Soil and Terrain Database for the Upper Tana, Kenya

World Soil Information

Green Water Credits Report 11

J.A. Dijkshoorn, P.N. Macharia, J.R.M. Huting, P.M. Maingi and C.R.K. Njoroge

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Green Water Credits Report 11

Foreword

The Soil and Terrain (SOTER) database for the Upper Tana River catchment, at scale 1:250,000, is the second SOTER database for Kenya, after the first release of Kenya's national SOTER database at the scale of 1:1 million.

The SOTER database for the Upper Tana was compiled in the framework of the Green Water Credits (GWC) programme. The GWC programme will develop a financial mechanism to reward upstream farmers for protecting their soils from erosion and degradation - and thus simultaneously attaining enhanced water storage. Quantification of water storage and flows is made with hydrologic models. To run such models baseline data of soil and landscape attributes are required. The Kenya Soil Survey (KSS), a department of the Kenya Agricultural Research Institute (KARI), harmonised the maps and legends of the various studies made in the Upper Tana river catchment, compiled the primary SOTER database by selecting representative soil profiles, and combined the maps of different scales into one digital map. The attribute data and the profiles form the basis for the hydrologic assessments using measured and derived soil data. The derived data are substitutes for the missing values and gaps in the primary database, and are estimated by the use of a taxotransfer procedure developed by ISRIC-World Soil Information, resulting in a secondary SOTER database that provides the input for modelling.

The development of regional and national SOTER databases is part of an ongoing programme of ISRIC–World Soil Information, which is supported by the Food and Agriculture Organisation of the United Nations (FAO) and ISRIC-World Soil Information. The programme is executed under the umbrella of the International Union of Soil Science (IUSS) and aimed at creating a global Soil and Terrain cover and subsequently replacing the "Soil Map of the World" (FAO-UNESCO 1974).

Under this programme, SOTER databases have been compiled for Latin America and the Caribbean (FAO et al. 1998), Central and Eastern Europe (FAO et al. 2000), several countries in Southern and Central Africa (FAO et al. 2003); (FAO et al. 2007) and also a number of sub-regional and national SOTER databases.

SOTER makes use of existing, published and freely available soil data, soil maps and soil profile data, as well as DEMs. In this respect, ISRIC-World Soil Information welcomes new and recently collected soil data for updating SOTER databases at various scales. ISRIC welcomes collaboration with national institutes with a mandate for soil resources inventories.

Dr ir Prem Bindraban
Director, ISRIC – World Soil Information

Key Points

- The SOTER concept is based on the relationship between physiography (landform), parent materials and soils. It identifies areas of land with a distinctive and often repetitive pattern of landform, parent material, surface form, slope, and soils. The methodology uses a stepwise approach, identifying major landforms or terrain units at its highest level of distinction.

- Methods used to compile the Soil and Terrain database for the Upper Tana catchment (SOTER-Upper Tana), Kenya are described.

- SOTER-Upper Tana, at a scale of 1:250,000, was compiled in the framework of the Green Water Credits programme. The database was made for use with the hydrologic assessment tool, the Soil and Water Assessment Tool (SWAT).

- The basis of the SOTER-Upper Tana has been to clip the Upper Tana catchment from the national KENSOTER database of Kenya. This was updated with information from several new reconnaissance surveys at a scale of 1:100,000 and more detailed soil studies in the catchment.

- SOTER-Upper Tana provides information on landform and soil properties at a 1:250,000 scale. It consists of 191 SOTER units, characterised by 109 representative profiles, and 33 virtual profiles for which there are no measured soil data.

- Prior to using the primary database for modelling, gaps in the primary data must be filled; this procedure is described in ISRIC Report 2010/06.

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Acronyms and Abbreviations

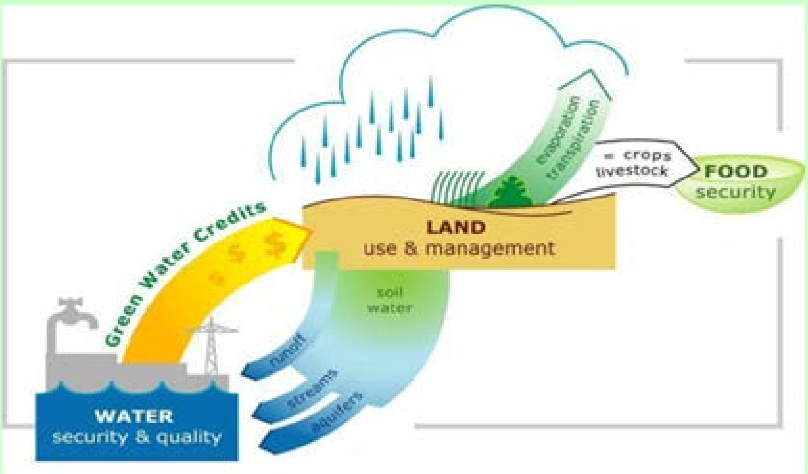
AGL	Land and Water Development Division of FAO
FAO	Food and Agriculture Organisation of the United Nations
GIS	Geographic Information System
GWC	Green Water Credits
IFAD	International Fund for Agricultural Development
IUSS	International Union of Soil Sciences
ISRIC	World Soil Information
ISSS	International Soil Science Society
KARI	Kenya Agricultural Research Institute
KENSOTER	Kenya Soil and Terrain database
KSS	Kenya Soil Survey
PRID	Profile ID
RDBMS	Relational Database Management System
SCID	Soil Component ID
SOTER	Soil and Terrain database
SWAT	Soil and Water Assessment Tool
SUID	SOTER Unit ID
TCID	Terrain component ID
UNEP	United Nations Environment Programme
WOCAT	World Overview of Conservation Approaches and Technologies
WRB	World Reference Base for Soil Resources

Green Water Credits: the concepts

Green water, Blue water, and the GWC mechanism

Green water is moisture held in the soil. Green water flow refers to its return as vapour to the atmosphere through transpiration by plants or from the soil surface through evaporation. *Green water* normally represents the largest component of precipitation, and can only be used *in situ*. It is managed by farmers, foresters, and pasture or rangeland users.

Blue water includes surface runoff, groundwater, stream flow and ponded water that is used elsewhere - for domestic and stock supplies, irrigation, industrial and urban consumption. It also supports aquatic and wetland ecosystems. *Blue water* flow and resources, in quantity and quality, are closely determined by the management practices of upstream land users.



Green water management comprises effective soil and water conservation practices put in place by land users. These practices address sustainable water resource utilisation in a catchment, or a river basin. *Green water* management increases productive transpiration, reduces soil surface evaporation, controls runoff, encourages groundwater recharge and decreases flooding. It links water that falls on rainfed land, and is used there, to the water resources of rivers, lakes and groundwater: *green water* management aims to optimise the partitioning between *green* and *blue water* to generate benefits both for upstream land users and downstream consumers.

Green Water Credits (GWC) is a financial mechanism that supports upstream farmers to invest in improved green water management practices. To achieve this, a GWC fund needs to be created by downstream private and public water-use beneficiaries. Initially, public funds may be required to bridge the gap between investments upstream and the realisation of the benefits downstream.

The concept of green water and blue water was originally proposed by Malin Falkenmark as a tool to help in the understanding of different water flows and resources - and the partitioning between the two (see Falkenmark M 1995 Land-water linkages. FAO Land and Water Bulletin 15-16, FAO, Rome).

1 Introduction

Up-to-date and readily available digital natural resource data are required for scenario assessments: in this context detailed and reliable soil and terrain data are needed for the upstream areas of the Tana river, where, in a joint effort by the Kenyan Government[1], the International Fund for Agricultural Development (IFAD) and ISRIC – World Soil Information, a pilot project on Green Water Credits is planned. The Upper Tana catchment in the Central Highlands of Kenya was selected as the pilot area to study the mechanisms of the Green Water Credits (GWC) programme. The programme aims at developing mechanisms in which downstream water users reward upstream land users for applying soil and water conservation measures or *"green water* management" measures as these are termed under GWC (see "Green Water Credits: the concepts" on page 8). For the Upper Tana, water users are mainly the electricity generating hydropower stations (Droogers et al. 2006; Kauffman et al. 2007) and a few downstream farms using River Tana water for irrigation. The associated hydrologic models[2] require data on climate, soils, land use and vegetation.

This report describes the methods and procedures used to compile the Soil and Terrain (SOTER) database for the Upper Tana catchment at a scale of 1:250,000 (SOTER_UT, ver. 1.0). SOTER stores attribute data on landform and soils in a standardised format that easily can be handled using GIS and programmes. The SOTER programme was launched in the mid-1980s as a joint effort of the Food and Agriculture Organization of the United Nations (FAO), ISRIC–World Soil Information and the United Nations Environment Programme (UNEP) under the aegis of the International Union of Soil Science (IUSS). The aim of the programme is to create a SOTER database (Baumgardner 1986; FAO/AGL 1986[3]; ISSS 1986) with global coverage at a scale of 1:1 million. The first SOTER database was compiled in 1994 with Kenya as the pilot country (KSS 1996[4]); the resulting national KENSOTER database was updated in 2007 (KSS and ISRIC 2007[5]).

SOTER-Upper Tana was compiled for the GWC programme to provide a more detailed soil map and database for its use in hydrologic assessments in the basin. The methodology and materials used for compiling SOTER-Upper Tana are described in Chapter 2. The database is discussed in Chapter 3. Chapter 4 describes the conclusions and recommendations for updates and improvements. The annexes present information on the harmonised legend, and include literature references to studies and reports on the natural resources for the Upper Tana catchment.

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1 Represented by the Kenya Soil Survey (KSS) of the Kenya Agricultural Research Institute (KARI)

2 SWAT-Development-Team 2009: Soil and Water Assessment Tool (SWAT), Texas A&M University http://swatmodel.tamu.edu/team

3 FAO/AGL 1986: Global Soil and Terrain Database (WORLD-SOTER), http://www.fao.org/ag/agl/agll/soter.stm

4 KSS 1996: The Soil and Terrain Database for Kenya at scale 1:1,000,000 (ver. 1.0) Kenya Soil Survey, National Agricultural Laboratory, Kenya Agricultural Research Institute. http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/SOTER+Kenya.htm

5 KSS and ISRIC 2007: http://www.isric.org/UK/about+ISRIC/Projects/Track+Record/SOTER+Kenya.htm

2 Materials and methods

2.1 Study area

The GWC programme focuses on the Upper Tana catchment, particularly between the crests of Mt Kenya and the Aberdare Ranges in the west and southwest, down to the Tana river, up to Usueni town in the northeast, and to Katheka and Tulia in the south (north of Kitui). The catchment area falls within the administrative boundaries of Thika, Murang'a, Nyeri, Kirinyaga, Embu, Meru, Mbeere and part of Machakos Districts. The total surface of this catchment covers an approximate area of 18,872 km^2.

The elevation of the area ranges from about 400 m.a.s.l. to over 4500 meters m.a.s.l. (Figure 1). The Upper Tana catchment experiences high precipitation and has soils dominantly derived from volcanic parent materials; changing at lower elevation to soils derived from Precambrian Basement System rocks, mainly gneiss, banded gneiss and schists. The combination of precipitation and relatively fertile soils on volcanic parent materials has resulted in a region used intensively for agriculture – and correspondingly densely populated. Except for tea cultivation areas at higher elevations with only one single perennial crop, most farming in the catchment is a mixture of food and cash crops.

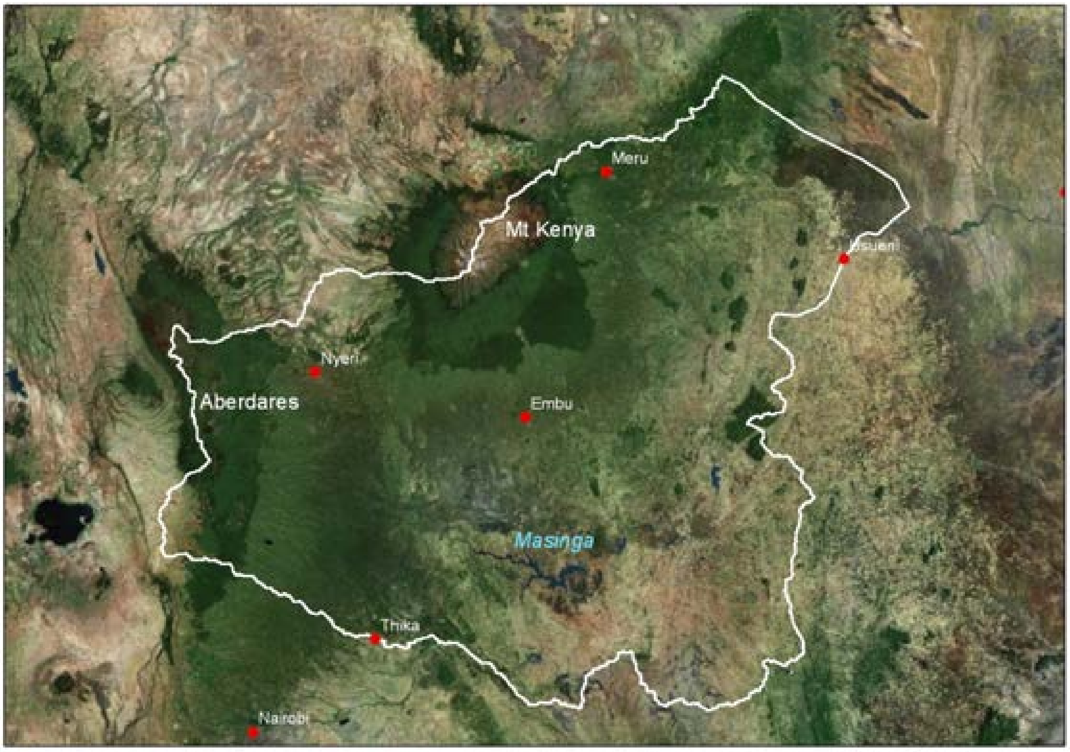

Figure 1
Location and boundary of the Upper Tana catchment in Central Kenya

In the higher, cooler and humid areas, tea cultivation and dairy farming is the dominant land use. In the sub-humid areas, mixed coffee/maize growing is practiced, while in the lower altitudes maize is the dominant staple food. In the lower and dryer areas of the eastern regions of the catchment, extensive ranching is the dominant land use.

Several national parks (Mt Kenya, Aberdare and Meru National Park) are (partly) situated in the Upper Tana catchment. There are five reservoirs in the Tana river itself, from which water is used by the hydropower stations to generate electricity.

2.2 SOTER methodology

The SOTER procedures manual (van Engelen and Dijkshoorn 2010) was used to compile SOTER-Upper Tana. The SOTER methodology was initially developed as a land resources information system at 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 physiography (landform), parent materials and soils. It identifies areas of land with a distinctive and often repetitive pattern of landform, parent material, surface form, slope, and soils. The methodology uses a stepwise approach, identifying major landforms or terrain units at its highest level of distinction. Subdivision of the terrain units is according to differences in e.g. surface features or parent material, and eventually on soil type.
Subdivisions, that cannot be mapped at the desired scale of 1:250,000 can only be characterised in the database. The map units thus created are termed SOTER units (Figure 2), and represent unique combinations of terrain and soil characteristics (Dijkshoorn 2002; van Engelen and Wen 1995).

The SOTER attribute database consists of various tables: terrain, terrain component and soil component, linked through primary keys. At the highest level, the terrain unit, the characteristics of landform and parent material are described. In the terrain unit, one or more terrain component(s) (TCID) are distinguished based on differences in landform, topographical features or parent material that, due to the scale of delineation, cannot be shown on the SOTER map, but can be described in the attribute database. Further discrimination is made according to soil components (SCID), characterised by a typical soil type (Figure 2). The tabulate data of the SOTER unit, with its soil components, is comparable to a mapping unit with its soil legend.

Each soil component is characterised according to the Revised Legend of the Soil Map of the World (FAO 1988) and also according to the Small-scale Map Legend of the World Reference Base for Soil Resources (IUSS Working Group WRB 2010). Further, a unique soil profile code (PRID) is given to soil profiles representing a specific area of the SOTER unit, linking the selected profile and its soil properties to the legend and mapping unit. Detailed soil horizon characteristics are stored in the "representative horizon" table (van Engelen and Dijkshoorn 2010).

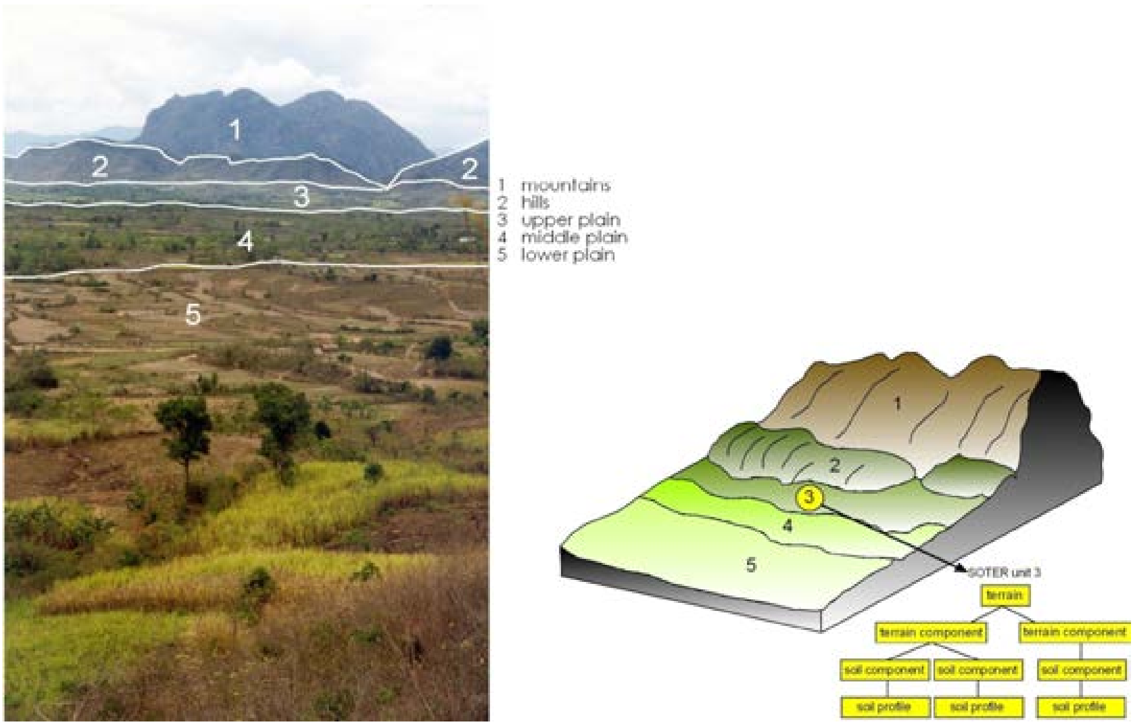

Figure 2
Representation of a SOTER unit and its structure

The SOTER methodology has been applied at a range of scales, from 1:50,000 to 1:5 million, (ISRIC et al*.* 2003; ISSS et al*.* 1998; van Engelen et al*.* 2004). SOTER can accommodate the attributes described in Table 1.

Figure 3 shows the relationships between the various data tables. Terrain units, terrain components and soil components are part of the landscape and represent the spatial components within the database, while only the terrain unit is represented in the geometric database and depicted in the SOTER map.

The scale of the SOTER database (currently 1:250,000) defines the delineation of the components and its 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 further subdivided on the basis of non-mappable parent material, deviating terrain characteristics or on differences in soils (van Engelen and Wen 1995). In extensive, plain areas, with uniform physiographic features, soil differences can also be the determining factor for the SOTER unit. Soil profile and profile horizon data are the point data that are considered representative of each SOTER unit.

SOTER coding conventions, the structure of the database, definitions of the SOTER relations, field definitions and content are detailed elsewhere (van Engelen and Wen 1995; Tempel 2002). The SOTER attribute database is structured in such a way that it can accommodate attribute data of non-mappable terrain differences in the underlying tables. These terrain components cannot be delineated on the map as a SOTER unit at the current scale; the coverage of the different terrain and soil components is accounted for as a percentage (proportion) of the SOTER unit in the database.

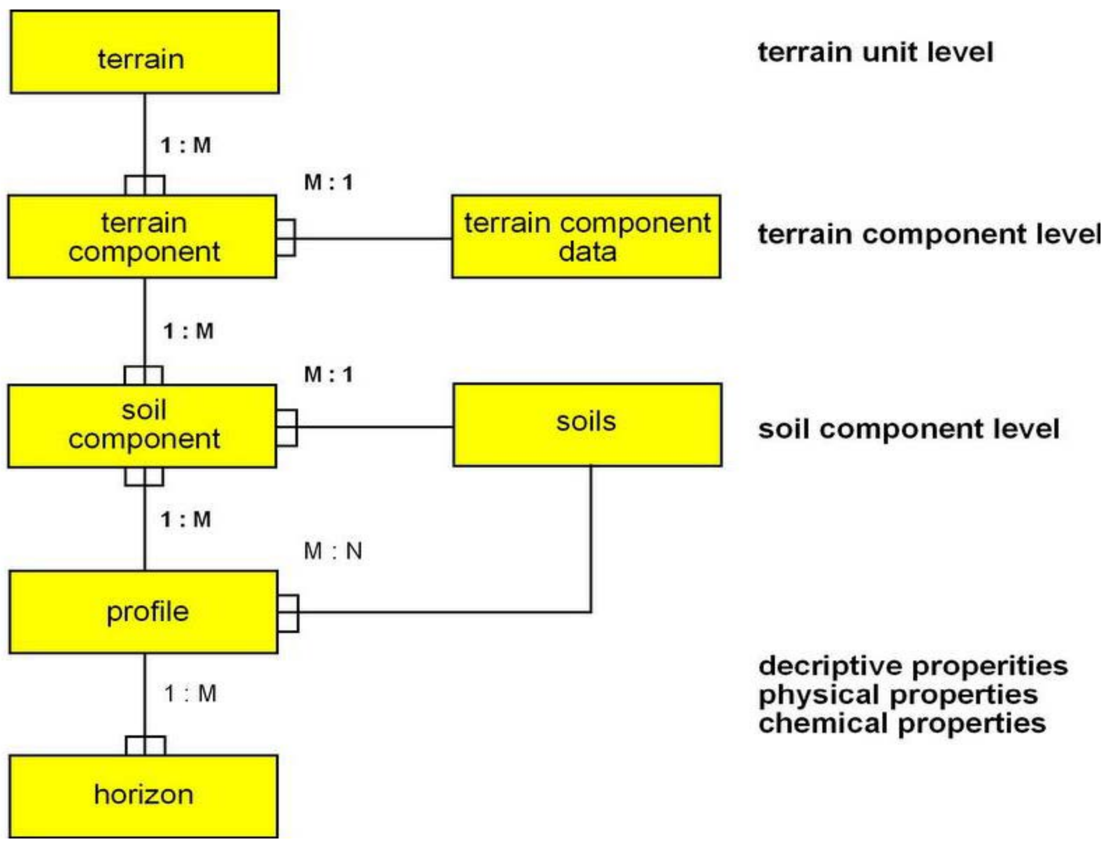

Figure 3

SOTER structure and the relation between the data storage tables

2.3 Data sources

The basis for compiling SOTER-Upper Tana was derived from the KENSOTER, at scale 1:1 million (KSS 1996[6]; KSS and ISRIC 2007[7]). The geometric database is clipped from KENSOTER, following the watershed divides of Tana river. The descriptive legend and coding system is given in Annex 1.

The available SOTER-Upper Tana data were updated using reconnaissance studies of the quarter degree sheets[8] 136 and 122, both east of Mt Kenya (KSS 1975, 2000) and studies covering Murang'a District (KSS 2007a, b, c), all at a scale of 1:100,000. A number of special purpose surveys were Also used, e.g. (Kinyanjui 1990; Njoroge and Kimani 2001; Thiang'au and Njoroge 1982) and others. The Kenya Soil Survey harmonised all these reconnaissance soil surveys in one legend (Annex 2). Legends of Annex 1 and Annex 2 have been adapted in the compilation of the dataset. In the final legend, a SOTER unit_ID and key code have been given, thus facilitating the compilation of the SOTER-Upper Tana database.

The GIS and DEM based approach of (Huting et al*.* 2008) was used to adjust the geometric database to a 1:250,000 resolution.

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6 KSS 1996: The Soil and Terrain Database for Kenya at scale 1:1,000,000 (ver. 1.0) Kenya Soil Survey, National Agricultural Laboratory, Kenya Agricultural Research Institute. http://www.isric.org/UK/About+ISRIC/Projects/Track+Record/SOTER+Kenya.htm

7 KSS and ISRIC 2007: http://www.isric.org/UK/about+ISRIC/Projects/Track+Record/SOTER+Kenya.htm

8 Base map compiled from Survey of Kenya topographical maps, scale 1:50,000

2.4 Primary soil and terrain data

Most soil and terrain data in the SOTER-Upper Tana database were derived from two natural resources surveys covering the quarter degree sheets 136 and 122 (KSS 1975, 2000) and the reconnaissance soil surveys of Murang'a District (KSS 2007a, b, c). The attribute data of representative soil profiles of these studies were added to the SOTER-Upper Tana database. A particularly large number of profiles were taken from the quarter degree-sheet 122, (Chuka South; the student's training project in pedology of the Wageningen Agricultural University (de Meester and Legger 1988) and the Chuka-Nkubu soil survey (de Meester and Legger 1988; KSS 2000); about 45% of the representative profiles in the database originate from this sheet.

Other information from surveys in the Upper Tana covers much smaller areas or is located in specific parts of the catchment. Many of these sites had been studied for purposes of their irrigation suitability, e.g. Njoroge and Kimani (2001). All natural resources studies and surveys within, or partly within, the Upper Tana catchment have been listed in an inventory of natural resources reports (Annex 4.). In most cases the coordinates of the survey areas are also given.

Only geo-referenced profiles are considered in SOTER-Upper Tana. Accurate description of the location has sometimes been accepted, only when the descriptive name was traceable on the maps and a geo-reference could be given. A few profiles have been included from studies outside the basin, but only where no suitable representative profile was available in the basin.

2.5 Map Legends

Soils are named according to the Revised Legend (FAO 1988); this is the standard legend for SOTER (see Chapter 2.2). However, in the description of the legend in Annex 1 and 2, some soil units still have the prefix Orthi-(c) in combination with other prefixes, but are otherwise similar to the Revised Legend (FAO 1988). Kenya Soil Survey uses this version, "the Kenyan variant" of the Revised Legend, which is only slightly different from the Revised Legend. In a later version (FAO 1988), Haplic has replaced Orthic, while both Orthic and Haplic are now omitted in the combined prefixes of the latest WRB version (IUSS Working Group WRB 2007).

This study uses also the Small-scale Map Legend of the World Reference Base for Soil Resources (IUSS Working Group WRB 2010) as a new development in the SOTER methodology. The selected representative soil profiles, however, should first comply with the map unit characterisation of the soil component according to the Revised Legend (FAO 1988). As the Revised Legend is still the standard reference classification for SOTER to maintain consistency with earlier SOTER databases. Finally, each representative soil profile is given a full classification according to the World Reference Base for Soil Resources (IUSS Working Group WRB 2007) and stored in the profile table.

3 Results and discussion

3.1 General

The SOTER-Upper Tana map and database are presented at an overall scale of 1:250,000. The source data, however, vary widely in detail and quality (Figure 4), and parts of the area are not covered by detailed soil surveys (Figure 5). Reconnaissance survey materials were used to consolidate the base material derived from KENSOTER (KSS 1996); and mapping unit boundaries have been modified to satisfy a higher resolution (see Chapter 3.2). Two areas (part I and II in Figure 4) have been surveyed at scale 1:100,000. All these maps were harmonised into one SOTER-Upper Tana database. Other available information of surveys in the Upper Tana covers much smaller areas or is located in specific parts of the landscape, for example many sites close to rivers have been studied for their irrigation suitability (see Figure 4 and Figure 5. These small surveys and site appraisal studies have contributed to the attribute database especially for the area with a 1:250,000 scale resolution. However, not all studies have been fully exploited for new selected representative soil profiles.

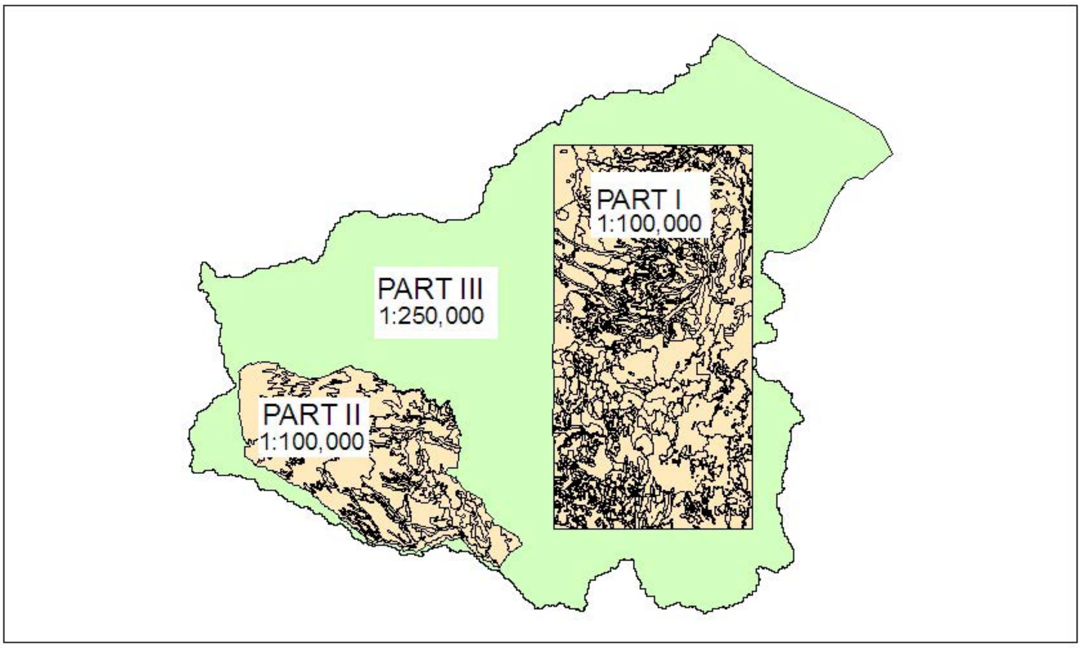

Figure 4
Resolution differences of SOTER data in the Upper Tana river catchment

The areas and locations of these studies can be viewed in Figure 5; note that the legend in Figure 5 gives only a part of the studies listed in Annex 4. The reconnaissance surveys, covering large areas, are indicated with coloured outline and blocks, they carry report numbers at the coordinate points, e.g. R1, R1a: P8, P8a, etc. The detailed, semi-detailed and PhD studies are indicated with label points and report numbers (D, S and PhD).

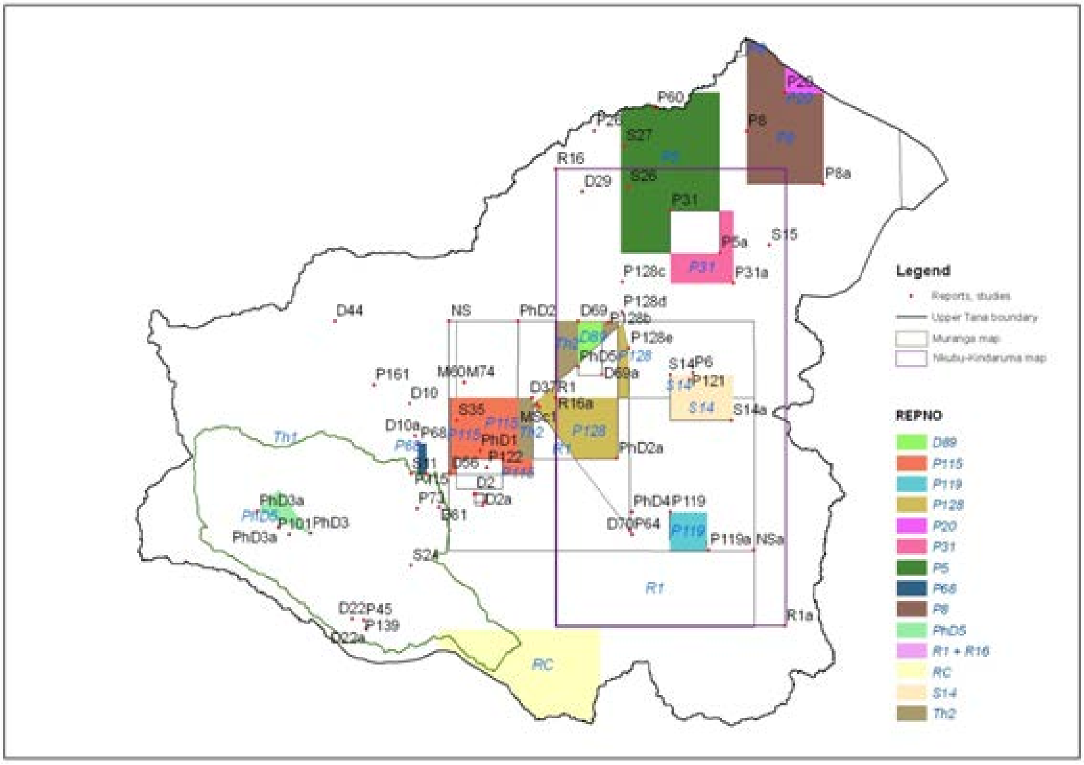

Figure 5

Approximate location or outline of natural resources studies in the Upper Tana with document reference

3.2 GIS based methodology for SOTER landform mapping.

For the Upper Tana catchment, single attribute maps of slope, relief intensity and elevation were produced using the ArcMap's Spatial Analyst tool for processing the DEM data. In particular, the relief intensity and slope maps have proved useful to adjust the SOTER unit boundaries from the 1:1 million scale resolution to 1:250,000. Visual effects on the single attribute maps can be accentuated by making use of "hillshade". Satellite imagery, freely available from the web (ESRI 2010), supported the adjustment of the soil boundaries. Results are shown in Figure 6 A and B. The new boundaries correspond better with the topographic features, derived from clustering of similarly classified 90m DEM pixels. Figure 6A gives the situation before adjustment; left of the central line shows the units of the 1:1 million scale map and the one to the right shows the units of the 1:100,000 scale map. Figure 6B gives the map units after adjustment of boundaries using the 90m-DEM and satellite imagery.

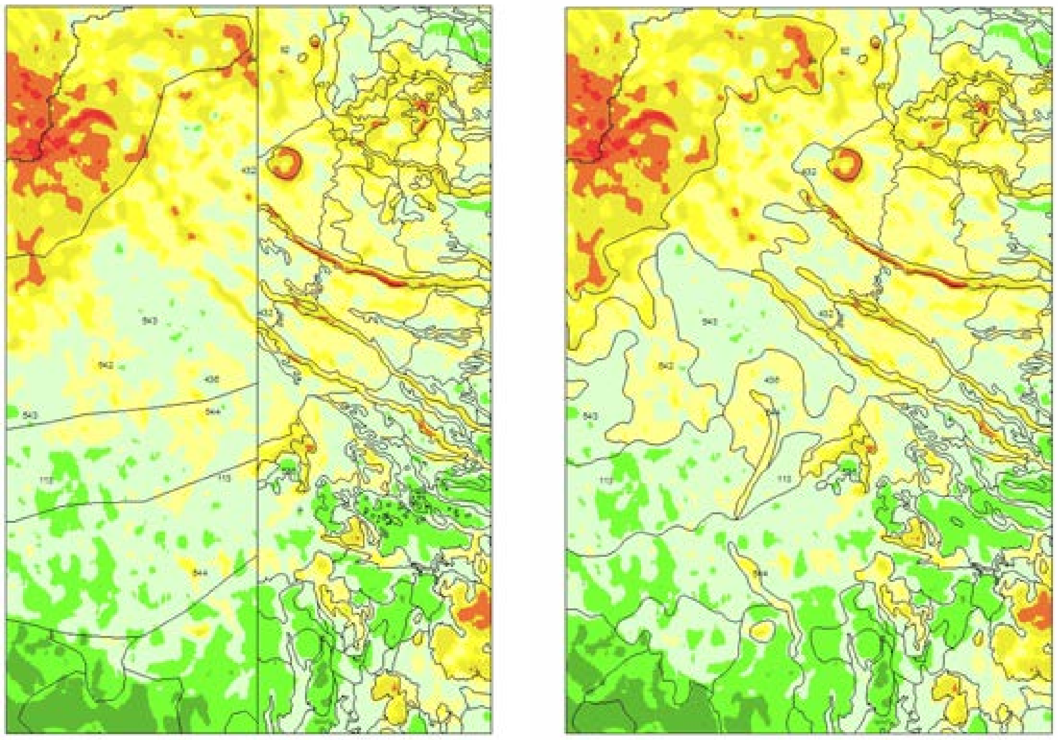

Figure 6
Before (A) and after (B) adjustment of SOTER unit boundaries at a 1:250,000 scale resolution, using slope and relief intensity maps derived from a 90m-DEM

3.3 SOTER attribute database

The SOTER-Upper Tana attribute database contains 191 unique SOTER units, comprising 193 terrain components and 263 soil components. It is linked to 752 polygons in the geometric database. These SOTER units are derived from maps of different scales; about 150 units originate from maps of 1:100,000 scale and 40 from the KENSOTER 1:1 million scale map. All SOTER map units were digitised from analogue maps. They are considered sufficiently accurate to present an overall scale of 1:250,000.

The soil components are represented by 109 real soil profiles, and 34 virtual profiles, for which there are no measured soil data. The soil unit name, according to the Revised Legend of the Soil Map of the World (FAO 1988), characterises each soil component and a unique profile_ID links to the attribute tables, profile and horizon data. A virtual profile was used, when there were no representative profiles with measured data available for the soil component. In such cases, the soil unit name taken from existing soil maps is the only attribute of a virtual profile in the database.
Table 1 gives the composition of the attribute data stored in the SOTER-Upper Tana database and the proportion of the data available. Particularly missing are physical soil data, such as data on water holding capacity.

Table 1
Overview of attribute proportion filled (%) of the SOTER Upper Tana

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	88	10 regional slope	100
5 minimum elevation	100	11 hypsometry	100
6 maximum elevation	100	12 general lithology	100
Attributes of terrain component table		**Attributes of terrain component table**	
13 terrain component number	100	20 depth to bedrock	78
14 proportion of SOTER unit	100	21 surface drainage	82
15 terrain component data_ID	100	22 depth to groundwater	-
16 dominant slope	97	23 frequency of flooding	80
17 length of slope	98	24 duration of flooding	-
18 surface parent material	60	25 start of flooding	-
19 texture of non-consolidated parent material	95		
Attributes of soil component table		**Attributes of soil component table**	
26 soil component number	100	34 position in terrain component	98
27 proportion of SOTER unit	100	35 surface rockiness	98
28 WRB-Legend	100	36 surface stoniness	90
29 WRB-Legend suffixes	57	37 types of erosion/deposition	60
30 Revised Legend (FAO 1988)	100	38 area affected	15
31 phase (FAO 1988)	30	39 degree of erosion	20
32 textural class topsoil	100	40 sensitivity to capping	57
33 profile_ID	100	41 rootable depth	100
Attributes of profile table		**Attributes of profile table**	
42 profile database_ID	79	51 vegetation	23
43 latitude	73	52 parent material	63
44 longitude	73	53 WRB soil group	68
45 elevation	63	54 WRB specifiers	65
46 description status	55	55 WRB version	68
47 sampling date	70	56 Revised legend (FAO 1988)	100
48 location status	50	57 national classification	-
49 drainage	100	58 Soil taxonomy	-
50 land use	50	59 Soil taxonomy version	

Attributes of horizon table		Attributes of horizon table	
60 diagnostic horizon	60	86 bulk density	33
61 diagnostic property	14	87 water holding capacity	8
62 diagnostic material	4	88 pH H2O	86
63 horizon designation	99	89 electrical conductivity	62
64 upper depth	100	90 pH KCl	74
65 lower depth	97	91 soluble Na+	-
66 distinctness of transition	70	92 soluble Ca++	-
67 moist colour	87	93 soluble Mg++	-
68 dry colour	19	94 soluble K+	-
69 mottles colour	4	95 soluble Cl-	-
70 grade of structure	83	96 soluble SO4–	-
71 size of structure elements	78	97 soluble HCO3-	-
72 type of structure	84	98 soluble CO3–	-
73 nature mineral nodules	7	99 exchangeable Ca++	74
74 abundance mineral nodules	55	100 exchangeable Mg++	75
75 abundance coarse fragments	35	101 exchangeable Na+	76
76 size of coarse fragments	5	102 exchangeable K+	77
77 very coarse sand	14	103 exchangeable Al+++	-
78 coarse sand	14	104 exchangeable acidity	-
79 medium sand	14	105 CEC soil	86
80 fine sand	14	106 total carbonate equivalent	19
81 very fine sand	14	107 gypsum	-
82 total sand	86	108 total organic carbon	68
83 silt	86	109 total nitrogen	13
84 clay	86	110 available P2O5	8
85 particle size class	87	111 phosphate retention	-

Generally, the soils of the Upper Tana have only been analysed for their chemical characteristics, because these attributes are important for soil fertility assessment, sometimes just within the top soil layers; for example for soil organic carbon. Soil physical characteristics were not determined in the routine reconnaissance surveys of the Upper Tana, except for a few profiles from the Kindaruma area, quarter degree sheet 136 (KSS 1975). Table 1 shows gaps of measured attributes, and the attributes that show a high incidence of missing values are due to a low percentage measured.

Attribute data is shown spatially in derived thematic maps or in tabulated form. Table 2 shows the dominant landform, according to updated SOTER landform criteria. Plains with slopes <10% (not further specified) dominate the area with 37%, followed by 28% by hills and ridges with slopes between 10 and 30%. High and medium gradient mountains comprise 13% of the Upper Tana catchment area.

Table 2
Landform composition according to SOTER

Landform	km^2	Proportion of area (%)
Footslope	366	1.9
Plateau	199	1.0
Plain	7064	37.3
Low gradient valley	308	1.6
Depressions	43	0.2
Hills and ridges	5264	27.8
Medium gradient mountain	1249	6.6
Dissected plain	2906	15.0
Medium gradient valley	243	1.3
High gradient mountain	1099	5.8
High gradient valley	122	0.6
Lakes, inland water	100	0.5
Total	18,963	99.6

3.4 Soil unit distribution

Nitisols (FAO 1988) are the dominant soil group of the Upper Tana basin; they cover more than a quarter of the area (Table 3). Humic Nitisol with 18.2% are the dominant soil unit, followed by the Rhodic and Haplic Nitisols subgroups. Generally, Nitisols develop on basic and intermediate basic volcanic rocks, which are widely spread on the ridges and the hilly areas around Mt Kenya and the Aberdares in the west and southwest of the basin (Table 3 and Figure 7).

Table 3
Distribution of the major soil groups and soil units in Upper Tana, according to the Revised Legend

Revised Legend soil units	Revised Legend code	Phase	Area km^2	Area %
Humic Nitisols	NTu		3443.3	18.2
Rhodic Nitisols	NTr		1333.8	7.1
Haplic Nitisols	NTh		488.7	2.5
Umbric Andosols	ANu		1046.2	5.5
Umbric Andosols, lithic phase	ANu	LI	701.2	3.7
Mollic Andosols	ANm		400.2	2.1
Rhodic Ferralsols	FRr		1054.5	5.6
Haplic Ferralsols	FRh		94.7	0.5
Haplic Acrisols	ACh		1248.6	6.6
Ferric Acrisols	ACf		272.7	1.4
Humic Acrisols	ACu		225.1	1.2
Plinthic Acrisol, petroferric phase	ACp	PF	110.1	0.6
Chromic Luvisols	LVx		761.6	4.0
Chromic Luvisols, lithic phase	LVx	LI	451.7	2.4
Chromic Luvisols, skeletic phase	LVx	SK	145.2	0.8
Ferric Luvisols	LVf		106.3	0.6
Haplic Luvisols, incl. lithic phase	LVh	(LI)	152.6	0.8
Chromic Cambisols, incl. lithic phase	CMx	(LI)	1874.8	9.9
Calcic Cambisols, skeletic phase	CMc	SK	255.1	1.4
Dystric Cambisols, incl. lithic phase	CMd	(LI)	154.9	0.8
Eutric Cambisols, incl. lithic phase	CMe	(LI)	174.3	0.9
Ferralic Cambisols, skeletic phase	CMo	SK	74.2	0.4
Gleyic Cambisols,incl. petroferric ph.	CMg	(PF)	142.8	0.8
Humic Cambisols, lithic phase	CMu	LI	123.6	0.7
Eutric Vertisols	VRe		722.2	3.8
Calcic Vertisols	VRk		231.4	1.2
Dystric Regosols, lithic phase	RGd	LI	713.1	3.8
Eutric Regosols	RGe		210.4	1.1
Eutric Regosols, lithic phase	RGe	LI	117.5	0.6
Luvic Phaeozems	PHl		100.8	0.5
Haplic Lixisols, incl. lithic phase	LXh		643.2	3.4
Ferralic Arenosols	ARo		262.8	1.4
Eutric Leptosols, incl. skeletic phase	LPe	(SK)	238.4	1.3
Dystric Leptosols	LPd		133.1	0.7
Dystric Leptosols, skeletic phase	LPd	SK	122.7	0.7
Lithic Leptosols	LPq		54.9	0.3
Umbric Gleysols, Umbric Fluvisols and Eutric Fluvisols	GLu Flu/FLe		100.6	0.5
Eutric and Dystric Planosols	PLe/PLd	SO	269.1	1.4
Fibric Histosols, lithic phase	HSf	LI	123.6	0.7
Total			18872.6	99.9

The second major soil group are Cambisols; the Chromic Cambisols cover almost 10%. This soil unit also includes a lithic phase with rock within 50 cm of the surface (FAO 1988). Most Cambisols have undifferentiated banded gneiss of the Precambrian Basement System rocks as parent material and occur in the east and southeast part of the basin.

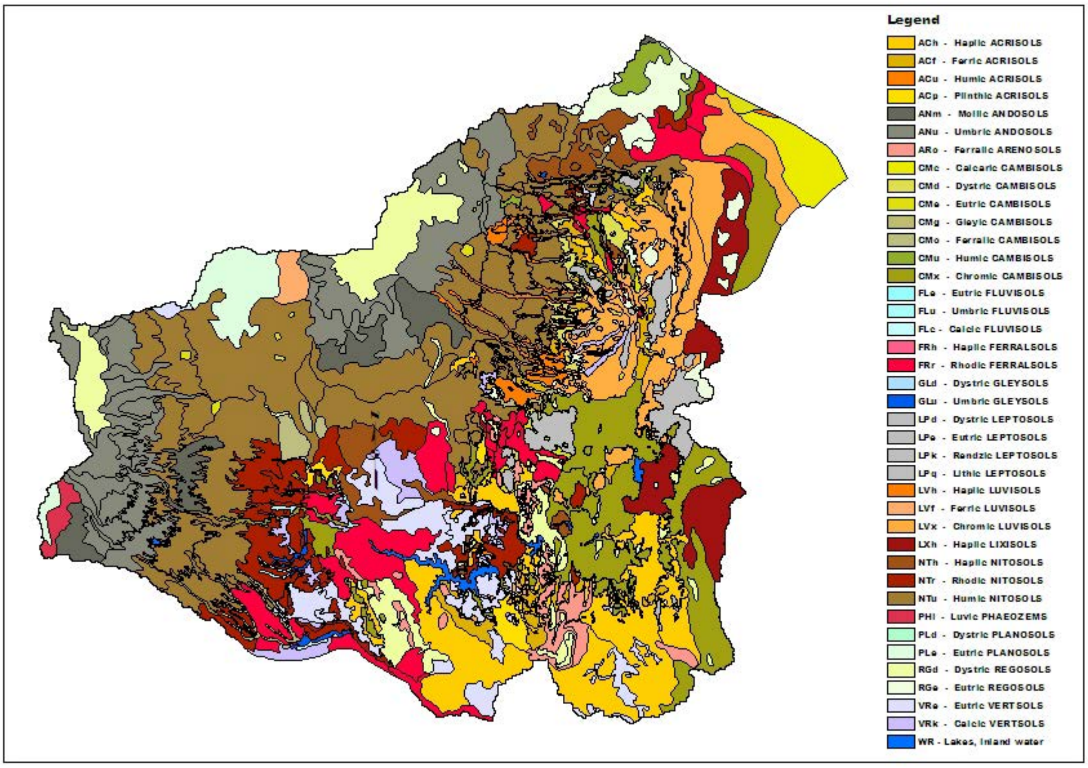

Figure 7
SOTER based soil map showing the dominant soils in the Upper Tana river catchment

The Andosols, particularly the Umbric and Mollic subgroups, dominate the soils at higher elevations. Andosols are developed on young volcanic, often unconsolidated rock (ashes) and they occur in a fringe around Mt Kenya and the Aberdare Range.
At lower elevations, roughly below 1000 m.a.s.l., soils vary widely. Parent materials are often strongly weathered. This has influenced the soil development; here Acrisols, Ferralsols and Vertisols dominate (Table 3 and Figure 7).

Figure 7 shows the spatial distribution of the soil units. In many places, the soils follow a toposequence, starting from Mt Kenya and the Aberdare tops down to the Tana river. Regosols dominate both volcanic cones, while Andosols are spread around the tops. At a lower elevation, beneath the Andosols, the Nitisols occur in a very wide belt; the Humic units in the higher and cooler parts, while the Rhodic soils occur in the lower and warmer areas. The Nitisols grade into various other major soil groups, such as Ferralsols and Acrisols, for the strongly weathered soils and Luvisols, Lixisols and Cambisols for the less weathered soils. Usually they are found at lower elevations, closer to the Tana river.

4 Conclusions and recommendations

SOTER-Upper Tana is a first approximation for the Upper Tana catchment area at a 1:250,000 scale. The SRTM 90m-DEM has proved useful for adjusting SOTER unit boundaries. However, some boundaries still need further verification and groundtruthing through checks in the field.

The source materials used for this study are of different resolution; this results in a variable map detail and reliability of attribute data.

There are few data on bulk density, soil moisture content, total available moisture content and infiltration rate in SOTER-Upper Tana.

Prior to using SOTER-Upper Tana in modelling, gaps in the measured data have had to be filled using consistent procedures (Batjes 2010)

SOTER-Upper Tana should be updated, when new soil profile data become available and studies using suitable data from the detailed surveys (Annex 4).

New fieldwork to improve data density should focus on the areas with little soil profile data as was shown in Figure 5. There is a special need soil physical data for in the Upper Tana catchment, to run the hydrologic models.

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Annex 1 Legend for the soil map of Upper Tana 1:250,000

The legend for the soil map of Upper Tana is based on the Exploratory Soil Map of Kenya at scale 1:1 million (KSS 1982). It follows comparable criteria and has a similar structure as the SOTER methodology at the highest-level *landform*, followed by the *parent material* (lithology) and *soils*. In the present legend of Upper Tana, however, the coding used for this legend, the soil mapping unit description and the composition of soils differ in a number of cases from the original legend of the National Exploratory Soil Map of Kenya. The code between brackets is the original soil mapping code of the 1:1 million scale map that was used to discriminate the SOTER units in the KENSOTER database (KSS and ISRIC 2007). The map at scale 1:250,000, shows more detail and the composition of soils is sometimes different. Therefore this map cannot be exchanged in a one to one relation to KENSOTER.

The SOTER-Upper Tana database was compiled using the updated version (in preparation) of the SOTER procedure manual (van Engelen and Dijkshoorn 2010b). One of the improvements of SOTER procedure is that the soil name extracted from the legend (units) is now directly linked to the SOTER-GIS file and map, which makes it much easier to display results of, for example, the dominant soil units. Representative profiles are still linked through their profile_ID codes (PRIDs) to the soil component, but the WRB classification of the soil profile might deviate slightly in the given WRB prefixes and suffixes from the WRB legend in the soil component table.

M MOUNTAINS AND MAJOR SCARPS (slopes predominantly over 30%, relief over 300 m).

	MV	**Soils developed on various rocks**
1	**MVC** (M2)	Complex of: - Well drained, very deep, dark reddish brown to dark brown, very friable and smeary, clay loam to clay, with a thick, acid humic topsoil **(Umbric and Haplic Andosols, partly lithic phase)**, and: - Well drained, moderately deep to very deep, dark yellowish brown to brown, friable, silty clay loam to clay: in places with humic topsoil **(Umbric Andosols, Haplic Nitisols and Humic Cambisols, partly lithic phase)**, and - Imperfectly drained, shallow to moderately deep, dark grayish brown, acid humic peat, loam to clay with rock outcrops and ice in the highest parts **(Fibric Histosols; lithic phase with Umbric Andosols and Dystric Leptosols.)**
	MB (MV)	**Soils develop on olivine basalts and ashes and major older volcanoes**
2	**MBrp** (M4)	Well drained, moderately deep, dark reddish brown, friable and smeary clay loam, with humic topsoil **(Umbric Andosols)**
3	**MBrP** (M5)	Well drained, shallow to moderately deep, dark reddish brown to dark brown, friable, rocky and stony, clay loam **(Humic Cambisols, rocky and partly lithic phase)**
4	**MBbP** (M9)	Imperfectly drained, shallow to moderately deep, dark greyish brown, very friable, acid humic to peaty, loam to clay loam, with rock outcrops and ice in the highest parts **(Terric Histosols, lithic phase; with Lithosols, rock outcrops and ice)**

H HILLS AND MINOR SCARPS (slope predominantly over 16%)

	HV	**Soils developed on basic igneous rocks (serpentinites, basalts, nepheline phonolites, older basic tuffs included)**
5	**HVrP** (H1)	Somewhat excessively drained, shallow to moderately deep, dark reddish brown, friable, gravelly clay, with an acid humic topsoil **(Humic Cambisols, partly paralithic phase)**
	HU	**Soils developed on undifferentiated Basement System rock (predominantly gneisses)**
6	**HUrp** (H12)	Somewhat excessively drained, moderately deep, red, very friable, sandy clay loam to sandy clay; in places rocky **(Ferralic Cambisols; and Rhodic or Haplic Ferralsols and rock outcrops)**
7	**HUrP** (H13)	Somewhat excessively drained, shallow, reddish brown, friable, rocky or stony, sandy clay loam **(Eutric Regosols, lithic phase with rock outcrops and Calcic Cambisols)**
8	**HUC** (H15)	Complex of excessively drained to well drained, friable soils of varying depths, colours, stoniness, rockiness and boulderness **(Dystric Regosols, Lithic Leptosols, Chromic and Ferralic Cambisols)**

L PLATEAUS AND HIGH-LEVEL STRUCTURAL PLAINS (flat to gently undulating slopes in general less than 8%)

	LV	**Soils developed on Tertiary basic igneous rocks (olivine basalts, nepheline-phonolites; older, basic tuffs included)**
9	**LVr1** (L1)	Well drained, deep to extremely deep, dusky red, to dark reddish brown, friable to very friable clay; in places imperfectly drained, shallow, rocky bouldery and gravelly **(Rhodic Ferralsols and Humic / Rhodic Nitisols)**
10	**LVr2** (L2)	Well drained, very deep, dark reddish brown to dark brown, friable to firm clay; in places with humic topsoil **(Humic and Rhodic Nitisols)**
11	**LVbp** (L3)	Well drained, moderately deep to deep, dark brown, firm clay, with thick humic topsoil **(Luvic Phaeozems)**
12	**LVC1** (L4)	Complex of well drained, shallow to very deep, dark red, friable, clay; in many places rocky and bouldery **(Rhodic Ferralsols and Chromic Cambisols, lithic and/or bouldery phase)**
13	**LVd1** (L11)	Imperfectly drained, deep to very deep, dark greyish brown to black, firm to very firm, bouldery and stony, cracking clay; in places with a calcareous, slightly saline deeper subsoil **(Eutric, Dystric or Calcic Vertisols, stony phase and partly saline phase)**
14	**LVd2** (L12)	Imperfectly drained, deep, black to dark grey, very firm, cracking clay **(Eutric or Dystric Vertisols and Luvic Phaeozems)**
15	**LVC2** (L17)	complex of: Moderately well drained, shallow, yellowish red to dark yellowish brown, friable, gravelly clay over petroplinthite or rock (50-70%) **(Ironstone soils with Leptosols)** and: Poorly drained, deep to very deep, dark brown to very dark grayish brown, mottled, firm to very deep over petroplinthite **(undifferentiated Vertisols and Vertic Gleysols)** and: Imperfectly drained, deep to very deep, dark greyish brown to dark grey, firm to very firm, cracking clay **(Calcic and Eutric Vertisols)**
	LP	**Soils developed on ashes and other pyroclastic rocks of recent volcanoes**
16	**LPd** (L21)	Imperfectly drained, deep, very grayish brown, mottled, firm clay, abruptly underlying a thick topsoil of friable silty clay loam **(Eutric Planosols)**

R VOLCANIC FOOTRIDGES (dissected lower slopes of major older volcanoes and mountains; undulating to hilly)

	RV	**Soils developed on Tertiary basic igneous rocks (olivine basalts, nepheline phonolites, pyroclastic; older basic tuffs included)**
17	**RVr1** (R1)	Well drained, deep to extremely deep, dusky red to dark reddish brown to dark brown friable to very friable clay loam, to clay; in places with acid humic topsoil **(Humic Nitisols and Humic Mollic Andosols)**
18	**RVr2** (R2)	Well drained, deep to extremely deep, dusky red to dark reddish brown, friable clay; in places with acid humic topsoil **(Humic Rhodic Nitisols and Andosols)**
19	**RVC** (R3)	Complex of: Well drained, very deep, dark reddish brown to dark brown, friable to firm clay; in places with humic topsoil **(Rhodic and Humic Nitisols)** and; Imperfectly drained, very deep, dark grey to black, firm to very firm, bouldery and rocky cracking clay; in places calcareous, slightly saline deeper subsoil **(Eutric Vertisols, stony phase and partly saline phase, partly pisoferric and partly petroferric phase)**
20	**RVr/3** (R4)	Well drained, deep to extremely deep, dark reddish brown to dark brown, friable to firm, clay; in places with humic topsoil or gravelly **(Rhodic/Humic Nitisols, Chromic Cambisol and Luvic Phaeozems)**
21	**RVrP1** (R5)	Well drained, moderately deep to very deep, dark reddish brown, friable to firm, clay **(Ferric Luvisols; and Humic Nitisols)**
22	**RVrP2** (R7)	Well drained, moderately deep to deep, dark reddish brown, firm, cracking clay, with humic topsoil **(Luvic Phaeozems)**

F FOOTSLOPES (gently sloping to sloping; slopes 2-8%)

	FB	**Soils developed on colluvium from various volcanic rocks (mainly basalts)**
23	**FBr** (F7)	Well drained, deep to very deep, reddish brown, friable clay, with acid humic topsoil **(Humic Acrisols)**
	FU	**Soils developed on colluvium from undifferentiated Basement System rocks (predominantly gneisses)**
24	**FUC** (F13)	Complex of: Somewhat excessively drained to well drained soils of varying depths, colour, consistence, rockiness, stoniness and texture **(Chromic Luvisols, Eutric Cambisols, Eutric Regosols and Lithic Leptosols partly lithic and stony phase)**
25	**Fur** (F16)	Well drained, deep red to very deep, dark red to dark yellowish red friable to very friable, sandy loam to clay; in places coarse textured, gravelly and stratified **(Rhodic Ferralsols, Chromic Luvisols and Ferralic Arenosols)**

U UPLANDS

	Um	**LOWER MIDDLE-LEVEL UPLANDS** (usually undulating; altitudes 1000-2000 meter; about 500 meter above level)
	UF	**Soils developed on Basement System rocks rich in ferromagnesian minerals**
26	**UFr** (Um15)	Well drained, deep to very deep, dark red to yellowish red, friable to firm (compact), clay **(Rhodic Nitisols and Rhodic Ferralsols)**
	UN	**Soil developed on biotite gneisses**
27	**UNr/bp** (Um17)	Well drained, moderately deep to deep, dark reddish brown to brown, friable to firm, sandy clay loam to clay; in places with an acid humic topsoil **(Ferrali-Orthic Acrisols; with Dystric and Humic Cambisols and Humic Acrisols)**
	UU	**Soils developed on undifferentiated Basement rocks (predominantly gneisses)**
28	**UUrp1** (Um19)	Well drained, moderately deep to very deep, dark reddish brown to dark yellowish brown, friable to firm, sandy clay to clay; in many places with a topsoil of loamy sand to sandy loam **(Ferrali-Chromic/Haplic /Ferric Acrisols; with Luvisols and Ferralsols)**
29	**UUrp2** (Um20)	Well drained, moderately deep to deep dark red to yellowish red, friable sandy clay loam to clay **(Rhodic and Haplic Ferralsols; with Ferrali-Chromic/ Orthi-Ferric Acrisols)**
30	**UUrp3** (Um21)	Well drained, moderately deep to deep, dark red to yellowish red, friable to firm, sandy clay to clay, often with a topsoil of loamy sand **(Chromic Luvisols and Ferrali-Chromic/Haplic/ Ferric Luvisols)**
	Ux	**UPLANDS, UNDIFFERENTIATED LEVELS** (undulating to rolling; altitudes and base level variable)
	UP	**Soils developed on pyroclastic rocks**
31	**UPr/b** (Ux4)	Well drained, very deep, dark reddish brown to dark brown, very friable and smeary, silty clay loam, with a humic topsoil **(Mollic Andosols)**
	UU	**Soils developed undifferentiated volcanic rocks (mainly basalts)**
32	**UUr/b** (Ux5)	Well drained, very deep dark reddish brown to very dark grayish brown, friable and slightly smeary clay, with a humic topsoil **(Ando-Luvic Phaeozems)**
	Up	**UPLANDS/HIGH-LEVEL PLAIN TRANSITIONAL LANDS** (gently undulating; altitude 1500-2100 m)
	UF	**Soils developed on gneisses rich in ferromagnesian minerals**
33	**UFC** (Up4)	complex of: Well to imperfectly drained, shallow to very deep, dark red to black, friable or friable to firm, cracking clay; in places sodic. **(Pellic Vertisols; with Verti-Eutric Nitisols, Verti-Eutric Planosols and Haplic Solonetz, partly lithic phase)**

P PLAINS

	Pn	**NON-DISSECTED EROSIONAL PLAINS**
	PnB	**Soils developed on basic igneous rocks (basalts, etc.)**
34	**PnBr** (Pn1)	Well drained, very deep, dark reddish brown to dusky red, friable clay; in places bouldery **(Niti-Rhodic Ferralsols)**
35	**PnBrP** (Pn2)	Well drained, shallow, very dark reddish brown, friable slightly calcareous, stony and bouldery, clay loam to clay **(Chromic Cambisols, lithic and bouldery phase)**
	PU	**Soils developed on undifferentiated Basement System rocks (predominantly gneisses)**
36	**PnUr/bp** (Pn13)	Well drained moderately deep to deep, dark red to strong brown, friable to firm, sandy clay loam to clay **(Ferric and Chromic Luvisols)**
	Pd	**DISSECTED EROSIONAL PLAINS**
	PdU	**Soils developed on undifferentiated Basement system rocks (predominantly gneisses)**
37	**PdUC1** (Pd3)	Well drained, shallow, dark red to yellowish red, friable to firm, rocky, stony gravelly loamy sand to sandy clay **(Chromic Cambisols, paralithic and stony phase; Lithic Leptosols, Dystrict Regosols, lithic and stony phase and Ferralic Arenosols, lithic phase)**
38	**PdUC2** (Pd4)	Complex of: Well drained, shallow to moderately deep, dark red to yellowish brown, non to moderately calcareous, friable to firm, stony sandy clay loam over petrocalcic material or quartz gravel **(Calcic Cambisols, lithic or petrocalcic phase; with Chromic Luvisols)**

A FLOOD PLAINS

	AA	**Soils developed on alluvium mainly from undifferentiated Basement System rocks (predominantly gneisses)**
39	**AAb** (A5)	Well drained to imperfectly drained, very deep, brown to dark brown, friable, micaceous, slightly calcareous, sandy loam to clay loam; in places with a saline-sodic deeper subsoil **(Eutric Fluvisols)**

B BOTTOM LANDS

	BA	**Soils developed on alluvium and colluvium from undifferentiated volcanic rocks**
40	**BAdck** (B6)	Poorly drained, deep very dark grayish brown, firm, moderately to strongly calcareous, slightly sodic clay, with a humic topsoil **(Calcic Chernozems, sodic phase)**

Annex 2 Harmonised legend based on reconnaissance surveys (scale 1:100,000)

This harmonized legend is a result of the combination of several legends. For the Upper Tana basin these are the soil maps of Kindaruma (KSS 1975), Chuka-Nkubu (KSS 2000) and Murang'a (KSS 2007a, b, c). In the harmonised legend, the criteria of the legend of the Exploratory Soil Map of Kenya (KSS 1982) are followed and the legend for the Upper Tana 1:250,000; see Annex 1. However, because of the higher resolution of maps at scale 1:100,000, much more detail can be shown and this is reflected in more subdivisions. A number follows the legend code, which is the new SOTER unit_ID (SUID) for the Upper Tana SOTER database. The code in brackets indicates the original code in one of the sources.

Key: M = Murang'a; C = Chuka-Nkubu; K = Kindaruma[9]

M MOUNTAINS AND MAJOR SCARPS (relief intensity over 300m, slopes over 30%)

	MV	**SOTER unit _ID**	**Soils developed on various igneous rocks**
1	**MVP**	489	Imperfectly drained, shallow to moderately deep, dark greyish brown, acid humic peat, loam to clay with rock outcrops and ice in the highest parts **(Fibric Histosols; lithic phase with Umbric Andosols and Dystric Leptosols) (1M)**
2	**MVr**	490	Well drained, very deep, dark reddish brown, friable to very friable, smeary clay loam to clay, with a thick humic acid topsoil; in places shallow to moderately deep and rocky **(Umbric Andosols, Niti-Umbric and Niti- Orthic Andosols) (2M)**
	MB		**Soils developed on gabbros and gabbro-norites**
3	**MBP**	421	Somewhat excessively drained, shallow to moderately deep, dark reddish brown, friable, rocky and stony sandy loam to clay loam. **(Lithosols, Eutric Regosols, partly lithic and stony phases) (3C)**
	MQ		**Soils developed on granitoid gneisses and migmatites**
4	**MQP (XB)**	397	Somewhat excessively drained, predominantly very shallow to shallow and rocky **(Dystric Lithosols/Regosols) (1K)**
5	**MQC**	422	Complex of somewhat excessively drained to well drained, reddish brown to brown soils of varying depth, consistence, rockiness, stoniness and texture. **(Lithosols, Eutric Regosols, Eutric Cambisols and Haplic Luvisols, partly lithic and stony phases) (1C)**

[9] Refers to the original code in the source report, See Appendix 3, original legend number and SOTER identification number.

H HILLS AND MINOR SCARPS (relief intensity 100-300m, slopes 8-30%)

	HG		**Soils developed on granites**
6	HGP	423	Well drained, shallow to moderately deep, red to dark reddish brown, friable, clay loam to clay; in places fairly rocky and stony **(Dystric Cambisols and Humic Acrisols; partly petroferric and stony phases) (4C)**
	HI		**Soils developed on nepheline phonolites**
7	HIp	425	Well drained, moderately deep to deep, red to dark reddish brown, friable, sandy clay loam to clay; in places fairly rocky and stony **(Dystric Cambisols and Chromic* Acrisols; partly stony phase) (9C)**
	HB		**Soils developed on gabbros, gabbro-norites and basalts**
8	HBP1	424	Somewhat excessively drained, shallow, dark red to dark reddish brown, rocky, stony, sandy clay loam to clay **(Lithosols and Eutric Cambisols, lithic and stony phases) (6C)**
9	HBP2	426	Well drained, shallow to moderately deep, dark yellowish brown, friable, clay loam to clay; in places rocky and stony **(7C)**
10	HBC	427	Complex of somewhat excessively drained, shallow to moderately deep, dark reddish brown, friable, sandy clay loam to clay; in places fairly rocky and stony **(Lithosols, Eutric and Calcaric Regosols; lithic and partly stony phases) (8C)**
	HV		**Soils developed on various volcanic rocks**
146	HVP	428	Well drained, shallow, dark reddish brown, fairly rocky and very stony, gravelly, clay loam to clay **(Nitisols and Eutric Regosols, partly stony phase) (73C)**
	HP		**Soils developed on consolidated pyroclastic rocks (lahar complex)**
11	HPC	429	Complex of well drained, dark red to brown, friable clay soils of varying depth; with acid humic topsoil **(Chromic and Haplic Acrisols; partly stony phase) (10C)**
	HN		**Soils developed on biotite gneisses**
12	HNp	491	Excessively drained, moderately deep to deep, yellowish red, rocky and bouldery gravelly clay to clay **(Rudic-Chromic Cambisols and Lithic Leptosols) (5M)**
	HQ		**Soils developed on granitoid gneisses and migmatites**
13	HQP	492	Excessively drained, shallow to deep, yellowish red to dark reddish brown, friable, rocky, and bouldery sandy clay to clay **(Rudi- Chromic Cambisols) (6M)**
14	HQP (xB)	398	Excessively drained very shallow to shallow and rocky **(Dystric Lithic/Regosols) (2K)**
15	HQC	430	Complex of somewhat excessively drained, dark reddish brown to strong brown, friable soils of varying depth, rockiness, stoniness and texture **(Lithosols, Eutric Regosols, Eutric Cambisols and Chromic Luvisols; partly lithic and stony phases) (3C)**
	HU		**Soils developed on various metamorphic rocks (mainly gneisses)**
16	HUC	431	Complex of well drained, dark reddish brown to brown, gravely soils of varying depth, consistence, rockiness, stoniness and texture. **(Lithosols, Eutric Regosols and Eutric and Dystric Cambisols, partly lithic and stony phases) (5C)**

R VOLCANIC FOOTRIDGES

R1 MOUNT KENYA FOREST LEVEL (relief intensity 8—200m, slopes 10-30%, altitude over 2000m).

	R1P		**Soils developed on pyroclastic rocks (lahar complex, tuffs and volcanic ashes)**
17	**R1Pr1** (RPr1)	493	Well drained, deep to extremely deep, dark reddish brown, friable clay loam to clay **(Umbric Andosols and Andi-Humic Nitisols) (9M)**
18	**R1Pr2** (RPr2)	494	Well drained, deep to very deep, dusky red to dark brown, friable to firm, silty clay to clay **(Haplic Andosols, Niti-Mollic Andosols and Andic-Humic Nitisols) (10M)**
19	**R1PC**	432	Complex of well drained, deep to very deep, dark yellowish brown to brown, friable, silty clay loam to clay; in places smeary **(Dystric and Ando-Cumulic Nitosols*, Humic Andosols and Humic Cambisols) (11C)**
	R1V		**Soils developed on various igneous rocks**
20	**R1Vr1** (RVr)	495	Well drained, very deep to extremely deep dusky red to,dark reddish brown, friable to very friable, smeary, clay loam to clay **(Andi-humic Nitisols and Mollic Andosols) (14M)**
21	**R1Vbp** (R1V)	433	Well drained, moderately deep to deep, dark yellowish brown to brown, friable, loam to clay loam, with 20-30cm acid humic topsoil; in places smeary **(Humic Cambisols and Humic Andosols; partly lithic phase) (12C)**

R2 KIONYO LEVEL (relief intensity 30-100m, slopes 3-30%, altitude 1600-2000m)

	R2B1		**Soils developed on basalts**
22	**R2Br** (RB2r)	496	Well drained, very deep to extremely deep, dark red to dark reddish brown, friable to firm, clay **(Umbric and Niti-Umbric Andosols, and Rhodic Nitisols) (8M)**
	R2P		**Soil developed on pyroclastic rocks (lahar complex, volcanic ashes and tuffs)**
23	**R2Pr1** (RPr3)	497	Well drained, deep to extremely deep, red to dark reddish brown, silty clay to clay **(Mollic Andosols and Andi-humic Nitisols) (11M)**
24	**R2Pb**	434	Well drained, deep to very deep, yellowish red to dark brown, friable and smeary, loam to clay loam; with 20-30cm acid humic topsoil **(Humic Andosols) (15C)**
25	**R2Pbp**	435	Well drained, moderately deep to deep, dark yellowish brown to dark brown, friable, silt loam to clay loam; with 20-30cm acid humic topsoil; in places fairly rocky and stony or smeary **(Humic Andosols and Humic Cambisols, partly stony phase) (16C)**
26	**R2Pr2** (Pr4)	498	Well drained, very deep to extremely deep, red to dark reddish brown, friable to firm, clay loam to clay **(Andi-Humic Nitisols) (12M)**
27	**R2Pr3** (R2Pr1)	436	Well drained, very deep, dark red to dark reddish brown, friable clay; with 20-30cm humic topsoil **(Humic Nitisols*1) (13C)**
28	**R2Pr4** (R2Pr2)	437	Well drained, deep to very deep, red to dark reddish brown, friable clay; in places with 20-30cm humic topsoil **(Humic Nitosols* and Haplic Acrisols) (14C)**
	R2V		**Soils developed on various igneous rocks (mainly tuffs and nepheline phonolites)**
29	**R2Vr1** (RVr2)	499	Well drained, very deep to extremely deep, dusky red dark reddish brown, friable to firm, clay loam to clay **(Mollic and Niti-Mollic Andosols, and Andi-Humic Nitisols) (15M)**
30	**R2Vr2** (R2Vr)	438	Well drained, very deep, red to dark reddish brown, friable to firm clay **(Dystric Nitisols*) (17C)**

R3 CHOGORIA LEVEL (relief intensity 10-80, slopes 5-25%, altitude 1200-1700m)

	R3B		**Soils developed on basalts**
31	**R3Br1** (RB1r)	500	Well drained, deep to extremely deep, dark red to dark reddish brown, friable to firm, clay; in places eroded and shallow to moderately deep **(Humic, Rhodic, Andic-Humic and Andi-Rhodic Nitisols) (7M)**
32	**R3Br2** (R3Br)	439	Well drained, very deep, red to dark reddish brown, friable to firm clay; with about 20cm acid humic top soil. **(Dystric and Humic Nitisols*) (18C)**
	R3P		**Soils developed on consolidated/pyroclastic rocks (rahar complex)**
33	**R3Pr1** (RPr5)	501	Well drained, very deep to extremely deep, red to dark reddish brown, friable to firm clay **(Niti-Molic and Niti-Umbric Andosols, and Rhodic Nitisols) (13M)**
34	**R3Pr2**	522	Well drained, very deep, dark red to dark reddish brown, friable clay; with humic topsoil **(Humic Nitisols*) (21C)**
35	**R3Pr3**	441	Well drained, deep to very deep, dark reddish brown, friable clay; in places with about 20cm humic topsoil **(Humic Nitisols* and Haplic Acrisols) (22C)**
	R3V		**Soils developed on various igneous rocks**
36	**R3Vr**	442	Well drained, very deep, dark red, friable to firm clay; with about 20cm of humic topsoil **(Humic Nitisols*) 23(C)**
	R3I		**Soils developed on nepheline phonolites**
37	**R3Ir**	440	Well drained, very deep, red to dark reddish brown, friable to firm clay; with about 20cm humic topsoil **(Humic Nitisols*) (19C)**
38	**R3IP**	443	Well drained, shallow to moderately deep, dark reddish brown, fairly rocky and stony, gravely clay **(Humic Cambisols, partly stony phase and Leptosols (20C)**

F FOOTSLOPES (relief intensity less than 100m, slopes 5 – 16%)

	FN		**Soils developed on biotite gneisses**
39	**FNC**	502	Complex of well drained to imperfectly drained, deep to very deep, dusky red to very dark grey, friable to firm, clay loam to clay; **(Rhodic Ferralsols, Ferrali-Orthic Acrisols, Ferralic Cambisols, and Ferralic Arenosols and Gleyic Solonetz) (16M)**
	FQ		**Soils developed on granitoid gneisses**
40	**FQC**	503	Complex of excessively drained to moderately well drained, moderately deep to deep, dark red to dark grey, loose to friable, sandy loam to clay; in places stony, rocky and bouldery **(Rhodic Ferralsols, Ferrali-Orthic Lixisols and Acrisols, Solonetz Chromic Cambisols and Ferralic Arenosols.) (17M)**
	FU		**Soils developed on undifferentiated metamorphic rocks**
41	**FUp**	444	Well drained to moderately well drained, moderately deep to deep, dark reddish brown to dark brown, loose to friable, sand to sandy clay loam **(Eutric Cambisols and Albic Arenosols) (25C)**
42	**FUP**	445	Well drained, shallow to moderately deep, red to dark reddish brown, friable, sandy loam to sandy clay loam; in places rocky and stony **(Leptosols and Chromic Cambisols, partly lithic and stony phases) (24C)**

	FV		**Soils developed on various igneous rocks**
43	**FVp**	446	Well drained, moderately deep to deep, reddish brown, friable, clay loam to clay; in places fairly rocky and stony **(Eutric Regosols and Chromic Cambisols, partly stony phase) (26C)**
	FX		**Soils developed on various rocks**
44	**FXC**	447	Complex of: - Somewhat excessively drained, shallow to moderately deep, dark red to dark reddish brown, friable sandy clay loam; in places rocky and stony **(Lithosols and Chromic Cambisols; partly Lithic and stony phases)**, and: - Somewhat excessively drained, shallow, dark red to dark reddish brown, friable, clay loam to clay **(Eutric Regosols and Chromic and Humic Cambisols, Lithic phase)** and: - Well drained, moderately deep to deep, very dark brown, friable to firm clay; in places slightly rocky and slightly stony **(Humic Cambisols, stony phase)(27C)**

L PLATEAUS

	Ld		**DISSECTED PLATEAUS** (relief intensity less than 30m, slopes 0-12%)
	LdB		**Soils developed on basalts of Mt. Kenya series**
45	**LdBr**	445	Well drained, deep to very deep, red to dark reddish brown, friable to frim, clay loam to clay; in places stony and gravely **(Humic Nitisols and Ferric Acrisols; partly pisoferric phase) (31C)**
	LdV		**Soils developed on various igneous rocks**
46	**LdVr**	449	Well drained, deep to very deep, dark reddish brown, friable to firm clay **(Luvic Phaeozems and Mollic Nitisols*) (32)C**
	Ln		**NON-DISSECTED PLATEAUS** (relief intensity less than 50m, slopes 0-8%)
	Lnl		**Soils developed on nepheline phonolite**
47	**LnlC**	450	Complex of well drained, dark reddish brown, friable, very gravely, sandy clay loam to sandy clay soils of varying depth, rockiness and stoniness **(Dystric Cambisols and Lithosols; stony phase) (28C)**
	LnP		**Soils developed on consolidated pyroclastic rocks**
48	**LnPr**	451	Well drained to moderately well drained; very deep, dark reddish brown, friable clay **(Humic, Chromic and Ferric Acrisols) (29C)**
49	**LnPC**	452	Complex of excessively drained, dark reddish brown to brown, very gravely, sandy clay loam to sandy clay soils of varying depth, consistence, rockiness and stoniness **(Dystric Cambisols, Pisoferric and partly lithic and stony phases and Lithosols) (30C)**

U UPLANDS

	U1		**HIGH LEVEL** (relief intensity less than 50m, slopes 0-16%, altitude over 900m)
	U1I		**Soil developed on intermediate and basic igneous rocks (phonolites, trachytes and nepheline phonolites)**
50	**U1Ir**	453	Well drained, very deep, dark red to dark reddish brown, friable firm clay **(Mollic Nitisols*) (34C)**
	U1I		**Soils developed on intermediate igneous rocks (phonolites, trachytes and trachytic agglomerates)**
51	**U1Ir1** (UIr1)	504	Well drained, very deep to extremely deep, dusky red to dark reddish brown, friable clay **(Rhodic and Niti-Rhodic Ferralsols).(20M)**
52	**U1Ir2** (UIr2)	505	Well drained, to moderately well drained, deep to extremely deep, dark red to dark reddish brown, friable to firm, clay; in places rocky and stony **(Rhodic Nitisols, Rudic-Stagnic and Plinthic Alisols and Ferralic Cambisols) (21M)**
	U1B		**Soils developed on basalts**
53	**U1Br1** (UBIr)	506	Well drained deep to xtremely deep, dusky red to dark reddish brown, friable, clay loam to clay **(Rhodic Nitisols, Ferral-Rhodic Nitisols and Niti-Rhodic Ferralsols). (18M)**
54	**U1Br2** (U1Br)	454	Well drained, very deep, dark red to dark reddish brown, friable to firm clay **(Mollic Nitisols* and Luvic Phaezems) (33C)**
55	**U1Br3**(UB2r)	523	Well drained, deep to very deep, dusky red to dark red, friable clay loam to clay **(Rhodic Ferralsols and Ferrali-Orthic Acrisols) (19M)**
56	**UIBr4** (VOr)	399	Well drained, deep to moderately deep, reddish brown, friable to very friable, clay **(Dystric Nitisols) (5K)**
57	**U1Bd** (VOd)	400	Imperfectly drained, deep, black, firm, cracking, moderately calcareous, clay **(Pellic Vertisols) (6K)**
	U1V		**Soils developed on various igneous rocks**
58	**U1Vr**	455	Well drained, very deep, dark red to dark reddish brown, friable to firm clay; in places with 20-30cm humic topsoil **(Mollic and Humic Nitisols*) (36C)**
59	**U1VrP**	456	Well drained, shallow to moderately deep, dark red to dark reddish brown, friable, sandy clay loam to clay **(Luvic and Haplic Phaeozems, Chromic Acrisols and Dystric Cambisols; partly lithic phase) (37C)**
	U1P		**Soils developed on pyroclastic rocks**
60	**U1Pr** (UPr)	507	Well drained, deep to extremely deep, dusky red to dark reddish brown, friable clay **(Rhodic Nitisols and Rhodic Ferralsols) (22M)**
61	**U1Prp** (VKbm	401	Well drained, moderately deep, dark reddish brown, friable, clay over petro plinthite (murram) **(Haplic Ferralsols, petroferric phase) (4K)**
62	**U1PP** (UPP)	508	Well drained to moderately well drained, shallow to very deep, dark yellowish brown to dark greyish brown, friable to very firm, gravelly clay **(Ferral-Rhodic Nitisols, Dystric Planosols Eutric Plinthosols and Gleyic Solonetz, sodic phase) (23M)**
63	**U1PC1** (UPC)	509	Complex of well drained to imperfectly drained, shallow to extremely deep, dark red to very dark greyish brown, friable to firm, gravelly sandy clay to clay, in places rocky and bouldery **(Ferral-Rhodic Nitisols, Acri-Rhodic Ferralsols, sodic phase, Gleyic Solonetz, Ferric Cambisols, Plinthic Alisols, Eutric Gleysols and Dystric Planosols, sodic phase) (24M)**
64	**U1PC2**	457	Complex of somewhat excessively drained to well drained, dark reddish brown to brown, gravely sandy clay soils of varying depth, consistence, rockiness and stoniness **(Lithosols, Ferric Acrisols and Dystric Cambisols, partly lithic and stony phases) (35C)**

	U1F		**Soils developed on fine textured Basement System rocks rich in ferro-magnesium minerals**
65	**U1Frc** (BFrc)	241	Well drained, deep, dark red, friable to firm (compact), clay **(Eutric Nitosols) (21K)**
66	**U1Frcp** (BFrcp)	402	Like U1Frc but moderately deep **(Eutric Nitosols) (22K)**
67	**U1FrcP** (BFrcP)	403	Like U1Frc but very shallow to shallow and stony **(Eutric Nitosols, lithic phase) (23K)**
68	**U1Fd** (BFd)	232	Imperfectly drained, deep, black, firm, cracking, moderately calcareous, clay **(Pellic Vertisols) (24K)**
69	**U1FdP** (BFdP)	404	Like U1Fd but very shallow to shallow, gravelly/stony and strongly calcareous, clay **(Pellic Vertisols, lithic phase) (25K)**
70	**U1Frcp / U1 FrcP** (BFrcp-BFrcP)	405	Complex of: Well drained, moderately deep, dark red, friable to firm (compact), clay and; well drained, very shallow to shallow, dark red, stony, clay **(31K)**
71	**U1FcP-U1FdP** (BFrcP-BFdP)	406	Complex of: Well drained, very shallow to shallow, dark red, stony, clay and; imperfectly drained, very shallow to shallow, black, cracking, gravely/stony, strongly calcareous, clay **(32K)**
	U1L		**Soils developed on crystalline limestone of Basement System rocks**
72	**U1LP** (BL1P)	419	Well drained, very shallow, very dark grey, stony, strongly calcareous, sandy clay loam **(Orthic Rendzina).(9K)**
	U1N		**Soils developed on biotite gneisses**
73	**U1Nr** (UNr)	510	Well drained, deep to extremely deep, dusky red to dark reddish brown, friable clay loam to clay **(Rhodic Ferralsols and Niti-Rhodic Ferralsols, sodic phase) (25M)**
74	**U1NP** (UNP)	511	Well drained, shallow to moderately deep, yellowish red to reddish brown, friable, gravelly clay to clay; in places rocky and bouldery **(Chromic and Ferralic Cambisols) (26M)**
	U1Q		**Soils developed on quartz rich Basement System rocks; predominantly granitoid gneises**
75	**U1Q** (BQ1)	25	Well drained, in places imperfectly drained, deep, yellowish red to reddish brown, loose, sand to loamy sand **(Ferralic Albic Arenosols) (7K)**
76	**U1QP1** (UQP)	512	Well drained, shallow to moderately deep, yellowish red to reddish brown, friable, rocky, bouldery, gravelly clay to clay **(Rhodic and Niti-Rhodic Ferralsols, sodic phase and Chromic Cambisols) (27M)**
77	**U1Q1P2** (BQ1P)	533	Like U1Q (BQ1) but very shallow and stony **(Ferralic Arenosols, lithic phase) (8K)**
	U1U		**Soils developed on undifferentiated Basement System metamorphic rocks; predominantly banded gneisses**
78	**U1Ur** (BUr)	535 or 534	Well drained, deep, dark red, very friable to friable, clay **(Rhodic*Ferralsols) (10K)**
79	**U1Urp** (BUrp)	407	Like U1Ur but moderately deep **(Rhodic*Ferralsols) (11K)**
80	**U1Ub** (BUb)	238	Well drained, deep, yellowish red to dark reddish brown, friable, sandy clay loam to sandy clay **(Haplic Ferralsols (12K)**
81	**U1Urc** (BUrc 1)	408	Well drained, deep, dark red to dark reddish brown, friable to firm (compact), clay **(Ferral*Chromic Luvisols) (13K)**
82	**U1Ub c1** (Bub c1)	409	Moderately well drained, deep, yellowish red to dark reddish brown, friable to firm (compact), fine sandy clay with topsoil of sandy loam **(Ferral*Ferric Acrisols) (17K)**
83	**U1Ubc2m** (BUbc2m)	410	Well drained, moderately deep, dark reddish brown, friable to firm (compact), sandy clay loam to sandy clay over petroplinthite (murram)/rock **(Ferrali Orthic Acrisols, petroferric phase) (18K)**

85	**U1Ur c2** (Bur c2)	10	Well drained, deep, yellowish red to dark red, friable to firm (compact), clay **(Acri*Orthic Ferralsols) (14K)**
86	**U1UP** (BUP)	420	Well drained, very shallow to shallow, yellowish red, dark reddish brown to dark red, stony, sandy clay loam to clay **(Chromic Cambisols, lithic phase) (20K)**
	U1X		**Soils developed on various rocks**
87	**U1Xrp** (U1X rp)	458	Well drained, moderately deep, yellowish red to dark reddish brown, friable, sandy clay loam to sandy clay, in places rocky and stony **(Ferric Acrisols, and Chromic Luvisols; stony phases) (38C)**
	U2		**LOW LEVEL** (relief intensity less than 50m, slopes 0-16%, altitudes < 900m)
	U2B		**Soils developed on basalts**
88	**U2Br1** (U2B r1)	459	Well drained, very deep, red to dark reddish brown, friable clay **(Mollic Nitisols*) (49C)**
89	**U2Br2** (U2B r2)	460	Well drained, very deep, dusky red to dark reddish brown, friable, clay loam to clay **(Acri*-Rhodic Ferralsols) (50C)**
90	**U2BP** (U2BP	461	Well drained, shallow to moderately deep, dark reddish brown to dark brown, friable, gravely, clay loam to clay **(Chromic and Eutric Cambisols, partly lithic or pisoferric phase) (51C)**
	U2F		**Soils developed on hornblende and biotite gneisses**
91	**U2Fr** (U2Fr)	462	Well drained, deep to very deep, dark red to dark reddish brown, friable, sandy clay to clay; in places **(Haplic and Chromic Luvisols) (42C)**
92	**U2Fr2** (U2Fr)	462?	Well drained, moderately deep, dark red to dark brown, friable to firm, sandy clay loam to clay; in places rocky, stony, gravely and/or calcareous **(Haplic and Chromic Luvisols and Calcic Cambisols; partly petroferric, lithic and stony phases) (44C)**
93	**U2Frp** (U2Frp	463	Well drained, moderately deep, dark red to dark reddish brown, friable, sandy clay to clay; in places gravely **(Haplic and Chromic Luvisols) (43C)**
94	**U2FrP** (U2FrP	464	Well drained shallow, red to dark reddish brown, friable, sandy loam to sandy clay loam; in places fairly rocky and stony **(Chromic Luvisols, partly Lithic and stony phases and Lithosols) (45C)**
95	**U2FC** (U2FC)	465	Complex of: - Well drained, moderately deep to deep, dark red to dark reddish brown, friable, clay loam to clay; in places fairly rocky and stony **(Haplic and Chromic Luvisols, partly stony phase)**, and: - Well drained, moderately deep to deep, dark red to dark reddish brown, friable to firm clay loam to clay; in places over pisoferric or pisocalcic material **(Haplic, Chromic and Calcic Luvisols, partly pisocalcic phase and Ferric Acrisols, pisoferric phase)**, and: - Well drained, shallow to moderately deep, dark red to strong brown, gravely, clay loam to clay; in places rocky in very rocky and stony to very stony **(Eutric Cambisols and Haplic Luvisols, partly lithic and stony phases and Lithosols) (46C)**
	U2Q		**Soils developed on granitoid gneisses and migmatites**
96	**U2Qp** (U2Qp)	466	Well drained, moderately deep, dark reddish brown, friable, gravelly, clay loam to sandy clay **(Chromic Luvisols, partly lithic phase) (39C)**
97	**U2QP** (U2QP)	467	Well drained, shallow, dark reddish brown, stony and gravely, clay loam to clay; in places rocky **(Chromic Luvisols, stony phase and partly lithic phase and Leptosols) (40C)**
98	**U2QC** (U2QC)	468	Complex of: Well drained, moderately deep to deep, red to dark reddish brown, fairly rocky and stony, ravelly,clay loam to clay **(Haplic and Chromic Luvisols, stony phases)**, and: Well drained, shallow to moderately deep, red to dark reddish brown, rocky to very rocky, stony to very stony, gravely, sandy clay loam to clay **(Eutric Regosols and Haplic Luvisols, lithic and stony phase) (41C)**

	U2U		**Soils developed on undifferentiated Basement System rocks; predominantly banded gneisses**
99	**U2Urc** (BUrc3	235	Well drained, deep, dark reddish brown, friable to firm (compact), clay to fine sandy clay **(Ferral*Chromic*Acrisols) (15K)**
100	**U2Urcp** (BUrc3p)	411	Like U2Urc but moderately deep **(Ferral*Chromic* Acrisols) (16K)**
101	**U2Ur** (BUra)	234	Well drained, deep, dark red to dark reddish brown, firm compact sandy clay with topsoil of loamy sand **(Chromic Luvisols) (19K)**
102	**U2Urp** (Bur ap)	412	Like U2Ur but moderately deep **(Chromic Luvisols) (40K)**
	U2U		**Soils developed on undifferentiated metamorphic rocks**
144	**U2Urp**	469	Well drained, moderately deep to deep, red to reddish brown, friable, slightly rocky to rocky, stony, sandy clay **(Chromic Luvisols, partly lithic and stony phases) (47C)**
103	**U2Urc** (Bur c2p)	525? or 10	Like U1Urc2 but moderately deep **(Acri*Orthic Ferralsols) (38K)**
104	**U2Ubc1p** (Bub c1p)	413	Like 82 U1Ub (BUbc1) but moderately deep **(Ferral*Ferric Acrisols) (39K)**
145	**U2UC**	470	Complex of: Well drained, deep, red to dark reddish brown, friable, slightly rocky, slightly stony, clay loam to clay **(Chromic Luvisols)**, and: Well drained, moderately deep to deep, red to dark reddish brown, friable to firm, fairly rocky, stony, gravely, clay loam to clay; in places over pisocalcic material **(Chromic and Chromo*-Calcic Luvisols, stony and partly pisocalcic phases)**, and: Well drained, shallow, dark reddish brown, friable, very rocky, very stony, gravely, sandy loam to sandy clay loam **(Lithosols and Eutric and Dystric Regosols, lithic and stony phases)(48C)**
	Complex of two mapping units		
105	**U1Ur-U1Ub** (BUr-BUb)	526	Well drained, deep, dark red, very friable to friable, clay and; well drained, deep, yellowish red to dark reddish brown, friable, sandy clay loam to sandy clay **(26K)**
106	**U1Urc2-U1Q** (BUrc2-BQ1)	527	Well drained, deep, yellowish red to dark red, friable to firm (compact), clay and; well drained, deep, yellowish red to reddish brown, loose, sand to loamy sand **(27K)**
107	**U2Urp-U1UP** (Bur ap-BUP)	528	Well drained, moderately deep, dark red to dark reddish brown, firm (compact), sandy clay with topsoil of loamy sand and; well drained, very shallow to shallow, yellowish red, dark reddish brown to dark red, stony, sandy clay loam to clay **(28K)**
108	**U1UP-U1Q 1P** (BUP-BQ1P)	529	Well drained, very shallow to shallow, yellowish red, dark reddish brown to dark red, stony, sandy clay loam to clay and; well drained, in places imperfectly drained, very shallow to shallow, yellowish red to reddish brown, stony, sand to loamy sand **(29K)**
	U2X		**Soils developed on various rocks**
109	**U2Xrp**	471	Well drained, moderately deep, red to dark red, friable clay loam to clay **(Chromic Luvisols, petric phase) (52C)**
110	**U2XA**	472	Association of soils of unit **U2Xrp**: Well drained, moderately deep to deep, dark reddish brown to dark greyish brown, calcareous, friable to firm, slightly gravely, sandy clay to clay **(Vertic and Calcic Luvisols) (53C)**
111	**U2XC**	473	Complex of: Well drained, moderately deep to deep, red to dark reddish brown, friable, slightly rocky, stony, clay loam to clay **(Chromic Luvisols and Haplic Acrisols, stony phase)**, and: Well drained, shallow, dark reddish brown, bouldery, very stony, gravely, sandy loam to clay loam; in places over petroplinthite (murram) **(Eutric Regosols and Dystric and Eutric Cambisols; partly lithic, petrofrerric and stony phases (54C)**

P PLAINS

	Pn		**NON-DISSECTED PLAINS (relief intensity less than 10 m, slopes 0-2%)**
	PnI		**Soils developed on intermediate igneous rocks (predominantly phonolites)**
112	**PnId (PId)**	513	Imperfectly drained to poorly drained, deep to very deep, grey to black, friable to firm, clay **(Calcic and Eutric Vertisols, inundic and gilgai phases, Mollic Gleysols and Mollic Planosols, pisoferric phase) (30M)**
	PnB		**Soils developed on basalts of Mt. Kenya and Nyambene series**
113	**PnBr1**	474	Well drained, very deep, red to reddish brown, friable clay **(Humic and Dystric Nitisols*) (55C)**
114	**PnBr2**	475	Well drained, very deep, dusky red to dark reddish brown, friable, clay loam to clay **(Acri*-Rhodic Ferralsols) (56C)**
115	**PnBrp**	476	Well drained, moderately deep to deep, dark red to dark reddish brown, friable, gravely, clay loam to clay; over pistoferric material (murram) **(Chromic Acrisols, pisoferric and petric phases) (57C)**
116	**PnBbP1**	477	Well drained, shallow to moderately deep, brown to dark greyish brown, friable, clay loam to clay, over pisoferric material or petroplinthite (murram) **(Haplic Acrisols and Ferric Cambisols, pisoferric phase and partly lithic or petroferric phases) (58C)**
117	**PnBbP2**	478	Well drained, shallow, dark reddish brown to very dark brown, gravely, clay loam to clay; over pisoferric material (murram) **(Dystric and Chromic Cambisols and Eutric Regosols; Petric, lithic and pisoferric phases) (59C)**
	PnB		**Soils developed on basalts**
118	**PnBd1**	514	Imperfectly drained, deep to very deep, dark greyish brown to dark grey, firm to very firm, cracking clay **(Calcic and Eutric Vertisols) (28M)**
119	**PnBd2**	515	Imperfectly drained, very deep, dark grey to very dark grey, friable to firm, cracking clay **(Calcic and Dystric Vertisols, inundic and gilgai phases) (29M)**
120	**PnBr1**	474	Association of: soils of unit PnBr1 and soils of unit PnBbP2 **(60C)**
	PnP		**Soils developed on consolidated pyroclastic rocks (lahar complex)**
121	**PnPC1**	531	Complex of well drained, dark reddish brown to dark brown, rocky, friable, sandy clay soils of varying depth and stoniness **(Haplic Luvisols, partly lithic phase and Lithosols) (61C)**
	PP		**Soils developed on pyroclastic rocks (predominantly tuffs**
122	**PnPC (PPC2)**	516	Complex of moderately drained, to imperfectly drained, shallow to moderately deep clay to, dark brown to very dark grey, friable to very firm, sandy clay to clay; in places over petro-plinthite **(Eutric Vertisols, sodic phase; Dystric Plinthosols and Humic Plinthosols, sodic phase; Eutric Gleysols and Eutric Planosols, sodic phase) (31M)**
	PnX		**Soils developed on various rocks**
123	**PnXr**	479	Well drained deep, dark red, friable clay **(Chromic* Acrisols) (62C)**
124	**PnXr- (PnBbP2)**	532	Association of: -Soils of unit PnXr- -Soils of unit PnBP2 **(63C)**
	Pd		**DISSECTED PLAINS (relief intensity up to 20m, slopes < 5%)**
	PdB		**Soils developed on basalts of Mt. Kenya and Mt. Nyambene series**
125	**PdBr**	480	Well drained, very deep, dark reddish brown, friable to firm, clay; with 30-40cm humic topsoil **(Mollic Nitisols*) (64C)**

V VALLEYS

	V1		**MAJOR VALLEYS (relief intensity 50-100m, slopes 8-30%)**
	V1B		**Soils developed on basaltic agglomerates**
126	**V1BP** (VBP)	517	Excessively drained, very shallow to moderately deep, dark yellowish brown, friable, rocky, bouldery clay **(Chromic and Eutric Cambisols, rudic phase) (34M)**
	VP		**Soils developed on pyroclastic rocks (predominantly tuffs)**
127	**V1PP** (VPP)	518	Well drained to moderately well drained, shallow to moderately deep, dark reddish brown to dark brown, friable, rocky, bouldery, gravelly clay loam; in places over petro-plinthite (murram) **(Gleyic, Humic, Ferralic and Dystric Cambisols, rudic and petroferric phases) (35M)**
	V1P		**Soils developed on consolidated pyroclastic rocks (lahar complex)**
128	**V1PC**	481	Complex of: Well drained, moderately deep to deep, dark reddish brown, friable clay **(Dystric Nitisols and Humic and Chromic* Acrisols)**, and: Well drained, shallow to moderately deep, dark reddish brown, friable, slightly rocky to rocky, slightly stony to stony clay; in places over petroferric material (murram) **(Chromic* Acrisols and Chromic Luvisols, partly petroferric, stony and lithic phases) (65C)**
	V1X		**Soils developed on various rocks**
129	**V1Xrp**	482	Well drained, moderately deep to deep, dark red to dark brown, friable to firm clay **(Humic Nitisols* and Chromic* Acrisols, partly lithic phase) (66C)**
130	**V1XC1** (CV2)	414	Predominantly well drained, deep, clay to sandy loam **(34K)**
131	**V1XC2** (CV1)	415	Predominantly well drained, shallow and rocky to deep and non rocky, clay to sandy clay loam **(33K)**
132	**V1XC3** (CS1)	416	Well drained, shallow to deep, sand to sandy clay **(35K)**
133	**V1XC4** (CS1t)	417	Like V1XC3 but rocky **(36K)**
	V2		**MINOR VALLEYS (relief intensity less than 50m, slopes 8-30%)**
	V2P		**Soils developed on consolidated pyroclastic rocks (lahar complex and tuffs)**
134	**V2Pr**	483	Well drained, deep to very deep, dark red to dark reddish brown, friable clay; in places rocky **(Dystric and Humic Nitisols and Humic and Plinthic Acrisols) (67C)**
135	**V2PC**	484	Complex of well drained, dark reddish brown, clay soils of varying depth, consistence, rockiness and stoniness **(Chromic, Ferric and Calcic Luvisols and Chromic Acrisols; partly lithic and stony phases and Lithosols) (68C)**
	V2X		**Soils developed on various rocks**
136	**V2XC**	485	Complex of well drained to imperfectly drained, friable soils of varying depth, colour, rockiness, stoniness and texture, in places mottled **(Ferric Acrisols, Gleyic Cambisols, Eutric Fluvisols and Lithosols) (69C)**

B **BOTTOMLANDS** (relief intensity less than 10m, slopes less than 2%)

	BP		**Soils developed on consolidated pyroclastic rocks (lahar complex)**
137	**BPC**	486	Complex of: Imperfectly drained, shallow to moderately deep, dark brown to dark greyish brown, friable, gravelly clay loam; in places over pisoferric material (murram) and mottled **(Ferric Acrisols, partly pisoferric phase)**, and: Imperfectly drained to poorly drained, moderately deep to deep, very dark greyish brown to black, mottled, friable to firm, clay loam to clay; in places cracking **(Plinthic and Vertic Gleysols and Pellic Vertisols) (70C)**
	BX		**Soils developed on various parent materials**
138	**BXd**	487	Imperfectly drained to poorly drained, moderately deep to deep, very dark greyish brown to black, firm, calcareous, cracking clay; in places stratified **(Pellic Vertisols and Eutric Fluvisols, pisocalcic phase) (71C)**
139	**BXg**	488	Poorly drained, very deep, very dark greyish brown, mottled, friable, clay loam to sandy clay; with topsoil of un-decomposed material of varying depth **(Humic Gleysols) (72C)**
140	**BXC**	519	Complex of moderately well drained to poorly drained, deep to very deep, dark brown to very dark grey, friable to firm, sandy loam to clay **(Plinthic Acrisols, sodic phase; Mollic and Eutric Planosols, Calcic and Eutric Vertisols, sodic phase, and Cambic Arenosols) (36M)**

A **FLOODPLAINS** (Slopes in general from 0-5%)

	AA		**Soils developed on alluvial deposits derived from various parent materials**
141	AAr	520	Well drained to moderately well drained, very deep, dark red to dark reddish brown, stratified, friable to firm, silty clay to clay **(Eutric and Dystric Fluvisols, sodic phase) (32 M)**
142	AAg (AA2g	521	Imperfectly drained to poorly drained, very deep, dark reddish brown to very dark grey, mottled, friable to firm, silty clay to clay; in places stratified and cracking **(Umbric Gleysols, Gleyi-Dystric Fluvisols and Eutric Vertisols) (33M)**
143	AAC (AR1)	418	Complex of deep, stratified soils of varying texture, colour and drainage conditions. **(Vertic and Eutric Fluvisols) (37K)**

Annex 3 Combined maps and legend codes for Murang'a, Kindaruma and Chuka[10]

MURANG'A		KINDARUMA		CHUKA	
Map	Combined Legend	Map	Combined Legend	Map	Combined Legend
1M.	1	1K	4	1C	5
2M.	2	2K	14	2C	3
		3K (+21C)	34	3C	15
		4K	61	4C	6
5M.	12	5K	56	5C	16
6M.	13	6K	57	6C	8
7M.	31	7K	75	7C	9
8M.	22	8K	77	8C	10
9M.	17	9K	72	9C	7
10M.	18	10K	78	10C	11
11M.	23	11K	79	11C	19
12M.	26	12K	80	12C	21
13M.	33	13K	81	13C	27
14M.	20	14K	85	14C	28
15M.	29	15K	99	15C	24
16M.	39	16K	100	16C	25
17M.	40	17K	82	17C	30
18M.	53	18K	83	18C	32
19M.	55	19K	101	19C	37
20M.	51	20K	86	20C	38
21M.	52	21K	65	21C (+3K)	34
22M.	60	22K	66	22C	35
23M.	62	23K	67	23C	36
24M.	63	24K	68	24C	42
25M.	73	25K	69	25C	41
26M.	74	26K	105	26C	43
27M.	76	27K	106	27C	44
28M.	118	28K	107	28C	47
29M.	119	29K	108	29C	48
30M.	112			30C	49
31M.	122	31K	70	31C	45
32M.	141	32K	71	32C	46
33M.	142	33K	131	33C	54
34M.	126	34K	130	34C	50
35M.	127	35K	132	35C	64
36M	140	36K	133	36C	58
		37K	143	37C	59

[10] Original legend numbers and new numbers in the combined SOTER map. In Annex 2, the original code is added to the description.

MURANG'A		KINDARUMA		CHUKA	
Map	Combined Legend	Map	Combined Legend	Map	Combined Legend
		38K	103	38C	87
		39K	104	39C	96
		40K	102	40C	97

		CHUKA			
		Map	Combined Legend		
		41C	98		
		42C	91		
		43C	93		
		44C	92		
		45C	94		
		46C	95		
		47C	144 (page12)		
		48C	145 (page12)		
		49C	88		
		50C	89		
		51C	90		
		52C	109		
		53C	110		
		54C	111		
		55C	113		
		56C	114		
		57C	115		
		58C	116		
		59C	117		
		60C	120		
		61C	121		
		62C	123		
		63C	124		
		64C	125		
		65C	128		
		66C	129		
		67C	134		
		68C	135		
		69C	136		
		70C	137		
		71C	138		
		72C	139		
		73C	146 (page2)		

Annex 4 Natural resources reports of the Upper Tana Basin

INVENTORY OF NATURAL RESOURCES REPORTS (SOILS & SOIL PROPERTIES) OF UPPER TANA CATCHMENT (MURANG'A, NYERI, KIRINYAGA, EMBU, MERU AND MBEERE DISTRICTS)

	Title	Rep No.	Author (s)	Yr	Publishing org.	Where available	Latitude				Longitude			
							N/ S	Degrees	Mins	Secs	E/W	Degrees	Mins	Secs
1	Soils of the Kindaruma area (Quarter degree sheet 136)	R1	Van de Weg, R.F. and Mbuvi, J.P. (eds)	1975	Kenya Soil Survey (KSS)	KSS	S	0 1	30 00		E	37 38	30 00	
2	Reconnaissance Soil Survey of Chuka-Nkubu Area (Quarter degree sheet 122)	R16	Gicheru, P.T. and Kiome, R.M	2000	KSS	KSS	S	0 0	0 30		E	37 38	30 00	
3	Reconnaissance soil survey of Murang'a North District	R 27	Wanjogu, S.N. and Kimani, P.K.	2007	KSS	KSS								
4	Reconnaissance soil survey of Murang'a South District	R28	Wanjogu, S.N. and Kimani, P.K.	2007	KSS	KSS								
5	Reconnaissance soil survey of the eastern part of Thika District	R29	Wanjogu, S.N. and Kimani, P.K.	2007	KSS	KSS								
6	Reconnaissance soil survey of the Machakos, Kitui, Embu area	RC	Sketchley, H.R, Scalley, F.M, Mbuvi J.P. and Wokabi, S.M.	1978	KSS	KSS	S	1 2	00 00		E	37 38	15 30	
7	Semi-detailed soil survey of the proposed Rurii and Sagana Fish Culture Irrigation Scheme, Kirinyaga District	S11	Kanake, P.J.K.	1987	KSS	KSS	S	0	40		E	37	11	
8	Semi-detailed soil survey of the Evurore catchment area, Embu District	S14	Gachene, C.K.K.	1983	KSS	KSS	S	0 0	27 33		E	37 37	45 53	
9	Semi-detailed soil survey of the proposed Marimanti research site, Meru District	S15	Kibe, J.M	1981	KSS	KSS	S	0	10		E	0	58	
10	Semi-detailed soil survey of the proposed Marura Self Help Irrigation Scheme, Makuyu Division, Murang'a District	S24	Waruru, B.K.	1996	KSS	KSS	S	0	52		E	37	11	
11	The soils of the Muguna Igoki Irrigation Scheme, Meru District	S26	Kimani, P.K. & Njoroge,C.R.K.	2001	KSS	KSS	N	0	02	17.7	E	37	39	28.9

	Title	Rep No.	Author (s)	Yr	Publishing org.	Where available	Latitude				Longitude			
							N/ S	Degrees	Mins	Secs	E/W	Degrees	Mins	Secs
12	The soils of Kioru Giaki irrigation Scheme, Meru Central District	S27	Njoroge, C.R.K & Kimani,P.K	2001	KSS	KSS	N	0	03	30	E	37	39	
13	The soil of the proposed Kunati Irrigation Project, Meru District	S32a	Wanjogu, S.N.	2006	KSS	KSS	N	0 0	5 20		E	36 37	30 00	
14	The soils of the proposed Kutus East Irrigation Scheme and their suitability for irrigation, Central, Kirinyaga District	S35	Wanjogu, S.N. and Macharia P.N.	2008	KSS	KSS	S	0 0	33 38		E	37 37	17 23	
15	Soils of the proposed Wamumu extension, Mwea Irrigation Settlement Scheme, Kirinyaga District	D2	Muchena, F.N. and Ngari, G.	1975	KSS	KSS	S	0 0	42 44	35.5 9.5	E	37 37	19 20	20.8 27.5
16	Detailed soil survey of the Kibirigwi Irrigation Scheme, Kirinyaga District	D10	Oswago, O.O.	1979	KSS	KSS	S	0 0	30 35	47 2.9	E	37 37	10 11	48.6 35.6
17	Detailed soil survey of the National Horticultural Research Centre, Thika	D22	Thiang'au, P.K. and Njoroge, C.R.K.	1982	KSS	KSS	S	0 1	58 00	59.8 17.8	E	37 37	03 05	19.3 11.3
18	Detailed soil survey of the Mariba Government Dairy Farm, Meru District	D29	Kanake, P.J.K.	1987	KSS	KSS	S	0	03		E	37	33.5	
19	Detailed soil survey of Embu Research Station, Block A, Embu District	D37	Shitakha, F.M.	1984	KSS	KSS	S	0	30		E	37	27	
20	Detailed soil survey of the Mathina farm, Kieni Division, Nyeri District	D44	Kinyanjui, H.C.K.	1996	KSS	KSS	S	0	20		E	37	01	
21	Soils of Mwea Irrigation Research Farm, Kirinyaga District	D56	Kamoni, P.T. and Kimotho, P.W.	1992	KSS	KSS	S	0	39	55	E	37	16	4
22	Detailed soil survey of the Gikuuri catchment, Runyenjes, Embu District	D69	Wanjogu, S.N.	2001	KSS	KSS	S	0 0	20 27		E	37 37	33 36	
23	Detailed soil survey of soil and water site for Machang'a, Embu District	D70	Njoroge, C.R.K. and Gicheru, P.T.	2001	KSS	KSS	S	0	48		E	37	40	
24	The land suitability of the soils of Thai Model Village Farm, Gikindu Location, Murang'a District	D81	Njoroge, C.R.K., Macharia, P.N., Chek, A. Owenga, P.O.	2008	KSS	KSS	S	0	44	24	E	37	14	42
25	A reconnaissance soil survey of arable land in the area east of Meru Town	P5	Nyandat, N.N.	1973	KSS	KSS	N S	0 0	10 11		E	37 37	38 51	30 30
26	Report of a visit to the experimental area of the Ishiara Irrigation Scheme	P6	Braun, H.M.H. and Nyandat, N.N.	1972	KSS	KSS	S	0	26	45.3	E	37	47	58.2

	Title	Rep No.	Author (s)	Yr	Publishing org.	Where available	Latitude				Longitude			
							N/ S	Degrees	Mins	Secs	E/W	Degrees	Mins	Secs
27	Report of a site evaluation for a proposed irrigation project at Kunati, Meru District	P8	Gelens, H.F. and Ngari, G.	1973	KSS	KSS	N S	0 0	05 02		E	37 38	55 05	
28	A preliminary investigation of the irrigation suitability of the lands in the Kanjoo area, Meru District	P20	Bonarius, H and Njoroge, P.N.	1974	KSS	KSS	N	0 0	10 15		E	38 38	00 05	
29	Soil conditions in the Muthangene Location, Meru District	P26	Siderius, W. and Njeru, E.B.	1976	KSS	KSS	N	0	05		E	37	35	
30	Soil conditions of the Mitunguu-Materi area, Meru District	P31	Van der Pouw, B.J.A., Kibe, J.M. and Njoroge, C.R.K.	1977	KSS	KSS	S	0 0	05 15	24.3	E	37 37	45 53	14.4
31	Soil investigations of part of the Thika Horticultural Research Station	P45	Legger, D.	1979	KSS	KSS	S	0	59	11.1	E	37	04	50
32	An assessment of irrigation suitability of the soils of the IDRP Mwea, Kirinyaga District	P54	Shitakha, F.M.	1984	KSS	KSS	N	0	30		E	37	17	
33	A preliminary investigation of the soils selected for upland rice production, Meru District	P55	Michieka, D.O.	1981	KSS	KSS	N S	0 0	15 30		E	37 38	30 15	
34	A preliminary investigation of the soils of the proposed site for the Meru College of Technology, Nchiru area, Meru District	P60	Kanake, P.J.K. and Kinyanjui, H.C.K.	1981	KSS	KSS	N	0	08		E	37	43	
35	A preliminary evaluation of the soils conditions of the experimental area of the Machang'a Soil Conservation Station, Embu District	P64	Weeda, A	1984	KSS	KSS	S	0	48		E	37	40	
36	Soil conditions of the Kiangwachi Irrigation Scheme, Kirinyaga District	P68	Kinyanjui, H.C.K.	1984	KSS	KSS	S	0 0	36 40		E	37 37	12 13	
37	Preliminary investigations of the soils of the proposed Kambirwa Irrigation Scheme, Murang'a District	P73	Kanake, P.J.K.	1984	KSS	KSS	S	0	44.6		E	37	11.8	
38	Soil conditions of Kigunda's farm, Meru District	P87	Rachilo, J.R.	1996	KSS	KSS	N	0	06	40	E	37	29	
39	An advisory report for horticulture on J.B. Mwaura's farm Samar, Maragua District	P101	Wanjogu, S.N.	2001	KSS	KSS	S	0	48		E	36	55	
40	The soil degradation and sustainable management aspects of selected sites in Kijiado, Thika, Kirinyaga, Embu, Nyandarua and Kiambu Districts	P115	Wanjogu, S.N. Waruru, B.K. and Gicheru, P.T.	2005	KSS	KSS	S	0 0	39 30	55 00	E	37 37	16 26	04 53

	Title	Rep No.	Author (s)	Yr	Publishing org.	Where available	Latitude				Longitude			
							N/ S	Degrees	Mins	Secs	E/W	Degrees	Mins	Secs
41	The soils of the proposed Kunati, Kathiga Gacheru and Mbogoni Irrigation Projects in Eastern Kenya	P119	Wanjogu, S.N.	2005	KSS	KSS	S	0 0	45 50		E	37 37	45 50	
42	Sustainable land management in Kiambindu Smallholder Irrigation Scheme, Mbeere District	P121	Wanjogu, S.N., Muya, E.M., Macharia, P.N. and Kamoni, P.T.	2006	KSS	KSS	S	0	27	38.8	E	37	47	32.3
43	Sustainable land management in Kiarukungu Smallholder Irrigation Scheme, Kirinyaga District	P122	Wanjogu, S.N., Muya, E.M., Macharia, P.N. and Kamoni, P.T.	2006	KSS	KSS	S	0	39	11.1	E	37	20	56.4
44	The soils conditions of Machang'a, Embu, Kirege, Murugi, Mucwa and Mukuuni Experimental Sites	P128	Njoroge, C.R.K. and Macharia, P.N.	2007	KSS	KSS	S S S	0 0 0 0 0	47 30 20 14 18 23	26.8 53.5 07.1 49.4 48.3 30.3	E E E	37 37 37 37 37	39 27 36 38 38 39	45.3 28.6 50.8 43.2 38.8 33.7
45	An advisory report on the soil fertility status and plant pathological conditions of Simlaw Seed Company experimental farms at KARI-Thika, Murang'a South District	P139	Njoroge, C.R.K. Otipa, M.J., Macharia, P.N. and Chek, A.	2008	KSS	KSS	S	0	59	11.1	E	37	4	50
46	The soil conditions of a wetland area in Karatina, Nyeri South District	P161	Njoroge, C.R.K. and Macharia, P.N.	2009	KSS	KSS	S	0	28	22.5	E	37	06	8
47	Embu Benchmark site characterization	M60	Muya, E.M. and Gachini, G.N.	2004	KSS	KSS	S	0	28		E	37	18	
48	Soils, their management problems, farmers' perceptions and existing solutions across land use intensity gradients in Embu BGBD project sites	M74	Muya, E.M., Roimen,H., Mutsotso, B., Karanja, N. and Wachira, P.	2008	KARI and University of Nairobi	KSS and University of Nairobi (Chiromo Campus)	S	0	28		E	37	18	
49	Land use practices in Mbeere District: Biophysical and socio-economic challenges, coping strategies and opportunities: A baseline survey report	NS*	Gachimbi, L.N. Kamoni, P.T., Wanjogu, S.N., Macharia, P.N, Gicheru, P.T.	2007	KSS	KSS	S	0 0	20 50		E	37 37	16 56	
50	The effect of different soil management practices on crust formation, soil moisture conservation and crop growth in Machang'a area, Mbeere District	PhD4	Gicheru P.T.	2002	University of Nairobi	KSS and University of Nairobi	S	0	45		E	37	40	

	Title	Rep No.	Author (s)	Yr	Publishing org.	Where available	Latitude				Longitude			
							N/ S	Degrees	Mins	Secs	E/W	Degrees	Mins	Secs
51	The influence of surface water management and fertilizer use on growth and yield of maize in vertisols of Kenya (Mwea Site)	PhD1	Ikitoo, E.C.	2008	Moi University	KSS and Moi University	S	0	37		E	37	20	
52	Quantified land evaluation for maize yield gap analysis at three sites on the eastern slope of Mount Kenya	PhD2	Wokabi, S.M.	1994	ITC Netherlands	KSS and ITC	S	0 0	20 38		E	37 37	25 38	
53	Yield gap analysis of farming systems on the south eastern slopes of Mount Kenya	MSc1	Staverman, J.B.	2003	Wageningen University	KSS and Wageninge n University	S	0	31	12.9	E	37	27	50.4
54	Soil conditions and evaluation of representative soils of the Wamumu area for irrigated agriculture (Kirinyaga District)	MSc2	Wokabi, S.M.	1983	University of Ghent, Belgium	KSS and University of Ghent	S	0 0	42 43	41.5 41.5	E	37 37	19 20	18.5 46.1
55	Fertility of Humic Andosols of the high bracken zone in Kenya (Experimental sites in Upper Murang'a)	PhD3	Mugambi, S.M.	1983	University of Nairobi	KSS and University Nairobi	S	0 0 0	47 47 44	50 02 54	E	36 36 36	57 53 50	50 39 52
56	Farmers' indicators for soil erosion mapping and crop yield estimation in central highlands of Kenya	PhD5	Okoba, B.O.	2005	Wageningen University	KSS and Wageninge n University	S	0	26		E	37	33	
57	Farmers' Decision-Making in their Preference for Soil Nutrient Replenishment Technologies in the Central Highlands Kenya	MSc3	Felista Muriu	2007	Kenyatta University	Kenyatta University								
58	Interaction between resource quality, aggregate turnover, carbon and nitrogen cycling in the Central Highlands of Kenya	MSc4	Agnes Kavoo	2008	Kenyatta University	Kenyatta University								
59	An evaluation of organic and inorganic technologies for soil nutrient replenishment in Mukuuni and Murugi, Central Kenya	MSc5	Justin Muriuki	2009	Kenyatta University	Kenyatta University								
60	Determination of partial nutrient balances for improved soil fertility management in smallholder farms of Kirege location, Central Highlands of Kenya	MSc6	Joses Muthamia	2008	Kenyatta University	Kenyatta University								
61	Exploring nitrogen replenishment options for improving soil productivity in sites with varied soil fertility status in the Central highlands of Kenya	PhD6	Monicah Mucheru-Muna	2008	Kenyatta University	Kenyatta University								

	Title	Rep No.	Author (s)	Yr	Publishing org.	Where available	Latitude				Longitude			
							N/ S	Degrees	Mins	Secs	E/W	Degrees	Mins	Secs
62	Effects of soil organic matter status on inorganic Nitrogen fertilizers use efficiency in Embu, Kabete and Maseno Kenya	MSc7	Mercy W. Karunditu	2005	Kenyatta University	Kenyatta University								
63	Informal Agroforestry trees quality and supply systems: A case of Peri-urban Nairobi, Meru and Western Kenya	MSc8	Kuriu J. Muriuki	2005	Kenyatta University	Kenyatta University								
64	Soil Invertebrate microfauna: Population dynamics and their role in litter decomposition within a hedgerow intercropping in Embu. Kenya	MSc9	Mwangi Margaret Kinyua	2002	Kenyatta University	Kenyatta University								
65	Soil Organic Matter Status under different agroforestry management practices in three selected sites in Kenya	MSc10	Waswa Boaz Shaban	2005	Kenyatta University	Kenyatta University								
66	Assessment of factors affecting adoption of soil fertility improvement technologies in Eastern Kenya: The case of Kirege Location, Chuka Division	MSc11	Ruth Kangai Adiel	2004	Kenyatta University	Kenyatta University								
67	Soil fertility technologies for increased food production in Chuka. Meru South District: Kenya	MSc12	Monicah Wanjiku Mucheru	2003	Kenyatta University	Kenyatta University								
68	An evaluation of integrated soil fertility management practices in Meru South District, Kenya	PhD7	Jayne Njeri Mugwe	2007	Kenyatta University	Kenyatta University								

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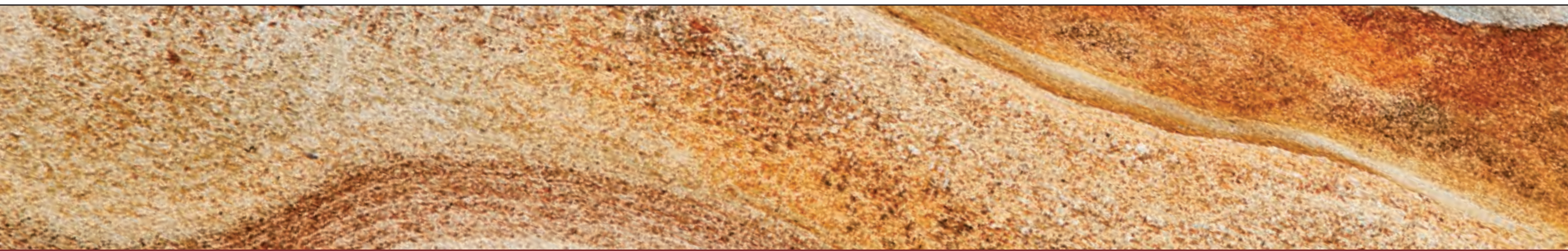

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