
		Series Rating		V Acid	Ext Acid	Ext Acid	V Low	V Low	Mod	Low	Mod	V Low	V Low	Mod	V Low	High	Mod	High	V Low									

APPENDIX II: SOIL STABILITY TEST

Sample	No reaction	Swell only	Slight slaking	Slaking/No dispersion	Slake/Sli-Mod slaking	Slake + dispersion	Stability class
PP031/1	√	-	-	-	-	-	Stable
PP031/2	√	-	-	-	-	-	Stable
PP031/3	-	√	-	-	-	-	Moderately stable
PP031/4	-	-	-	√	-	-	Unstable
PP032/1	√	-	-	-	-	-	Stable
PP032/2	-	√	-	-	-	-	Moderately stable
PP032/3	-	-	-	-	-	√	Very unstable
PP033/1	√	-	-	-	-	-	Stable
PP033/2	√	-	-	-	-	-	Stable
PP033/3	√	-	-	-	-	-	Stable
PP034/1	√	-	-	-	-	-	Stable
PP034/2	-	√	-	-	-	-	Moderately stable
PP034/3	-	√	-	-	-	-	Moderately stable
PP034/4	-	-	-	-	√	-	Moderately unstable
PP035/1	√	-	-	-	-	-	Stable
PP035/2	√	-	-	-	-	-	Stable
PP035/3	-	√	-	-	-	-	Moderately stable
PP035/4	-	√	-	-	-	-	Moderately stable
PP035/5	-	-	-	-	√	-	Moderately unstable
PP036/1	√	-	-	-	-	-	Stable
PP036/2	√	-	-	-	-	-	Stable
PP036/3	-	√	-	-	-	-	Moderately stable
PP037/1	√	-	-	-	-	-	Stable
PP037/2	√	-	-	-	-	-	Stable
PP037/3	-	√	-	-	-	-	Moderately stable
PP037/4	-	-	√	-	-	-	Slightly unstable

APPENDIX III: SOIL PROFILE DESCRIPTIONS

Profile Report

Profile:	PP031
Described & sampled:	Kinley Penjor, Yeshey Chedup and Chencho Dorji
Survey area:	RBRP, Dochula
Map unit:	
Soil Classification	
BSS Soil Series:	
Soil Taxonomy:	ND
WRB:	ND
Coordinates:	27° 30.0' 24.7" N and 89° 45' 09.2" E
Topographic Map:	No. 78E14, Scale 50000
Location:	Ca 150 m NW of main entrance gate
Altitude:	2671 masl
Climate	
General:	Cool temperate
Recent Weather:	Sunny
Parent material	
Solid:	Thimphu, gneiss
Drift:	Colluvium
Topography	
Landform:	Mountain
Site position:	Mid slope
Aspect:	ESE (109°)
Slope:	11° (moderately sloping), rectilinear
Erosion:	None
None	
Site drainage:	Good
Microrelief:	<25 cm from undulations
Surface	
Surface condition:	Dry, slightly hard
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	None
Surface litter:	Dense, raw decomposed grass about 4 cm deep
Surface outcrops:	None
Surface stone:	None
Land category:	National Park
Landuse:	National Park
Soil Depth Limit:	No
Soil Drainage Class:	Well drained

Cm	Horizon Type	Description
0-10	Ah	Very dark grayish brown (10YR 3/2) moist; Sandy Loam with no mottles; no stones; no concretions; moist & very friable; non sticky and non plastic; weak medium crumb structure; very weak discontinuous organic matter coating on roots; many very fine tubular pores; abundant very fine fibrous vertical and few very coarse horizontal woody roots; no faunal activity; no reaction to dilute HCL; sampled (PP031/1)
10-50	Bw	Dark yellowish brown (10YR 3/4) moist; Sandy Loam with no mottles; few very coarse slightly hard subangular quartzite stones; no concretions; moist & very friable; non sticky and non plastic; moderate very coarse sub angular blocky structure; many very fine tubular pores; many very fine fibrous irregular and few very coarse horizontal roots; no reaction to dilute HCL; sampled (PP031/2)
50-80	Bw1	Dark yellowish brown (10YR 4/6) moist; Sandy Loam with few medium dark red (2.5YR 4/3) faint mottles; common very coarse slightly hard quartzite and granite stones; no concretions; slightly firm; non sticky and non plastic; moderate coarse subangular blocky structure; many very fine tubular pores; common very fine fibrous and rare very coarse irregular roots; no reaction to dilute HCL; sampled (PP031/3)
80-150	Bw2	Olive brown (2.5Y 4/3) moist; loamy Sand with no mottles; rare medium slightly hard quartzite and granite stones; no concretions; moist & slightly firm; non sticky and non plastic; moderate very coarse subangular blocky structure; many very fine tubular pores; rare very fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP031/4)

SPAL analytical results for Profile PP031

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP031/1	0-20	32825	4.72	4.09	0.63	ND	4.62	24.83	8.50	0.46	18
PP031/2	20-50	32826	4.88	4.42	0.46	ND	0.44	5.05	3.10	0.14	22
PP031/3	50-80	32827	5.29	4.66	0.63	ND	0.19	3.72	1.90	0.07	27
PP031/4	80-150	32828	5.36	4.62	0.74	ND	4.37	4.44	0.50	0.05	10

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP031/1	3.77	0.56	0.54	0.09	4.96	ND	46.71	ND	11	ND
PP031/2	0.14	0.05	0.30	0.08	0.57	ND	44.66	ND	1	ND
PP031/3	0.21	0.12	0.35	0.02	0.70	ND	38.96	ND	2	ND
PP031/4	0.20	0.12	0.55	0.38	1.25	ND	21.08	ND	6	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425- 1000	212- 425	106- 212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP031/1	ND	ND	ND	ND	ND	79.90	2.70	17.50	14.80	5.30	SL
PP031/2	ND	ND	ND	ND	ND	70.40	3.10	13.80	16.90	12.70	SL
PP031/3	ND	ND	ND	ND	ND	72.00	7.10	12.40	19.50	8.50	SL
PP031/4	ND	ND	ND	ND	ND	74.60	7.10	13.00	21.10	5.30	LS

Profile Report

Profile: PP032
 Described & sampled: Kinley Penjor, Yeshey Chedup and Chencho Dorji
 Survey area: RBRP, Dochula
 Map unit:
 Soil Classification
 BSS Soil Series: ND
 Soil Taxonomy: ND
 WRB: ND
 Coordinates: 27° 30.0' 30.7" N and 89° 45' 04.1" E
 Topographic Map: No. 78E14, Scale 50000
 Location: Ca 200 m NW of the main entrance gate
 Altitude: 2723 masl
 Climate
 General: Cool temperate
 Recent Weather: Sunny
 Parent material
 Solid: Thimphu, gneiss
 Drift: Colluvium
 Topography
 Landform: Mountain
 Site position: Mid slope
 Aspect: SE (127°)
 Slope: 29° (strongly sloping), rectilinear
 Erosion: None
 None
 Site drainage: Good
 Microrelief: <25 cm from undulations
 Surface
 Surface condition: Dry, slightly hard
 Surface cracks: None
 Surface capping: None
 Lichen/Algae: None
 Surface litter: Dense, raw decomposed grass about 7 cm deep
 Surface outcrops: None
 Surface stone: None
 Land category: National Park
 Landuse: National Park
 Soil Depth Limit: No
 Soil Drainage Class: Well drained
 Notes / Comments: ND

Cm	Horizon Type	Description
0-25	Ah	Dark brown (10YR 3/3) moist; Sandy Loam with no mottles; rare very coarse quartzite and granite boulders; no concretions; slightly moist & friable; non sticky and non plastic; weak fine crumb structure; many very fine tubular pores; many very fine fibrous irregular and rare coarse horizontal woody roots; no faunal activity; no reaction to dilute HCL; sampled (PP032/1)
25-85	Bw	Dark yellowish brown (10YR 4/6) moist; Sandy Loam with no mottles; few coarse hard subangular quartzite and granite stones; no concretions; slightly moist & slightly friable; non sticky and non plastic; moderate coarse subangular blocky structure; many very fine tubular pores; common very fine fibrous irregular and rare very coarse horizontal woody roots; no reaction to dilute HCL; sampled (PP032/2)
85-140	Bw1	Light olive brown (2.5Y 5/4) moist; Loamy Sand with no mottles; common fine slightly hard quartzite and granite stones; no concretions; moist & loose; non sticky and non plastic; weak coarse subangular blocky structure; many fine tubular pores; few very fine and common very fine fibrous roots; no reaction to dilute HCL; sampled (PP032/3)

SPAL analytical results for Profile PP032

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP032/1	0-20	32829	4.28	3.97	0.31	ND	0.93	26.37	7.60	0.36	21
PP032/2	20-85	32830	4.81	4.47	0.34	ND	0.09	0.09	2.30	0.13	18
PP032/3	85-140	32831	5.31	4.48	0.83	ND	18.79	2.32	0.10	0.05	2

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP032/1	0.01	0.04	0.70	0.18	0.93	ND	44.85	ND	2	ND
PP032/2	0.21	0.13	0.17	0.25	0.76	ND	40.63	ND	2	ND
PP032/3	0.01	0.12	0.23	0.33	0.69	ND	15.15	ND	5	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP032/1	ND	ND	ND	ND	ND	4.80	15.00	19.80	15.40	1.00	SL
PP032/2	ND	ND	ND	ND	ND	5.50	21.50	27.00	19.20	1.00	SL
PP032/3	ND	ND	ND	ND	ND	5.30	12.30	17.60	6.40	1.00	LS

Profile Report

Profile: PP033
 Described & sampled: Kinley Penjor, Yeshey Chedup and Chencho Dorji
 Survey area: RBRP, Dochula
 Map unit:
 Soil Classification
 BSS Soil Series:
 Soil Taxonomy: ND
 WRB: ND
 Coordinates: 27° 29.0' 52.5" N and 89° 45' 29.3" E
 Topographic Map: No. 78E14, Scale 50000
 Location: Ca 150 m south of the main entrance gate
 Altitude: 2730 masl
 Climate
 General: Cool temperate
 Recent Weather: Sunny
 Parent material
 Solid: Thimphu, gneiss
 Drift: Colluvium
 Topography
 Landform: Mountain
 Site position: Mid slope
 Aspect: N (352°)
 Slope: 17° (strongly sloping), rectilinear
 Erosion: None
 None
 Site drainage: Good
 Microrelief: <25 cm from undulations
 Surface
 Surface condition: Slightly moist, moderately hard
 Surface cracks: None
 Surface capping: None
 Lichen/Algae: None
 Surface litter: Dense, raw decomposed grass about 2 cm deep
 Surface outcrops: None
 Surface stone: None
 Land category: National Park
 Landuse: National Park
 Soil Depth Limit: No
 Soil Drainage Class: Well drained
 Notes / Comments: ND

Cm	Horizon Type	Description
0-15	Ah	Very dark grayish brown (10YR 3/2) moist; Silty Loam with no mottles; few fine soft subangular schist gravels and few very coarse hard subangular quartzite stones; no concretions; slightly moist & friable; slightly sticky and slightly plastic; moderate coarse subangular blocky structure; common fine tubular pores; many very fine fibrous and common coarse irregular woody roots; few worms; no reaction to dilute HCL; sampled (PP033/1)
15-60	Bw	Dark brown (10YR 3/3) moist; Silty Loam with no mottles; common fine soft subangular schist and common hard subangular hard quartzite gravels & stones; no concretions; moist & slightly firm; slightly sticky and slightly plastic; moderate coarse subangular blocky structure; many very fine tubular pores; common very fine fibrous irregular and few coarse irregular woody roots; no reaction to dilute HCL; sampled (PP033/2)
60-120	Bw1	Dark yellowish brown (10YR 4/6) moist; Silty Clay Loam with no mottles; many very coarse subangular soft schist and hard quartzite gravels; no concretions; moist & slightly firm; sticky and plastic; moderate coarse subangular blocky structure; many fine tubular pores; few very fine fibrous roots; no reaction to dilute HCL; sampled (PP033/3)

SPAL analytical results for Profile PP033

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP033/1	0-20	32832	4.56	4.03	0.53	ND	1.93	48.89	8.30	0.49	17
PP033/2	20-60	32833	4.74	4.23	0.37	ND	3.90	13.31	3.90	0.30	13
PP033/3	60-120	32834	4.88	4.45	0.08	ND	3.00	7.53	3.00	0.18	17

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP033/1	0.57	0.30	1.52	0.49	2.88	ND	50.70	ND	6	ND
PP033/2	0.21	0.02	0.53	0.66	1.42	ND	47.22	ND	3	ND
PP033/3	0.21	0.08	0.35	0.40	1.04	ND	43.33	ND	2	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP033/1	ND	ND	ND	ND	ND	50.30	1.00	26.50	27.50	22.20	SCL
PP033/2	ND	ND	ND	ND	ND	43.70	7.50	27.10	34.60	21.70	L
PP033/3	ND	ND	ND	ND	ND	54.90	7.30	22.90	30.20	14.90	SL

Profile Report

Profile: PP034
 Described & sampled: Kinley Penjor, Yeshey Chedup and Chencho Dorji
 Survey area: RBRP, Dochula
 Map unit:
 Soil Classification
 BSS Soil Series: ND
 Soil Taxonomy: ND
 WRB: ND
 Coordinates: 27° 29.0' 55.7" N and 89° 45' 36.0" E
 Topographic Map: No. 78E14, Scale 50000
 Location: Ca 150 m NW of main entrance gate
 Altitude: 2698 masl
 Climate
 General: Cool temperate
 Recent Weather: Sunny
 Parent material
 Solid: Thimphu, gneiss
 Drift: Colluvium
 Topography
 Landform: Mountain
 Site position: Mid slope
 Aspect: NNW (340 °)
 Slope: 11 ° (moderately sloping), rectilinear
 Erosion: None
 None
 Site drainage: Good
 Microrelief: <25 cm from undulations
 Surface
 Surface condition: Moist, slightly hard
 Surface cracks: None
 Surface capping: None
 Lichen/Algae: None
 Surface litter: Dense, raw decomposed leaves about 1 cm deep
 Surface outcrops: None
 Surface stone: None
 Land category: National Park
 Landuse: National Park
 Soil Depth Limit: No
 Soil Drainage Class: Well drained
 Notes / Comments: ND

Cm	Horizon Type	Description
0-10	Ah	Dark brown (10YR 3/3) moist; Silty Loam with no mottles; no stones; no concretions; slightly moist & friable; slightly sticky and slightly plastic; moderate medium granular structure; many fine tubular pores; many very fine fibrous irregular roots; no faunal activity; no reaction to dilute HCL; sampled (PP034/1)
10-35	Bw	Dark yellowish brown (10YR 3/4) moist; Silty Loam with no mottles; rare fine subangular hard quartzite stones; no concretions; slightly moist & friable; slightly sticky and slightly plastic; moderate medium granular structure; many fine tubular pores; many very fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP034/2)
35-70	Bw1	Dark yellowish brown (10YR 4/6) moist; Loamy Sand with no mottles; common coarse hard subangular quartzite and schist stones; no concretions; moist & slightly firm; non sticky and non plastic; moderate coarse subangular blocky structure; many fine tubular pores; few very fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP034/3)
70-120	Bw2	Yellowish brown (10YR5/8) moist; Loamy Sand with no mottles; many coarse hard subangular quartzite and schist stones; no concretions; moist & slightly firm; non sticky and non plastic; moderate coarse subangular blocky structure; many medium tubular pores; rare very fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP034/4)

SPAL analytical results for Profile PP034

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP034/1	0-20	32835	4.85	4.21	0.64	ND	4.39	38.26	10.80	0.53	20
PP034/2	20-35	32836	5.02	4.37	0.65	ND	0.60	14.90	4.70	0.37	13
PP034/3	35-70	32837	5.12	4.51	0.61	ND	0.81	6.36	2.50	0.19	13
PP034/4	70-120	32838	5.55	4.52	1.03	ND	12.04	26.67	0.50	0.05	10

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP034/1	3.04	0.56	1.20	0.81	5.61	ND	46.42	ND	12	ND
PP034/2	0.07	0.01	0.47	0.60	1.15	ND	46.15	ND	2	ND
PP034/3	0.07	0.06	0.53	0.70	1.36	ND	41.75	ND	3	ND
PP034/4	0.14	0.13	1.55	0.49	2.31	ND	26.29	ND	9	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP034/1	ND	ND	ND	ND	ND	50.00	5.30	31.10	36.40	13.60	L
PP034/2	ND	ND	ND	ND	ND	67.30	7.00	18.20	25.20	7.50	SL
PP034/3	ND	ND	ND	ND	ND	55.30	6.50	28.20	34.70	10.00	SL
PP034/4	ND	ND	ND	ND	ND	72.10	4.70	12.90	17.60	10.30	SL

Profile Report

Profile: PP035
 Described & sampled: Kinley Penjor, Yeshey Chedup and Chencho Dorji
 Survey area: RBRP, Dochula
 Map unit:
 Soil Classification
 BSS Soil Series: ND
 Soil Taxonomy: ND
 WRB: ND
 Coordinates: 27° 30.0' 19.6" N and 89° 45' 03.5" E
 Topographic Map: No. 78E14, Scale 50000
 Location: Ca 250 m SW of the main entrance gate
 Altitude: 2774 masl
 Climate
 General: Cool temperate
 Recent Weather: Sunny
 Parent material
 Solid: Thimphu, gneiss
 Drift: Colluvium
 Topography
 Landform: Mountain
 Site position: Mid slope
 Aspect: ENE (75°)
 Slope: 22° (strongly sloping), rectilinear
 Erosion: None
 None
 Site drainage: Good
 Microrelief: <25 cm from undulations
 Surface
 Surface condition: Slightly moist, moderately hard
 Surface cracks: None
 Surface capping: None
 Lichen/Algae: None
 Surface litter: Dense, raw decomposed leaves about 4 cm deep
 Surface outcrops: None
 Surface stone: None
 Land category: National Park
 Landuse: National Park
 Soil Depth Limit: No
 Soil Drainage Class: Well drained
 Notes / Comments: ND

Cm	Horizon Type	Description
0-20	Ah	Dark brown (10YR 3/3) moist; Sandy Loam with no mottles; rare fine slightly hard subangular gneiss gravels & stones; no concretions; slightly moist & slightly firm; non sticky and non plastic; moderate medium subangular blocky structure; many fine tubular pores; common very fine fibrous and few coarse irregular woody roots; common worm cast activity; no reaction to dilute HCL; sampled (PP035/1)
20-45	Bw	Dark grayish brown (10YR 3/6) moist; Sandy Loam with no mottles; few fine hard subangular quartzite & gneiss stones; no concretions; slightly moist & friable; non sticky and non plastic; weak medium subangular structure; many fine tubular pores; common very fine fibrous and rare coarse irregular roots; common worm cast activity; no reaction to dilute HCL; sampled (PP035/2)
45-70	Bw1	Yellowish brown (10YR 5/6) moist; Sandy Loam with no mottles; few very coarse hard subangular quartzite and granite stones; no concretions; moist & friable; non sticky and non plastic; moderate medium subangular blocky structure; many fine tubular pores; rare very fine and few coarse irregular woody roots; no reaction to dilute HCL; sampled (PP035/3)
70-90	Bw2	Yellowish brown (10YR 5/8) moist; Loamy Sand with no mottles; common very coarse slightly hard subangular quartzite and granite stones; no concretions; moist & loose; non sticky and non plastic; weak medium crumb structure; many fine tubular pores; rare very fine and few coarse irregular woody roots; no reaction to dilute HCL; sampled (PP035/4)

90-110 Bw3

Yellowish brown (10YR 5/8) moist; Loamy Sand with no mottles; weathered rock; no concretions; soft & friable; non sticky and non plastic; very weak medium crumb structure; common fine tubular pores; none crack and none roots; no reaction to dilute HCL; not sampled

110-130 C

Paralithic layer

SPAL analytical results for Profile PP035

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP035/1	0-20	32839	4.72	4.29	0.43	ND	1.37	15.30	5.90	0.28	21
PP035/2	20-45	32840	5.07	4.65	0.42	ND	0.22	5.00	4.40	0.26	17
PP035/3	45-70	32841	5.20	4.75	0.45	ND	0.05	1.14	1.70	0.11	15
PP035/4	70-90	32842	5.45	4.81	0.64	ND	0.67	1.43	0.60	0.05	12
PP035/5	90-130	32843	5.35	4.78	0.57	ND	1.09	4.37	0.60	0.05	12

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP035/1	0.14	0.03	0.48	0.68	1.33	ND	100	ND	1	ND
PP035/2	0.22	0.13	0.17	0.48	1.00	ND	36.15	ND	3	ND
PP035/3	0.21	0.13	0.08	0.74	1.16	ND	30.35	ND	4	ND
PP035/4	0.21	0.14	0.72	0.77	1.84	ND	19.99	ND	9	ND
PP035/5	0.21	0.13	0.95	0.64	1.93	ND	19.31	ND	10	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425- 1000	212- 425	106- 212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP035/1	ND	ND	ND	ND	ND	67.40	4.80	14.70	19.50	13.10	SL
PP035/2	ND	ND	ND	ND	ND	52.20	8.80	23.10	31.90	15.90	SL
PP035/3	ND	ND	ND	ND	ND	61.90	7.10	17.50	24.60	13.50	SL
PP035/4	ND	ND	ND	ND	ND	68.50	5.50	12.70	18.20	13.30	SL
PP035/5	ND	ND	ND	ND	ND	68.30	8.00	12.50	20.50	11.20	SL

Profile Report

Profile: PP036
 Described & sampled: Kinley Penjor, Yeshey Chedup and Chencho Dorji
 Survey area: RBRP, Dochula
 Map unit:
 Soil Classification
 BSS Soil Series: ND
 Soil Taxonomy: ND
 WRB: ND
 Coordinates: 27° 29.0' 50.8" N and 89° 45' 40.5" E
 Topographic Map: No. 78E14, Scale 50000
 Location: Ca 900 m SE of RBRP guest house
 Altitude: 2757 masl
 Climate
 General: Cool temperate
 Recent Weather: Sunny
 Parent material
 Solid: Thimphu, gneiss
 Drift: Colluvium
 Topography
 Landform: Mountain
 Site position: Mid slope
 Aspect: N (1°)
 Slope: 11° (moderately sloping), rectilinear
 Erosion: None
 None
 Site drainage: Good
 Microrelief: <25 cm from undulations
 Surface
 Surface condition: Slightly moist, slightly hard
 Surface cracks: None
 Surface capping: None
 Lichen/Algae: None
 Surface litter: Dense, raw decomposed leaves about 1 cm deep
 Surface outcrops: None
 Surface stone: None
 Land category: National Park
 Land use: National Park
 Soil Depth Limit: No
 Soil Drainage Class: Well drained
 Notes / Comments: ND

Cm	Horizon Type	Description
0-15	Ah	Dark brown (10YR 3/3) moist; Silty Loam with no mottles; no stones; no concretions; slightly moist & slightly friable; slightly plastic & slightly sticky; moderate medium granular structure; many fine tubular pores; common very fine fibrous irregular roots; common worm cast activity; no reaction to dilute HCL; sampled (PP036/1)
15-40	Bw	Dark yellowish brown (10YR 4/6) moist; Silty Clay Loam with no mottles; no stones; no concretions; moist & friable; sticky and plastic; moderate medium subangular blocky structure; many fine tubular pores; common very fine fibrous irregular roots; common worm cast activity; no reaction to dilute HCL; sampled (PP036/2)
40-110	Bw1	Yellowish brown (10YR 5/8) moist; Silty Clay with no mottles; many coarse hard subangular quartzite and schist stones; no concretions; moist & friable; sticky and plastic; moderate medium subangular blocky structure; many very fine tubular pores; no roots; no reaction to dilute HCL; sampled (PP036/3)

SPAL analytical results for Profile PP036

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP036/1	0-20	32844	4.89	4.16	0.73	ND	0.92	29.66	10.20	0.58	18
PP036/2	20-40	32845	4.85	4.29	0.56	ND	0.27	10.09	3.30	0.12	28
PP036/3	40-110	32846	5.20	4.63	0.57	ND	0.20	4.33	1.90	0.05	38

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP036/1	2.21	0.24	1.30	0.95	4.70	ND	47.84	ND	10	ND
PP036/2	0.14	0.08	0.47	0.62	1.31	ND	45.46	ND	3	ND
PP036/3	0.21	0.14	0.54	0.91	1.80	ND	43.59	ND	4	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP036/1	ND	ND	ND	ND	ND	27.00	8.30	32.50	40.80	32.20	CL
PP036/2	ND	ND	ND	ND	ND	17.70	8.10	37.00	45.10	37.20	ZCL
PP036/3	ND	ND	ND	ND	ND	23.60	10.20	39.30	49.50	26.90	L

Profile Report

Profile: PP037
 Described & sampled: Kinley Penjor, Yeshey Chedup and Chencho Dorji
 Survey area: RBRP, Dochula
 Map unit:
 Soil Classification
 BSS Soil Series:
 Soil Taxonomy: ND
 WRB: ND
 Coordinates: 27° 29.0' 50.7" N and 89° 45' 40.5" E
 Topographic Map: No. 78E14, Scale 50000
 Location: Ca 900 m W of RBRP guest house
 Altitude: 2683 masl
 Climate
 General: Cool temperate
 Recent Weather: Sunny
 Parent material
 Solid: Thimphu, gneiss
 Drift: Colluvium
 Topography
 Landform: Mountain
 Site position: Mid slope
 Aspect: ESE (110°)
 Slope: 20° (strongly sloping), irregular
 Erosion: None
 None
 Site drainage: Good
 Microrelief: <25 cm from undulations
 Surface
 Surface condition: Slightly moist, slightly hard
 Surface cracks: None
 Surface capping: None
 Lichen/Algae: None
 Surface litter: Dense, raw decomposed grass and weeds about 7 cm deep
 Surface outcrops: None
 Surface stone: None
 Land category: National Park
 Landuse: National Park
 Soil Depth Limit: No
 Soil Drainage Class: Well drained
 Notes / Comments: ND

Cm	Horizon Type	Description
0-10	Ah	Very dark grayish brown (10YR 3/2) moist; Loam with no mottles; no stones; no concretions; moist & slightly firm; non sticky and non plastic; moderate medium subangular blocky structure; common very fine tubular pores; many very fine fibrous irregular roots; common worm cast faunal activity; no reaction to dilute HCL; sampled (PP037/1)
10-40	Bw	Dark yellowish brown (10YR 3/6) moist; Sandy Clay Loam with no mottles; no stones; no concretions; moist & firm; sticky and plastic; moderate coarse subangular blocky structure; common very fine tubular pores; many very fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP037/2)
40-55	Bw1	Dark yellowish brown (10YR 4/6) moist; Sandy Clay Loam with no mottles; no stones; no concretions; moist & firm; sticky and plastic; moderate coarse subangular blocky structure; many very fine tubular pores; few very fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP037/3)
55-130	Bw2	Dark yellowish brown (10YR 4/6) moist; Clay Loam with no mottles; no stones; no concretions; moist & firm; very sticky and very plastic; moderate coarse subangular blocky structure; common very fine tubular pores; rare fine fibrous irregular roots; no reaction to dilute HCL; sampled (PP037/4)

SPAL analytical results for Profile PP037

Survey area: RBRP/Lamperi

Reaction, P, K & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Avail. K ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff						
PP037/1	0-15	32847	4.09	3.85	0.24	ND	0.84	65.60	12.70	0.61	21
PP037/2	15-40	32848	4.67	4.32	0.35	ND	0.43	11.54	4.10	0.35	12
PP037/3	40-55	32849	5.01	4.60	0.41	ND	0.11	2.40	1.90	0.15	13
PP037/4	55-130	32850	5.28	4.69	0.59	ND	0.00	0.00	1.00	0.10	10

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PP037/1	0.22	0.13	0.42	0.34	1.11	ND	39.74	ND	3	ND
PP037/2	0.21	0.16	0.70	0.95	2.02	ND	42.10	ND	5	ND
PP037/3	0.21	0.11	0.34	0.76	1.42	ND	40.93	ND	3	ND
PP037/4	0.20	0.12	0.59	0.68	1.59	ND	11.37	ND	14	ND

Fine earth granulometric

SSU No.	Sand						Silt			Clay	Texture class
	>1000 micron	425-1000	212-425	106-212	50-106	Total sand	20-50 micron	2-20	Total silt		
PP037/1	ND	ND	ND	ND	ND	70.20	7.10	15.80	22.90	6.90	SL
PP037/2	ND	ND	ND	ND	ND	38.80	7.30	29.80	37.10	24.10	L
PP037/3	ND	ND	ND	ND	ND	44.00	9.80	26.00	35.80	20.20	L
PP037/4	ND	ND	ND	ND	ND	37.10	9.80	31.30	41.10	21.80	L