Royal Government of Bhutan
Soil Survey Unit (SSU)
National Soil Services Centre (NSSC)
Department of Agriculture (DoA)
Ministry of Agriculture & Forests (MoAF)

TECHNICAL REPORT ON DETAILED SOIL SURVEY OF CHIMIPANG

Report No. SS 25
January, 2016

CONTENTS

SUMMARY

S.1 Background

This is the technical report of detailed soil survey of Chimipang located in Lobesa under Punakha Dzongkhag. In the past, Soil Survey Unit (SSU) has been producing a general report for such studies but the present intention is to compile a detailed report that can be, more or less, an independent free-standing document for use by non-technical staff.

The survey was completed at detailed level at mapping scale of 1:7,500 and the density of sites fall low to mid-way on the recommended scale, according to Food and Agriculture Organisation (FAO). A total of 39 observations were made during the fieldwork. The soils were examined on routine basis at 25 sites, with the Edelman soil auger. Furthermore, the soils were described in more detail in 14 full-size soil profile pits. All data were recorded on the soil survey's field description cards.

All sites were logged on the base map which was totally updated and refined during the survey, soils were grouped, described and mapped, soil units were defined and all sites were placed into soil groups.

S.2 Location and Environment

The survey area is located below Metsina town, under Baap gewog. Its five minutes drive from Metsina town towards Punakha. It is situated on the true right bank of Punatsangchu which is opposite to Samthang Technical Training Institute (STTI). It stretches from latitude 27° 31' 05.3"N to 27° 31' 25.3"N and longitude 89°52' 32.0"E to 89° 52' 47.7"E. The survey area is 65.78 ha (162.55 acres).

The survey area stretches from an altitude between 1223m and 1311m asl (above sea level). The area falls under subtropical (SSU Working Paper WP26) climatic zone on the account of its altitude. The survey area has predominantly south east to north east aspect with coniferous forest as the dominant natural vegetation as observed on the adjacent hill slopes.

There is no meteorological data specific for Chimipang survey area. However, the climatic data collected from the meteorology station at Renewable Natural Resources Development Centre (RNRDC) in Bajo has been taken as near equivalent.

Table 2 summarises the main features of the climate of Chimipang for the period 2003-2013 and shows that the mean minimum temperature drops to about 4.6^{o}C in January, and rise to about 17.4^{o}C in June and July. The mean maximum rises from about 16.1^{o}C in January to 24.7^{o}C during the month of June. The mean air temperature is over 14^{o}C and the difference between winter and summer means is greater than 7^{o}C.

The summation of monthly mean in Table 2 indicates that the mean annual rainfall at Chimipang is 657.3 mm.

The Chimipang area falls under the Thimphu Formation and mainly comprises of gneiss & schist. Large parts of the survey area consist of young alluvial deposits and have a mixed geology.The soils on the lower hill slopes along the eastern boundary of the survey area are colluvial and have moderately deep soils overlying weathered schist and gneiss. About 58% of the total survey area is underlain by alluvial deposits and has at least four distinct levels of river terraces.

S.3 Soils

The Chimipang survey area has a limited range of soils, on account of the small size of the area and homogeneous geology. The soils are slightly acid to very acid with pH values less than 5.54 in the topsoil and neutral pH with value less than 6.83 in the subsoil. The organic carbon content is low to moderate in the topsoil and very low in the subsoil, while total nitrogen is low to very low. There is Magnesium deficiency in both the topsoil and subsoil.

The main differences in Chimipang soils relate to their physical properties. There are differences in texture of fine earth fractions. Texture in the topsoil varies from sandy loam to silty loam and sandy loam to sandy clay in the subsoil formed mainly due to the interplay of the mixed geology. The soil profile excavation indicated that the soils depths are deep to deep (110cm - 140cm).

There are mainly three types of soils series recognized namely Chimipang, Yuwakha and Sopsokha. The series were recognized based on the typifying pedons identified.

Figure 1 Soil Map

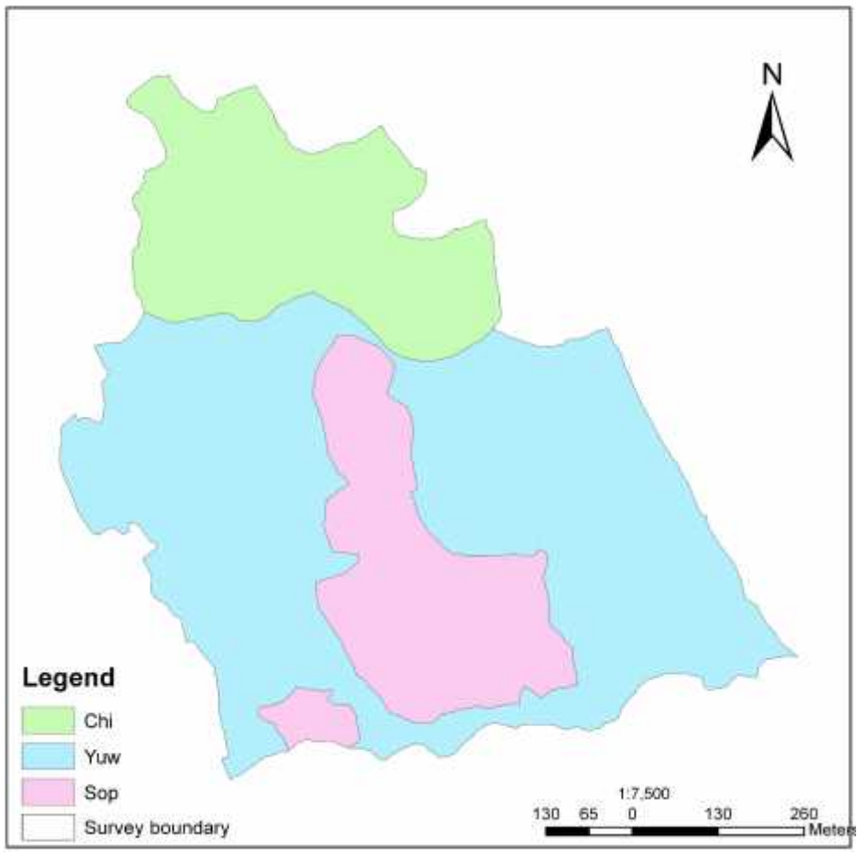


Table 1 Description for Soil Map

Map Unit	Soil Series	Brief Description	Ha	%
Chi	Chimipang	Deep soil with dark brown sandy loam topsoil underlain by dark brown sandy loam subsoil, no mottles, no stones, very strong very coarse subangular blocky structure, few to common fine interstitial pores, no roots, no reaction to dilute HCL, slightly acid to neutral pH (6.14/6.97), low CEC (8.26/7.66) and high to very high BS (73.55/98.65)	14.35	21.81
Yuw	Yuwakha	Deep soil with grayish brown to silty loam topsoil underlain with very dark grayish brown gravelly sandy clay subsoil, few fine faint mottles, common medium subangular hard gneiss, common fine interstitial pores, no roots, no reaction to dilute HCL, very acid to neutral pH (5.54/6.83), low CEC (8.57/7.65) and moderate to very high BS (50.95/134.37)	39.05	59.37
Sop	Sopsokha	Deep soil with gray silty clay loam topsoil underlain by brown sandy clay subsoil, common fine faint mottles, few to common medium hard subangular gneiss and slightly hard schist stones, moderate medium subangular blocky structure, common fine interstitial pores, no roots, no reaction to dilute HCL, very acid to neutral pH (5.29/6.69), low CEC (7.81/8.70) and moderate to very high BS (56.02/89.02)	12.38	18.82
		Total	**65.78**	**100**

S.4 Recommendations

Based on the physical and chemical characteristics of the soils, following recommendations are suggested to improve the soil nutrient status of the site.

- The soil pH is slightly acid to very acid in the topsoil. Based on the soil pH requirement by different plants, the soil needs to be ameliorated, either by raising the pH through incorporation of lime or reducing the pH by adding sphagnum peat, acidifying fertilizers[1] and organic mulches. This is to bring soil pH to a desirable range, where nutrients are easily available for uptake by the plants. Most agronomic crops grow well within moderate pH range and flowers in slightly acid to acid soils.

- Nitrogen is the other primary nutrient needed by plants in larger quantities. The N content is within low to very low range, demanding addition of urea or ammonium nitrate fertilizer.

- The CEC of the soil samples is low in range and this could be improved by incorporating well decomposed FYM and other organic materials.

- There is Mg deficiency and this could be improved by applying dolomite, which is a good source of calcium (Ca) and magnesium (Mg).

[1] *Acidifying fertilizers such as ammonium sulfate, urea, and ammonium nitrate*

ACKNOWLEDGEMENT

The fieldwork for the survey was done in the month of March 2013 by Mr. Yeshey Chedup (Soil Surveyor).

The location, base and provisional soil maps were all drafted and digitized by Mrs. Sangita Pradhan.

Other logistics such as labourers during the entire fieldwork was arranged by RNDDC, Bajo.

Soil analyses were done by the staff at Soil and Plant Analytical Laboratory (SPAL), National Soil Services Centre (NSSC).

The final report is compiled by Mr. Yeshey Chedup and Mr. Kinley Penjor

ABBREVIATIONS & GLOSSARY

(Simple metric units and chemical element symbols not included*)*

Acre	Area of measurement, = 0.405 ha
asl	Above sea level
AvP, AP	Available Phosphate
BHUSOD	Bhutan Soil Databank
SSU	Soil Survey Unit
BS%	Base saturation percentage
ca	Approximately
CEC	Cation exchange capacity
Chhu	Term used for river or stream
cm	Centimetre
C: N	Carbon to Nitrogen Ratio
Consociation	Soil mapping unit with one soil class dominant but others as minor constituents
DoA	Department of Agriculture.
DoHS	Department of Hydro-Met Services
DSLR	Department of Survey and Land Records
Exch	Exchangeable (for cations)
EWD	Extremely well drained (soil)
FAO	Food and Agricultural Organisation of the United Nations
Fine earth	Soil particle size < 2mm
GIS	Geographical information system
GPS	Global positioning system
ha	Hectare
HCl	Hydrochloric acid
Horizon	Soil layer
Kamzhing	Rainfed agriculture
MoAF	Ministry of Agriculture and Forests
MoEA	Ministry of Economic Affairs
NSSC	National Soil Services Centre, DoA, Semtokha
OC%	Percentage of Organic Carbon Content
PM	(Soil) Parent Material
ppm	Part per million
pH	Measure of acidity - alkalinity
Profile	Sequence of horizons from surface down to unaltered parent material
Series	Main group of soil classes in Bhutan. Also sixth highest level of subdivision in USDA Soil Taxonomy
SMR	Soil Moisture Regime, defined in Soil Taxonomy
SMU	Soil mapping unit
SOM	Soil Organic Matter
sp, spp	Species (singular & plural)
SPAL	Soils and Plant Analysis Laboratory, NSSC, DoA, Semtokha.
STR	Soil temperature regime, defined in Soil Taxonomy
TN	Total nitrogen
USDA	United States Department of Agriculture
WD	Well drained (soil)
WRB	World Reference Base

1. INTRODUCTION

This technical report on soils of Chimipang under Punakha was produced at the scale of 1:7500 on detailed survey level. It provides sufficient information on the characteristics and geographic distribution of the soils for broad scale development planning and execution based on the detailed soil profile descriptions and soil chemistry (fertility).

1.1 Background

As per the directive from Ministry of Agriculture and Forests, the National Soil Services Centre (NSSC) was called upon to conduct a detail soil survey of the site at Chimipang for the purpose of developing into an exemplary agricultural demonstration site.

1.2 Aims of the Survey

The survey was undertaken with following objectives:

- Provide sufficient detailed information on nature and spatial distribution of the soils
- Provide soil map at a suitable scale for better utilization and management
- Provide information on soil chemistry (fertility)
- Provide SSU with data for the further development of the national soil classification system and to build up the database of national and regional soil maps
- Add soil information to the existing soil database (BHUSOD)

2. THE SURVEY AREA

2.1 Location and Extent

The proposed area is located below Metsina town, under Baap gewog. Its only five minutes drive from Metsina town towards Punakha. It is situated on the true right bank of Punatsangchu which is opposite to Samthang Technical Training Institute (STTI). It stretches from latitude 27° 31' 05.3"N to 27° 31' 25.3"N and longitude 89°52' 32.0"E to 89° 52' 47.7"E. The site has a maximum North-East length of about 500m and a maximum East-West width of about 250m. It covers about 65.78 ha (162.55 acres).

2.2 Climate

The survey area stretches from an altitude between 2386m and 2453m asl (above sea level). The site falls in the Sub-tropical (SSU Working Paper WP26) climatic zone on the account of its altitude. The site has predominantly easterly to east south east aspect with coniferous forest as the dominant natural vegetation as observed on the adjacent sites.

There is no meteorological data for the survey area. However, the climatic data from meteorology station in RNRDC, Bajo under the Ministry of Agriculture and Forests has been taken as near equivalent as it lies in the same altitude zone.

Table 2 summarises the main features of the climate of Chimipang for the period 2003-2013 and shows that the mean minimum temperature drops to about 4.6^{o}C in January, and rise to about 17.4^{o}C in June and July. The mean maximum rises from about 16.1^{o}C in January to 24.7^{o}C during the month of June. The mean air temperature is over 14^{o}C and the difference between winter and summer means is greater than 7^{o}C.

The summation of monthly mean in Table 2 indicates that the mean annual rainfall at the technology park is about 657.3 mm.

Figure 2 Location of the survey site

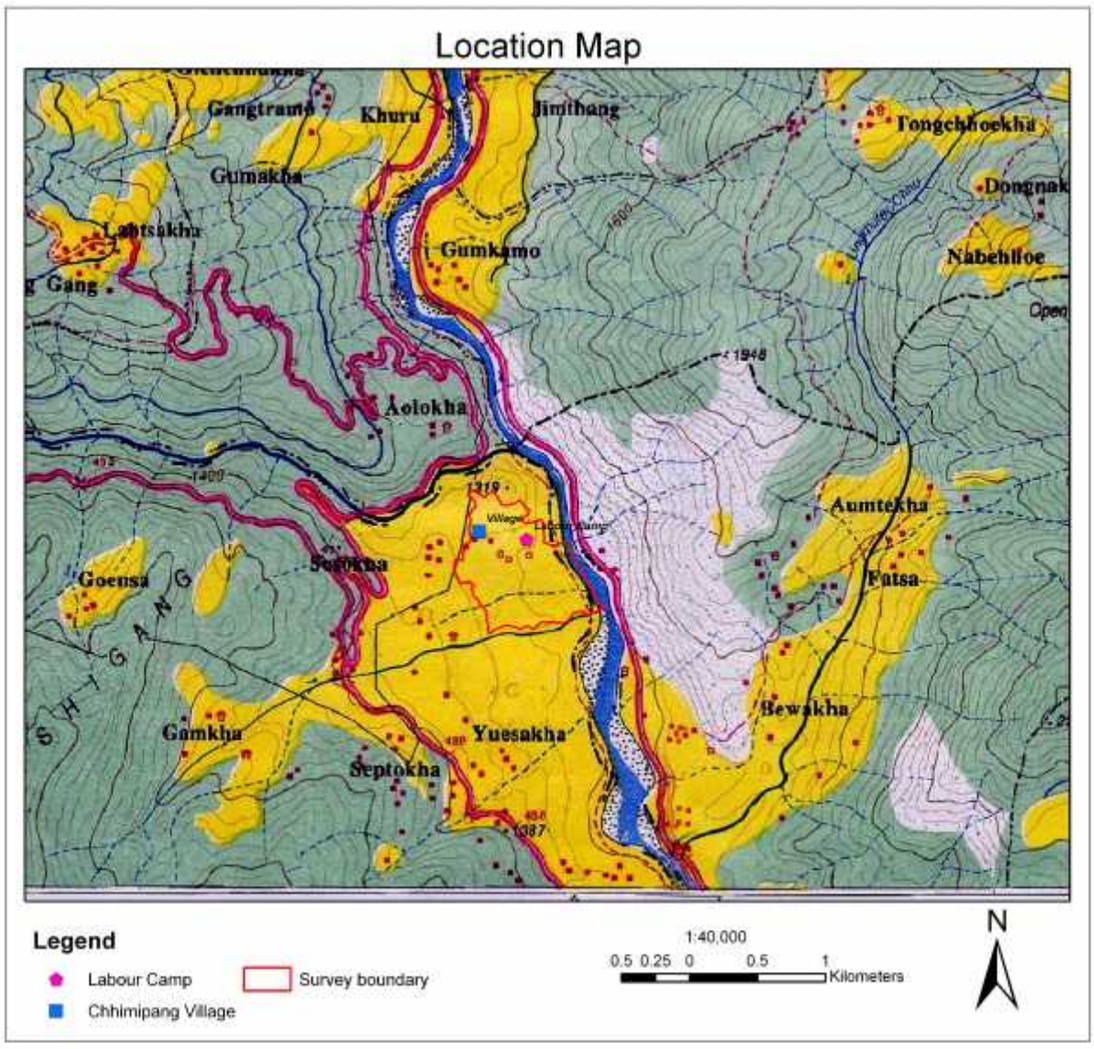


Table 2 Climatic Summary from RNRDC, Bajo, Wangduephodrang (2003 – 2012)

Months	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year mean or total**
Temperature (^{o}C)													
n (number of complete records)	12	12	12	12	12	12	12	12	12	12	12	12	*12 (Years with complete data*
Mean	10.4	11.9	14.6	17.3	19.2	20.9	21.0	21.0	20.2	17.6	13.9	11.5	16.6 (Average of monthly means)
Mean minimum	4.6	6.7	9.3	12.3	14.4	17.0	17.4	17.4	16.5	12.7	8.2	5.4	12.2 (Average of monthly *minimum)*
Mean maximum	16.1	17.2	19.9	22.3	24.0	24.7	24.5	24.5	23.9	22.6	19.6	17.6	(Average of monthly maximum)

Rainfall (mm)

Months	**J**	**F**	**M**	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**Year mean or total**
n (number of complete records)	12	12	12	12	12	12	12	12	12	12	12	12	Total
Mean	5.7	9.7	14.5	38.2	60.4	101.1	149.2	115.4	96.5	61.4	3.9	1.4	**657.30**
Monthly maximum	0.8	1.2	1.1	2.8	4.3	6.9	7.6	5.5	4.9	4.0	0.5	0.3	
Monthly minimum	0.0	0.0	0.1	0.3	0.1	1.3	3.0	2.0	1.3	0.4	0.0	0.0	

Source data from Meteorology Section, DoHS, MoEA

2.3 Geology and Soil Parent Materials (SPM)

The Chimipang area falls under the Thimphu Formation and mainly comprises of gneiss & schist. Large parts of the survey area consist of young alluvial deposits and have a mixed geology.

The soils on the lower hill slopes along the eastern boundary of the survey area are colluvial and have moderately deep soils overlying weathered schist and gneiss. About 58% of the total survey area is underlain by alluvial deposits and has at least four distinct levels of river terraces.

The Centre is located almost entirely on the alluvial deposits of the Tsang Chhu and there are no outcrops of bedrock. The alluvium is derived from the rocks of the upstream catchment.

The alluvial history of the section of the Tsang Chhu valley is complex. The rapid but irregular movement downwards of the erosional base level has resulted in the deposition and subsequent dissection of successive levels of alluvium. The terraces of the highest and oldest group in the vicinity of the survey area are at about 100-130 m above the current river level. The full depth of these deposits is exposed in the road cuttings along the Khuru -Wangdi Highway down from Samthang Technical Training Institute. This section shows that this alluvium is very heterogeneous, with beds of rounded boulders, inter-layered with beds of sand and pebbles. There are also massive boulders (of up to 100 m3) which have been hardly rounded. These may be colluviums fragments that have rolled down local slopes and been incorporated into the more traveled alluvium.

The middle group of terraces in the survey area is at about 25–40 m above the current river. The upper part of the survey area (dry land) is located on these deposits. The steep slope at their lower edge reveals rounded boulders at depths of 2-3 m. From the Auger/profile boreholes on this terrace, the fragment of free alluvium is much deeper. The drilling data indicated that up to 40 m of sand, silt and clay alluvium overlies a dense bed of rounded boulders.

2.4 Topography and Drainage

The proposed site is located at the true right hand side of Punatsang Chhu. This section of the valley is very wide as it is downstream, but it still forms a relatively wide basin of moderately sloping land. This area of gentle topography is mostly used as wetland cultivation. There are settlements at the proposed site, but on the other side of the river the STTI is located.

As noted above, most of the area is located on the lower and middle groups of terraces of the main valley of Tsang Chhu. The natural drainage lines are drained into Tsangchhu. Above the main steep slope the middle terrace slopes gently uphill (about 2–4% natural slope) to the concave lower slope of the foothills which come down to the eastern boundary of the survey area. There appear to be two levels within the middle group of terraces, separated by a minor bluff 2 – 4 m high, running across just below the level of the borehole. However the land surface has been much modified by the construction of agricultural irrigation terraces, and these obscure the natural break of slope. There do not appear be any significant natural drainage lines on the main expanse of the middle terrace, but there may have been one along the base of the riser slope up to high terraces.

2.5 Land Use and Vegetation

Virtually the whole of the survey area is under irrigated agriculture farming. The bulk of it is left fallow (dry land) without cultivation for so many years. The main cropping systems investigated are summer rice; winter wheat and mustard; summer and winter vegetable; and warm temperate and subtropical fruit tree crops, including peaches, guava and few mandarins. The survey area falls under the subtropical climate dominated by the Chirpine and the broadleaf forests.

There are large areas left fallow uncultivated for long time situated at the upper slope hills areas along the riverbanks, the lowest parts of the floodplain and on the steep sections of the terrace riser slopes and the foot slope of Tsang Chhu valley. On the steep land slopes there is a scrub of tall local grasses, Artemisia vulgaris and some chirpine seedlings in the vicinity of Chimi Lhakhang.

3. METHODS

3.1 Pre-field Work

The topographic map at scale of 1:50,000 from National Land Commission (NLC) was used to prepare the base map of the survey area, as no other maps at larger scales were available during the time of fieldwork. GPS was used as a mapping tool for collecting information like survey boundary, foot path, infrastructure, which was later downloaded on an ortho-image captured from Google Earth and subsequently processed to produce the base map at an appropriate scale.

Other necessary field equipments such as field data recording cards, camping and high-tech instruments such as GPS, clinometers, compass, laptop, sampling materials were all checked and arranged for the fieldwork.

3.2 Field

3.2.1 General

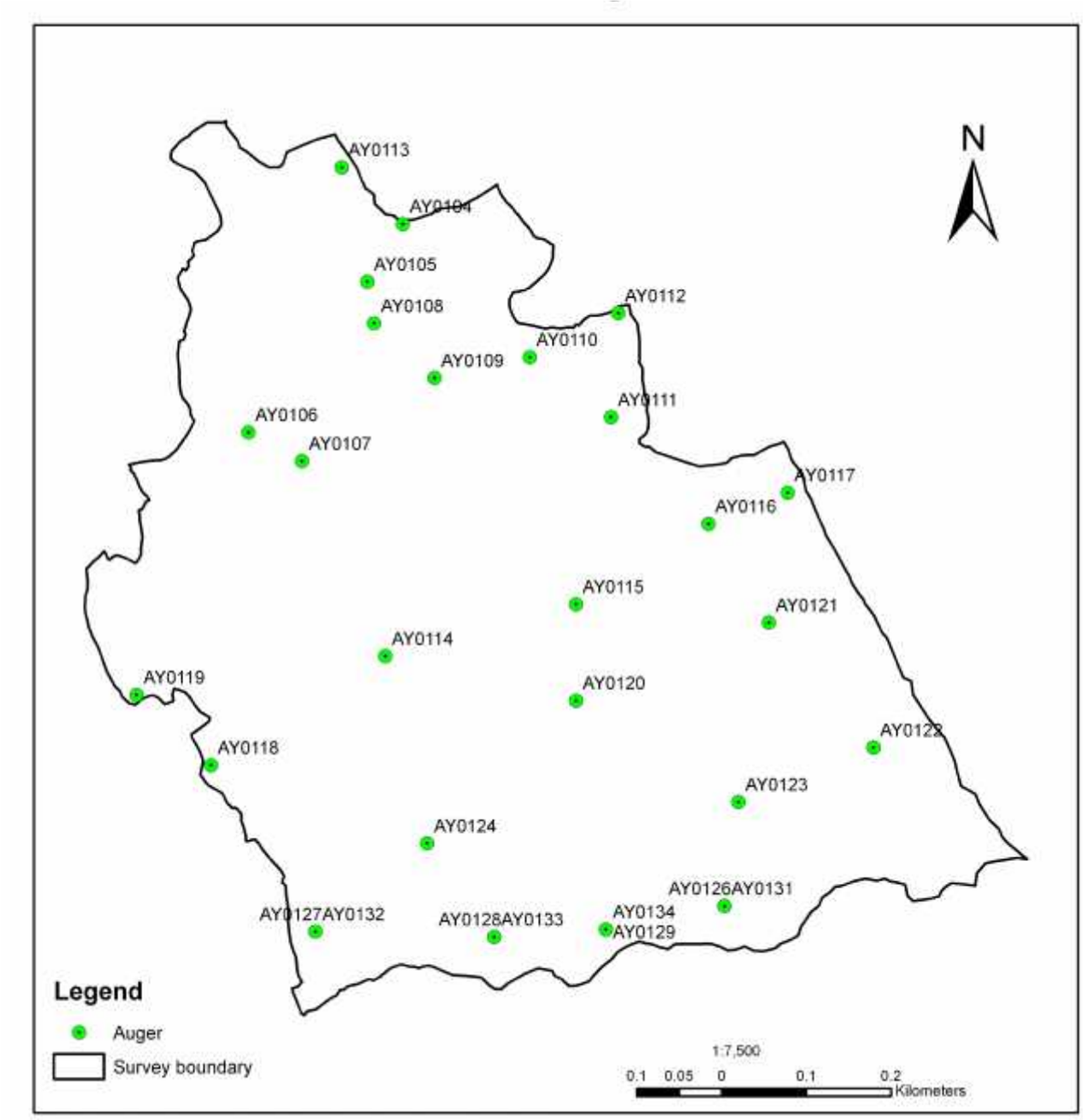
On arrival at the site the following actions were taken:

- Courtesy call to concerned authority
- Arrangement of labourers for fieldwork
- Prepare survey plan based on the base map prepared by SSU

The fieldwork for this survey was carried out from 17th – 30th March, 2013. The soils were examined on a routine basis at 25 sites (Figure 3), mainly with a 1.2m Edelman auger, fitted with a 7cm combination head where possible, but switching to a 7cm stony soil head where necessary. Soil profile pits were excavated based on the soils encountered during augering – in total, 14 soil profile pits (Figure 4) were dug, described and sampled. All the routine observations were located based on the differences in the landforms along transects at approximately 50 metres apart.

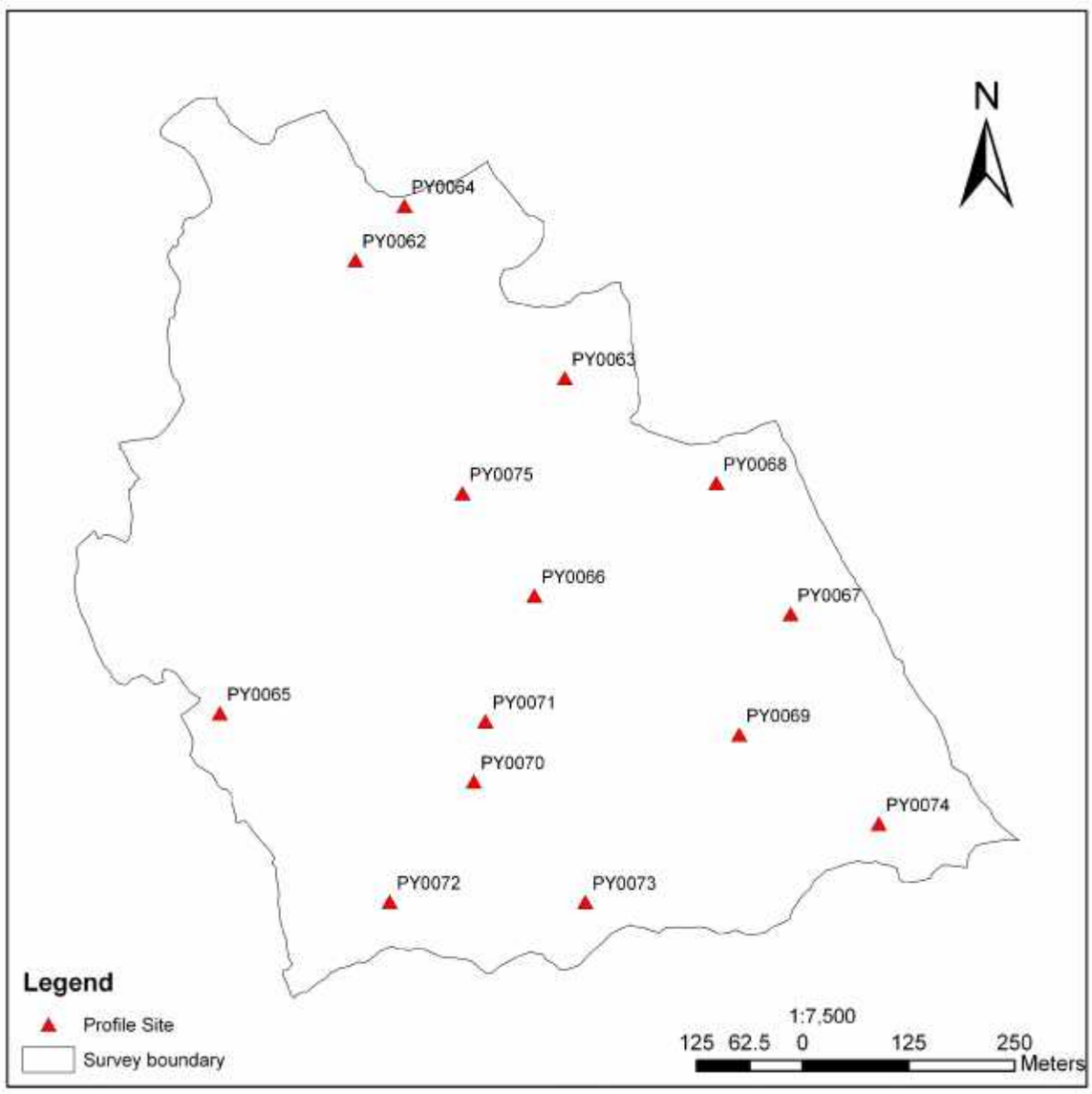
Under FAO, this survey would be classified as detailed with mapping scale of 1:7500 and the density of sites falling low to mid way on the FAO recommended scale (FAO includes “Minimum”, “Low”, “Mid” and “High” site density classes).

Figure 3 Distribution of Soil Auger Sites



*Note: *Auger and profile distribution maps were presented separately to make the distribution map more intuitive and prevent overcrowding of observation sites.*

Figure 4 Distribution of Soil Profile Sites



3.2.2 Site Data

All data were collected on the SSU field description cards which have been specifically designed to enable uniform data collection for easy entry into the Bhutan Soil Databank (BHUSOD) system. For all soil observations 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, GPS coordinates, altitude, general topographic and site position
- Solid, or mapped geology and drift cover or parent material
- The gradient (in %), aspect and form of the slope with estimated run-off and site drainage
- Previous erosion and risk of flooding based on height above the nearest stream line
- Micro-relief, hardness of the surface, presence of capping or cracks
- Estimates (%) of outcropping rock plus stone or gravel cover and any surface litter (organic)
- General land use and current crops/vegetation and any known previous land uses
- Artificial land shaping features, irrigation type plus fertiliser use, if present or known.

3.2.3 Soil Data

All data were collected on the SSU field description cards which have been specifically designed to enable uniform data collection for easy entry into the Bhutan Soil Databank (BHUSOD) system. The cards for the auger descriptions are considerably smaller than those for the profile data since many soil features cannot be described while augering.

(a) Auger Sites

Auger samples were collected by withdrawing the auger each time the “head” was full of soil. Each sample was then laid in the ground next to the auger hole in order - each sample accounting for approximately 10cm depth of the excavation. Surveyors could then easily determine the depths at which changes in the soil occurred. The soils were described according to their natural layering (horizons), throughout the depth to which the auger reached, which at best, is just over 1 metre, and not at fixed depths. The following data were collected for each horizon:

- Horizon number, depth and type
- Munsell colour of matrix – dry and moist when conditions permit
- Number, size, contrast and colour of mottles
- Field texture including coarse material prefix and particle size class (PSC)
- Number, size, shape, hardness and type of stones
- Reaction to dilute hydrochloric acid (HCL) (to test for presence of free carbonate minerals)
- Number, size, shape, form type, hardness and colour of concentrations or concretions
- Field moisture status of the soil and, when possible, consistency and plasticity of each horizon in dry, moist and wet condition.

Soil samples were collected from auger sites in addition to the samples from profile pits.

(b) Profile Pit Sites

The soils were described in more detail at fourteen sites. All the detailed descriptions were done in purpose-dug profile pits. Profile pits were normally excavated to 150cm depth or to a limiting layer such as solid rock or boulders. The site data were exactly the same as for the auger sites. The soils were described by horizons according to international conventions (FAO 1990). The data collected for each horizon were the same as in the auger descriptions, with the addition of:

- Whether the horizon was 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, size, type, continuity and location of any coatings or cutans (shiny coatings on surfaces of soil structural units)
- Number, size and type or shape of pores,
- Consistence *in situ* and in hand;
- Number size and type of roots
- Frequency and size of cracks
- Presence and artifacts or effects of fauna (worm casts etc.);
- Frequency, size type and orientation of roots.

All data were collected on purpose designed proforma which are computer compatible and allow easy entry of the collected data into the BHUSOD system.

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

3.3 Mapping

The survey site falls within the 1:50,000 topographic map sheet No. 78E14 of 2000 and contours at 40m interval of the National Land Commission. This map scale is very small and is not suitable for detailed site planning and also to use as a base map. Therefore, the soil survey team prepared a base map at 1: 7500 scale using GPS and Ozi Explorer software.

3.3.1 Maps produced and used during the survey

The following maps were constructed in Arc GIS environment based on the NLC map sheet 78E14 by the survey team and used or compiled during and after the survey.

Table 3 Maps Compiled and Used during the Survey

Map	Scale	Content and Use
Base map	1:7,500	Geographic registration coordinates, foot path, farm boundary and infrastructural detail
Auger and profile distribution	1:7,500	Location of all sites described and located via GPS readings but checked as locational accuracy in the field and via detail of the base and land unit maps
Soil Series	1:7,500	Shows the soil series number code for each site. Used for the construction of the actual soil map
Soil Map	1:7,500	Shows the boundaries between the various soil mapping units defined and mapped. Compiled by interpretation and integration of the soil series and land units
Location Map	1: 40,000	Shows the position of the survey area with respect to other nearby places, roads and water bodies

3.3.2 Final Map Presentation

Once all the draft maps were compiled and modified, it was then digitized using the GIS Software. The following maps were appended:

- Location map
- Auger and profile distribution map
- Soil mapping unit
- Soil map and
- Soil series map

The final maps were produced at a scale of 1:7,500 and copies are appended in the report.

3.4 Laboratory

A total of 48 soil samples were collected from the main horizons of the 14 detailed profile pits and submitted for analysis by the Soil and Plant Analytical Laboratory (SPAL), NSSC at Semtokha.

3.5 Data Storage

As stated above all data were collected on the SSU computer compatible field data cards and subsequently all the data were entered into the BHUSOD system for storage and data manipulation.

4. SOIL CLASSIFICATION, CHARACTERISTICS & CORRELATION

4.1 Soil Classification

The soils of Chimipang are basically derived from alluvial deposits. They are grouped into three provisional soil series based on thickness, arrangement of horizons, structure, colour, texture, reaction, consistence, stone contents, rooting depth, mottle content as summarised in Table 4.

Table 4 below summarises the soil series of Chimipang. The table is intended to show the soil characteristics and the typifying profile in every series.

The overall distribution of soil series is shown in Figure 5.

Table 4 Summary of the Soil Series

Series code	Soil Series	Brief description	Typifying profile	No. of Samples
Chi	Chimipang	Deep soil with dark brown sandy loam topsoil underlain by dark brown sandy loam subsoil, no mottles, no stones, very strong very coarse subangular blocky structure, few to common fine interstitial pores, no root, no reaction to dilute HCL	PY0064	9
Yuw	Yuwakha	Deep soil with grayish brown silty loam topsoil underlain with very dark grayish brown gravelly sandy clay subsoil, few fine faint mottles, common medium subangular hard gneiss, common fine interstitial pores, no roots, no reaction to dilute HCL	PY0065	21
Sop	Sopsokha	Deep soil with gray silty clay loam topsoil underlain by brown sandy clay subsoil, common fine faint mottles, few to common medium hard subangular gneiss and slightly hard schist stones, moderate medium subangular blocky structure, common fine interstitial pores, no roots, no reaction to dilute HCL	PY0070	18

Figure 5 Distribution of Soil Series

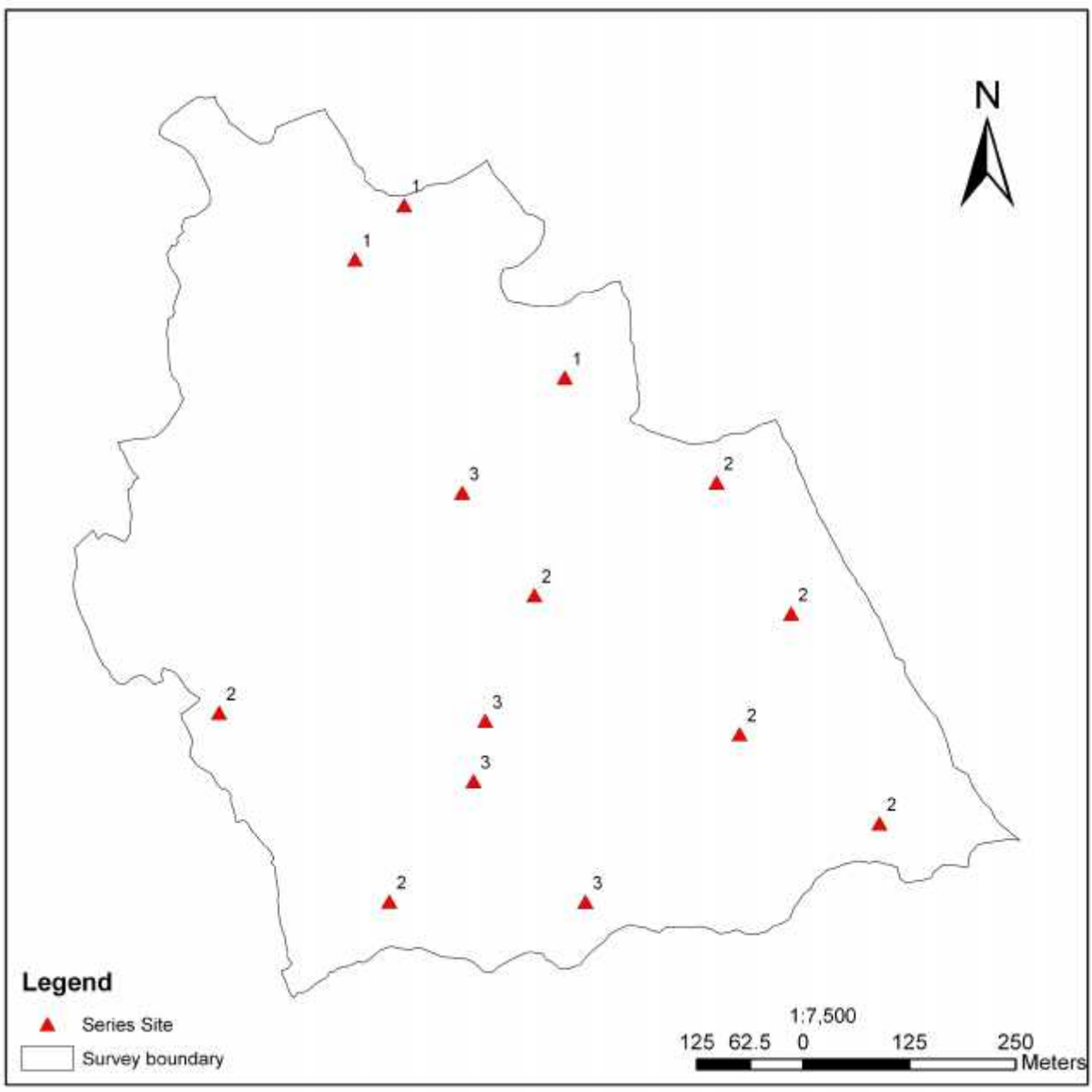


Table 5 General Characteristics of Soil Series

Series code	Series Name	Process / Drift PM	Land use System	Formation	Climate Class	Av. soil depth (cm)	*PSC	Colour Group	*Drainage Class	HCl	Mineralogy Class	Temp Class	Moisture Class
Chi	Chimipang	Alluvium	Kamzhing	Thimphu	Sub-tropical	Deep	L	Dark	WD	-ve	Mixed	Mesic	Ustic
Yuw	Yuwakha	Alluvium	Chuzhing	Thimphu	Sub-tropical	Moderately deep to deep	V	Normal	MWD	-ve	Mixed	Mesic	Ustic
Sop	Sopsokha	Alluvium	Chuzhing	Thimphu	Sub-tropical	Deep	V	Gleyic	Imperfect	-ve	Mixed	Mesic	Ustic

*Note: *PSC – Particle Size Class (Refer SSU WP No. 15)*
**Drainage Class WD – Well drained, MWD- Moderately Well Drained, IWD – Imperfectly Well Drained (Refer SSU WP No. 23)*

Table 6 Description of Soil Series

Soil Series	Series size	Topsoil Description	Subsoil Description	Soil pH	CEC	BS	Diagnostic horizon
Chimipang	Major	At 20 cm deep, brown sandy loam, no mottles, no stones, moist slightly firm non sticky non plastic, moderate medium to coarse subangular blocky structure, few to common fine interstitial pores, few to common fine fibrous roots	At 140 cm deep, dark yellowish brown silty clay, no mottles, no stones, moist firm sticky plastic, strong coarse subangular blocky structure, few to common fine interstitial pores, no roots	6.14/6.97	8.26/7.66	73.55/98.65	Cambic
Yuwakha	Major	At 20 cm deep, grayish brown silty loam texture, no mottles, rare fine hard subangular gneiss gravels, moist slightly friable slightly sticky slightly plastic, moderate medium subangular blocky structure, few to common fine interstitial pores, rare to few very fine to fine fibrous roots	At 130 cm deep, very dark grayish brown gravelly sandy clay, few very fine faint mottles, few to common fine angular subangular hard gravels and stones, moist slightly firm sticky plastic consistence, moderate medium subangular blocky structure, common fine interstitial pores, no roots	5.54/6.83	8.57/7.65	50.95/134.37	Cambic
Sopsokha	Major	At 20 cm deep, gray silty clay loam, rare very fine faint mottles, few to common subangular gneiss, quartzite hard gravels and stones, moist firm sticky and plastic, moderate medium subangular blocky structure, few to common fine interstitial pores, few fine fibrous roots	At 110 cm deep, very dark brown gravelly sandy clay, no mottles, few to common medium subangular gneiss and quartzite gravels and stones, moist firm sticky and plastic consistence, moderate medium subangular blocky structure, few to common fine interstitial pores, no roots	5.29/6.69	7.81/8.70	56.02/89.02	Cambic

Note: Chemical properties of topsoil and subsoil are indicated correspondingly as 6.14 / 6.97 for soil pH (Topsoil / Subsoil)

Table 7 Description of Soil Chemistry / Fertility

Reaction + Nutrients											Exchangeable					
	pH (Water)		Total N		Av. P		Av. K		OC		TEB		CEC		BS	
Series	Values	Class	%	Class	ppm	Class	ppm	Class	%	Class	Me/100g	Class	Me/100g	Class	%	Class
Chimipang	6.14 /6.97	Slightly acid - neutral	0.33/ 0.03	Moderate /very low	18.08 / 49.56	Moderate /high	50.83 / 43.20	Very high	0.77 /0.36	Low /very low	6.00 /8.10	Low /moderate	8.26 /7.66	Low	73.55 /98.65	High /very high
Yuwakha	5.54 /6.83	Very acid - neutral	0.17 / 0.04	Low / very low	4.54 / 5.62	Very low / low	53.48 /46.33	Very high	1.72 /0.43	Moderate / very low	6.03 /10.15	Low /moderate	8.57 /7.65	Low	50.95 /134.37	Moderate /very high
Sopsokha	5.29 /6.69	Very acid - neutral	0.06 / 0.03	Very low /very low	4.11 / 4.11	Very low	44.15 /51.02	Very high	1.34/ 0.59	Moderate / very low	4.45 /8.25	Low / moderate	7.81 /8.70	Low	56.02 /89.02	Moderate / very high

Note: Both the topsoil and subsoil's chemical data are presented – e.g. soil pH as 6.14/6.97 (Topsoil / Subsoil respectively)

4.2 Soil Fertility Status

This section aims to present an overall picture of the soils studied in the survey area.

4.2.1 Soil Reaction

The topsoil is slightly acid to very acid with pH values between 6.14 – 5.29. The soil pH in the subsoil is neutral, indicating perfect pH range for growing any crops. However, some liming might be required for very sensitive crops but present calculations indicate only around 1-2 tons/ acre might be required to counteract the effects of acidity (Fertilizer guide, 2013), if application of lime is considered.

4.2.2 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. The phosphorous level in the topsoil is low with average value 8.91 ppm and moderate in the subsoil with 19.76 ppm. The available potassium in both the topsoil and subsoil is very high (43.20 – 53.48 ppm). Topsoils are rated as having moderate level of organic carbon with C:N ratios rated as poor. The subsoils have very low levels of organic carbon with good C:N ratio. Study of the various ratios of Ca:Mg and Mg:K indicate that there are some imbalances and possible deficiencies of nutrients – in particular Mg in the topsoil and subsoil respectively. The low to moderate levels of total exchangeable bases plus the cation ratios indicate the need for addition of fertilizer or FYM - refer Appendix A.

4.2.3 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 as evidenced by low CEC. CEC is all rated as low in both topsoils and subsoils with average values of 8.21 and 8.00 me/100g. Fertility potential could be improved by the application and or incorporation of FYM.

Overall, application of FYM would improve the existing fertility status and improve the fertility potential.

4.3 Soil Correlation

4.3.1 Previous Survey

In order to see how Chimipang soils fit into a wider context, it is necessary to correlate them with soils elsewhere in Bhutan and also with the international system of soil classification.

From many of the soil surveys carried out in Bhutan, the detailed soil survey at RNR-DC in Bajo, Lingmutey Chhu Watershed and Nyakalumpa valley soils were taken for correlation. This is because the soils of above areas lie in the same valley under similar landform, within same geology and climatic conditions.

The soil units “Chi” of Chimipang have more similarities with the “GD” soil class of the Lingmutey Watershed and soil unit “Yuw” with the soil class HD of Nyakalumpa valley. However, three new series name has been designated for the Chimipang soils based on the typifying pedons identified. The typifying pedons were recognized taking into criteria such as kind, thickness, arrangement of horizons, structure, colour, texture, reaction, consistence, content of carbonates and other salts, content of humus, content of rock fragments and mineralogical composition.

Table 8 Correlation with Soils Classes of Lingmutey Chhu Watershed and Nyakalumpa

Soil unit	Chimipang soil Series name	Brief Description
Chi	Chimipang	Deep soil with dark brown sandy loam topsoil underlain by dark brown sandy loam subsoil, no mottles, no stones, very strong very coarse subangular blocky structure, few to common fine interstitial pores, no roots, no reaction to dilute HCL
Yuw	Yuwakha	Deep soil with grayish brown silty loam topsoil underlain with very dark grayish brown gravelly sandy clay subsoil, few fine faint mottles, common medium subangular hard gneiss, common fine interstitial pores, no roots, no reaction to dilute HCL
Sop	Sopsokha	Deep soil with gray silty clay loam topsoil underlain by brown sandy clay subsoil, common fine faint mottles, few to common medium hard subangular gneiss and slightly hard schist stones, moderate medium subangular blocky structure, common fine interstitial pores, no roots, no reaction to dilute HCL

Table 9 Soils of Lingmutey Chhu Watershed

SOIL CLASS		Brief description	Profiles and analyses
Code	Name		
GD	Deep brown sandy loam	Grey & brown sandy loam over yellowish brown sandy clay loam; more than 1 m deep to weathered gneiss; hill slopes	PH016 PH031 PH018 PK033 PH024 PK037

Table 10 Soils of Nyakalumpa valley

SOIL CLASS		Main Features	Representative profile & analyses
Code	Name		
HD	Deep hill soil	Greyish brown to dark brown silty loam to sandy clay loam+; more than 1.5m deep to the weathered gneiss.	PT015

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 systems of FAO and the US Department of Agriculture. Table 11 correlates the soil series with the 1998 version of the FAO World Reference Base for Soil Resources, and with the 2nd edition (1999) of the USDA Soil Taxonomy.

Because full and definite correlations require somewhat detailed and extensive laboratory and environmental data, which are not available for the soils of Chimipang, the correlations in Table 11 are just an approximate. The Soil Moisture Regime (SMR) is assigned as *udic* and the Soil Temperature Regime (STR) is clearly *mesic* as the mean annual temperature is lower than 22ºC and difference between mean summer and mean winter temperature more than 6ºC. The Particle Size Classes (PSC) is M and V.

The soils at Chimipang are classified as Cambisols (WRB) and Inceptisols (USDA), since there is very limited soil development as the soils are relatively young compared to other soils around the world and or since it is considered that the development of the soil structure, often associated with colour changes, qualify as cambic horizon.

Table 11 Correlation with International Systems of Soil Classification

Series Name	Series in Brief	Subunit in FAO World Reference Base for Soil Resources (FAO 1998)	Subgroup in USDA Soil Taxonomy (Soil Survey Staff 1999)
Chimipang	Deep soil with dark brown sandy loam topsoil underlain by dark brown sandy loam subsoil, no mottles, no stones, very strong very coarse subangular blocky structure, few to common fine interstitial pores, no roots, no reaction to dilute HCL, slightly acid to neutral pH (6.14/6.97), low CEC (8.26/7.66) and high to very high BS (73.55/98.65)	Typic Dystrudepts	Cambisols
Yuwakha	Deep soil with grayish brown silty loam topsoil underlain with very dark grayish brown gravelly sandy clay subsoil, few fine faint mottles, common medium subangular hard gneiss, common fine interstitial pores, no roots, no reaction to dilute HCL, very acid to neutral pH (5.54/6.83), low CEC (8.57/7.65) and moderate to very high BS (50.95/134.37)	Typic Dystrudepts	Cambisols
Sopsokha	Deep soil with gray silty clay loam topsoil underlain by brown sandy clay subsoil, common fine faint mottles, few to common medium hard subangular gneiss and slightly hard schist stones, moderate medium subangular blocky structure, common fine interstitial pores, no roots, no reaction to dilute HCL, very acid to neutral pH (5.29/6.69), low CEC (7.81/8.70) and moderate to very high BS (56.02/89.02)	Typic Endoaquepts	Cambisols

5. SOIL DISTRIBUTION AND MAPPING

5.1 Soil Distribution

There are three map units covering the entire survey area and each map unit is relatively pure in that the soils are quite uniform within each unit.

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.

Majority of the soil series are dominated by the sandy to silty loam (SL, ZL) and sandy clay (SC) textures, with particle size class (PSC) of “M” and “V”.

Figure 6 shows the distribution of soil mapping units. The soils under each mapping units with their chemical properties are discussed briefly in Table 13.

5.2 Soil Mapping Units

All the soils are mapped as consociation. The mapping units are summarised in Table 12 in terms of type, series type and their respective areas etc.

Table 12 Composition and Extent of Soil Mapping Units

Map unit	Type	Main soil series	Minor soil series	Extents		
				Ha	Acres	%
Chi	Consociation	Chimipang	-	14.35	35.46	21.81
Yuw	Consociation	Yuwakha	-	39.05	96.5	59.37
Sop	Consociation	Sopsokha	-	12.38	30.59	18.82
			Total	**65.78**	**162.55**	**100**

Figure 6 Distribution of Soil Mapping Units

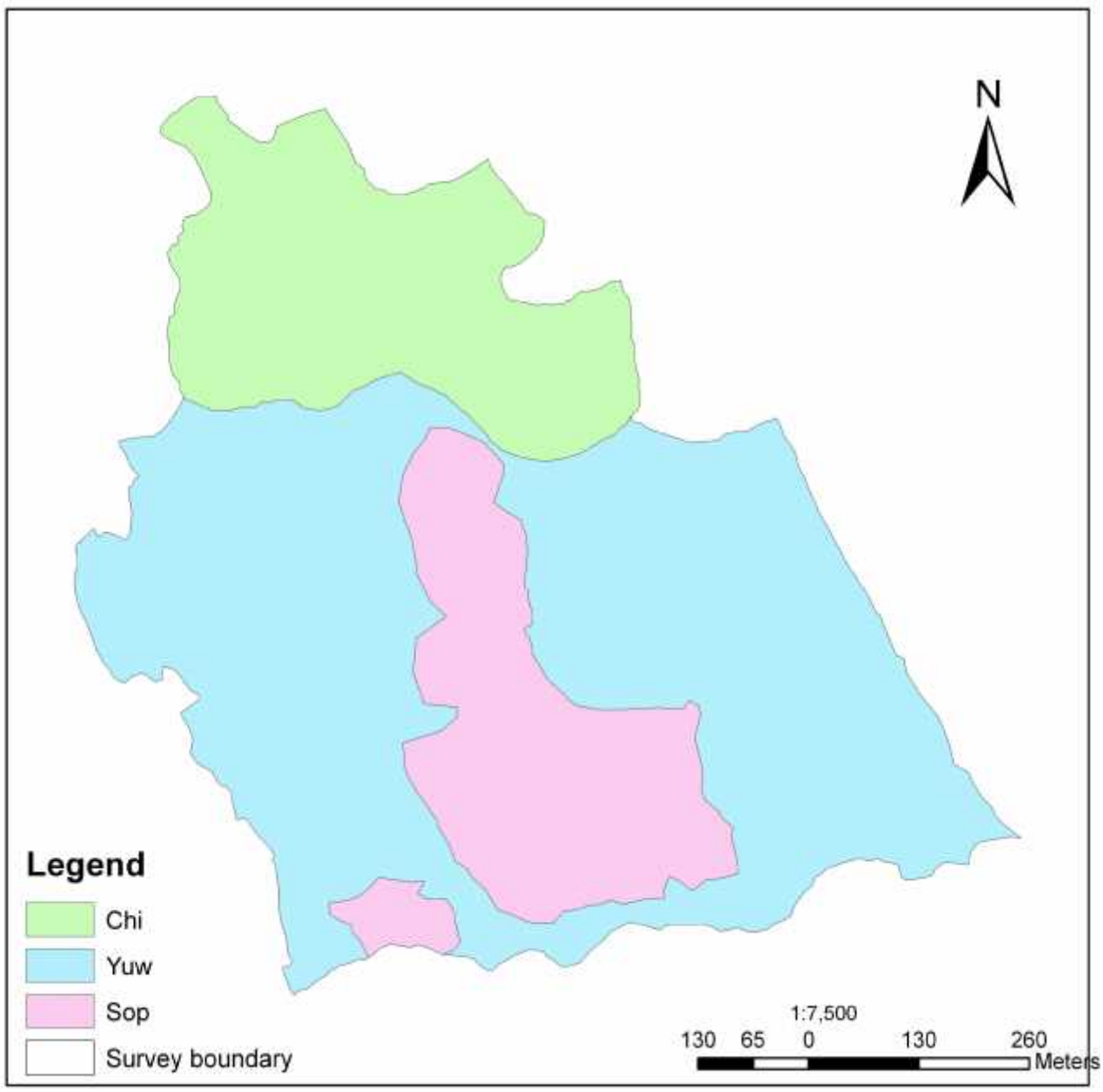


Table 13 Brief Description of Soil Mapping Units

Map Units	Soil Series	Brief Description	Ha	%
Chi	Chimipang	Deep soil with dark brown sandy loam topsoil underlain by dark brown sandy loam subsoil, no mottles, no stones, very strong very coarse subangular blocky structure, few to common fine interstitial pores, no roots, no reaction to dilute HCL, slightly acid to neutral pH (6.14/6.97), low CEC (8.26/7.66) and high to very high BS (73.55/98.65)	14.35	21.81
Yuw	Yuwakha	Deep soil with grayish brown to silty loam topsoil underlain with very dark grayish brown gravelly sandy clay subsoil, few fine faint mottles, common medium subangular hard gneiss, common fine interstitial pores, no roots, no reaction to dilute HCL, very acid to neutral pH (5.54/6.83), low CEC (8.57/7.65) and moderate to very high BS (50.95/134.37)	39.05	59.37
Sop	Sopsokha	Deep soil with gray silty clay loam topsoil underlain by brown sandy clay subsoil, common fine faint mottles, few to common medium hard subangular gneiss and slightly hard schist stones, moderate medium subangular blocky structure, common fine interstitial pores, no roots, no reaction to dilute HCL, very acid to neutral pH (5.29/6.69), low CEC (7.81/8.70) and moderate to very high BS (56.02/89.02)	12.38	18.82
		Total	**65.78**	**100**

5.2.1 "Chi" map unit

The "Chi" map unit covers an area of 14.35 ha and comprises the uppermost area under Kamzhing land use. The map unit falls within the hill top where Chimi Lhakhang is located till the toe slope of the hill area till it touches the paddy fields. It is mapped as a consociation as delineated areas are dominated by a single soil taxon and similar soils. The mapping unit is located on gentle slopes with slope gradients ranging from 5^{o} to12^{o}.

5.2.2 "Yuw" map unit

The "Yuw" map unit is found as a major occurrence on the lower part of the survey area. The terraces lie on slope gradients ranging from 1^{o} to 5^{o} dominated under paddy cultivation in summer and wheat/mustard in winter. It is mapped as a consociation and covers an area of 39.05 ha or 59.37% of the survey area.

5.2.3 "Sop" map unit

The "Sop" map unit is located in the centre of the wetlands. The map unit falls under marshy area during the time of the survey and supposedly will remain marshy throughout the year. It is also mapped as consociation and covers an area about 12.38 ha. This map unit is also located on a gentle

slope with gradients ranging from 1^{o} to 5^{o}) and generally have easterly aspect. The site is dominated under paddy cultivation in summer and left fallow during winter.

6. OVERVIEW AND IMPLICATIONS

6.1 Overview of the Soils

The Chimipang survey area has a limited range of soils, on account of the small size of the area and homogeneous geology. The soils are slightly acid to very acid with pH values less than 5.54 in the topsoil and neutral pH with value less than 6.83 in the subsoil. The organic carbon content is low to moderate in the topsoil and very low in the subsoil, while total nitrogen is low to very low. There is Magnesium deficiency in both the topsoil and subsoil.

The main differences in Chimipang soils relate to their physical properties. There are differences in texture of fine earth fractions. Texture in the topsoil varies from sandy loam to silty loam and sandy loam to sandy clay in the subsoil formed mainly due to the interplay of the mixed geology. The soil profile excavation indicated that the soils depths are deep to deep (110 cm - 140 cm).

There are mainly three types of soils series recognized namely Chimipang, Yuwakha and Sopsokha. The series were recognized based on the typifying pedons identified.

7. RECOMMENDATIONS

Based on the physical and chemical characteristics of the soils, following recommendations are suggested to improve the soil nutrient status of the site.

- The soil pH is slightly acid to very acid in the topsoil. Based on the soil pH requirement by different plants, the soil needs to be ameliorated, either by raising the pH through incorporation of lime or reducing the pH by adding sphagnum peat, acidifying fertilizers[2] and organic mulches. This is to bring soil pH to a desirable range, where nutrients are easily available for uptake by the plants. Most agronomic crops grow well within moderate pH range and flowers in slightly acid to acid soils.

- Nitrogen is the other primary nutrient needed by plants in larger quantities. The N content is within low to very low range, demanding addition of urea or ammonium nitrate fertilizer.

- The CEC of the soil samples is low in range and this could be improved by incorporating well decomposed FYM and other organic materials.

- There is Mg deficiency and this could be improved by applying dolomite, which is a good source of calcium (Ca) and magnesium (Mg).

[2] *Acidifying fertilizers such as ammonium sulfate, urea, and ammonium nitrate*

APPENDIX A CHEMICAL CHARATERISTICS

Table Chemical Characteristics of Topsoils

Series code	Site No.	Depth	pH H2O	pH KCl	pH diff	Avail P ppm	Avail K ppm	Org C %	Total N %	C:N	Exchangeables mcq / 100g Ca	Mg	K	Na	TEB	Al	CEC	(Effective CEC) Mg Sat%	K Sat%	Al Sat%	BS %	Cation Ratios Ca/Mg	Rating	Cation Ratios Mg/K	Rating
	PY0065/1	0-20	5.10	5.02	0.08	8.70	41.17	1.30	0.11	11.82	2.80	0.55	0.12	0.07	3.54		8.66	6	1	41		5.10	Mg sl deficient	0.22	Mg deficient
	PY0066/1	0-20	5.12	5.10	0.02	2.00	64.36	1.80	0.12	15.00	6.17	1.41	0.29	0.10	7.97		12.71	5	2	63		4.38	OK	0.20	Mg deficient
	PY0067/1	0-15	6.10	5.85	0.25	3.84	41.41	0.80	0.01	80.00	3.76	0.86	0.15	0.05	4.85		8.71	13	2	72		4.26	OK	0.17	Mg deficient
Yuw	PY0068/1	0-25	5.68	4.97	0.71	3.29	69.32	1.00	0.08	12.50	7.46	1.70	0.38	0.10	9.63		7.71	22	5			4.39	OK	0.22	Mg deficient
	PY0069/1	0-20	5.84	4.62	1.22	5.09	50.95	1.40	0.16	8.75	4.39	0.99	0.28	0.09	5.75		8.16	12	3	70		4.44	OK	0.29	Mg deficient
	PY0074/1	0-20	5.39	4.45	0.94	4.33	55.13	4.00	0.51	7.84	3.52	0.84	0.16	0.09	4.41		7.44	9	2	59		5.54	Mg sl deficient	0.25	Mg deficient
		Mean	**5.54**	**5.00**	**0.54**	**4.54**	**53.48**	**1.72**	**0.17**	**22.35**	**4.68**	**1.03**	**0.23**	**0.08**	**6.03**		**8.57**	**11.21**	**2.74**	**50.95**		**4.59**	OK	**0.23**	Mg deficient
	Series Mean		**5.54**	**5.00**	**0.54**	**4.54**	**53.48**	**1.72**	**0.17**	**22.55**	**4.68**	**1.03**	**0.23**	**0.08**	**6.03**		**8.57**	**11.21**	**2.74**	**50.95**		**4.59**	OK	**0.23**	Mg deficient
	Series Rating		**V.Acid**	**V.Acid**	**Ext Acid**	**V Low**	**V High**	**Mod**	**Low**	**Poor**	**Low**	**Low**	**Low**	**V Low**	**Low**		**Low**	**V High**	**V Low**	**Mod**					
	PY0062/1	0-20	6.18	5.44	0.74	38.97	10.22	0.90	0.06	15.00	6.71	0.72	0.34	0.04	7.81		8.37	9	1	93		9.33	Mg deficient with P inhibition	0.18	Mg deficient
Chi	PY0063/1	0-22	5.98	4.96	1.03	9.41	68.33	1.10	0.03	36.67	8.05	1.06	0.30	0.04	9.45		9.11	12	3	49		2.38	Ca sl deficient	0.29	Mg deficient
	PY0064/1	0-20	6.25	5.80	0.45	5.81	43.93	0.30	0.80	0.37	4.40	0.99	0.28	0.05	5.73		7.30	14	1	78		4.44	OK	0.29	Mg deficient
		Mean	**6.14**	**5.40**	**0.74**	**18.06**	**50.83**	**0.77**	**0.33**	**17.25**	**4.72**	**0.92**	**0.31**	**0.04**	**6.00**		**8.26**	**11.27**	**3.73**	**73.66**		**5.56**	Mg sl deficient	**0.35**	Mg deficient
	Series Mean		**6.14**	**5.40**	**0.74**	**18.08**	**50.83**	**0.77**	**0.33**	**17.25**	**4.72**	**0.92**	**0.31**	**0.04**	**6.00**		**8.26**	**11.27**	**3.73**	**73.55**		**5.55**	Mg sl deficient	**0.35**	Mg deficient
	Series Rating		**Sli Acid**	**V.Acid**	**Ext Acid**	**Mod**	**V High**	**Low**	**Med**	**Mod**	**Low**	**Low**	**Med**	**V Low**	**Low**		**Low**	**V High**	**V Low**	**High**					
	PY0070/1	0-15	5.41	4.28	1.13	0.94	40.37	1.00	0.10	10.00	2.50	1.10	0.18	0.00	3.94		7.92	14	2	50		2.04	Ca sl deficient	0.17	Mg deficient
	PY0071/1	0-20	5.23	4.29	0.94	4.50	57.02	1.00	0.03	33.33	4.77	0.90	0.24	0.09	6.07		10.14	9	2	60		4.96	OK	0.20	Mg deficient
Sop	PY0072/1	0-25	4.99	4.09	0.94	2.17	49.44	0.90	0.09	10.00	1.06	0.21	0.19	0.09	1.57		5.72	4	3	27		5.17	Mg sl deficient	0.52	Mg deficient
	PY0073/1	0-15	5.26	4.15	1.11	9.75	2.00	1.20	0.00	15.00	2.64	0.50	0.18	0.10	3.40		8.11	7	2	42		4.30	OK	0.31	Mg deficient
	PY0075/1	0-30	5.56	4.90	0.66	0.18	68.34	1.40	0.04	35.00	5.49	1.35	0.29	0.13	7.28		7.18	19	4	101		4.06	OK	0.22	Mg deficient
		Mean	**5.29**	**4.33**	**0.96**	**4.11**	**44.15**	**1.34**	**0.06**	**26.37**	**3.29**	**0.84**	**0.22**	**0.10**	**4.45**		**7.81**	**10.60**	**2.84**	**56.02**		**4.18**	OK	**0.37**	Mg deficient
	Series Mean		**5.29**	**4.33**	**0.96**	**4.11**	**44.15**	**1.34**	**0.06**	**26.37**	**3.29**	**0.84**	**0.22**	**0.10**	**4.45**		**7.81**	**10.60**	**2.84**	**56.02**		**4.18**	OK	**0.37**	Mg deficient
	Series Rating		**V Acid**	**Ext Acid**	**Ext Acid**	**V Low**	**V High**	**Mod**	**V Low**	**Poor**	**Low**	**Low**	**Low**	**V Low**	**Low**		**Low**	**V High**	**V Low**	**Mod**					

Table Chemical Characteristics of Subsoils

Series code	Site No.	Depth	pH	pH	pH	Avail P	Avail K	Org C	Total N	C:N	Exchangeables meq / 100g					Al	CEC	Mg	K	Al	BS	Cation Ratios		Cation Ratios	
			H2O	KC	diff	ppm	ppm	%	%		Ca	Mg	K	Na	TEB			Sat%	Sat%	Sat%	%	Ca/Mg	Rating	Mg/K	Rating
	PY0065/2	20-50	6.46	4.03	2.45	3.31	32.38	0.30	0.04	7.50	3.18	0.73	0.14	0.12	4.17		5.49	13	3		76	4.37	OK	0.20	Mg deficient
	PY0065/3	50-80	6.61	5.01	1.60	2.83	43.18	0.50	0.06	8.33	5.11	1.13	0.28	0.05	6.53		6.78	17	4		112	5.41	Mg all deficient	0.25	Mg deficient
	PY0065/4	80-130	6.76	4.00	1.86	18.28	40.64	0.40	0.02	20.00	5.74	1.75	0.29	0.07	7.25		7.00	14	4		91	4.98	OK	0.26	Mg deficient
	PY0066/2	20-40	6.40	4.35	2.10	2.40	52.98	0.00	0.00	26.67	30.04	2.05	0.20	0.00	40.43		12.08	17	2		334	10.50	Mg deficient with P inhibition	0.11	Mg deficient
	PY0066/3	40-80	6.86	5.43	1.43	2.32	48.85	0.40	0.05	8.00	5.11	1.13	0.28	0.05	7.53		6.79	17	4		112	4.75	OK	0.17	Mg deficient
	PY0066/4	80-120	6.96	5.62	1.34	2.71	44.11	0.50	0.04	12.50	5.74	1.75	0.29	0.07	7.25		7.00	14	4		91	4.81	OK	0.17	Mg deficient
	PY0067/2	15-35	6.70	5.21	1.49	3.00	39.38	0.50	0.07	7.14	7.23	1.57	0.19	0.00	9.00		9.60	16	2		94	4.62	OK	0.12	Mg deficient
Yaw	PY0067/3	35-70	7.05	5.50	1.55	4.57	44.44	0.70	0.04	17.50	12.22	2.19	0.28	0.11	14.78		12.51	18	2		120	5.57	Mg all deficient	0.12	Mg deficient
	PY0068/2	25-60	7.09	5.63	1.46	3.33	56.25	0.20	0.02	10.00	9.82	2.09	0.36	0.08	12.37		10.85	19	3		111	4.69	OK	0.17	Mg deficient
	PY0069/2	20-80	6.76	5.38	1.38	5.91	44.95	0.40	0.04	10.00	5.71	1.14	0.21	0.07	7.13		3.32	34	8		215	5.00	Mg slideficient	0.19	Mg deficient
	PY0069/3	80-115	7.66	5.53	2.15	7.68	46.10	0.60	0.05	12.00	5.86	1.20	0.28	0.08	8.43		9.33	13	3		90	5.72	Mg all deficient	0.24	Mg deficient
	PY0074/2	20-45	6.46	5.20	1.26	2.31	48.32	0.40	0.05	13.33	4.87	0.95	0.14	0.06	6.03		6.08	14	2		86	5.12	Mg all deficient	0.15	Mg deficient
	PY0074/3	45-80	6.65	5.30	1.35	5.15	47.77	0.50	0.02	25.00	3.89	0.89	0.18	0.06	4.83		6.05	13	2		73	4.61	Mg all deficient	0.20	Mg deficient
	PY0074/4	80-105	6.82	5.09	1.73	5.18	50.30	0.20	0.01	20.00	7.67	1.29	0.14	0.07	9.16		3.11	41	5		295	5.96	Mg all deficient	0.11	Mg deficient
		Mean	6.83	5.17	1.66	5.62	46.33	0.43	0.04	13.36	8.54	1.30	0.23	0.07	10.15		7.65	18.45	3.32		134.37	5.00	Mg all deficient	0.18	Mg deficient
	Series Mean		6.83	5.17	1.66	5.62	46.33	0.43	0.04	13.36	8.54	1.30	0.23	0.07	10.15		7.65	18.45	3.32		134.37	5.00	Mg all deficient	0.18	Mg deficient
	Series Rating		Neutral	V.Acid	Ext Acid	Low	V High	V Low	V Low	Good	Mod	Low	Low	V Low	Mod		Low	V High	V Low		V High				
	PY0062/2	20-50	6.79	5.88	0.93	59.19	80.32	1.00	0.04	25.00	10.58	1.29	0.42	0.08	12.33		11.94	11	4		103	8.21	Mg deficient with P inhibition	0.33	Mg deficient
	PY0062/3	50-80	7.31	6.07	1.27	80.27	44.08	0.60	0.03	20.00	14.33	2.32	0.36	0.13	17.06		13.49	17	2		126	6.17	Mg all deficient	0.17	Mg deficient
	PY0062/4	80-100	7.62	6.18	1.44	102.43	44.11	0.10	0.02	5.00	9.25	2.47	0.46	0.11	12.29		5.37	46	9		229	3.75	OK	0.18	Mg deficient
Ch	PY0063/2	20-75	5.99	4.36	1.63	49.21	40.20	0.40	0.02	20.00	2.55	0.60	0.12	0.04	3.31		5.91	10	2		56	4.24	OK	0.20	Mg deficient
	PY0063/3	75-100	6.84	5.22	1.62	66.19	41.65	0.02	0.01	2.00	0.10	0.09	0.11	0.12	0.45		2.21	4	6		20	1.13	Ca slideficient	1.56	Mg deficient
	PY0064/2	20-110	7.12	5.30	1.82	9.71	36.33	0.20	0.01	20.00	5.77	1.08	0.16	0.15	7.16		6.01	18	3		86	5.50	OK	0.15	Mg deficient
	PY0064/3	110-140	6.98	5.00	1.98	22.90	0.20	0.04	5.00	4.17	1.38	0.25	0.30	0.09	0.71		10.43	7	3		70	5.03	OK	0.18	Mg deficient
		Mean	6.97	5.59	1.38	49.56	43.20	0.36	0.03	12.50	8.39	1.52	0.26	0.13	8.10		7.66	17.43	3.99		98.65	4.29	OK	0.39	Mg deficient
	Series Mean		6.97	5.59	1.38	49.56	43.20	0.36	0.03	12.50	8.39	1.52	0.26	0.13	8.10		7.66	17.43	3.99		98.65	4.29	OK	0.39	Mg deficient
	Series Rating		Neutral	V.Acid	Ext Acid	High	V High	V Low	V Low	Good	Mod	Low	Low	Low	Mod		Low	V High	V Low		V High				
	PY0070/2	15-55	6.56	4.97	1.61	5.16	46.70	0.50	0.05	10.00	5.01	1.26	0.26	0.07	6.60		7.08	15	3		83	3.98	OK	0.27	Mg deficient
	PY0070/3	55-110	6.85	5.20	1.65	7.52	40.68	1.10	0.04	27.50	9.81	1.77	0.33	0.11	12.02		11.26	10	3		6	5.43	OK	0.18	Mg deficient
	PY0071/2	20-50	6.29	5.14	1.15	4.02	48.87	0.70	0.02	35.00	5.26	1.17	0.17	0.08	8.68		7.95	15	2		84	4.47	OK	0.15	Mg deficient
	PY0071/3	50-75	6.72	5.30	1.42	5.05	46.36	1.10	0.05	22.00	8.70	1.45	0.27	0.08	10.44		10.88	13	2		96	6.02	Mg all deficient	0.15	Mg deficient
	PY0071/4	75-130	6.82	5.27	1.55	4.81	47.30	0.40	0.03	13.33	7.69	1.50	0.22	0.08	9.49		8.16	18	3		116	5.15	Mg slideficient	0.15	Mg deficient
	PY0072/2	25-45	6.45	5.23	1.22	2.56	43.34	0.60	0.04	15.00	4.02	1.10	0.15	0.07	5.34		6.74	18	2		79	3.67	OK	0.14	Mg deficient
Soo	PY0072/3	45-75	6.76	5.39	1.18	4.18	43.82	1.10	0.03	36.67	8.22	1.39	0.25	0.11	9.97		11.92	12	2		84	5.93	Mg all deficient	0.18	Mg deficient
	PY0072/4	75-110	6.84	5.39	1.45	8.47	47.30	0.20	0.01	20.00	7.04	0.56	0.15	0.00	7.82		4.13	11	4		92	12.56	Mg slideficient	0.28	Mg deficient
	PY0073/2	15-45	6.54	4.95	1.59	0.76	45.87	0.40	0.03	13.33	4.65	1.11	0.21	0.08	6.05		7.89	14	3		77	4.20	OK	0.19	Mg deficient
	PY0073/3	45-65	6.69	5.30	1.39	0.63	50.34	0.10	0.01	10.00	5.02	1.16	0.34	0.09	6.60		9.55	12	4		69	4.32	OK	0.29	Mg deficient
	PY0073/4	65-90	6.72	5.28	1.44	0.71	58.90	0.40	0.01	40.00	5.45	1.84	0.55	0.12	8.96		11.36	15	5		75	3.50	OK	0.30	Mg deficient
	PY0075/2	10-30	6.07	5.20	1.38	4.82	58.10	0.30	0.02	15.00	7.45	1.91	0.23	0.10	9.79		7.90	24	4		120	3.91	OK	0.17	Mg deficient
	PY0075/3	90-140	7.03	5.56	1.47	1.69	68.31	0.50	0.01	50.00	8.98	2.18	0.31	0.10	11.57		6.64	33	5		171	4.11	OK	0.14	Mg deficient
		Mean	6.80	5.23	1.46	4.11	51.02	0.59	0.03	24.96	5.48	1.41	0.27	0.09	8.25		8.70	15.74	3.12		89.02	4.56	OK	0.19	Mg deficient
	Series Mean		6.89	5.23	1.48	4.11	51.02	0.59	0.03	24.96	5.48	1.41	0.27	0.09	8.25		8.70	15.74	3.12		89.02	4.56	OK	0.19	Mg deficient
	Series Rating		Neutral	V.Acid	Ext Acid	V Low	V High	V Low	V Low	Poor	Mod	Low	Low	V Low	Mod		Low	V High	V Low		V High				

APPENDIX B TYPICAL SOIL PROFILE DESCRIPTIONS

Profile:	**PY0064**
Described & sampled:	Yeshey Chedup, 21/03/2013
Survey area:	Chimipang,Punakha Dzongkhag
Map unit:	"Chi"
Soil Classification	
SSU Soil Series:	Chimipang
Soil Taxonomy:	Typic Dystrudepts
WRB:	Cambisols
Coordinates:	27° 31' 32.2" N and 89° 52' 39.9" E
Topographic Map:	No. 78 E/14 Scale 50,000 Date: 2000
Location:	Ca 120 ° SSW from Chimi lhakhang
Altitude:	1313 masl
Climate	
General:	Warm temperate
Recent Weather:	Sunny
Parent material	
Solid:	Thimphu gneiss
Drift:	Colluvium
Topography	
Landform:	Hill
Site position:	Mid slope
Aspect:	SE (50 deg)
Slope:	4%
Erosion:	None
Run-off:	None
Site drainage:	Good
Micro relief:	ND
Surface	
Surface condition:	Dry
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	None, none
Surface litter:	Partial, raw decomposed grasses about 2 cm deep
Surface outcrops:	None
Surface stone:	None
Vegetation category:	Dry land
Land use:	Chhuzhing
Soil Depth Limit:	None
Soil Drainage Class:	Well drained
Notes / Comments:	None

Cm	Horizon	Description
0-20	Ap	Dark brown (10YR3/3) dry; sandy loam with no mottles; hard dry; moderate medium angular and sub angular structure; common fine interstitial pores; few fine fibrous and irregular roots; nil reaction to dilute HCL; clear and smooth boundary: [Sample No. PY0064/1]
20-110	Bw	Dark brown (10YR3/3) moist; sandy loam with no mottles; none course materials; friable, friable non sticky and non plastic; weak medium granular structure; common fine interstitial pores; few fine fibrous and irregular roots; nil reaction to dilute HCL; clear and smooth boundary: [Sample No. PY0064/2]
110-140	Bw1	Dark yellowish brown (10YR 4/4) moist; silt clay with no mottles; no stone; content; moderate medium slightly sticky and slightly plastic; moderate medium angular and sub angular structure; few fine tubular pores; few very fine fibrous roots; nil reaction to dilute HCL: [Sample No. PY0064/3]

Reaction + Nutrients

BSS No.	Depth cm	Lab No.	pH Water	pH KCL	pH Diff	Avail-P ppm	OC %	Total-N	C:N Ratio	Avail-K ppm
PY0064/1	0-20	46640	6.25	5.80	0.45	5.84	0.90	0.07	0.07	43.93
PY0064/2	20-110	46641	7.12	5.30	1.82	9.71	0.02	0.01	19.76	36.33
PY0064/3	110-140	46642	6.99	5.63	1.36	9.91	0.02	0.04	4.90	32.98

Exchangeables

BSS No.	Exch Ca Me/100g	Exch- mg Me/100g	Exch-K Me/100g	Exch-Na Me/100g	TEB Me/100g	CEC AmOAc Me/100g	ECEC Me/100g	BS %
PY0064/1	4.40	0.99	0.28	0.05	5.73	7.30	5.73	78.45
PY0064/2	3.77	1.08	0.16	0.15	5.16	6.01	5.16	85.82
PY0064/3	4.17	1.38	0.25	0.30	6.09	8.71	6.09	69.94

Profile:	**PY0065**
Described & sampled:	Yeshey Chedup, 23/03/2013
Survey area:	Chimipang, Punakha Dzongkhag
Map unit:	"Yuw"
Soil Classification	
SSU Soil Series:	Yuwakha
Soil Taxonomy:	Typic Dystrudepts
WRB:	Cambisols
Coordinates:	27° 31' 12.4" N and 89° 52' 32.00" E
Topographic Map:	No. 78 E/14 Scale 50,000 Date: 2000
Location:	NR
Altitude:	1289 masl
Climate	
General:	Warm temperate
Recent Weather:	Sunny
Parent material	
Solid:	Thimphu gneiss
Drift:	Colluvium
Topography	
Landform:	Valley
Site position:	Lower slope
Aspect:	NW (40 deg)
Slope:	3%
Erosion:	None
Run-off:	None
Site drainage:	Good
Micro relief:	ND
Surface	
Surface condition:	Slightly moist
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	None, none
Surface litter:	Partial, raw decomposed grasses about 1 cm deep
Surface outcrops:	None
Surface stone:	Rare (1%), fine, subangular gneiss and schist stones
Vegetation category:	Dry land
Land use:	Chhuzhing
Soil Depth Limit:	None
Soil Drainage Class:	Well drained
Notes / Comments:	None

Cm	Horizon	Description
0-20	Ap	Grayish brown (10YR 5/2) moist; silt loam with common fine prominent mottles; few (2%) fine hard angular and sub angular gneiss and schist; slightly moist friable slightly sticky slightly plastic; moderate medium angular and sub angular structure; common fine tubular pores; many fine medium fibrous and irregular roots; nil reaction to dilute HCL; clear and smooth boundary: [Sample No. PY0065/1]
20-50	Bw	Dark grayish brown (10YR 4/2) moist; sandy loam with few fine prominent mottles (5YR6/8); common (15%) fine medium hard subangular gneiss and schist stones; friable, non sticky and non plastic; strong coarse to very coarse subangular blocky structure; common very fine tubular pores; rare very fine fibrous roots; nil reaction to dilute HCL; abrupt and smooth boundary: [Sample No. PY0065/2]
50-80	Bw1	Very dark grayish brown (10YR 3/2) moist; gravelly sandy clay loam with few fine prominent mottles (5YR6/8); common (15%) fine medium hard subangular gneiss and schist stones; friable, sticky and plastic; medium coarse sub angular and angular blocky structure; many fine tubular pores; rare very fine fibrous roots; nil reaction to dilute HCL: [Sample No. PY0065/3]
80-130	Bw2	Very dark grayish brown (10YR 3/2) moist; gravelly sandy clay loam with few fine prominent mottles (5YR6/8); common (15%) fine medium hard sub angular gneiss and schist stones; friable, sticky and plastic; fine medium coarse sub angular and angular blocky structure; many fine tubular pores; no roots; nil reaction to dilute HCL: [Sample No. PY0065/4]

Reaction + Nutrients

BSS No.	Depth cm	Lab No.	pH Water	pH KCL	pH Diff	Avail-P ppm	OC %	Total-N	C:N Ratio	Avail-K ppm
PY0065/1	0-20	46643	5.10	5.02	0.08	8.70	1.30	0.11	11.66	41.17
PY0065/2	20-50	46644	6.48	4.03	2.45	3.31	0.30	0.04	7.37	32.88
PY0065/3	50-80	46645	6.61	5.01	1.60	12.83	0.50	0.06	8.20	43.48
PY0065/4	80-130	46646	6.76	4.90	1.86		0.40	0.02	19.70	49.84

Exchangeables

BSS No.	Exch Ca Me/100g	Exch- mg Me/100g	Exch-K Me/100g	Exch-Na Me/100g	TEB Me/100g	CEC AmOAc Me/100g	ECEC Me/100g	BS %
PY0065/1	2.80	0.55	0.12	0.07	3.54	8.66	5.16	40.85
PY0065/2	3.18	0.73	0.14	0.12	4.17	5.49	4.17	75.95
PY0065/3	6.11	1.13	0.28	0.05	7.58	6.79	7.58	111.68
PY0065/4	5.74	1.15	0.29	0.07	7.26	7.99	7.26	90.88

Profile:	**PY0070**
Described & sampled:	Yeshey Chedup, 25/03/2013
Survey area:	Chimipang
Map unit:	“Sopsokha”
Soil Classification	
SSU Soil Series:	Sopsokha
Soil Taxonomy:	Typic Endoaquepts
WRB:	Cambisols
Coordinates:	27° 31' 09.9" N and 89° 52' 42.9" E
Topographic Map:	No. 78 E/14 Scale 50,000 Date: 2000
Location:	
Altitude:	1262 masl
Climate	
General:	Warm temperate
Recent Weather:	Sunny
Parent material	
Solid:	Thimphu gneiss
Drift:	Colluvium
Topography	
Landform:	Valley
Site position:	Lower slope
Aspect:	E (90 deg)
Slope:	2%
Erosion:	None
Run-off:	None
Site drainage:	Good
Micro relief:	ND
Surface	
Surface condition:	Slightly moist
Surface cracks:	None
Surface capping:	None
Lichen/Algae:	None, none
Surface litter:	Sparse, raw decomposed grasses and straw about 1 cm deep
Surface outcrops:	None
Surface stone:	None
Vegetation category:	Chhuzhing
Land use:	Chhuzhing
Soil Depth Limit:	None
Soil Drainage Class:	Well drained
Notes / Comments:	None

Cm	Horizon	Description
0-15	Ap	Grayish brown (10YR 5/1) moist; silty clay loam with rare and very fine mottles; common (5%) fine hard medium angular and subangular gneiss and schist stones; slightly moist slightly sticky slightly plastic; moderate medium to coarse subangular blocky structure; many fine tubular pores; common very fine to medium fibrous and irregular roots; nil reaction to dilute HCL; clear and wavy boundary: [Sample No. PY0070/1]
15-65	Bw	Brown (10YR 4/3) moist; sandy clay with common fine prominent mottles; common (10%) medium hard subangular gneiss and schist stones; friable, slightly sticky slightly plastic; moderately hard medium subangular blocky structure; common very fine tubular pores; no roots; nil reaction to dilute HCL; clear smooth boundary: [Sample No. PY0070/2]
65-110	Bw1	Very dark grayish brown (10YR 2/2) moist; gravelly sandy clay with no mottles; common (10%) fine medium hard subangular gneiss and schist stone; slightly hard, sticky and plastic; moderate strong fine angular and sub angular structure; many fine tubular pores; no roots; nil reaction to dilute HCL: [Sample No. PY0070/3]

Reaction + Nutrients

BSS No.	Depth cm	Lab No.	pH Water	pH KCL	pH Diff	Avail-P ppm	OC %	Total-N	C:N Ratio	Avail-K ppm
PY0070/1	0-15	46660	5.41	4.28	1.13	3.94	1.60	0.10	15.72	43.37
PY0070/2	15-65	46661	6.58	4.97	1.61	5.16	0.50	0.05	9.87	46.70
PY0070/3	65-110	46662	6.83	5.28	1.55	7.52	1.10	0.04	27.01	48.66

Exchangeables

BSS No.	Exch Ca Me/100g	Exch- mg Me/100g	Exch-K Me/100g	Exch-Na Me/100g	TEB Me/100g	CEC AmOAc Me/100g	ECEC Me/100g	BS %
PY0070/1	2.58	1.10	0.18	0.08	3.94	7.92	6.17	49.81
PY0070/2	5.01	1.26	0.26	0.07	6.60	7.98	6.60	82.64
PY0070/3	9.81	1.77	0.33	0.11	12.02	11.26	12.02	106.79