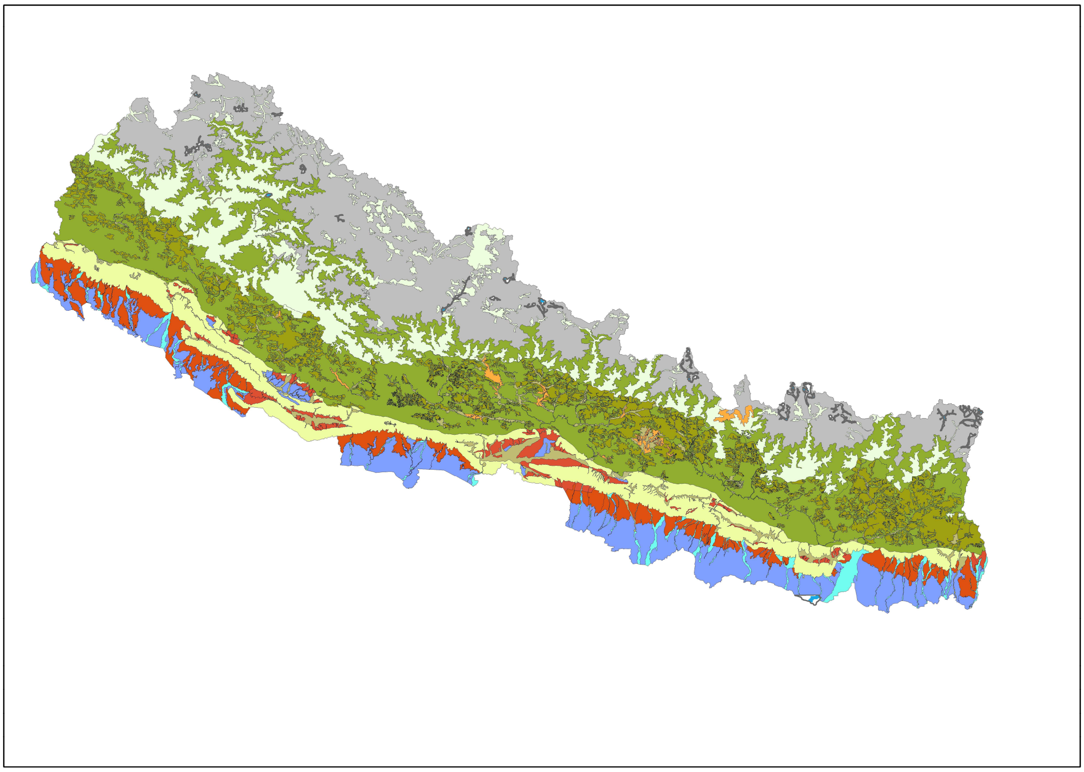
Report 2009/01

Soil and Terrain database for Nepal

(1:1 million)

Koos Dijkshoorn
Jan Huting

(June 2009)



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Inquiries:

c/o Director, ISRIC – World Soil Information
PO Box 353
6700 AJ Wageningen
The Netherlands
Telefax: +31-(0)317-471700
E-mail: soil.isric@wur.nl
Web: www.isric.org

Front cover: Soils of the SOTER map for Nepal

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Foreword

The Soil and Terrain (SOTER) database for Nepal at scale 1:1 million is the second national SOTER database for Asia, after the database of the People's Republic of China. The development of national SOTER databases is part of an ongoing programme, which is supported by Food and Agriculture Organisation of the United Nations (FAO), ISRIC-World Soil Information and United Nations Environmental Programme (UNEP) under the umbrella of the International Union of Soil Science (IUSS) to create a global Soil and Terrain cover and subsequently replace the current FAO-Unesco 'Soil Map of the World' (FAO-Unesco 1974).

Under this programme SOTER databases have been compiled for the regions Latin America and the Caribbean (FAO *et al.* 1998), Central and Eastern Europe (FAO *et al.* 2000), for several countries in Southern (FAO *et al.* 2003) and Central Africa (FAO *et al.* 2007) and a number of national SOTER databases for individual countries, like Nepal.

SOTER makes use of existing, published and freely available soil data, soil maps and soil profile data. This information can partly be obsolete. To keep the SOTER database up to date ISRIC-World Soil Information welcomes new and recently collected soil data for updating the existing SOTER databases at scale 1:1 million. In this respect, ISRIC is seeking collaboration with national institutes, which have mandate on the natural resources inventory.

Dr. ir. Prem Bindraban
Director ISRIC-World Soil Information

SUMMARY

This report describes the methods used to compile the Soil and Terrain (SOTER) database of Nepal. The SOTER database is generalized from the original soils and terrain digital database of Nepal at scale 1:50,000 (Rotmans 2004). The presented SOTER database provides generalized information on landform and soil properties at a scale 1:1 million. It consists of 17 SOTER units, characterized by 56 representative and four synthetic profiles for which there are no measured soil data. The SOTER database includes also attribute data of 99 profiles initially selected as references to soil components that have already a representative profile.

Keywords: Soil and terrain database, SOTER database, natural resources, Nepal, soils, soil data, landform and land system.

1 INTRODUCTION

Up-to-date and readily available digital natural resource information is required for scenario assessments. The Soil and Terrain digital database (SOTER) stores attribute data on landform and soils that are easily accessible. Initially, the idea of the SOTER programme was launched in the mid eighties, as a joint effort of FAO, ISRIC–World Soil Information and the United Nations Environmental Programme (UNEP), to create a soil and terrain digital database (Baumgardner 1986; FAO/AGL; ISSS 1986) with a global coverage of SOTER attribute data at a scale of 1:1 million. The actual SOTER database compilation started in 1994 with a cooperative agreement between ISRIC and some Latin American countries. This resulted in a regional SOTER database for Latin America and the Caribbean (SOTERLAC) at a scale of 1:5 million (FAO *et al.* 1998; ISRIC *et al.* 1998). In the years following, SOTER databases for Central and Eastern Europe (SOVEUR) (Batjes 2000; FAO *et al.* 2000), Southern Africa (SOTERSAF) (FAO *et al.* 2003; ISRIC *et al.* 2003) and for Central Africa (SOTERCAF) (FAO *et al.* 2007; ISRIC *et al.* 2006) have been completed at scales 1:2 million. National SOTER databases for individual countries, like Senegal, Tunisia and China at scale 1:1 million were compiled in a FAO coordinated programme of Land Degradation Assessment in Drylands (Dijkshoorn *et al.* 2008; FAO and UNEP 2007; ISRIC 2009).

Nepal is a land of extremes, its physiography ranges from alluvial plains in the tropical-low lands, to very rugged and permanently-snow and ice covered high mountains. The world's highest mountain peaks occur in Nepal. Climatic conditions can vary so much that tropical and temperate agriculture occurs a few kilometres apart. In such landscapes, topography is an overruling soil forming factor and responsible for a large variability in soil characteristics, distribution and soil depth. Soil depth is so variable that traditional soil survey is considered less meaningful. The land system classification (Carson *et al.* 1986; Nelson *et al.* 1980) can provide better, albeit more generalized, information on landform and soils; such an approach has also been followed in the compilation of this SOTER database.

The present SOTER database of Nepal is largely based on the conversion of the soils and landscapes from the land system classification (Carson *et al.* 1986) to SOTER. This report describes the methods and procedures used to compile a Soil and Terrain (SOTER) database for the country at scale 1:1 Million.

2 MATERIALS AND METHODS

2.1 SOTER source materials

The current compilation of a generalized SOTER database for Nepal at scale of 1:1 million is based on the work of (Rotmans 2004).

This work of a detailed soil and terrain database relied largely on the land system map of the Land Resource Mapping Project. The map was compiled in the eighties in an assignment of the Canadian International Development Agency (CIDA) and in cooperation with Nepal's Survey Department (Carson *et al.* 1986).

At national level, this land system map gives a detailed description of landform and soil properties at scale 1:50,000; the original SOTER database was based on the same scale (Rotmans 2004). The compilation of such a detailed digital database demanded an intensive cooperation between various organisations working on national resources mapping, such as the HMG Survey Department of Nepal, the Food and Agricultural Organisation of the United Nations (FAO) and the former Himalayan Eco-Regional Fund Project of ICIMOD.

2.2 SOTER methodology

The SOTER methodology was initially developed as a land resources information system for the scale of 1:1 million (van Engelen and Wen 1995). SOTER combines a geometric database with an attribute database, storing the SOTER units' location, extent and topology, and the units' soils and terrain characteristics. A geographic information system (GIS) manages the geometric database using a unique identifier, the SOTER unit-ID (SUID), that links to the attributes stored in a relational database management system (RDBMS).

The SOTER concept is based on the relationship between the physiography (landform), parent materials and soils within a certain area. It identifies areas of land with a distinctive and often repetitive, pattern of landform, lithology, surface form, slope, parent material and soils. The methodology uses a stepwise approach identifying major landforms or terrain units at its highest level of distinction, followed by subdividing the terrain units on basis of differences in e.g. surface features or parent material, and ultimately on differences in soils. The subdivisions, being often not mappable at the considered scale, can only be characterized in the database. The so-created map units are called SOTER units (Figure 1), and represent unique combinations of terrain and soil characteristics (Dijkshoorn 2002; van Engelen and Wen 1995).

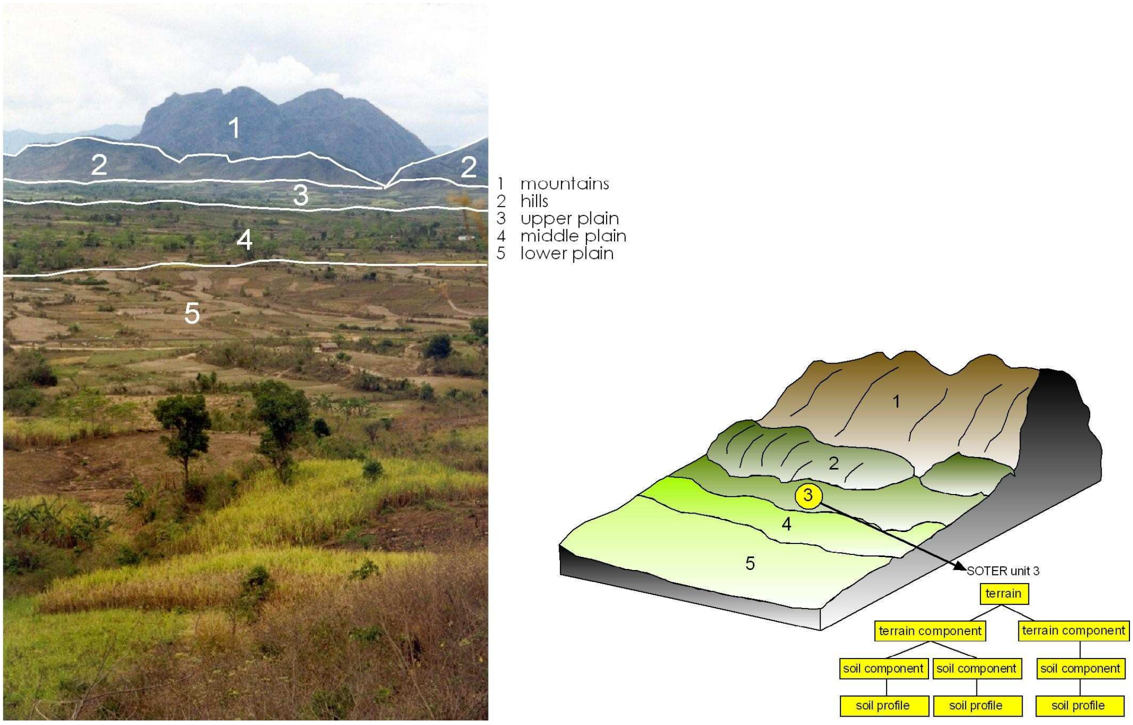


Figure 1: Representation of SOTER units and the structure of a SOTER unit

The SOTER attribute database consists of various tables: terrain, terrain component and soil component; they are linked through primary keys. At the highest level, the characteristics of landform and parent material are described under terrain. In the terrain table, one or more terrain component(s) (TCID) may be distinguished based on differences in landform, topographical features or parent material that, due to the scale of delineation, cannot be shown in the SOTER map, but can be described in the attribute database. Further discrimination is made according to soils, the soil components (SCID), (Figure 1). The SOTER unit with soil components is comparable to a mapping unit depicting an association of soils.

Each soil component is described by a soil profile (PRID), considered to be representative for a specific area of the SOTER unit. Detailed soil horizon characteristics can be stored in the representative horizon table, using SOTER conventions (van Engelen and Wen 1995).

The SOTER methodology has been applied at a range of scales, from 1:50,000 to 1:5 million, using a similar standard database structure (ISRIC *et al.* 2003; ISSS *et al.* 1998) (van Engelen *et al.* 2004). The present SOTER database for Nepal stores the complete composition of all attributes available for the selected representative profiles; see Table 3 for attributes that can be stored in the database

Figure 2 shows the relationships between the various data tables. Terrain units, terrain components and soil components are parts of the landscape and represent the spatial components within the database, while only the terrain unit is contained in the geometric database and depicted on the SOTER map. The scale of the SOTER database, usually 1:1 million, limits the delineation of the components and spatial distribution in the geometric database. In many cases, the terrain unit is identical to the SOTER unit. Frequently, if scale allows and information is available, it is also further subdivided on basis of non-mappable parent material, deviating terrain characteristics or on differences in soils (van Engelen and Wen 1995), e.g. in large, plain areas with almost no physiographical features. Soil profile and soil profile horizon data are the point data being representative for the SOTER unit.

SOTER coding convention are detailed in (van Engelen and Wen 1995).

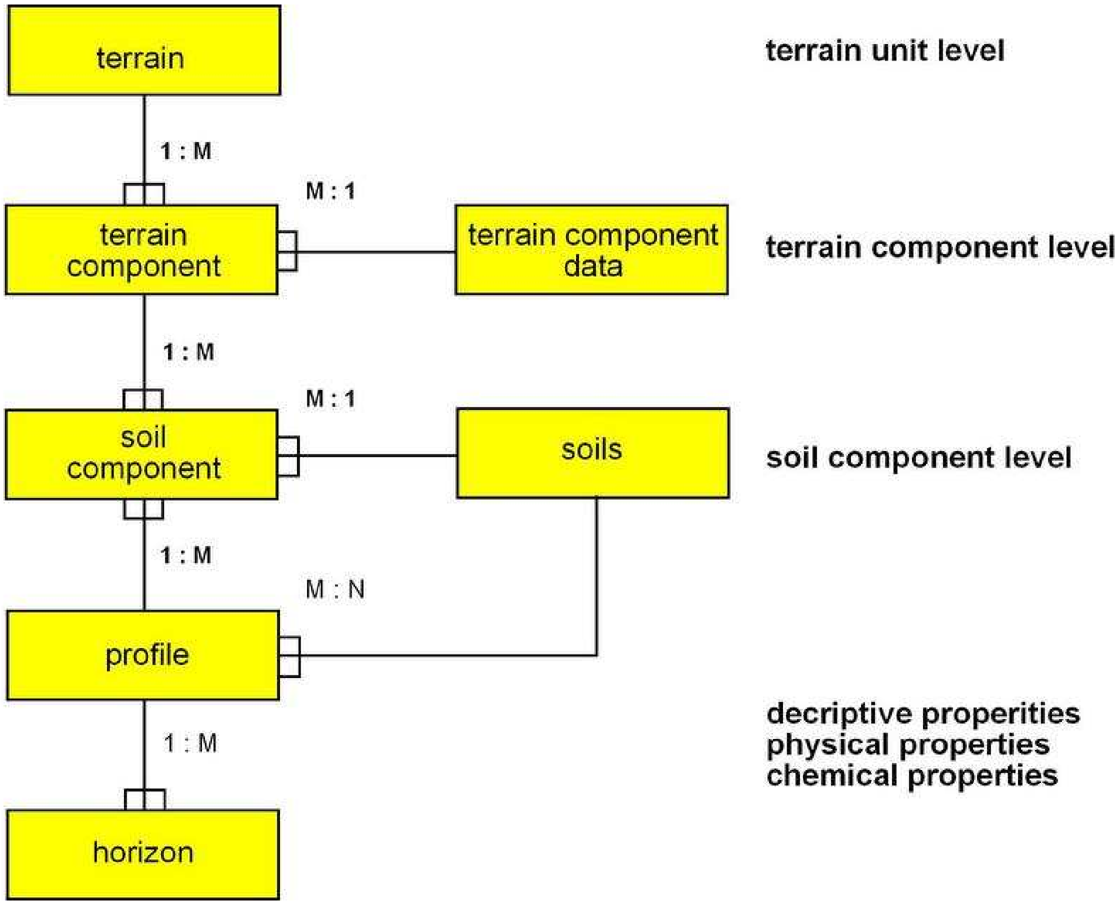


Figure 2: SOTER structure and relation between the data storage tables (see Figure 1).

The structure of the SOTER database, definitions of the SOTER relations, field definitions, content and coding conventions are detailed in the SOTER Database Structure Manual (Tempel 2002)

The attribute database is structured in such a way that it can accommodate differences in terrain in the underlying table. These terrain components cannot be delineated on the map as a SOTER unit at the current scale. The difference of coverage in the SOTER unit is accounted for as percentage (proportion) of the SOTER unit in the database.

2.3 Primary soil and terrain data

The compilation of the current SOTER for Nepal was based on work of Rotmans (2004) and on the earlier work of the Land Resource Mapping Project (LRMP) executed by Kenting Earth Sciences Limited in collaboration with various offices and the departments of the Ministry of Agriculture and the Ministry of Forests and Soil Conservation (Carson *et al.* 1986). In the LRMP study, land units and land systems are distinguished, within the broader "physiographic regions" (Nelson *et al.* 1980). The distinction of physiographic regions, based on watershed conditions, is commonly used to characterize the ecological different regions of Nepal. See Table 2 for a summary and Annex 1 to Annex 5 for schematic cross sections of the landscapes. In the LRMP report the identified land systems, their land units and their dominant soil groups are described and characterized. Nearly all profile attribute data originate from the profile descriptions and analysis of this study.

2.4 Modifications

The geometric database of the SOTER map of Nepal has been made congruous to the Digital Chart of the World (DCW) (DMA 1993).

All maps are given in geographic projection with GCS_WGS_1984 as coordinate system. The geo-referenced profiles have coordinates in decimal degrees.

3 RESULTS AND DISCUSSION

3.1 Generalization procedures

A stepwise generalization procedure was applied. First, all subdivisions (land units) that fall within a similar land system were aggregated. This included also several complex land units that were distinguished in the various land systems. It meant that in the GIS file all common boundaries between the land units of a similar land system have been dissolved, creating a larger mapping unit; e.g. in the Terai region, which is the lower plains area, all bordering 1a, 1b, 1c and 1d land units have been aggregated to one land system unit (see Annex 1). Similar procedures are applied to aggregate other land units in the Siwaliks, the hilly often rugged area between the Terai region and the Middle mountain region (see Annex 2 and Annex 3).

Next, a generalization of the physiographic Middle mountain region has been applied. The many small polygons of land system 9 (alluvial plains and fans) and 10 (lake and river terraces) have been aggregated. See Table 1. Only when land system 10 has polygons larger than 10 km^2 they retained their (separate) land system. Isolated polygons of land system 9 smaller than 10 km^2 remained as a separate unit.

All small polygons of land system 12 (< 10 km^2) have been aggregated to land system 11, both are found in the Middle mountain region (see Annex 3)
The generalization procedure was finalized by the elimination of all remaining polygons smaller than 10 km^2.

Table 1: Summary of the generalization procedures

1. Join all land units of one land system, if bordering to each other; e.g. 16a +16b+16c+etc.
2. Join land system 10 to 9, if bordering and, if < 10 km^2. Land system 10 > 10 km^2 retained.
3. Join land system 12 to land system 11, if < 10 km^2. Join to longest common boundary.
4. Eliminate all remaining polygons, if < 10 km^2. Add them to the largest neighboring polygon.

The generalization inherently leads to changes in the SOTER attribute database. The former SOTER units, depicted at scale 1:50.000, are the land units, a subdivision of the land system; the land units have now become terrain components and are included in the attribute database only when they cover an area larger than 5 % of the SOTER unit. This very low percentage of occurrence of the terrain component is only acceptable here to maintain the link with the land system map.

The generalization procedure has diminished the number of polygons from 16354 to 942. The number of SOTER units decreased from 71, at scale 1:50,000 to 17 at scale 1:1,000,000.

3.2 Results

Table 2 gives the number of SOTER units at scale 1:1 million, the former land system units, per physiographic region.

The LRMP-study identified five physiographic regions and 17 land systems for Nepal (Carson *et al.* 1986). Table 2 gives also some general characteristics of the physiographic region identified in the study.

Table 2: Physiographic region of Nepal and their general characteristics

Physiographic regions	Propor-tion of Nepal	Number of land system units	General elevation (m.a.s.l.)	Description
Terai	14	3	60-330	recent post Pleistocene alluvial deposits forming a piedmont plain
Siwaliks	13	5	<1000	semi-consolidated Tertiary sandstone siltstone, shale and conglomerate
Middle mountains	30	4	<2500	dominantly Precambrian phyllite, quartzite, schist, granite and limestone
High mountains	20	3	<4000	Precambrian metamorphosed gneisses and micaschist
High Himalaya	23	2	>3500	dominatly glaciated bedrock surfaces of gneiss, schist, limestone and shale.

Totally 17 SOTER units are identified for Nepal and subdivided into 53 terrain components and 118 soil components. The soil components are characterized by 60 representative profiles, which on their turn are composed of 56 measured profiles and 4 synthetic (not represented with a real soil profile). Additionally, attribute data of another 99 soil profiles is stored in the database with a link to a soil component for which they are a reference. Most of these profiles are comparable to the chosen representative profiles. In total, the database harbours 155 measured soil profiles. There are 526 entries storing the horizon attribute data of these profiles.

Three entries in the database are for miscellaneous landforms, viz. land ice/glaciers, rock outcrop and small lakes.

Table 3 gives an overview of attribute data in the database. In case measured values of attributes are missing, the percentages given are smaller than 100 % and some attributes are not measured at all. Missing data (gaps) in a primary database can be estimated using taxo-transfer rules. These databases are than available as secondary SOTER databases (Batjes 2003).

Table 4 gives an overview of the dominant soils occurring within the national territory of Nepal. About one third of the country (35 %) is covered by the soil group of the Cambisols (FAO 1988, 1990).

Table 3: Overview of content of SOTER database for Nepal 1:1 million.

Attributes of terrain table	%	Attributes of terrain table	%
1 ISO country code	100	7 median slope gradient	100
2 SOTER unit_ID	100	8 median relief intensity	100
3 year of data collection	100	9 major landform	100
4 map_ID	100	10 regional slope	-
5 minimum elevation	100	11 hypsometry	-
6 maximum elevation	100	12 general lithology	100
Attributes of terrain component table		Attributes of terrain component table	
15 terrain component number	100	parent material	-
16 proportion of SOTER unit	100	27 depth to bedrock	-
17 terrain component data_ID	100	28 surface drainage	-
19 dominant slope	-	29 depth to groundwater	21
20 length of slope	-	30 frequency of flooding	-
25 surface parent material	100	31 duration of flooding	-
26 texture group non-consolidated	-	32 start of flooding	-
Attributes of soil component table		Attributes of soil component table	
35 soil component number	100	42 types of erosion/deposition	-
36 proportion of SOTER unit	100	43 area affected	-
37 profile_ID	100	44 degree of erosion	-
38 number of reference profiles	-	45 sensitivity to capping	-
39 position in terrain component	-	46 rootable depth	90
40 surface rockiness	31	47 relation with other soil components	-
41 surface stoniness	31		
Attributes of profile table		Attributes of profile table	
54 profile database_ID	97	62 surface organic matter	-
55 latitude	80	63 WRB classification	100
56 longitude	80	64 WRB specifier	6
57 elevation	97	65 classification FAO	100
58 sampling date	8	66 phase	16
59 lab_ID	-	67 classification version	100
60 drainage	100	68 national classification	-
61 infiltration rate	-	69 Soil Taxonomy	100
Attributes of horizon table		Attributes of horizon table	
71 horizon number	100	96 infiltration rate	-
72 diagnostic horizon	54	97 pH H2O	98
73 diagnostic property	22	98 pH $CaCl_2$	98
74 horizon designation	100	99 electrical conductivity 1	98
75 lower depth	100	100 soluble Na+	-
76 distinctness of transition	7	101 soluble Ca++	-
77 moist colour	9	102 soluble Mg++	-
78 dry colour	0	103 soluble K+	-
79 grade of structure	9	104 soluble Cl-	-
80 size of structure elements	6	105 soluble SO4--	-
81 type of structure	9	106 soluble HCO3-	-
82 abun. coarse fragments	13	107 soluble CO3--	-
83 size of coarse fragments	4	108 exchangeable Ca++	98
84 very coarse sand	-	109 exchangeable Mg++	98
85 coarse sand	-	110 exchangeable Na+	98
86 medium sand	-	111 exchangeable K+	98
87 fine sand	-	112 exchangeable Al+++	-
88 very fine sand	-	113 exchangeable acidity	-
89 total sand	98	114 CEC soil	98
90 silt	98	115 total carbonate equivalent	97
91 clay	98	116 gypsum	-
92 particle size class	98	117 total organic carbon	98
93 bulk density	-	118 total nitrogen	98
94water holding capacity	98	119 P2O5	98
95 hydraulic conductivity	-	120 phosphate retention	-

Table 4: Dominant soils derived from the SOTER database for Nepal

Dominant soils according to FAO-Unesco Revised Legend[1]	FAO codes	Phase	Area (km^2)	Percentage
Humic Cambisols	CMu		22039	15
Rock outcrop	RK		20228	14
Eutric Regosols	RGe	LI	12984	9
Dystric Regosols	RGd	LI	11409	8
Gelic Leptosols	LPi		9392	6
Eutric Gleysols	GLe		9262	6
Eutric Cambisols	CMe		9165	6
Glaciers	GG		9051	6
Chromic Cambisols	CMx	LI	7230	5
Dystric Cambisols	CMd	LI	6673	5
Humic Leptosols	LPu		5378	4
Haplic Luvisols	LVh		4223	3
Calcaric Phaeozems	PHc		3483	2
Ferralic Cambisols	CMo		2906	2
Aric Anthrosols	ATa		2874	2
Humic Regosols	RGu	LI	2070	1
Dystric Cambisols	CMd		1490	1
Eutric Fluvisols	FLe		1362	1
Haplic Arenosols	ARh		976	1
Gleyic Cambisols	CMg		964	1
Haplic Phaeozems	PHh		869	1
Other soils				1

LI = Lithic phase (hard rock subsoil within 50 cm of the surface)

Non-soils as rock outcrop and glaciers, defined according to the legend of FAO–Unesco Soil Map of the World, cover 20 percent of the country.

[1] FAO-Unesco Revised Legend of the Soil map of the World (FAO 1988, 1990. *FAO/Unesco Soil Map of the World, Revised Legend (with corrections in the 1990 version)*. World Resources Report 60. FAO, Rome

4 CONCLUSIONS

Following a GIS-based generalisation of the original SOTER soil and terrain database of Nepal from a 1:50,000 to 1:1 million scale, the number of polygons of the geometric database diminished from 16354 to 942 polygons and the number of mapping units from 47 to 17.

For generalisation of the polygon map a computer-based GIS tool was applied that followed rigidly defined algorithms (see Table 1). Assumed is that these newly created units comply fully with the definition of the SOTER unit. This product should be seen as a first version of the primary database at 1:1 million scale..

The database has inherited some limitations from the original Land System Map (LRMP) in that the accuracy of mapping is less accurate for the high mountain areas and the Himalayas. As from SOTER unit 13 and higher, there is less confidence in the extent of the units and in the soil composition.

A number of representative profiles for the soil components are lacking. These should be included in future updates; particularly representatives of the Soil Reference Group (SRG) Arenosols and Fluvisols of the Terai region are missing. In addition, also lacking are representative profiles of shallow soils of the steep mountainous regions, in particular the profiles of the SRG of Regosols.

Not for all attributes are measured data available e.g. bulk density is missing. Gaps in the database can be filled with estimates following taxo-transfer rules (Batjes 2003). This will make the dataset more applicable to run models.

Laboratory methods were not well documented. A list of applied methods is given in the SOTER database under laboratory methods. Very short descriptions are given and e.g. no information at all over the method used to determine the moisture retention. As bulk density was not determined, we assume the water holding capacity of soils is given in weights percentage.

Along the northern border with Tibet (China) a correlation with the SOTER database of China (Dijkshoorn *et al.* 2008) has been made .

REFERENCES

Batjes NH 2000. *SOTER summary file for Central and Eastern Europe (SOVEUR Project), verion1.0*. ISRIC Report 2000/06, ISRIC, Wageningen

Batjes NH 2003. *A taxotransfer rule-based approach for filling gaps in measured soil data in primary SOTER databases (version 1.0)*. Technical report 2003/03, ISRIC World Soil Information, Wageningen

Baumgardner MF 1986. World Soils and Terrain Digital Database at a scale of 1:1M (SOTER). ISSS, Wageningen

Carson B, Shah PB and Maharjan PB 1986. *Land Systems Report, the soil landscapes of Nepal*, HMG of Nepal Land Resource Mapping Project carried out by Kenting Earth Sciences Limited, Kathmandu, Nepal

Dijkshoorn JA 2002. From soil map to digital land resources database; land resources inventeries, SOTER and its applications. *Revista de Ciências Agrárias* XXV, 30-41

Dijkshoorn JA, van Engelen VWP and Huting JRM 2008. *Soil and landform properties for LADA partner countries (Argentina, China, Cuba, Senegal and Gambia, South Africa and Tunisia)*, ISRIC- World Soil Information, Wageningen

DMA 1993. Digital Chart of the World, Defence Mapping Agency (http://www.maproom.psu.edu/dcw/)

FAO-Unesco 1974. *Soil map of the World 1:5000000. Legend*, Volume 1. Unesco, Paris

FAO 1988, 1990. *FAO/Unesco Soil Map of the World, Revised Legend (with corrections in the 1990 version)*. World Resources Report 60. FAO, Rome

FAO and UNEP 2007. Land Degradation Assessments for Drylands, FAO (http://www.fao.org/nr/lada/)

FAO, ISRIC and National_Institutes 2000. Soil and Terrain database for Central and Eastern Europe, version 1.0, (scale 1:2.5 million). CD-ROM, FAO Rome

FAO, ISRIC and UNEP 2003. Soil and Terrain Database for Southern Africa, version1.0, (1:2 M. scale), CD-ROM, FAO Rome (http://www.fao.org/ag/agl/lwdms.stm http://www.isric.org/isric/CheckRegistration.aspx?dataset=18)

FAO, ISRIC and Universiteit_Gent 2007. Soil and Terrain Database for Central Africa. (Burundi and Rwanda 1:1 million, Democratic Republic of the Congo 1:2 million scale). CD-Rom, FAO Rome

FAO, ISRIC, UNEP and CIP 1998. Soil and Terrain database for Latin America and the Caribbean, (1:5M. scale). CD-ROM, FAO Rome (http://www.isric.org/isric/CheckRegistration.aspx?dataset=27)

FAO/AGL Global Soil and Terrain Database (WORLD-SOTER), The Food and Agricultural Organization of the United Nations (http://www.fao.org/ag/agl/agll/soter.stm)

ISRIC 2009. SOTER database for LADA partners countries (http://www.isric.org/UK/About+Soils/Soil+data/Geographic+data/National/default.htm)

ISRIC, FAO and UNEP 2003. Soil and Terrain Database for Southern Africa (1:2 million scale), *FAO Land and Water Digital Media Series No. 25*. FAO, Rome

ISRIC, FAO and Ghent-University 2006. Soil and Terrain database for Central Africa (Burundi and Rwanda 1:1 million; Democratic Republic of Congo 1:2 million), *FAO Land and Water Digital Media Series 33*. FAO, Rome

ISRIC, FAO, UNEP and CIP 1998. Soil and Terrain Database for Latin America and the Caribbean (1:5 million) *FAO Land and Water Digital Media Series No. 5*. FAO, Rome

ISSS 1986. Proceedings of an International Workshop on the Structure of a Digital International Soil Resources Map annex Database. In: Baumgardner M and L Oldeman, (editors), *International Workshop on the Structure of a Digital International Soil Resources Map annex Database*. SOTER Report 1. ISSS, Wageningen, pp 138

ISSS, ISRIC and FAO 1998. *World Reference Base for Soil Resources*, Food and Agriculture Organization of the United Nations, Rome

Nelson D, Laban P, Shrestha BD and Kandel GP 1980. *A Reconnaissance Inventory of the Major Ecological Land Units and their Watershed Conditions in Nepal-Summary Report*. FO: DP/NEP/74/020, FAO, HMG of Nepal and UNEP Rome

Rotmans A 2004. SOTER Digital Soil and Terrain database of Nepal (version1), CD-rom. Land Resource Mapping Project, DG Survey Department, Kathmandu

Tempel P 2002. *SOTER Global and National Soils and Terrain Digital Databases, Database Structure v3*. working paper 2002/01, ISRIC - World Soil Information, Wageningen

van Engelen VWP and Wen TT 1995. *Global and National Soil and Terrain Digital Database (SOTER). Procedures Manual*. ISRIC - World Soil Information, Wageningen

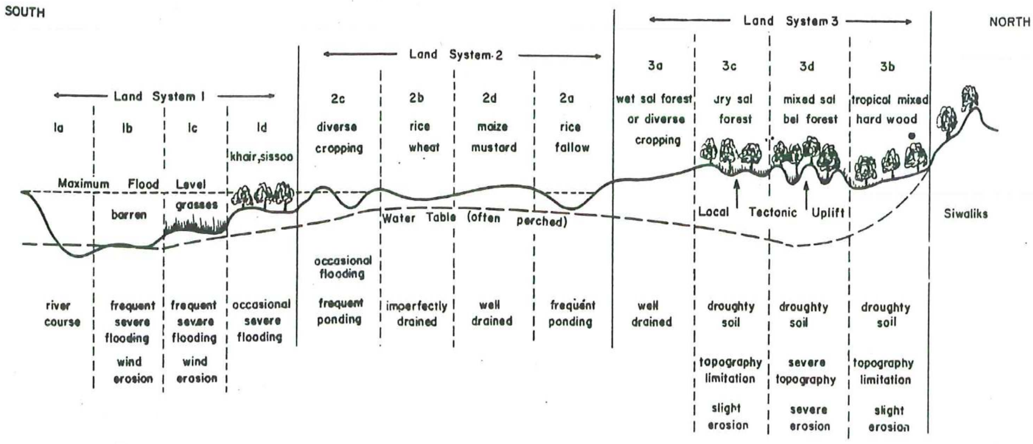
van Engelen VWP, Mantel S, J.A.Dijkshoorn and Huting JRM 2004. *The Impact of Desertification on Food Security in Southern Africa: A Case Study in Zimbabwe*. 2004/02, ISRIC - World Soil Information and UNEP

ANNEXES: Overview of landscapes and soil units: (Carson *et al.* 1986)

Annex 1: Terai region

SCHEMATIC CROSS SECTION OF LAND SYSTEMS IN THE TERAI REGION

(Vertical scale greatly exaggerated)



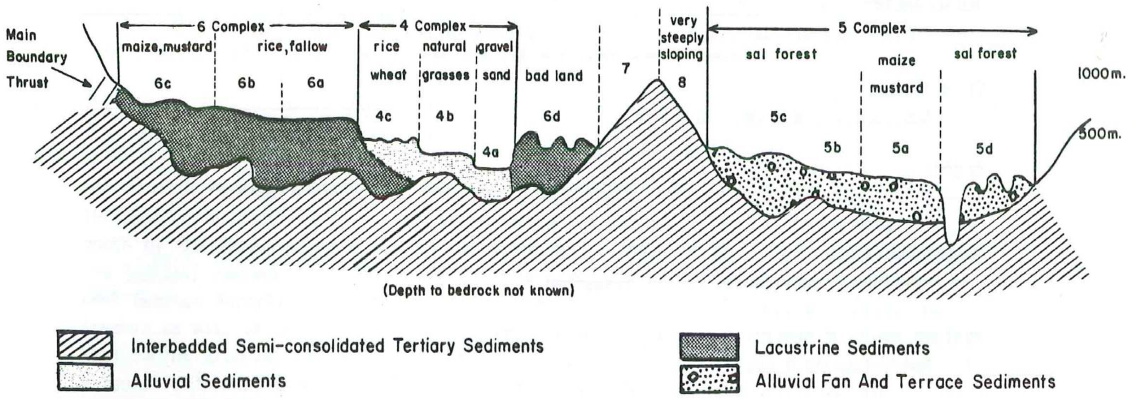
TERAI REGION Quaternary alluvium, Subtropical

Land System	Land form	Land Unit	Dominant Soils	Dominant Slopes	Dominant Texture	Seasonal Range of Depth to Water Table	Drainage
1	Active Alluvial Plain (depositional)	1a present river channel	—	—	—	—	—
		1b sand and gravel bars	Ustorthents Psamments	<1°	Sandy/ Cobbly	0 – 2m	subject to severe river flooding
		1c low terrace	Ustifluvents Fluvaquents	<1°	Sandy	0 – 2m	variable; subject to severe river flooding
		1d higher terrace	Ustochrepts Haplaquepts	<1°	Loamy	0 – 4m	variable; subject to occasional river flooding
2	Recent Alluvial Plain "Lower Piedmont" (depositional and erosional)	2a depressional	Haplaquepts	<½°	Fine Loamy	0 – 2m	poor
		2b Intermediate position; level	Haplaquepts (Aeric)	<½°	Loamy	0 – 6 m	imperfect
		2c intermediate position, undulating	Haplaquepts Ustochrepts	<1°	variable	dependent on position	variable; low areas subject to flooding
		2d high position	Haplustolls Ustochrepts	<1°	Loamy	1 – 10m	moderately well
3	Alluvial Fan Apron Complex "Upper Piedmont" (erosional)	3a very gentle slopes	Haplustolls Dystochrepts Ustochrepts	<1°	Loamy	1 – 10m	moderately well
		3b gentle slopes	Haplustolls	1–5°	Loamy/ Bouldery	2 – 10m	rapid
		3c undulating	Haplustolls	1–3°	Loamy	2 – 10m	well
		3d highly dissected	Ustochrepts	0–20°	Loamy	>2m	rapid

Fig 14.

Annex 2: Siwaliks region

SCHEMATIC CROSS SECTION OF LAND SYSTEMS IN THE SIWALIKS



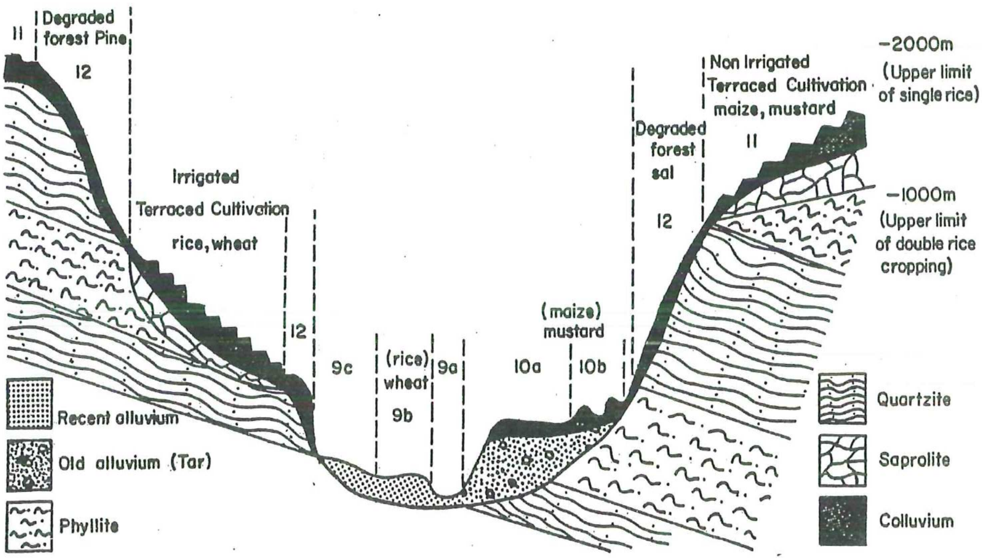
B. SIWALIK REGION Tertiary interbedded sandstone,shale,conglomerate and Quaternary alluvium;Subtropical.

Land system	Land form	Land Unit	Dominant Soils	Dominant Slopes	Dominant Texture	Seasonal Range of Depth to Water Table	Drainage
4	Active and recent Alluvial Plains	4a sand and gravel bars	Ustorthents Psamments	<1°	Sandy/ Cobbly	0 – 2 m	subject to severe river flooding
		4b low terrace	Ustifluvents Fluvaquents	<1°	Sandy	0 – 2 m	variable;subject to severe river flooding
		4c higher terrace undulating	Ustochrepts Haplaquepts	<1°	variable	dependent on position	variable,low areas subject to flooding
5	Fans,Aprons and ancient River Terraces(Tars)	5a very gentle slopes	Haplustolls Dystrochrepts Rhodustalfs	<1°	Loamy	1 – 15 m	moderately well
		5b gentle slopes	"	1-5°	Loamy/ Bouldery	2 – 15 m	rapid
		5c undulating	"	1-5°	Loamy	2 – 15m	well
		5d rolling	"	0-20°	Loamy	2 – 15m	rapid
6	Depositional Basin (Duns)	6a depressional	Haplaquepts	<1/2°	Fine Loamy	0 – 2m (perched)	poor
		6b non dissected high position	Ustochrepts Haplaquepts	<2°	Fine Loamy	0–6 m (perched)	imperfect
		6c gently rolling	"	1-5°	Fine Loamy	2–15m	variable
		6d highly dissected	Ustochrepts	0–30°	Fine Loamy	>15m	rapid
7	Moderately to Steeply Sloping Hilly and Mountainous Terrain		Lithic,Typic and Anthropic Subgroups of Dystrochrepts Ustochrepts	<20°	Loamy Skeletal	no water table <1m to bedrock	well
8	Steeply to very Steeply Sloping Hilly and Mountainous Terrain		Lithic Subgroups of 7 and Ustorthents	>20°	Loamy Skeletal	no water table <50 cm to bedrock	rapid

Fig 17.

Annex 3: Middle mountain region

SCHEMATIC CROSS SECTION OF LAND SYSTEMS
IN THE MIDDLE MOUNTAIN REGION



MIDDLE MOUNTAIN REGION Precambrian to Eocene phyllites, quartzites, schists, limestones and gneisses, generally deeply weathered; Subtropical to Warm Temperate.

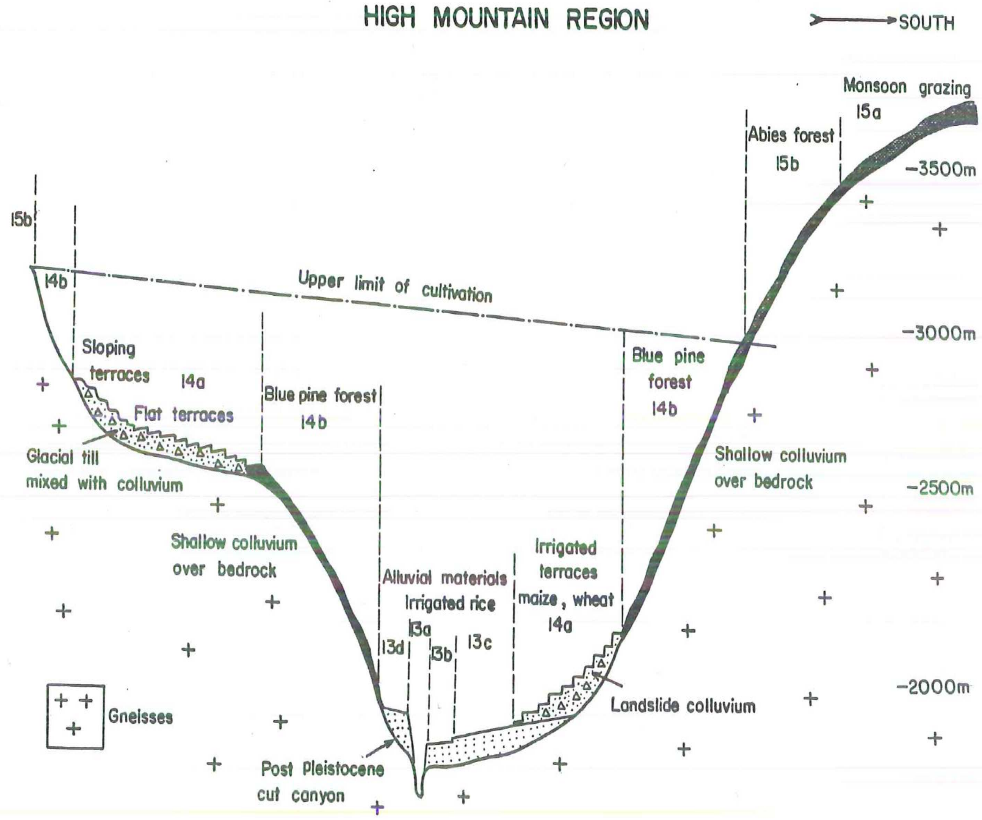
Land System	Landform	Land Unit	Dominant Soils	Dominant Slopes	Dominant Texture	Seasonal Range of Depth to Water Table	Drainage
9	Alluvial Plains and Fans (depositional)	9a river channel	Psamments Ustorthents	<1°	Fragmental Sandy	0 - 2m	variable
		9b alluvial plains	Ustifluvents Fluvaquents Ustochrepts	<1°	Loamy/ Bouldery	0 - 2m	well
		9c alluvial fans	Ustochrepts Haplustalfs	1 - 5°	Loamy/ Bouldery	1 - 15m	well
10	Ancient Lake and River Terraces(Tars) (erosional)	10a non-dissected	Typic & Rhodic Haplustalfs Ustochrepts	0-5°	Loamy	> 2m	well
		10b dissected	"	0-5°	Loamy	> 2m	well
11	Moderately to Steeply Sloping Mountainous Terrain		Typic, Rhodic, Udic, Anthropic Subgroups of Ustochrepts Dystrochrepts Haplumbrepts	< 30°	Loamy Skeletal	> 50cm to bedrock	moderately well to well
12	Steeply to Very Steeply Sloping Mountainous Terrain		Lithic Subgroups of 11 and Ustorthents	> 30°	Loamy Skeletal	< 50cm to bedrock	well

Fig 20

Annex 4: High mountain region

SCHEMATIC CROSS SECTION OF LAND SYSTEMS IN THE

HIGH MOUNTAIN REGION



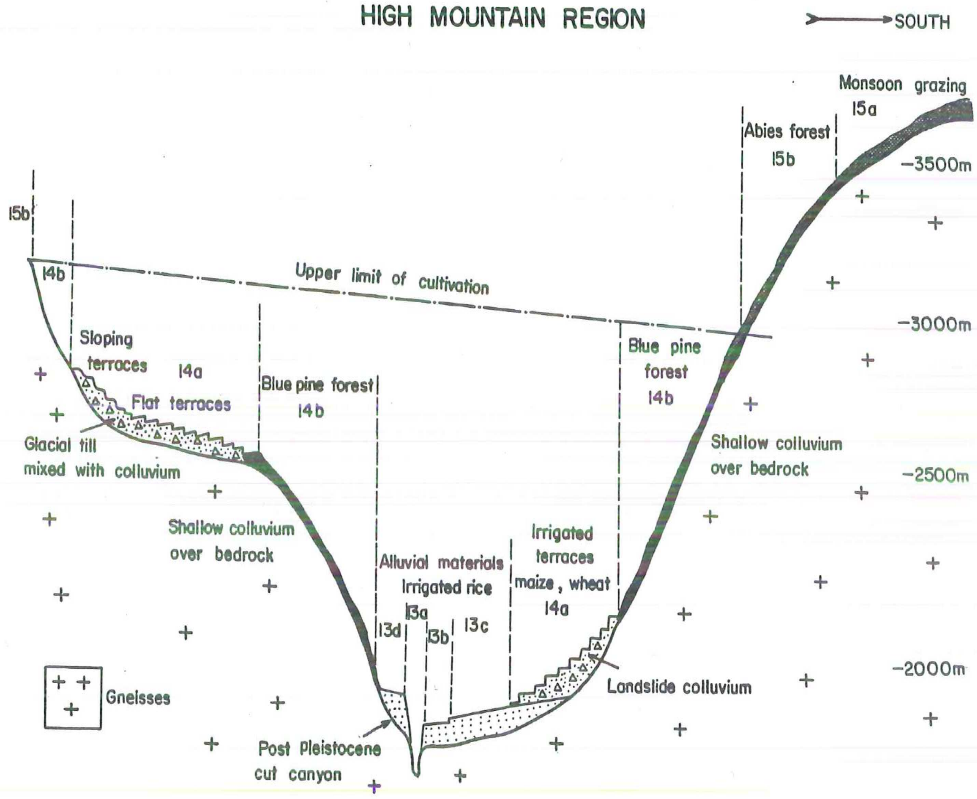
HIGH MOUNTAIN REGION Precambrian to Eocene gneisses, quartzites, schists, phyllites and limestones, generally not deeply weathered; Glaciated; Warm Temperate to Alpine.

13	Alluvial Plains Fans	13a active alluvial plain	Ustifluvents	<1°	Loamy	0 - 2m	variable
		13b recent alluvial plain	Eutrochrepts Dystrochrepts	<2°	Loamy/ Bouldery	0 - 2m	moderately well
		13c fans	"	1-10°	Loamy/ Bouldery	> 2m	well
		13d ancient alluvial terraces	"	<5°	Loamy/ Bouldery	> 2m	moderately well
14	Past Glaciated Mountainous Terrain below Upper Altitudinal Limit of Arable Agriculture	14a moderate to steep slopes	Anthropic and Typic Eutrochrepts Dystrochrepts Haplumbrepts	< 30°	Loamy Skeletal	> 50cm to bedrock	moderately well to well
		14b steep to very steep slopes	Lithic Subgroups of 14a and Ustorthents	> 30°	Loamy Skeletal	< 50cm to bedrock	well
15	Past Glaciated Mountainous Terrain above Upper Altitudinal Limit of Arable Agriculture	15a moderate to steep slopes	Typic and Lithic Haplumbrepts Cryumbrepts	< 40°	Loamy Skeletal	> 20cm to bedrock	moderately well
		15b very steep slopes	Lithic Subgroups of 15a and Cryorthents	> 40°	Loamy Skeletal	< 20cm to bedrock	moderately well

Fig 23.

Annex 5: High Himalayan region

SCHEMATIC CROSS SECTION OF LAND SYSTEMS IN THE HIGH MOUNTAIN REGION



HIGH MOUNTAIN REGION Precambrian to Eocene gneisses, quartzites, schists, phyllites and limestones, generally not deeply weathered; Glaciated; Warm Temperate to Alpine.

13	Alluvial Plains Fans	13a active alluvial plain	Ustifluvents	<1°	Loamy	0 - 2m	variable
		13b recent alluvial plain	Eutrochrepts Dystrochrepts	<2°	Loamy/ Bouldery	0 - 2m	moderately well
		13c fans	"	1-10°	Loamy/ Bouldery	> 2m	well
		13d ancient alluvial terraces	"	<5°	Loamy/ Bouldery	> 2m	moderately well
14	Past Glaciated Mountainous Terrain below Upper Altitudinal Limit of Arable Agriculture	14a moderate to steep slopes	Anthropic and Typic Eutrochrepts Dystrochrepts Haplumbrepts	< 30°	Loamy Skeletal	> 50cm to bedrock	moderately well to well
		14b steep to very steep slopes	Lithic Subgroups of 14a and Ustorthents	> 30°	Loamy Skeletal	< 50cm to bedrock	well
15	Past Glaciated Mountainous Terrain above Upper Altitudinal Limit of Arable Agriculture	15a moderate to steep slopes	Typic and Lithic Haplumbrepts Cryumbrepts	< 40°	Loamy Skeletal	> 20cm to bedrock	moderately well
		15b very steep slopes	Lithic Subgroups of 15a and Cryorthents	> 40°	Loamy Skeletal	< 20cm to bedrock	moderately well

Fig 23.

Annex 6: Technical information dataset

- Availability

The datasets of the 1:1M SOTER for the Kingdom of Nepal is only available from the ISRIC-website. It is downloadable from http://www.isric.org/ .

- Formats

The SOTER datasets have been compiled using MS Office-Access®, version 2004. The SOTER input software for the input of attribute data in the SOTER database is version 3.40 (Tempel 2002). All older versions are compatible.

The GIS files are created using ArcGIS9/ArcMap9.2®, the shapefiles may also be imported/ viewed in ArcView3.3®.

- Projection

The 'projection' of all SOTER maps is geographic WGS 1984 with coordinates given in decimal degrees.

- Size of files

Dataset	zipped (Mb)	unzipped (Mb)
Nepal 1:1M	37	48
Nepal 1:50.000 (on request from HMG Survey Department, and FAO)	22.3	244

World Soil Information

ISRIC - World Soil Information is an independent foundation with a global mandate, funded by the Netherlands Government. We have a strategic association with Wageningen University and Research Centre.

Our aims:

- *To inform and educate - through the World Soil Museum, public information, discussion and publication*
- *As ICSU World Data Centre for Soils, to serve the scientific community as custodian of global soil information*
- *To undertake applied research on land and water resources*