National Soil Services Centre (NSSC)
Department of Agriculture (DoA)
Ministry of Agriculture & Forests (MoAF)

Detailed Soil Survey Report of the proposed site for GNH Centre, Dingdingma, Choekhor Geog; Bumthang Dzongkhag

Report No. SS -23

July 2010

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SUMMARY

The Hon'ble Prime Minister's office is planning to set up a Gross National Happiness (GNH) Centre at Dingdingma under Choekhor Geog in Bumthang to create a very conducive environment whereby one can understand and interpret the GNH concepts and put these into practice. One of the main activities in establishing the GNH Centre is plantation of bamboos and medicinal plants to diversify the vegetation at the Centre. Since detail soil information is required for any plantation activities, the National Soil Services Centre (NSSC) under the Department of Agriculture was called upon to carry out a detailed soil survey of the proposed site. The fieldwork was carried out from 21st to 24th May 2010. This is the 4th soil survey done in Bumthang Dzongkhag by the National Soil Services Centre.

The proposed site for the GNH Centre is located about 1 hr drive from Chamkhar town to Damphel Bridge and then about half an hour walk from the bridge to the site along the Chamkhar Chhu. It is located on the true left bank of Chamkhar Chhu which is just opposite to Napsephel village. The site has a maximum North-South length of about 700m and a maximum East-West width of about 250m. It covers about 20ha (50 acres). The major part of the site includes Government Reserve Forest but also some private land. Currently the whole site is used as grazing land by the local communities.

The soils were examined in 5 routine observations and 4 detailed description and sampling profiles. The soils are divided into two main topography groups: lower hill slope and alluvial terraces. These groups are further subdivided to give 5 soil classes.

There are two soil classes within the lower hill slope group: moderately deep greyish brown over dark yellowish brown (Hd) and very bouldery (Hb) soils.

- The Hd soils have fine sandy loam to humic loam top soils over sandy clay loam sub soils. The soils are moderately well drained with soil depth varying from 70-100cm. The Hb soils lies within the Hd soils and are quite similar to Hd soils except that they contain many stones and huge boulders reducing the soil depth, water holding capacity and agronomic potential for plantation activities. The topsoil is very acidic with moderate organic carbon. However, the subsoil is slightly acidic with very low organic carbon, base saturation (BS) and low cation exchange capacity (CEC).

The soils of the very gentle alluvial terraces have been divided into three classes according to their relative position and degree of soil profile development i.e. Ts, Td and Tu.

- The very shallow terrace soils (Ts) are predominant in the lower alluvial terraces. These soils are very young and have brown to dark greyish brown fine to medium sandy loam topsoil over light yellowish brown to brown fine to coarse sand (river sand) subsoil. The soils are somewhat excessively drained with soil depth not more than 40cm. The topsoil is very acidic with high organic carbon. The subsoil is slightly acidic with very low organic carbon and BS and low CEC.

- The moderately deep terrace soils (Td) are mostly found in the 15m terrace. These soils are moderately young and have dark greyish brown to very dark brown fine to medium sandy loam topsoil over brown to light olive brown fine to coarse sand (river sand) subsoil. The soils are somewhat excessively drained with soil depth more than 90cm. The topsoil is very acidic with moderate organic carbon. The subsoil is slightly acidic with very low organic carbon and BS and low CEC.

- The deep upper terrace soils (Tu) are the older soils and present only on the 25m terrace. These soils have dark greyish brown to dark brown fine sandy loam to sandy clay loam topsoil over dark yellowish brown to yellowish brown sandy clay loam to sandy clay subsoil. The soils are moderately well drained with soil depth more than 100cm. Both the topsoil and subsoil are very acidic with moderate organic carbon. The subsoil CEC is high with very low BS.

An ortho-rectified Quick Bird satellite image at 60cm resolution was used as a base map for the detailed soil survey. The landform map with soil observation points and final soil map are being produced at 1:14000 using the Quick Bird image and is included in this report.

In general, the soils of the proposed site are not really suitable for plantation activities except for the Tu soils due to very high content of stones and boulders (Hb), very steep slopes (Hd & Hb), very shallow and coarse textured subsoil (Ts & Td). The soil pH is very low with very low Total Exchangeable Bases (TEB) and Base Saturation (BS). However, the site could be used for plantation activities by improving the water holding capacity, soil pH and fertility of the soils through application of leaf litter and Farm Yard Manure, arranging irrigation facility and selecting the most suitable plant species for plantation at the proposed site.

ABBREVIATIONS AND GLOSSARY

(Simple metric units and chemical element symbols not included)

AAS	Atomic Absorption Spectrophotometry
Alluvial fan	Poorly stratified and sorted material deposited in a fan shape by tributary mountain stream as it reaches flatter part of the valley
AmOAc	Ammonium acetate (extractant for exchangeable cations and for measuring CEC)
Av	Available
AWC	Available Water Capacity
amsl	Above mean seal level
BS%	Base Saturation percentage
C	Clay
CEC	Cation Exchange Capacity
Chhu	Stream or river
CL	Clay loam
Colluvium	Local hillwash, moved by surface erosion or or mass movement.
Dzongkhag	Administrative district
EC	Electrical Conductivity
Exch	Exchangeable (for cations)
Extr	Extractable (for soil nutrients)
fe	fine earth (particle size < 2mm)
Geog	Block or sub-district, administrative subdivision of Dzongkhag
GIS	Geographical Information System
GNH	Gross National Happiness
Gompa	Monastery
GPS	Global Positioning System
ha	Hectare
HCl	Hydrochloric acid
L	Loam
me%	Milliequivalents per 100 g fine earth
MoAF	Ministry of Agriculture & Forests
mS/cm	milliSiemens per centimetre (unit of electrical conductivity)
NH4OAC	Ammonium acetate
NSSC	National Soil Services Centre
OM	Organic matter
p.a	Per annum
pH	Measure of acidity - alkalinity
PM	Parent material
ppm	Parts per million
PSC	Particle size class (Soil Taxonomy)
RGOB	Royal Government of Bhutan
S	Sand
SMU	Soil Mapping Unit
Solum	True soil with no remaining rock structures
SPAL	Soils and Plant Analysis Laboratory, Semtokha.
TEB	Total Exchangeable Bases (= exchangeable Ca + Mg + Na + K)
TLB	True left bank (facing downstream)
WR	Weathered Rock

1. INTRODUCTION

1.1 GNH Centre

The Hon'ble Prime Minister's (PM) office is planning to set up a Gross National Happiness (GNH) Centre at Dingdingma, Choekhor Geog under Bumthang Dzongkhag. One of the main objectives of setting up this Centre is to create a very enabling environment whereby one can understand and interpret the GNH concepts and put these into practice.

Even though the proposed site for GNH Centre has very good natural blue pine forest, it is proposed to go for plantation of bamboos, medicinal plants, etc. to diversify the vegetation cover at the proposed site. It is also planned that the entire infrastructure at the Centre shall be built with minimum destruction to the natural environment using environment friendly materials like bamboos.

Since detail soil information is required for any plantation activities, the National Soil Services Centre (NSSC) under the Department of Agriculture was called upon to carry out a detailed soil survey of the proposed site. The fieldwork was carried out from 21st to 24th May 2010. This is the 4th soil survey done in Bumthang Dzongkhag by the National Soil Services Centre.

2. SURVEY AREA

2.1 Location and extent

The proposed site for the GNH Centre is located at Dingdingma, Choekhortoe under Choekhor geog. It is about 1hr drive from Chamkhar town to Damphel Bridge and then about half an hour walk from the bridge to the site along the Chamkhar Chhu. It is situated on the true left bank of Chamkhar Chhu which is opposite to Napsephel village. It stretches from latitude 27° 41' 10.95"N to 27° 40' 49.38"N and from longitude 90° 43' 44.13"E to 90° 43' 27.53"E. The site has a maximum North-South length of about 700m and a maximum East-West width of about 250m. It covers about 20ha (50 acres).

2.2 Climate

There is no meteorological station at the proposed site. However, the climatic condition of Lame Gompa which is quite comparable with the proposed site as it lies within the Chamkhar Valley and has almost the same altitude range. Table 2.1 summarises the meteorological data for Lame Gompa (at 2900m asl).

The mean minimum temperature is about -1.5°C in January and rises to 10°C in July. The mean maximum is about 7°C in January and rises to about 18°C in July. Mean annual precipitation is about 1100mm, of which about 900mm (about 80%) fall in the monsoon months of May – September. The proposed site seems considerably wetter than Bathpalathang Farm (ca 750 mm p.a), which is at an altitude of about 2700m asl in the main Bumthang valley (BSS Report SS-07).

Table 2.1 Climate summary for Lame Gompa

Months	J	F	M	A	M	J	J	A	S	O	N	D	Year average / total
Mean daily temperature (0C)													
1994-1997	0.3	0.9	5.6	7.6	9.8	11.1	13.0	13.4	12.1	8.6	5.5	2.0	**7.6**
Average rainfall (mm)													
1994-1997	28.0	21.2	47.6	60.0	92.0	179.4	156.5	270.1	166.1	34.8	35.9	12.3	**1100**

Source: BSS Report SS- 07

2.3 Geology and soil parent materials

The proposed site falls under the Naspe Formation. It mainly comprises garnet-staurolite-mica schist which is commonly graphitic and contains kynite at several localities (Golani and Singh, 1992-93). However, 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.

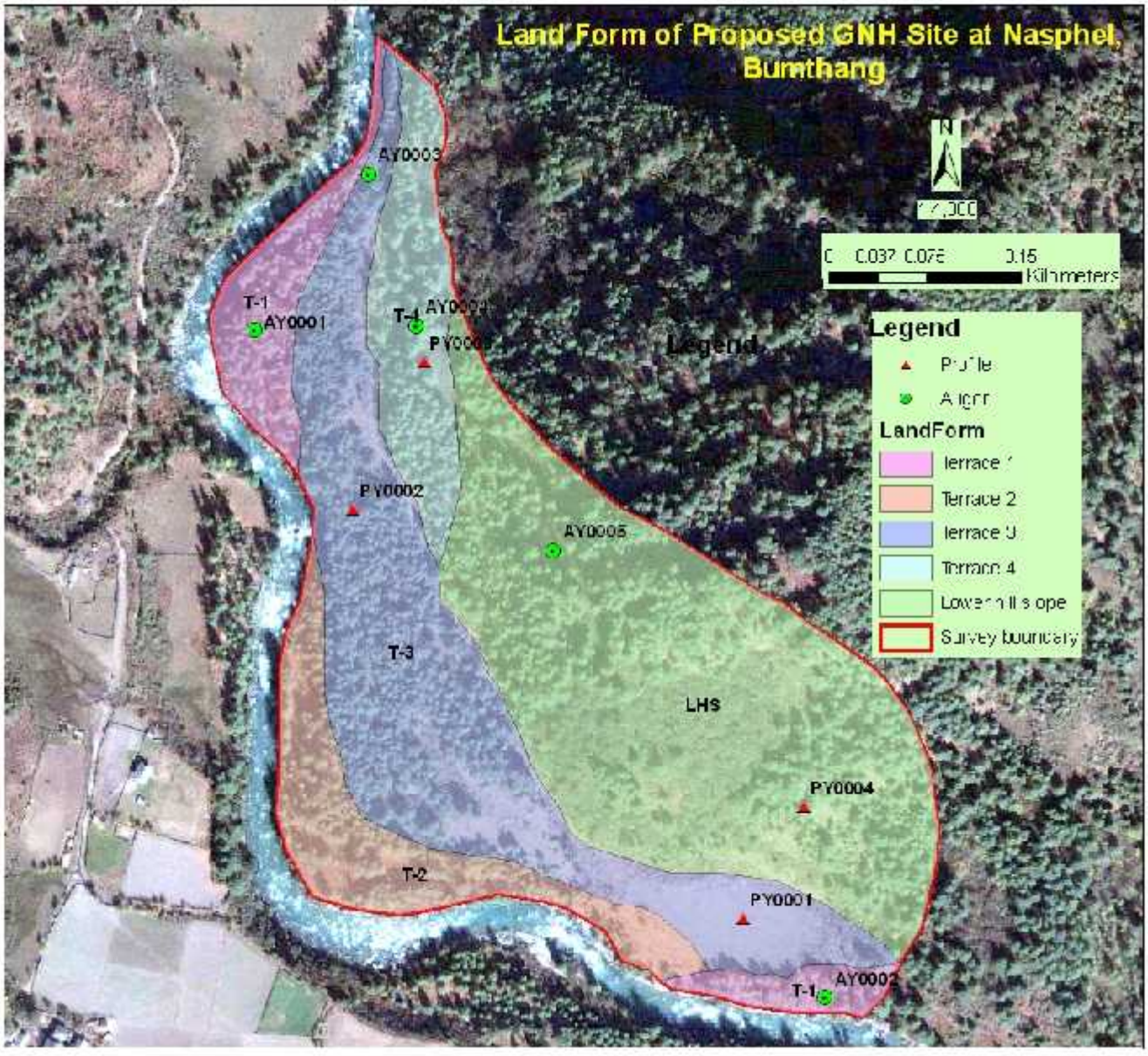
2.4 Topography and drainage

The proposed site is located at the true left hand side of Chamkhar Chhu. This section of the valley is not as 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 grazing land irrespective of the land category. There are no settlements at the proposed site, but on the other side of the river the Napsephel village is located.

The Bumthang valley in general is characterized by a complex set of landforms. The main valley is flanked by a sequence of river terraces, which range from the current floodplain at 1-4 m above the river bed to a fluvial boulder deposit found at more than 300m relative elevation. It is possible that there are deposits at even greater elevations, but these have not yet been seen. In addition the valley has alluvial fans originating out of some of the main side valleys. There are also extensive areas of colluvial/residual hill slopes, covered by hill wash and creep deposits, or having bluffs of hard rock outcrops (BSS, Report SS-02(a) & Dorji, et. al., 2009).

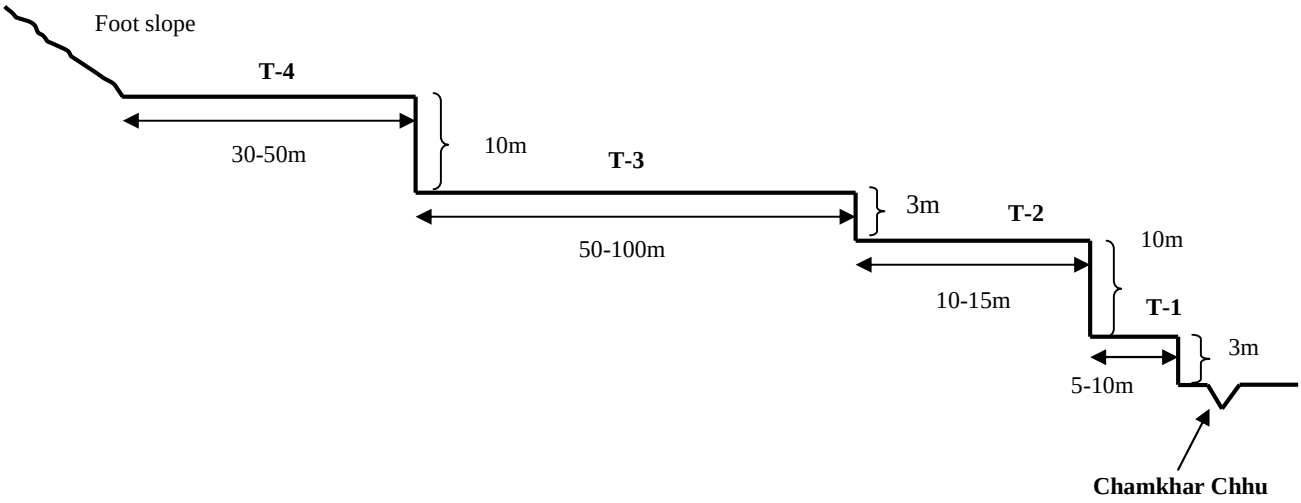
The proposed site consists of four distinct river terraces (Refer Figure 2.1) along the western and southern parts of the survey area. Most of these river terraces are not continuous except for the 15m terrace. They occur as two to three isolated benches but with similar relative heights from the river basin. The different levels of terraces are mostly fronted by steep (gradients more than 70°) rectilinear connecting slopes, which have few rounded boulders and cobbles outcropping at the surface. The terrace tops are relatively flat, with back-to-front slopes ranging from 3-5%.

Figure 2.1 Landform Map of the proposed site for the GNH Centre, Nagsephel, Bumthang



Sl #	Alluvial terrace level	Average height from the river (m)	Area (ac)	Area %
1	Terrace 1 (T-1)	3m	3.98	8.0
2	Terrace 2 (T-2)	12m	5.06	10.1
3	Terrace 3 (T-3)	15m	15.04	30.1
4	Terrace 4 (T-4)	25m	4.30	8.6
5	Lower hill slope (LHS)	>25m	21.57	43.2
		Total	**49.95**	**100.0**

Figure 2.2 Cross section of the river terraces



The river terraces abut with the steep rectilinear lower hill slope toward the eastern part of the survey area. The break of slope at the base, to the upper terrace, is quite distinct. The upper hill slope runs quite high but the survey boundary runs only midway of the hill slope.

2.5 Land use and vegetation.

Majority of the proposed site falls under the Government Reserve Forest. However, about half of the 15m terrace is private land, but at the moment, it is been kept fallow. Currently, the whole proposed site is being used for cattle grazing, collecting household timber, fuel wood and fire splints. The range of crops that can be grown appears to be partly limited by the cold temperatures.

The blue pine (Pinus wallichiana) forest dominates the natural vegetation of the proposed site. It has an understory vegetation of shrubs, young pines, bamboo (Yushania spp), rose (Rosa sericea, etc. The blue pine trees on the lower hill slopes are much bigger and older than the pine trees on the alluvial terraces. However, within the alluvial terraces, larger pine trees are mostly seen on the higher terraces. This is quite obvious as the higher alluvial terraces are much older with moderate soil development compared to the lower alluvial terraces.

3. METHOD

3.1 Field

The soils were examined on a routine basis at 5 sites, mainly with a 1.2m Edelman auger, fitted with a 7cm combination head. Duplicate augering were done at 2 of the sites where the first attempt was stopped by stones at less than 40cm. The observation sites were located based on the landform features of the survey area.

For routine soil observations the following site data were collected:

Location, GPS coordinates; climatic condition; general topography, site position; the slope (°), aspect (°), length and form of the slope; solid and drift parent materials; land degradation; general land use and crops/vegetation; irrigation and type; artificial land shaping features; fertilizer use, if known; surface stones; and site drainage.

The soils were described by natural layers (= horizons), with the following data collected for each horizon:

> Munsell colour of matrix (in field moisture condition); number, size, contrast and colour of mottles; field texture; number, size and type of stones; moisture condition; reaction to HCl (to test for presence of free carbonate minerals) and consistence on the auger.

The soils were described in more detail at 4 sites and the detailed descriptions were done in purpose-dug profile pits. The site data are the same as for the routine sites.

The soils were described by horizons according to international conventions (FAO 1990). The data collected for each horizon were as in the routine descriptions, with the addition of:

> Strength, size and type of soil structure; number and size of pores, presence strength and continuity of cutans (shiny coatings on surfaces of soil structural units); consistence in situ and in hand; number size and type of roots; concretions of iron, manganese or other secondary formations; presence and effects of animals (worm casts etc.); any other features (e.g. charcoal); clarity and shape of lower boundary.

Samples were collected for laboratory analysis from the main horizons of the 4 described profiles.

3.2 Mapping

The proposed site is covered by the Department of Survey and Land Records (DSLR) topographic sheet # 78 I-4, at scale 1:50000. However, the geo-referenced Quick Bird satellite image (60cm spatial resolution) from the Department of Geology and Mines (DGM) was used as a base map to carry out the soil survey at the proposed site.

The delineation of different landform units of the survey area was done through visual observation on the ground rather than using a GPS. This was done so because the GPS could not receive very good satellite signal due to thick forest cover. However, GPS coordinates of all soil observation sites were noted to enable easily plotting of the observation sites on the map. Two separate maps are being produced: the landform map with soil observation sites on it and the soil map. Both the maps are produced at 1:4000.

3.3 Laboratory

A total of 11 soil samples are being analysed at the Soil and Plant Analytical Laboratory (SPAL) under the National Soil Services Centre, Semtokha. The methods of analysis used by SPAL are summarized in APPENDIX-II.

4. SOIL CLASSIFICATION AND CHARACTERISTICS

4.1 Soil classification

The soils of the survey area are classified into two main groups based on their drift parent material i.e. colluvial and alluvial soils. These soils are further classified into 5 groups based on soil depth, texture and coarse material content.

4.2 Lower hill slope soils (Colluvium)

The lower hill slope soils of the survey area are mainly formed due to hill slope process from the upper slope. The colluvial soils are subdivided into two classes:

4.2.1 Moderately deep greyish brown – dark yellowish brown hill soils (Hd)

These soils occupy the steep slopes of the northeast to east part of the survey area. They were examined in detail in one profile and one auger description (see PY004 & AY0005 in Appendix B). The topsoil is greyish brown to very dark brown with fine sandy loam to humic loam. It has a moderate medium subangular blocky structure with moderate porosity. The subsoil is dark yellowish brown to brown with sandy clay loam in texture, and has moderately developed subangular blocky structures. Both topsoil and subsoil contain few fragments of weathered schist and hard quartzite. The soil is moderately well drained with soil depth varying from 70-100cm.

PY004

AY0005

The topsoil is very acidic (pH 5.27) but the subsoil is slightly acidic (pH 5.87). Very low soil pH in both the topsoil and subsoil might prove to be harmful as it will determine the uptake of soil nutrients.

The normal yardsticks for inherent fertility (TEB & BS) are very low with subsoil TEB averaging 0.44me/100g and BS averaging 3%. Available subsoil phosphorus is very low (average 1.47ppm). The individual nutrient elements in the subsoil are rated as “very low” for calcium (0.07 me/100g) and magnesium (0.01 me/100g), and “low” for potassium (0.21 me/100g) and sodium (0.15 me/100g). Level of organic carbon in the topsoil is high (3.9%) but low (0.8%) in the subsoil. Total-N is moderate in the topsoil (0.21%) and very low in subsoil (0.05%). The Ca:Mg ratio for the topsoil is 2.03 (Ca slightly deficient) and for the subsoil is 7.0 (Mg slightly defiant). The Mg:K ratio for the topsoil is 0.51 (Mg deficient) and for the subsoil is 0.05 (Mg deficient) – refer APPENDIX-I for details.

The fertility potential of this soil (the ability of the soil to retain added nutrients) as reflected by the Cation Exchange Capacity (CEC) is very high in the topsoil (44.42me/100g) and low in the subsoil (14.89me/100g) and might retain the added nutrients in the soil.

4.2.2 Very bouldery soil (Hb)

Some part of the lower hill slope consists of these soils. The soil type as such is similar to Hd soils but the only difference is presence of many huge boulders (1-4m diameter) and stones reducing the soil depth, water holding capacity and agronomic potential for plantation activities. Most of this site is inaccessible due to abundant surface stones and boulders and thick growth of bamboos and shrubs.

4.3 Alluvial terrace soils (Alluvium)

The soils of the flat tops of the alluvial terraces have been divided according to the relative height and age of the deposits. These differences are associated with the degree of profile development and characteristics of the soils.

4.3.1 Very shallow terrace soils (Ts)

These are very young and extensive in the lower alluvial terraces below 15m from the river bed. One profile and two auger descriptions were done (see PY002, AY0001 & AY0002 in Appendix B). The topsoil is brown to dark greyish brown with fine to medium sandy loam texture. It is weakly structured crumb, friable and moderately porous. The subsoil is light yellowish brown to brown with fine to coarse sand (river sand) texture. The soils are somewhat excessively drained with soil depth not more than 40cm. The subsoil is underlain by a bed of alluvial boulders and cobbles which are hard and highly rounded and have been little weathered since deposition. The interstitial fine material is moist, light grey, un-mottled, coarse and medium sand.

PY002

AY0001

The topsoil is very acidic (pH 5.27) but the subsoil is slightly acidic (pH 5.82). Very low soil pH in both the topsoil and subsoil might prove to be harmful as it will determine the uptake of soil nutrients.

The normal yardsticks for inherent fertility (TEB & BS) are very low with subsoil TEB averaging 0.14me/100g and BS averaging 2%. Available subsoil phosphorus is low (average 12.98ppm). The individual nutrient elements in the subsoil are rated as “very low” for calcium (0.07me/100g), magnesium (0.03me/100g), potassium (0.01me/100g) and sodium (0.04me/100g). Level of organic carbon in the topsoil is high (3.55%) but very low (0.03%) in the subsoil. Total-N is moderate in the topsoil (0.20%) but very low in subsoil (0.05%). The Ca:Mg ratio for the topsoil is 2.67 (Ca slightly deficient) and for the subsoil is 4.38 (no deficient). The Mg:K ratio for the topsoil is 0.13 (Mg deficient) and for the subsoil is 2.50 (Mg slightly deficient) – – refer APPENDIX-I for details.

The fertility potential of this soil (the ability of the soil to retain added nutrients) as reflected by the Cation Exchange Capacity (CEC) is moderate in the topsoil (24.07me/100g) and low in the subsoil (7.96me/100g) and might retain some added nutrients in the soil.

4.3.2 Deep middle terrace soils (Td)

These soils are moderately young and occupy the flat top of the 12m and 15m terraces, and form an almost continuous North - South strip through the site. One detail and one auger descriptions were made (see PY001 & AY0003 in Appendix B). The topsoil is dark greyish brown to very dark brown with fine to medium sandy loam texture. It has moderately medium subangular blocky structures with moderate porosity. The subsoil is brown to light olive brown with fine to coarse sand (river sand) texture. Many fine to medium angular and sub-rounded gneiss, granite and quartzite gravels are present. Few well rounded granite and quartzite stones are also present in the subsoil. The soils are somewhat excessively drained with soil depth more than 100cm.

PY001

The topsoil is very acidic (pH 5.53) but the subsoil is slightly acidic (pH 6.03). Very low soil pH in both the topsoil and subsoil might prove to be harmful as it will determine the uptake of soil nutrients.

The normal yardsticks for inherent fertility (TEB & BS) are very low with subsoil TEB averaging 0.64me/100g and BS averaging 11%. Available subsoil phosphorus is high (average 67.73ppm). The individual nutrient elements in the subsoil are rated as "very low" for calcium (0.11me/100g), magnesium (0.11me/100g) and potassium (0.02me/100g) and "low" for sodium (0.23me/100g). Level of organic carbon in the topsoil is moderate (3.0%) but very low (0.55%) in the subsoil. Total-N is moderate in the topsoil (0.29%) but very low in subsoil (0.05%). The Ca:Mg ratio for the topsoil is 29.33 (Mg deficient with P inhibition) and for the subsoil is 1.03 (Ca slightly deficient). The Mg:K ratio for the topsoil is 0.02 (Mg deficient) and for the subsoil is 5.14 (no deficient) – – refer APPENDIX-I for details.

The fertility potential of this soil (the ability of the soil to retain added nutrients) as reflected by the Cation Exchange Capacity (CEC) is moderate in the topsoil (20.15me/100g) and low in the subsoil (5.51me/100g) and might retain some added nutrients in the soil.

4.3.3 Deep upper terrace soils (Tu)

These soils are comparatively older than Ts and Td soils and occur in the 25m terrace toward the northern part of the survey area. They were examined in detail in one profile and one auger description (see PY0003 & AY0004 in Appendix B). The topsoil is dark greyish brown to dark brown with fine sandy loam to sandy clay loam texture. It has moderately medium subangular blocky structure with moderate porosity. It has buried topsoil from 30cm to 48cm of the soil profile. The subsoil is dark yellowish brown to yellowish brown with sandy clay loam to sandy clay texture. It has moderately fine to medium angular blocky structure with low porosity. Few well rounded granite and quartzite stones were also seen in the subsoil. The soils are moderately well drained with soil depth more than 100cm.

PY003

Both the topsoil (pH 5.59) and subsoil (pH 5.41) are very acidic. Due to very low soil pH in both topsoil and subsoil, the uptake of soil nutrients would be affected.

The normal yardsticks for inherent fertility (TEB & BS) are very low with subsoil TEB averaging 0.43me/100g and BS averaging 1%. Available subsoil phosphorus is very low (average 0.16ppm). The individual nutrient elements in the subsoil are rated as "very low" for calcium (0.08me/100g) and magnesium (0.05me/100g) and "low" for potassium (0.11me/100g) and sodium (0.20me/100g). Level of organic carbon is moderate in both the topsoil (2.0%) and subsoil (1.95%). Total-N is low in both the topsoil (0.19%) and subsoil (0.10%). The Ca:Mg ratio for the topsoil is 1.60 (Ca slightly deficient) and for the subsoil is 1.80 (Ca slightly deficient). The Mg:K ratio for the topsoil is 0.63 (Mg deficient) and for the subsoil is 0.41 (Mg deficient) – – refer APPENDIX-I for details.

The fertility potential of this soil (the ability of the soil to retain added nutrients) as reflected by the Cation Exchange Capacity (CEC) is high both in the topsoil (34.20me/100g) and subsoil (34.56me/100g) and might retain all the added nutrients in the soil.

5. SOIL DISTRIBUTION AND MAPPING

5.1 Soil distribution

Because the soil classification has a strong geomorphological basis, the distributions of the soil classes are closely related to topography and landform features. The deep and boulder hill soils are predominate on the lower hill slopes of the survey area. Very shallow to deep somewhat excessively drained alluvial soils are mostly found in the alluvial terraces.

5.2 Soil mapping units

It is possible to map all of the area as simple units in which one class of soil is predominant (consociation). The consociations are not pure, and contain minor inclusions of other soil classes. However there is no need for complex mapping units with two or more classes that are more or less coequal. The compositions of the mapping units are summarised in Table 5.1.

The soil map at scale 1:4000 is included in Figure 5.1. The areas and proportions of the soil mapping units are summarised in Table 5.2

Table 5.1 Composition of soil mapping units and acreage

Mapping unit	Type	Main soil classes	Minor soil classes	Acres	Survey area %
Hd	Consociation	Hd	Hb	12.33	24.7
Hb	"	Hb	Hd	8.93	17.9
Ts	"	Ts	-	10.93	21.9
Td	"	Td	Ts	13.40	26.8
Tu	"	Tu	Td	4.36	8.9
			Total	**49.94**	**100**

Figure 5.1 Soil Map of the proposed site for GNH Centre, Nagsephel, Bumthang

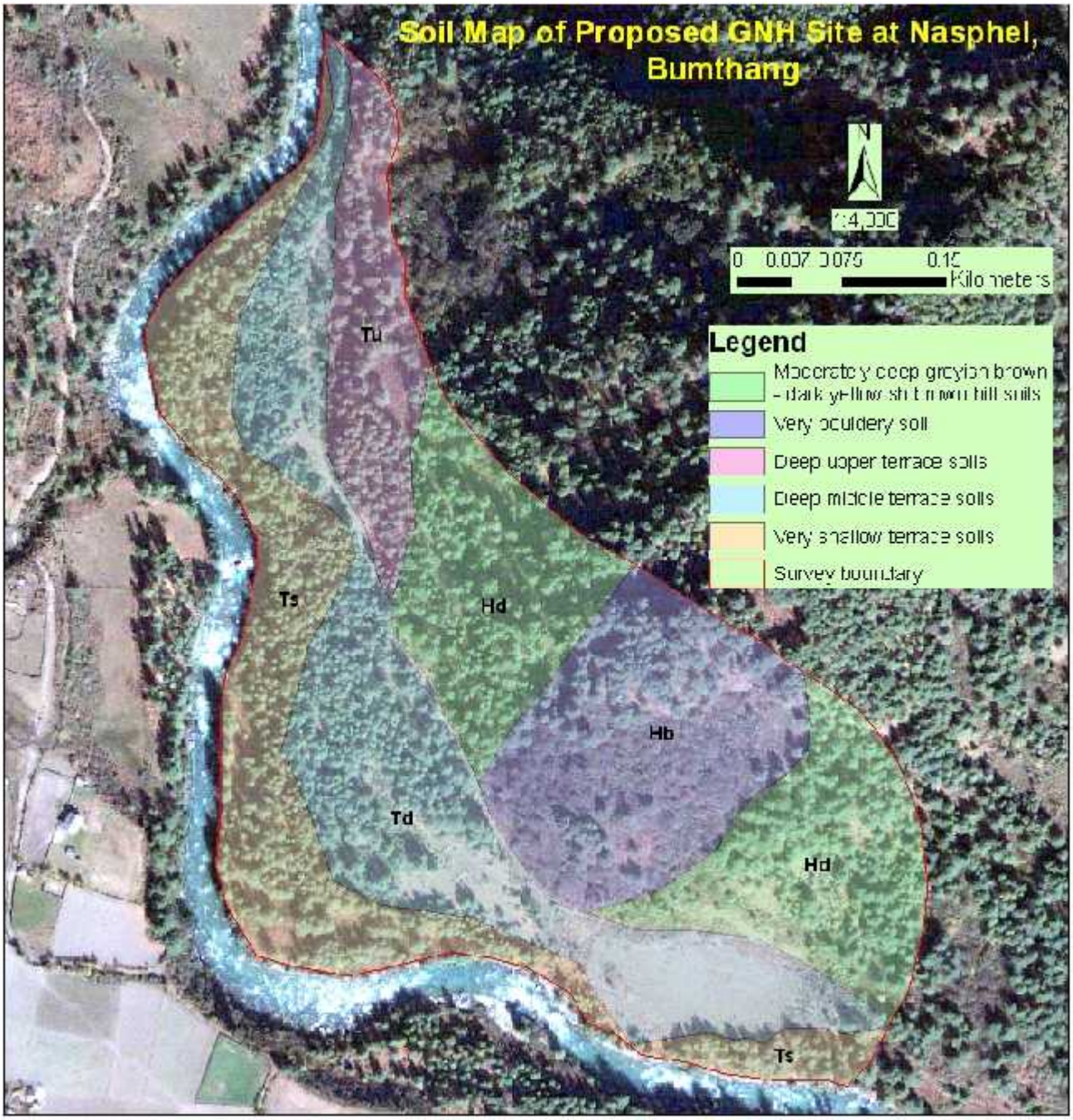


Table 5.2 Soil classes of the proposed GNH Centre

SOIL CLASS		Main Features	Representative profile and auger descriptions
Code	**Name**		
Lower hill slope soils (Colluvium)			
Hd	Moderately deep greyish brown – dark yellowish brown hill soils	Greyish brown to very dark brown fine sandy loam to humic loam topsoil over dark yellowish brown to brown sandy clay loam subsoil over weathered rock within 1m. Topsoil - very acidic (pH 5.27), high OC (3.9%), very high CEC (44.42me/100g) and very low BS (8%). Subsoil – slightly acidic (pH 5.87), low OC (0.8%), low CEC (14.89me/100g) and very low BS (3%).	PY004 AY0005
Hb	Very bouldery soil (Hb)	Same has Hd soils plus presence many huge surface boulders and stones	-
Alluvial terrace soils (Alluvium)			
Ts	Very shallow terrace soils - (*very young soils)*	Brown to dark greyish brown sandy loam topsoil over light yellowish brown to pale brown coarse sand subsoil over bed of hard and well rounded alluvial boulders and cobbles at 40cm depth. Topsoil - very acidic (pH 5.27), high OC (3.55%), moderate CEC (24.07me/100g) and very low BS (2%). Subsoil – slightly acidic (pH 5.82), very low OC (0.3%), low CEC (7.96me/100g) and very low BS (2%).	PY002 AY0001 AY0002
Td	Deep middle terrace soils - *(moderately young soils)*	Dark greyish brown to very dark brown sandy loam topsoil over brown to light olive brown coarse sand subsoil over hard and well rounded alluvial boulders and cobbles within 100cm depth. Topsoil - very acidic (pH 5.53), moderate OC (3.00%), moderate CEC (20.15me/100g) and very low BS (14%). Subsoil – slightly acidic (pH 6.03), very low OC (0.55%), low CEC (5.51me/100g) and very low BS (11%).	PY001 AY0003
Tu	Deep upper terrace soils - *(older soils)*	Dark greyish brown to dark brown sandy loam to sandy clay loam topsoil over dark yellowish brown to yellowish brown sandy clay loam to sandy clay subsoil – soil depth more than 100cm. Topsoil - very acidic (pH 5.59), moderate OC (2.00%), high CEC (34.20me/100g) and very low BS (1%). Subsoil – very acidic (pH 5.41), moderate OC (1.96%), high CEC (34.56me/100g) and very low BS (1%).	PY003 AY0004

6. OVERVIEW AND IMPLICATIONS

6.1 Overview of soils

The site encompasses a wide range of soils. They vary in texture from coarse sand to sandy clay. The soils of the lower river terraces have undergone very limited soil development since its deposition and most of the materials are still fresh. This is inferred by presence of very coarse river sand just below the topsoil of 20-30cm thick. However, the highest terrace and the lower hill slope soils show some extent of soil development with thicker accumulation of organic matter in the top soils followed by moderately developed "B' horizon of the soil profile. Moisture stress problems may not occur in these soil types.

The soil pH of all the soil types varies from slightly acidic to very acidic. It could be probably due to slow decomposition of pine needles due to low temperature and precipitation. Soil organic carbon of the topsoil is moderate to very high but is very low in the subsoil in all soil types. Available K is generally high however available P is low. Exchangeable bases in all the soil types are low to very low with TEB not more than 3.56me/100g. Ca and Mg are deficient in most of the soil types with P inhibition in one of the soil types. However, CEC seems to be moderate to very high in the top soil but low to moderate in the subsoil probably due to high content of soil organic matter.

6.2 Implications of results

The presence of many stones, huge boulders and cliff (Hb soils) in the lower hill slopes of the survey area might impede the full utilization of the land for plantation activities. The moderately deep Hd soils would be suitable for plantation but the very steep slope gradient might prove to be a challenge. The soil development of the relatively young river terraces is very limited and might have very low inherent soil fertility and may not be suitable for plantation activities. Furthermore, due to very coarse soil texture in the young terraces, the water infiltration rate would be very high reducing the water holding capacity of the soil. As a result, it would lead to moisture stress problems. In certain sections of the survey area, the lowest terrace (T-1) is not more than 1m from the river bed and this possesses a very high risk of inundating it during flash floods.

Soils of the proposed site are generally very low in soil pH and this might affect the uptake of soil nutrients by the plant roots. This is because most of soil nutrients are available to the plants when the soil pH range is between 6 and 7. Very low organic carbon, total nitrogen and exchangeable bases in the subsoil might also affect the plant growth as they are the main nutrients required by the plants. Though CEC is high to very high in the topsoil but it is low to moderate in the subsoil and it may not retain all the added soil nutrients given the fact that the soil infiltration rate is also very high because of very coarse soil texture.

7. RECOMMENDATIONS

In general, the soils of the proposed site are not really suitable for plantation activities except for the Tu soils due to very high content of stones and boulders (Hb), very steep slopes (Hd & Hb), very shallow and coarse textured sub soils (Ts & Td) and poor soil fertility. However with certain amendments, the site could be used for plantation activities and they are:

- Due to high water infiltration rate and low water holding capacities of the river terrace soils (Ts & Td), irrigation facilities need to be put in place to irrigate the plants especially during dry spells.
- Very bouldery soils (Hb) should be avoided for plantation activities and use for other purposes e.g. meditation caves.
- The lower hill slope soils (Hd) can be used for plantation activities but this needs to be done carefully because of the very steep slope gradient.
- In order to increase the water holding capacity, improve soil fertility and raise the soil pH, leaf litter and/or Farm Yard Manure (FYM) needs to be incorporated while planting the trees and bamboos.
- Planting hole needs to be wide and deep enough to accommodate sufficient leaf litter and/or FYM during plantation.
- Most suitable plant species should be selected for plantation at the site to make it more successful.
- Plantation of high value plant species or construction of infrastructure along the lowest river terraces should be avoided as they are prone to flash floods.
- Before any plantation, physical or social fencing needs to be put in place as the proposed site is used as grazing land by the local communities.

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APPENDIX-I Summary of lab data

Topsoils											Exchangeables									Cation Ratios		Cation Ratios	
Soil Types	Site No.	Depth	pH	pH	pH	Avail P	Avail K	Org C	Total N	C:N	meq / 100g							Mg	K	BS			
			H2O	KCl	diff	ppm	ppm	%	%		Ca	Mg	K	Na	TEB	Al	CEC	Sat%	Sat%	%	Ca/Mg	Rating	Mg/K	Rating
	PY001	0-20	5.83	4.97	0.86	20.10	39.24	3.00	0.29	10	0.88	0.03	1.50	0.46	2.87		20.15	0	1	14	29.33	Mg deficient with P inhibition	0.02	Mg deficient
Td		Mean	5.83	4.97	0.86	20.10	39.24	3.00	0.29	10.34	0.88	0.03	1.50	0.46	2.87		20.15	0.15	1.00	14.24	29.33	Mg deficient with P inhibition	0.02	Mg deficient
	Overall Mean		5.83	4.97	0.86	20.10	39.24	3.00	0.29	10.34	0.88	0.03	1.50	0.46	2.87		20.15	0.15	1.00	14.24	29.33	Mg deficient with P inhibition	0.02	Mg deficient
	Rating		V.Acid	Ext Acid	Ext Acid	Mod	V High	Med	Med	Good	V Low	V Low	V High	Med	V Low		Med	V Low	V Low	V Low				
	PY002	0-20	5.27	4.41	0.86	5.74	12.21	3.65	0.20	18	0.08	0.03	0.24	0.02	0.37		24.07	0	1	3	2.67	Ca deficient	0.13	Mg deficient
Ts		Mean	6.27	4.41	0.86	5.74	12.21	3.65	0.20	17.75	0.08	0.03	0.24	0.02	0.37		24.07	0.12	1.00	1.64	2.67	Ca deficient	0.13	Mg deficient
	Overall Mean		5.27	4.41	0.86	5.74	12.21	3.65	0.20	17.75	0.08	0.03	0.24	0.02	0.37		24.07	0.12	1.00	1.64	2.67	Ca deficient	0.13	Mg deficient
	Rating		V.Acid	Ext Acid	Ext Acid	Low	V High	High	Med	Med	V Low	V Low	Low	V Low	V Low		Med	V Low	V Low	V Low				
	PY003	0-20	5.59	4.85	0.74	3.10	9.33	2.00	0.19	11	0.08	0.05	0.08	0.04	0.25		34.20	0	1	1	1.60	Ca deficient	0.63	Mg deficient
Tu		Mean	5.59	4.85	0.74	3.10	9.33	2.00	0.19	10.53	0.08	0.05	0.08	0.04	0.25		34.20	0.05	1.00	0.73	1.60	Ca deficient	0.63	Mg deficient
	Overall Mean		5.59	4.85	0.74	3.10	9.33	2.00	0.19	10.53	0.08	0.05	0.08	0.04	0.25		34.20	0.05	1.00	0.73	1.60	Ca deficient	0.63	Mg deficient
	Rating		V.Acid	V.Acid	Ext Acid	V Low	V High	Med	Low	Good	V Low	V Low	V Low	V Low	V Low		High	V Low	V Low	V Low				
	PY004	0-20	5.27	4.36	0.91	0.05	24.76	3.90	0.21	19	1.32	0.55	1.28	0.31	3.56		44.42	1	1	8	2.03	Ca deficient	0.51	Mg deficient
Hd		Mean	5.27	4.36	0.91	0.05	24.76	3.90	0.21	18.57	1.32	0.55	1.28	0.31	3.56		44.42	1.46	1.00	8.01	2.03	Ca deficient	0.51	Mg deficient
	Overall Mean		5.27	4.36	0.91	0.05	24.76	3.90	0.21	18.57	1.32	0.55	1.28	0.31	3.56		44.42	1.46	1.00	8.01	2.03	Ca deficient	0.51	Mg deficient
	Rating		V.Acid	Ext Acid	Ext Acid	V Low	V High	High	Med	Med	V Low	Low	V High	Med	Low		V High	V Low	V Low	V Low				

Table Chemical Characteristics of - Subsoils

Subsoils											Exchangeables									Cation Ratios		Cation Ratios	
Soil Series	Site No.	Depth	pH	pH	pH	Avail P	Avail K	Org C	Total N	C:N	meq / 100g							Mg	K	BS			
			H2O	KCl	Diff	ppm	ppm	%	%		Ca	Mg	K	Na	TED	Al	CEC	Sat%	Sat%	%	Ca/Mg	Rating	Mg/K	Rating
	PY001/2		5.09	4.04	1.00	90.40	9.01	1.10	0.05	22	0.10	0.11	0.20	0.42	1.00		0.39	2	0	17	1.00	Ca slideficient	0.29	Mg deficient
	PY001/3		6.16	5.13	1.03	79.80	0.17	0.01	0.05		0.07	0.10	0.01	0.23	0.21		4.02	2	1	1	1.00	Ca deficient	1.00	K slideficient
Td		Mean	6.03	4.04	1.00	67.73	8.99	0.55	0.05	22.00	0.11	0.11	0.20	0.23	0.64		5.51	1.94	3.08	10.57	1.03	Ca deficient	5.14	OK
	Overall Mean		6.03	4.04	1.00	67.73	8.99	0.55	0.05	22.00	0.11	0.11	0.20	0.23	0.64		5.51	1.94	3.08	10.57	1.03	Ca deficient	5.14	OK
	Rating		Sli Acid	V.Acid	V Low	High	Low	V Low	V Low	Poor	V Low	V Low	Low	Low	V Low		Low	V Low	V Low	V Low				
	PY002/2		5.62	4.98	0.63	0.61	0.40	0.63	0.05	12	0.07	0.04	0.01	0.36	0.18		10.47	0	0	2	1.75	Ca deficient	1.00	OK
	PY002/3		6.01	4.98	1.03	25.42	0.05	0.03	0.05		0.07	0.01	0.01	0.01	0.10		5.45	0	0	2	7.00	Mg slideficient	1.00	Mg deficient
Ts		Mean	5.82	4.98	0.84	12.90	0.23	0.33	0.05	12.00	0.07	0.03	0.01	0.04	0.14		7.96	0.20	0.14	1.70	4.30	OK	2.50	Mg slideficient
	Overall Mean		5.82	4.98	0.84	12.90	0.23	0.33	0.05	12.00	0.07	0.03	0.01	0.04	0.14		7.96	0.20	0.14	1.70	4.30	OK	2.50	Mg slideficient
	Rating		Sli Acid	V Acid	V Low	Low	V Low	V Low	V Low	Good	V Low	V Low	V Low	V Low	V Low		Low	V Low	V Low	V Low				
	PY003/2		5.41	4.45	0.96	0.26	0.46	2.61	0.10	26	0.08	0.04	0.11	0.24	0.45		35.08	0	0	2	2.00	Ca deficient	0.44	Mg deficient
	PY003/3		5.41	4.45	0.96	0.26	0.46	1.41	0.10	14	0.08	0.05	0.11	0.24	0.43		34.56	0	1	1	1.60	Ca deficient	0.44	Mg deficient
Tu		Mean	5.41	4.52	0.90	0.16	0.26	1.05	0.10	10.50	0.08	0.05	0.11	0.20	0.43		34.56	0.03	0.32	1.23	1.80	Ca deficient	0.41	Mg deficient
	Overall Mean		5.41	4.52	0.90	0.16	0.26	1.05	0.10	10.50	0.08	0.05	0.11	0.20	0.43		34.56	0.03	0.32	1.23	1.80	Ca deficient	0.41	Mg deficient
	Rating		V.Acid	Ext Acid	V Low	V Low	V Low	Med	Low	Poor	V Low	V Low	Low	Low	V Low		High	V Low	V Low	V Low				
	PY004/2		5.87	4.19	1.68	1.47	3.21	0.80	0.05	16	0.07	0.01	0.21	0.15	0.14		11.89	0	1	3	7.00	Mg deficient	0.05	Mg deficient
Hd		Mean	5.87	4.19	1.68	1.47	3.21	0.80	0.06	16.00	0.07	0.01	0.21	0.15	0.14		11.89	0.07	1.41	2.86	7.00	Mg deficient	0.06	Mg deficient
	Overall Mean		5.87	4.19	1.68	1.47	3.21	0.80	0.06	16.00	0.07	0.01	0.21	0.15	0.14		11.89	0.07	1.41	2.86	7.00	Mg deficient	0.06	Mg deficient
	Rating		Sli Acid	Ext Acid	V Low	V Low	V Low	Low	V Low	Med	V Low	V Low	Low	Low	V Low		Low	V Low	V Low	V Low				

APPENDIX-II Summary of soil analysis methods

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

The SPAL methods vary slightly according to soil pH. The methods summarized below are those for soils of pH (water) > 4.5 and < 7, as these apply to all of the samples from the proposed GNH Centre.

Sample preparation

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

pH

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

Soil extracts

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

Total N is extracted and converted into ammonium form by micro-Kjeldahl digestion with H2SO4 and a Se-based catalyst

Ammonium – N and nitrate – N are extracted by shaking with 0.01 M CaCl2 for two hours.

Available P is extracted by shaking 5 g of fine earth with 35 ml of the Bray and Kurtz extractant of 0.5 M HCl and 1 M NH4F for 1 minute.

Available K is extracted by shaking 5 g of fine earth with 50 ml of 0.01 M CaCl2 for 2 hours.

Exchangeable Ca, Mg, K and Na are extracted by leaching 5 g of fine earth with 100 ml of 1 M ammonium acetate (NH4OAc).

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

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

Assays of extracts

The NH4 from the Total N digestion, and from the KCl leaching for CEC determination, the NH4 – N, NO3 – N, available P, available K, and exchangeable K and Na in the various extracts are measured with the Skalar Segmented Flow Analyser system which includes

Colourimeters for NH4, NO3 and available P, and a flame spectrophotometer for available K, and for exchangeable K and Na.

Exchangeable Ca and Mg in the NH4OAc leachate are measured with a Unicam Atomic Adsorption Spectrophotometer.

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

Organic carbon

OC is measured by the Walkley – Black method of low temperature oxidation with acidified K2Cr2O7 and titration of the excess dichromate.

Particle size analysis

Particle size fractions are measured by the pipette method after pre-treatment of the fine earth with H2O2 to remove organic binding effects, and with HCl to remove aggregation effects by carbonates, Fe and Al oxides, and other mineral cementing agents, and dispersion of the clay with sodium hexametaphosphate.

TEB, ECEC, BS and C:N.

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

TEB	=	Exchangeable Ca + Mg + K + Na.
ECEC	=	TEB + Extractable Al.
BS (NH4OAc)	=	TEB / CEC (NH4OAc).
EBS	=	TEB / ECEC.
C:N	=	Organic C / Total N.

Table APPX-II/1 Summary of 1995 recommendations for interpretation of SPAL soil analyses

	V. High	**High**	**Moderate**	**Low**	**V. Low**
pH	> 7.6 * (alkaline)	6.6 - 7.5 (neutral)	5.6 - 6.5 (s. acid)	4.6 - 5.5 (v. acid)	< 4.5 (ext. acid)
EC mS/cm	> 2.00	0.8 - 1.99	0.4 - 0.79	0.15 - 0.39	< 0.15
CEC (NH_4OAC) me%	> 40	25 - 39.9	15 - 24.9	5 - 14.9	< 5
XCa me%	> 20	10 - 19.9	5 - 9.9	2 - 4.9	< 2
XMg me%	> 8	3 - 7.9	1.5 - 2.9	0.5 - 1.4	< 0.5
XK me%	> 1.2	0.6 - 1.19	0.3 - 0.59	0.1 - 0.29	< 0.1
XNa me%	> 2	0.7 - 1.99	0.3 - 0.69	0.1 - 0.29	< 0.1
TEB me%	> 30	15 - 29.9	7.5 - 14.9	3 - 7.4	< 3
XAl me%	> 10	5 - 9.9	2 - 4.9	0.5 - 1.9	< 0.5
ECEC me%	> 30	20 - 29.9	12 - 19.9	4 - 11.9	< 4
BS % (NH_4OAc)	> 80	65 - 79	50 - 64	35 - 49	< 35
EBS %	> 80	50 - 79	35 - 49	20 - 34	< 20
Ca:Mg	> 20	13 - 19.9	7 - 12.9	3 - 6.9	< 3
AvK ppm	> 300	200 - 299	100 - 199	40 - 99	< 40
AvP ppm	> 30		15 - 29	5 - 14	< 5
Org. C %	> 5	3.1 - 4.9	1.2 - 3	0.6 - 1.1	< 0.6
Total N %	> 1	0.5 - 0.99	0.2 - 0.49	0.1 - 0.19	< 0.1
C:N	> 50	20 - 49	15 - 19	10 - 14	< 10

Source: AHT 1995.

APPENDIX-III Soil Profile and auger descriptions

This appendix includes the detailed descriptions of 4 profiles and 5 augers, and analyses of the 4 soil profiles. The profiles are in the sequence in Table APPX-III/1.

Table APPX –III/1 Summary of soil profiles

Profile & Auger #	GNH Centre soil class	Number of horizons analysed	Sample #
PY0004	Hd	2	PY004/1 & PY004/2
AY0005	Hd	-	
-	Hb	-	
PY0002	Ts	3	PY002/1, PY002/2 & PY002/3
AY0001	Ts	-	
AY0002	Ts	-	
PY0001	Td	3	PY001/1, PY001/2 & PY001/3
AY0003	Td	-	
PY0003	Tu	3	PY003/1, PY003/2 & PY003/3
AY0004	Tu	-	

Profile Report

Profile:	**PY001**
Described & sampled:	Yeshey Chedup, 22.5.2010
Survey area:	Dingdingma
Map unit:	Td
Soil Classification	
BSS Soil Series:	
Soil Taxonomy:	
WRB:	
Coordinates:	27° 40' 51.8"N & 90° 43' 39.5" E
Topographic Map:	No. 78I-14
Location:	Ca 3 km ENE from the Napsephel Lhakhang
Altitude:	2830 masl
Climate	
General:	Cold temperate
Recent Weather:	Sunny
Parent material	
Solid:	Mixed
Drift:	Alluvium
Topography	
Landform:	
Site position:	Alluvial terrace (15m)
Aspect:	SSW (210 deg)
Slope:	9% (moderately sloping), convex
Erosion:	None
Run-off:	None
Site drainage:	Good
Microrelief:	None
Surface	
Surface condition:	Slightly moist
Surface cracks:	None
Surface capping:	None
Surface litter:	Scattered, raw grass, about 2 cm deep.
Surface outcrops:	None (0 %)
Surface stone:	None (0 %)
Land category:	Kamshing
Land use:	Tsamdo
Soil Drainage Class:	Somewhat excessively drained

Notes / Comments:

Cm	Horizon	Type	Description
0-25	Ah		Very dark brown (10YR 2/2); fine sandy loam with no mottles; few (3%) medium hard rounded gneiss gravels; no concretions; moist & very friable; slightly sticky and slightly plastic; moderate medium subangular blocky structure; no cutans; common very fine interstitial pores; few worm channel and few grubs; no cracks; common vertical fine fibrous roots; no reaction to dilute HCl; abrupt smooth boundary to: [Sample No. PY001\1]
25-50	C1		Brown (10YR 4/3); coarse sand with no mottles; many (30%) fine hard angular quartz gravels; no concretions; moist & loose; non sticky and non plastic; single grain; no cutans; many very fine interstitial pores; no worm activity; no cracks; no roots; no reaction to dilute HCl; clear wavy boundary to: [Sample No. PY001\2]
50-120	C2		Light olive brown (2.5Y 5/3); very coarse sand with no mottles; many medium hard subrounded granite & quartz; no concretions; moist & very friable; non sticky and non plastic; single grain; no cutans; many very fine interstitial pores; no worm activity; no cracks; no roots; no reaction to dilute HCl; [Sample No. PY001\3]

SPAL analytical results for Profile PY001 Survey area: Proposed site for GNH Centre

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PY001/1	0-25	33255	5.53	4.57	0.96	ND	20.10	3.00	0.29	10.44
PY001/2	25-50	33256	5.89	4.84	1.05	ND	56.40	1.10	0.05	21.87
PY001/3	50-120	33257	6.16	5.03	1.13	ND	79.06	0.00	0.05	0.00

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PY001/1	0.88	0.03	1.50	0.46	2.88	ND	20.15	ND	14.28	ND
PY001/2	0.15	0.11	0.38	0.42	0.85	ND	6.39	ND	13.31	ND
PY001/3	0.07	0.10	0.01	0.03	0.01	ND	4.62	ND	0.30	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		
PY001/1	ND	ND	ND	ND	ND	69.80	10.40	10.50	20.90	9.30	SL
PY001/2	ND	ND	ND	ND	ND	87.20	6.40	3.50	9.90	2.90	S
PY001/3	ND	ND	ND	ND	ND	90.20	3.90	3.60	7.50	2.30	S

Profile Report

Profile:	**PY002**
Described & sampled:	Yeshey Chedup 22.5.2010
Survey area:	Dindingma
Map unit:	Ts
Soil Classification	
BSS Soil Series:	
Soil Taxonomy:	
WRB:	
Coordinates:	27° 40' 59.7"N & 90° 43' 30.9" E
Topographic Map:	No. 78I-14
Location:	Ca 1 km E from the Nagsephel village under Choekhor geog
Altitude:	2907 masl
Climate	
General:	Cold temperate
Recent Weather:	Sunny
Parent material	
Solid:	Mixed
Drift:	Alluvium
Topography	
Landform:	
Site position:	Alluvial terrace (15m)
Aspect:	SSE (169 deg)
Slope:	4% (gently sloping), convex
Erosion:	None
Run-off:	None
Site drainage:	Good
Microrelief:	None
Surface	
Surface condition:	Slightly moist
Surface cracks:	None
Surface capping:	None
Surface litter:	Scattered, fresh pine needles and grasses, 4 cm deep.
Surface outcrops:	Common (25 %) hard subrounded gneiss boulder > 1 m
Surface stone:	Common (20 %) fine & medium hard rounded gneiss stones
Land category:	Government Reserve Forest
Landuse:	Government Forest
Soil Depth Limit:	Stone contact at 40 cm
Soil Drainage Class:	Somewhat excessive

Cm	Horizon	Type	Description
0-18	Ah		Very dark brown (10YR 2/2); fine sandy loam with no mottles; few fine hard subangular quartz gravels; no concretions; moist & friable; slightly sticky and slightly plastic; moderate fine subangular blocky structure; no cutans; common very fine interstitial pores; no worm activity; no cracks; few irregular fine fibrous & woody roots; no reaction to dilute HCl; abrupt smooth boundary to: [Sample No. PY002\1]
18-30	C1		Dark yellowish brown (10YR 4/4); medium sand with no mottles; few fine slightly hard subangular quartz gravel; no concretions; moist & very friable; non sticky and non plastic; single grain; no cutans; many very fine interstitial pores; no worm activity; no cracks; few irregular fine fibrous & woody roots; nil reaction to dilute HCl; diffuse wavy boundary to: [Sample No. PY002\2]
30-40	C2		Light olive brown (2.5Y 5/3); coarse sand with no mottles; many fine hard rounded gneiss and quartzite stones; no concretions; moist & friable; non sticky and non plastic; single grain; no cutans; many very fine interstitial pores; no worm activity; no cracks; rare irregular fine woody roots; no reaction to dilute HCl; [Sample No. PY002\3]
40+			Beds of well rounded boulders and stones (Granite, Gneiss & Quartzite)

SPAL analytical results for Profile PY002 Survey area: Proposed site for GNH Centre

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PY002/1	0-18	33258	5.27	4.41	0.86	ND	5.74	3.55	0.20	18.14
PY002/2	18-30	33259	5.62	4.99	0.63	ND	0.54	0.60	0.05	11.86
PY002/3	30-40	33260	6.01	4.96	1.05	ND	25.42	0.00	0.05	0.00

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PY002/1	0.08	0.03	0.24	0.02	0.30	ND	24.07	ND	1.25	ND
PY002/2	0.07	0.04	0.01	0.06	0.18	ND	10.47	ND	1.73	ND
PY002/3	0.07	0.01	0.01	0.01	0.07	ND	5.45	ND	2.00	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		
PY002/1	ND	ND	ND	ND	ND	77.70	5.70	8.60	14.30	8.00	SL
PY002/2	ND	ND	ND	ND	ND	79.00	9.70	5.70	15.40	5.60	LS
PY002/3	ND	ND	ND	ND	ND	83.00	8.00	5.20	13.20	3.80	LS

Profile Report

Profile:	**PY003**
Described & sampled:	Administrator 22.5.2010
Survey area:	Dingdingma
Map unit:	Tu
Soil Classification	
BSS Soil Series:	
Soil Taxonomy:	
WRB:	
Coordinates:	27° 41’4.2"N & 90° 43' 30.6" E
Topographic Map:	No. 78I-14
Location:	Ca 1 km E from the Nagsephel village, Choekhor geog
Altitude:	2849 masl
Climate	
General:	Cold temperate
Recent Weather:	Sunny
Parent material	
Solid:	Mixed
Drift:	Alluvium
Topography	
Landform:	
Site position:	Alluvial terrace (25m)
Aspect:	SSW (210 deg)
Slope:	9% (moderately sloping), rectilinear
Erosion:	None
Run-off:	None
Site drainage:	Good
Micro relief:	25 - 50 cm from undulations
Surface	
Surface condition:	Moist
Surface cracks:	None
Surface capping:	None
Surface litter:	Scattered, raw moss and pine needles, about 3cm deep
Surface outcrops:	None (0 %)
Surface stone:	None (0 %)
Land category:	Government Reserve Forest
Landuse:	Government Forest
Soil Depth Limit:	Stone contact at 95 cm
Soil Drainage Class:	Moderately well drained

Notes / Comments:

Cm	Horizon	Type	Description
0-30	Ah		Dark brown (7.5YR 3/2); fine sandy loam with no mottles; few fine slightly hard subangular gneiss gravels ; no concretions; moist & friable; slightly sticky and slightly plastic; moderate medium subangular blocky structure; no cutans; common very fine interstitial pores; common krotovinas & ants; no cracks; many irregular fine fibrous & woody roots; nil reaction to dilute HCl; abrupt smooth boundary to: [Sample No. PY003\1]
30-48	Ab		Very dark brown (10YR 2/2); fine sandy loam with no mottles; few medium hard rounded gneiss & quartz gravels; no concretions; moist & friable; moderately sticky and moderately plastic; moderate fine subangular blocky structure; no cutans; many very fine interstitial pores; no worm activity; no cracks; common irregular fine woody roots; nil reaction to dilute HCl; [Sample No. PY003\2]
48-100	BC		Dark yellowish brown (10YR 4/4); sandy clay loam with no mottles; many fine hard rounded quartzite & granite stones; no concretions; moist & friable; very sticky and very plastic; moderate medium angular blocky structure; no cutans; few very fine interstitial pores; no worm activity; no cracks; few vertical medium woody roots; nil reaction to dilute HCl; [Sample No. PY003\3]

SPAL analytical results for Profile PY003 Survey area: Proposed site for GNH Centre

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PY003/1	0-30	33261	5.59	4.85	0.74	ND	3.10	2.00	0.19	11.00
PY003/2	30-48	33262	5.31	4.45	0.86	ND	0.26	2.50	0.10	24.20
PY003/3	48-100	33263	5.51	4.58	0.93	ND	0.05	1.40	0.10	14.72

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PY003/1	0.08	0.05	0.08	0.04	0.08	ND	34.20	ND	1	ND
PY003/2	0.08	0.04	0.09	0.34	0.55	ND	35.78	ND	1.55	ND
PY003/3	0.08	0.05	0.13	0.05	0.30	ND	33.34	ND	0.91	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		
PY003/1	ND	ND	ND	ND	ND	42.70	18.10	23.60	41.70	15.60	L
PY003/2	ND	ND	ND	ND	ND	53.00	14.40	18.50	32.90	14.10	SL
PY003/3	ND	ND	ND	ND	ND	40.30	12.30	23.60	35.90	23.80	L

Profile Report

Profile:	**PY004**
Described & sampled:	Administrator 22.5.2010
Survey area:	Dingdingma
Map unit:	Hd

Soil Classification

BSS Soil Series:	
Soil Taxonomy:	
WRB:	

Coordinates:	27° 40' 43.8"N & 90° 43' 34.9" E
Topographic Map:	No. 78I-14
Location:	Ca 1.5 km ENE from the Nagsephel village, Choekhor geog
Altitude:	2865 masl

Climate

General:	Cold temperate
Recent Weather:	Sunny

Parent material

Solid:	Schist & gneiss
Drift:	Colluvium

Topography

Landform:	
Site position:	Lower slope
Aspect:	S (190 deg)
Slope:	82% (extremely steep), rectilinear
Erosion:	None
Run-off:	None
Site drainage:	Good
Microrelief:	25 - 50cm from bench

Surface

Surface condition:	Slightly moist
Surface cracks:	None
Surface capping:	None
Surface litter:	Dense, dried grass, about 3 cm deep.
Surface outcrops:	Few (2 %) hard rounded gneiss boulders (>1m)
Surface stone:	None (0 %)

Land category:	Government Reserve Forest
Landuse:	Government forest
Soil Depth Limit:	
Soil Drainage Class:	Moderately well drained

Notes / Comment:

Cm	Horizon	Type	Description
0-20	Ah		Grayish brown (10YR 5/2); fine sandy loam with no mottles; few fine hard subangular gneiss gravels; no concretions; moist & friable; slightly sticky and slightly plastic; moderate medium subangular blocky structure; no cutans; rare fine vesicular & many very fine interstitial pores; few burrows & earth worms; no cracks; few irregular fine fibrous & woody roots; nil reaction to dilute HCl; gradual wavy boundary to: [Sample No. PY004\1]
20-100	BC		Yellowish brown (10YR 5/4); sandy clay loam with no mottles; few fine hard subangular schist & quartzite gravels; no concretions; moist & friable; very sticky and very plastic; moderate medium subangular blocky structure; no cutans; rare very fine interstitial pores; no worm activity; no cracks; few irregular fine fibrous & woody roots; nil reaction to dilute HCl; [Sample No. PY004\2]

SPAL analytical results for Profile PY004 Survey area: Proposed site for GNH Centre

Reaction, P & organic matter

SSU No.	Depth cm	SPAL Lab No	pH			EC mS/cm	Avail. P ppm	Organic C%	Total N %	C:N
			H2O	KCl	Diff					
PY004/1	0-20	33264	5.27	4.36	0.91	ND	0.05	3.90	0.21	18.62
PY004/2	20-100	33265	5.87	4.19	1.68	ND	1.47	0.80	0.05	15.70

Exchangeable base status

SSU No.	Exchangeable				TEB	Extr Al	CEC		BS%	
	Ca	Mg	K	Na			AmOAc	ECEC	AmOAc	EBS%
PY004/1	1.32	0.65	1.28	0.31	3.55	ND	44.42	ND	8.00	ND
PY004/2	0.07	0.01	0.21	0.15	0.44	ND	14.89	ND	2.96	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		
PY004/1	ND	ND	ND	ND	ND	30.70	13.80	28.90	42.70	26.60	L
PY004/1	ND	ND	ND	ND	ND	34.40	14.50	25.40	39.90	25.70	L

Auger Report

Auger: **AY0001**
Described & sampled: Yeshey Chedup 22.5.2010
Survey area: Dingdingma
Map unit: Ts

Soil Classification
BSS Soil Series:
Soil Taxonomy:
WRB:

Coordinates: 27°41'05.3" N & 90°43'27.6" E
Topographic Map: No. 78I-14
Location: Ca 1 km ENE from the Napsephel Lhakhang
Altitude: 2893 masl

Climate
General: Cold temperate
Recent Weather: Sunny

Parent material
Solid: Mixed
Drift: Alluvium

Topography
Landform: Valley
Site position: Alluvial terrace (3m)
Aspect: SSW (160 deg)
Slope: 5% (moderately sloping), convex
Erosion: None
Run-off: None
Site drainage: Good
Micro relief: None

Surface
Surface condition: Slightly moist
Surface cracks: None
Surface capping: None
Surface litter: Dense, raw grass, about 2 cm deep.
Surface outcrops: few
Surface stone: 2%

Land category: Govt. forest
Land use: Govt. forest

Soil Drainage Class: Somewhat excessively drained

Notes / Comment:

Cm	Horizon	Type	Description
0-13	Ah		Brown (10YR 5/3); fine sandy loam with no mottles; few (3%) fine hard angular quartz gravels; no concretions; moist & friable; slightly sticky and slightly plastic; no reaction to dilute HCl; [Not Sampled]
13-30	C1		Brownish yellow (10YR 6/6); fine sand with no mottles; no stones and gravels; no concretions; moist & friable; non sticky and non plastic; no reaction to dilute HCl; [Not Sampled]
30+			Stopped by stones and boulders

Auger Report

Auger: **AY0002**
Described & sampled: Yeshey Chedup 22.5.2010
Survey area: Dingdingma
Map unit: Ts

Soil Classification
BSS Soil Series:
Soil Taxonomy:
WRB:

Coordinates: 27°40'49.7"N & 90°43'41.4"E
Topographic Map: No. 78I-14
Location: Ca 2km E of Napsephel village
Altitude: 2827 masl

Climate
General: Cold temperate
Recent Weather: Partially cloudy

Parent material
Solid: Mixed
Drift: Alluvium

Topography
Landform: Valley
Site position: Alluvial terrace (3m)
Aspect: SSW (90 deg)
Slope: 2% (moderately sloping), convex
Erosion: None
Run-off: None
Site drainage: Good
Micro relief: None

Surface
Surface condition: Slightly moist
Surface cracks: None
Surface capping: None
Surface litter: dense, raw grass, about 3cm deep.
Surface outcrops: few
Surface stone: 5%

Land category: Govt. forest
Land use: Govt. forest

Soil Drainage Class: Well drained

Notes / Comments:

Cm	Horizon	Type	Description
0-20	Ah		Dark greyish brown (10YR 4/2); medium sandy loam with no mottles; few (5%) fine hard angular quartz gravels; no concretions; moist and slightly firm; slightly sticky and slightly plastic; no reaction to dilute HCl; [Not Sampled]
20-40	C1		Brown (10YR 5/3); coarse sand with no mottles; common (30%) fine subangular and rounded quartz and gneiss gravels; no concretions; moist & friable; non sticky and non plastic; no reaction to dilute HCl; [Not Sampled]
40+			Stopped by stones and boulders

Auger Report

Auger: **AY0003**
Described & sampled: Yeshey Chedup 22.5.2010
Survey area: Dingdingma
Map unit: Td

Soil Classification
BSS Soil Series:
Soil Taxonomy:
WRB:

Coordinates: 27°41'09.3" E & 90°
Topographic Map: No. 78I-14
Location: Ca 1km NE of Napsephel village, Chokor geog
Altitude: 2849 masl

Climate
General: Cold temperate
Recent Weather: Cloudy

Parent material
Solid: Mixed
Drift: Alluvium

Topography
Landform: Valley
Site position: Alluvial terrace (15m)
Aspect: SSW (290 deg)
Slope: 3% rectilinear
Erosion: None
Run-off: None
Site drainage: Good
Micro relief: None

Surface
Surface condition: Slightly moist
Surface cracks: None
Surface capping: None
Surface litter: dense, raw grass, about 3cm deep.
Surface outcrops: few
Surface stone:

Land category: Govt. forest
Land use: Govt. forest

Soil Drainage Class: Somewhat excessive

Notes / Comment:

Cm	Horizon	Type	Description
0-20	Ah		Dark greyish brown (10YR 4/2); medium sandy loam with no mottles; few (5%) fine hard angular quartz gravels; no concretions; moist and very friable; slightly sticky and slightly plastic; no reaction to dilute HCl; [Not Sampled]
20-40	C1		Brown yellow (10YR 6/6); coarse sand with no mottles; common (20%) fine hard angular quartz gravels; no concretions; moist and friable; non sticky and non plastic; no reaction to dilute HCl; [Not Sampled]
40+			Stopped by stones and boulders

Auger Report

Auger: **AY0004**
Described & sampled: Yeshey Chedup 23.5.2010
Survey area: Dingdingma
Map unit: Tu

Soil Classification
BSS Soil Series:
Soil Taxonomy:
WRB:

Coordinates: 27°41'0.1"N & 90°43'34.4" E
Topographic Map: No. 78I-14
Location: Ca 1.5km NE of Napsephel lhakhang, Chokor geog
Altitude: 2860 masl

Climate
General: Cold temperate
Recent Weather: Cloudy

Parent material
Solid: Mixed
Drift: Alluvium

Topography
Landform: Valley
Site position: Alluvial terrace (25m)
Aspect: SSW (250 deg)
Slope: 1% rectilinear
Erosion: None
Run-off: None
Site drainage: Good
Micro relief: None

Surface
Surface condition: Slightly moist
Surface cracks: None
Surface capping: None
Surface litter: Dense, raw grass, about 5cm deep.
Surface outcrops: Few
Surface stone:

Land category: Govt. forest
Land use: Govt. forest

Soil Drainage Class: Somewhat excessive

Notes / Comments:

Cm	Horizon	Type	Description
0-20	Ah		Dark greyish brown (10YR 4/2); fine sandy clay loam with no mottles; no stones and gravels; no concretions; moist friable; slightly sticky and plastic; no reaction to dilute HCl; [Not Sampled]
20-45	Bw1		Light yellowish brown (10YR 6/3); clay loam with no mottles; no stones and gravels; no concretions; moist and friable; sticky and plastic; no reaction to dilute HCl; [Not Sampled]
45-70			Yellowish brown (10YR 5/4); fine sandy clay with no mottles, few fine angular with hard quartz gravels; no concretions; moist and friable; sticky and plastic; no reaction to dilute HCl; [Not Sampled]
70+			Stopped by stones and boulders

Auger Report

Auger: **AY0005**
Described & sampled: Yeshey Chedup, 23.5.2010
Survey area: Dingdingma
Map unit: Hd

Soil Classification
BSS Soil Series:
Soil Taxonomy:
WRB:

Coordinates: 27°41'0.1" N & 90°43'34.4"E
Topographic Map: No. 78I-14
Location: Ca 2km E from Napsephel lhakhang, Chokor geog
Altitude: 2860 masl

Climate
General: Cold temperate
Recent Weather: Sunny

Parent material
Solid: Mixed
Drift: Alluvium

Topography
Landform: Hill
Site position: Foot slope
Aspect: SSW (270 deg)
Slope: 35% rectilinear
Erosion: None
Run-off: None
Site drainage: Good
Micro relief: None

Surface
Surface condition: Moist
Surface cracks: None
Surface capping: None
Surface litter: All over, dried leaves about 5cm deep.
Surface outcrops: few
Surface stone:

Land category: Govt. forest
Land use: Govt. forest

Soil Drainage Class: Moderately well drained

Notes / Comment:

Cm	Horizon	Type	Description
0-30	Ah		Black (10YR 2/1); humic loam with no mottles; few (3%) medium slightly hard angular quartzite gravels; not concretions; moist and friable, slightly sticky and slightly plastic; no reaction to dilute HCl; [Not Sampled]
30-70	Bw		Brown (10YR 4/3); sandy clay loam with no mottles; common (20%) medium slightly hard angular quartzite gravels; no concretions; moist and slightly friable; slightly sticky and plastic; no reaction to dilute HCl; [Not Sampled]
70+			Stopped by stones and boulders