Current Urban Studies, 2022, 10, 525-539
https://www.scirp.org/journal/cus
ISSN Online: 2328-4919
ISSN Print: 2328-4900

Conception and Practice of Data-Based System for Soil Qualities and Town Planning Information

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How to cite this paper: Pori, D. B., Hieronimo, P., & Massawe, B. H. (2022). Conception and Practice of Data-Based System for Soil Qualities and Town Planning Information. *Current Urban Studies, 10,* 525-539.
https://doi.org/10.4236/cus.2022.104031

Received: August 12, 2022
Accepted: October 23, 2022
Published: October 26, 2022

Abstract

Sustainable land use planning is the one that takes into consideration land suitability among other land properties. Sustainable planning is crucial for sustainable land and natural resources management. In Tanzania, conventional urban land planning has been a multidisciplinary process. Nevertheless, this process has been built to follow a procedure which can be considered as a rigid set of procedures set out in planning manuals, and the focus has largely been on the use of few land qualities, mainly slope, steepness, hills, elevation, valleys, vegetation, roads, social-economic data and disregarding other important land qualities such as soil properties. The process is even tedious, because the available data is outdated and in non-spatial order. Other useful information such as base maps is stored in hardcopy format, making it hard for the technicians and decision makers to explore, integrate and analyze the crucial information regarding land use planning. This study was designed to address this missing piece in a jigsaw, by providing a means to collect, manage and integrate land use properties with town planning through the use of geodatabase in ArcGis 10.5. With a basic license, a user can access the information from the database offline using Arc Catalog in ArcGis 10.5. The database was proven to be useful for data collection and management by the end of the study. Integration is convenient in a small scale specifically in offline manner. Web interface will be more reliable in a large scale manner to be accessed through online.

Keywords

GIS Database, Land Management, Land use Constraints, Urban Planning, Spatial Integrations

1. Introduction

Plans-makers do not consider the situation of the remote areas and the benefit of these land-owners, usually been made in the offices of government departments, remote from the areas being planned or the people who would be affected and, usually, without their involvement. Conventional urban land planning has followed rigid procedures, set out in planning manuals, and the focus has largely been on the use of few land qualities mainly slope, steepness, hills, elevation, valleys, vegetation, roads, social-economic data and disregarding other important land qualities such as soil properties. Planning process has been technical, relying first on the gathering of basic information about natural resources and socio-economic conditions in the areas concerned, followed by analysis and interpretation (land evaluation). Much of this information has been provided by natural resources professionals and institutions (Magnuson et al., 2000).

One area where integration of soil knowledge could help in urban planning is considering the role soils play in water cycle regulation, a function that gets lost when soils are flooded (McGrane, 2016). Exploiting this role of soils will become increasingly important as climate change exacerbates current issues, for example it is expected that precipitation events will become more intense, resulting in floods in residential areas (McGranahan et al., 2007).

There is already an extensive knowledge on the properties and performance (in terms of productivity) of soil and more recently many advances have been made regarding the development of soil ecosystem services frameworks (Costantini et al., 2016; Dominati et al., 2010; Schwilch et al., 2016). However, the biggest gap is the management of the data for sustainable usage and the availability of the knowledge to the user community (planners and the society). Majority of the land properties spatial data are stored in hardcopy paper format; others are in softcopy format but they are in non-spatial representation formats making it hard to explore the required information. Spatial data management is the key to a better spatial representation, analysis and visualization (Pan et al., 2019). Proper functioning spatial web apps and spatial mobile apps both depend on a proper database with a good managed data (ESRI, 2004). In this chapter of the study, we are focusing on collection and management of land properties and land use constraints data into a database that will provide a linkage between land properties and town planning information. Thus the specific objectives of this study are:

1) Collecting and providing a means for management of data concerning land properties and land use constraints data through a geodatabase.

2) Providing a linkage between land properties and town planning information.

2. Methodology

2.1. Designing of the Geo-Database

Proper design is crucial for the successful implemented geodatabase. Various factors are considered when planning for geodatabase implementation. Goals and purpose of the geodatabase dictates its designs while Alternatives of approaches and vision of the user also determines the implementations of the geodatabase. After a satisfying literature review and case study analysis, five main steps were identified for a proper geodatabase designing (Armstrong & Densham, 1990; Ellis et al., 2019; Talebi et al., 2015):

1) Modeling of the user's view

This is such a crucial part of the geodatabase designing. The main goal of this stage is to develop a clear understanding between the designing team and the users of the geodatabase. Functions of the user community, data required to support the functions, data location implementation plan and the organization of the user community are crucial in modeling user's view.

In this study, the geodatabase was designed for land use planning officials in Morogoro. The main user community is land use planners, land department officials and environmental officials in Morogoro municipal (**Figure 1**). Other users can be members of the society and GIS users in the industry. This geodatabase was designed to provide the user community with land use constraints associated with land use plans in Morogoro municipal. Nevertheless, type and the level of user community requires a different GIS capabilities compared to the other community level.

2) Define objects and their relationship

In the proceeding step objects of the database were identified. In this step these objects are further defined to understand their relationships and any common properties shared between them. This is one of the most demanding and time-consuming stage of geodatabase designing as it concerning with management and validation of the dataset to be used in the implementation of the geodatabase. Documentation of the identified relationships is also important.

In the current study, various factors associated with land use constraints were considered. These constraints were documented and grouped into determining factors as shown in **Table 1** below. The selection of important features was done in order to avoid data duplication and messy features as it was necessary to

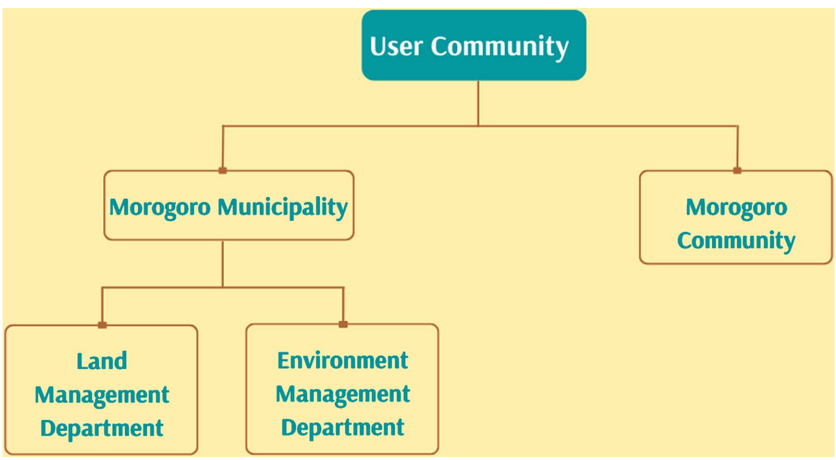

Figure 1. User community.

create a very specific geodatabase for the very specific functionalities. This helps to remove unusable features from our geodatabase.

3) Identify representation of the objects

In this stage of geodatabase designing, the identified and selected objects are classified based on their representation. Geodatabase designed was containing various data types and data formats. Some objects represented on a map for points, lines, polygons, surfaces and raster while others such as photos and images couldn't. Some objects have different scales from one another; other objects are significant to geospatial analysis of the identified functions while others aren't. This information is considered in this stage of geodatabase designing. In this study a variety of the object representation was identified as summarized on the Table 2 below.

4) Match to Geodatabase Data Model

In this stage of geodatabase management it is crucial for deciding the way and format in which the identified objects will be represented in the ArcInfo. In this stage the identified objects are assigned their respective ArcInfo representation models. The main focus of this stage is to move from understanding user requirements to development of effective database plan. In this study it is crucial to determine the means of representation for both complex, simple data and objects. In the current project various ArcInfo data representation types were identified and

Table 1. Factors datasets and the identified features used in this study.

Topographical factors	Climatological factors	Land forms
Slope	Flood hazards	Erosion hazards
Water logging areas		Rock outcrop
Landsat images		Soil depth

Table 2. Breakdown of various data types.

Polygons	Lines	Points	Image
Municipal boundary	Road networks	Soil sampling points	Landsat time series images (1990-2020)
Land use classification	Water lines		
Soil type map	Railway		
Soil features map	Contours		
Water logging areas map			
Soil depth map			
Flood hazards map			
Erosion hazards map			
Rock outcrop map			
Land plan schemes			

prepared as summarized on the Table 3 below.

Furthermore, crucial information of these objects was shared from the appropriate authorities i.e. Morogoro Municipality, Wami-Ruvu basin management council and soil department. This information was summarized on objects metadata and attribute tables.

5) Organization into geographic datasets

In this final step of geodatabase designing, the created datasets were grouped into feature classes. A total of three feature datasets (Base map, Soil Information and Constraints) is presented in Figure 2 were created using projection and the coordinate system of the respective consistent objects. In each feature class, the Object ID in the attribute table was used as a primary key while the feature name was used as the super key of a database. These datasets were projected into a

Table 3. Breakdown of ArcInfo data representation types.

Polygon Features	Planar Topology	lines	Point feature
Municipal boundary	Land use classification	Road networks	Soil sampling points
Land plan schemes	Soil type map	Water lines	
	Soil features map	Railway	
	Water logging areas map	Contours	
	Soil depth map		
	Flood hazards map		
	Erosion hazards map		
	Rock outcrop map Land constraints		

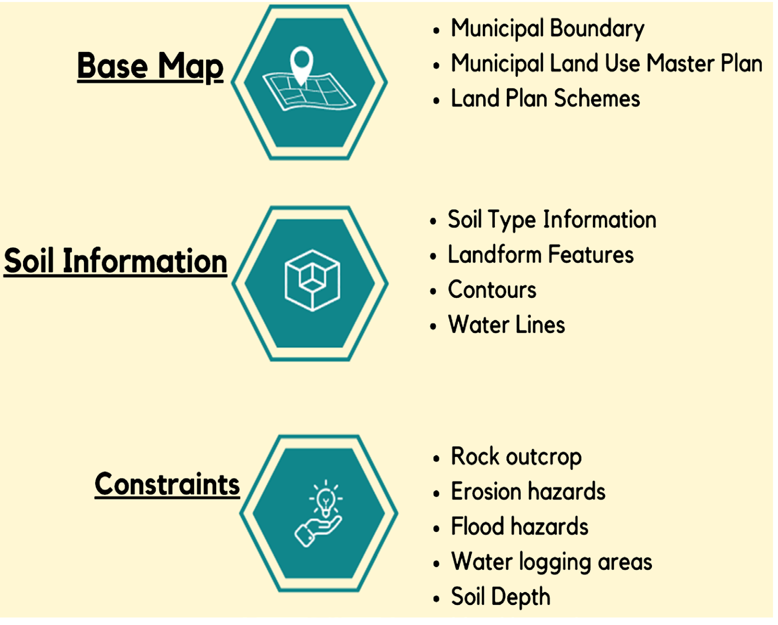

Figure 2. Feature classes.

uniform spatial reference (Arc_1960_UTM_Zone_37S) to ensure maintenance of high consistency level for the data incorporated in the geodatabase.

3. Results and Discussion

The main objective of this study was to design a data based system (a Geodata-Base) that will provide a linkage between soil properties and detailed town planning information. The aim is to integrate both spatial and non-spatial information to assist town planning officer and reduce the incidences concerning with land use constraints in already planned schemes. Figure 3 below demonstrates the several data inputs that were generated an incorporated to our Geodata-Base. The main inputs for our Geodata-Base are:

1) Map vector features

These features include lines, polygons and lines that were created using ArcGIS 10.5. Some features for example land use constraints such as soil depth, flood map, waterlogging areas, rock outcrops and erosion hazards were created through analysis of the available soil information, climate data and historical captured satellite imageries. Soil sampling points were retrieved from the available database of soil surveys conducted in Morogoro Municipal. Contours and slope percentage datasets were created by analysis of Digital Elevation Model (DEM).

2) Base maps

Three base map features were used in creation of our geodatabase. Morogoro Municipal boundary layer was used to map demarcations of the municipality and the respective wards. A total of 28 wards were identified in Morogoro municipal.

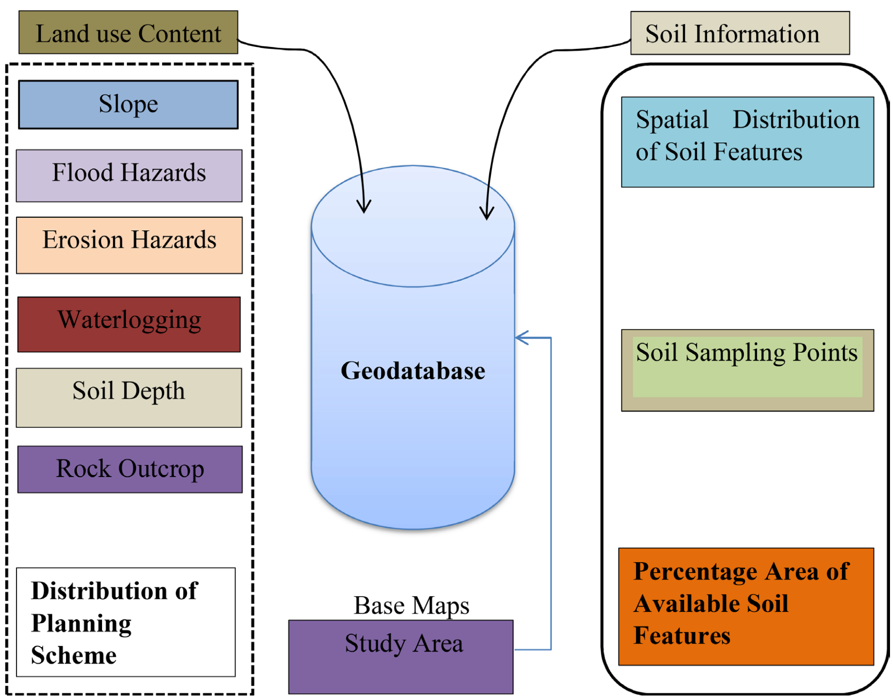

Figure 3. Geodatabase data contents.

Municipal land use master plan is the spatial information pre identified land use plan schemes as planned by the governing other small land use plan schemes in Morogoro municipal.

Geodatabase Implementation

This study was conducted to design the geodatabase that will create a linkage between land planning schemes and soil information. The steps taken as explained on the proceeding sessions are effective to create a functional geodatabase that will improve land monitoring and planning activities in Morogoro municipal with respect to soil information and land use constraints. Also the available and used datasets are enough just to move the authorities and the municipal in a right direction towards sustainable town planning schemes.

Nevertheless these mapped soil properties and landform features are not as detailed enough. There is a room for improvement especially to make a more detailed geodatabase for more improved management and planning schemes. In the municipal office, there are several departments with an access to appropriate software for geodatabase implementation. Land monitoring and administration and environmental department for instance though with a limited access i.e. basic license which by the way is enough for the management and implementation of geodatabase.

A file geodatabase was created in this project using ArcGIS 10.5. File geodatabase was chosen to accomplish the targeted task because through it datasets can be edited and manipulated by various users at the same time. To make this information accessible to the target authorities and the community is a bit challenge because of lack of enough resources especially licensed computer. To deal with that challenge, although one computer will be selected by the respective office which will be provided with ArcGIS 10.5 license to show the status of the datasets in the database as added by the admin of the system. This computer will give the opportunity for the staff members to view data and provide the required information such as soil properties and landform features for the respective customers regarding land use constraints and other soil information.

The solution is not sustainable but it is feasible considering the situation at the end of designing, test data were included in order to check and confirm the functionality of the geodatabase.

4. Conclusion

This study was conducted originally to assess the available soil information and the land planning schemes in spatial perspectives. Further land use constraints were assessed in relation to approved detailed land planning schemes in Morogoro. The ultimate aim of this study is to create a web based geospatial app that will visualize land use constraints in Morogoro so as to ensure proper and sustainable land use plans approving in Morogoro municipal and prevent some preventable disasters and losses unforeseeable future caused by improper land use plans. The result of this study shows that there is enough data for designing a web based app to start with in the quest of making a complete and functional app.

Nevertheless, updating and improvement of the available data by the associated authorities will be crucial, because the available data for example soil surveys and land form features were collected in 1999 which is more than 20 years ago, enough room for some changes on the land features, and it is easy to update and improve of the available data.

Otherwise, the output of this study is very positive as it paves a way for open access data for various uses to implement sustainable development goals. The information provided by the database is crucial for disaster management and land management practices by the authorities and the community as well. It also sheds the light for the implementation in other municipalities in Tanzania towards another approach of land management practices.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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Appendices

Appendix 1. Detailed Soil Information of Map Units

Name	Description	Landforms	Slope (%)	Comprises
Mountains	These are soils developed on hornblende pyroxene granulites with some banded pyroxene granulites	Strongly dissected ridges	50-more than 80	Rockland and shallow to moderately deep, excessively drained dark yellowish-brown gravelly clay loams and sandy clays on saprolite occurring at variable depths
		Moderately to strongly dissected ridge crests and slopes	30 - 80	Shallow/deep to very deep, well to somewhat excessively drained, yellowish-brown to yellowish-red gravelly sandy clay loams to clays and moderately deep to deep well to somewhat excessively drained, brown to dark yellowish-brown, gravelly sandy clay loams. Topsoils are relatively thick and deep to very deep, moderately well to well-drained, dark brown to brown gravelly sandy clay loams to sandy (clays) with thick black sandy clay loam to clay loam topsoils. Surface stoniness and rock outcrops are common.
		Talus Slopes	10 - 25	Scattered rock outcrops and cliffs of rockfall and deep to very deep well-drained dark grayish brown to yellowish-brown, sandy clay loams to sandy clays. Topsoils are thick, sandy clay loams. Surface stones are common.
	Developed on muscovite biotitemigmatites	Strongly dissected hills	45-80	Rockland and shallow, excessively, drained, very dark gray, extremely gravelly sandy clay loams
Piedmonts	Developed on colluvium derived from hornblende pyroxene granulites and micaceous gneiss	Foothills	15 - 45	Deep to Very deep, well-drained, red to dark reddish-brown, clays with dark brown topsoil. Stone lines comprised mainly of fresh angular quartz gravel and stones are common.
		Glacis	2 - 15	Deep to very deep. Well-drained, reddish-brown to dark red, clays with weak to moderate structure
	Developed on colluvial/alluvial deposits derived from pyroxene granulites and micaceous gneiss	Alluvial fan	0 - 2	Very deep, well-drained, highly weathered, red, sandy clays to clays with humiferoustopsoils
	Developed on colluvial/alluvial derived from biotite muscovite migmatites.	Alluvial fan	2 - 10	Very deep, well-drained, dark reddish-brown, sandy clay loams to sandy clays, with very thick loamy sand topsoils and very deep, excessively drained, very pale, sands and sandy clay loams with weak structure and profile development.
Peneplains	Developed on muscovite biotitemigmatites	Isolated hills	10 - 30	Rock outcrops and shallow excessively drained, gravelly sandy clay loams and sandy clays.
	Developed on colluvium with variable mineralogical composition	Ridge crests	0 - 2	Deep to very deep, well-drained, dark reddish-brown (reddish-brown) to red clays with moderate structure and profile development. The topsoils are brownish loams. Thick, ferruginous, gravelly subsoil layers are common

Continued

		Ridge slopes	5 - 8	Deep to very deep, well-drained, brownish sandy clay loams to clays with moderate structure and profile development
	Developed on muscovite biotitemigmatites	Ridge crests and slopes	2 - 5	Moderately deep to deep, well to excessively drained, brownish and very pale sands on mixed bouldery and rocky subsoil and Deep to very deep, well-drained, brownish. Sandy clay loams to sand clays with poor to moderate structure and profile development.
Valleys	Developed on alluvial-colluvium with variable mineralogical composition	Ridge terrace	0 - 1	Very deep moderately well to imperfectly drained, very dark brown to brown, sandy clays to sandy clay loams with variable salinity and levels and very deep, moderately well to imperfectly drained, dark brown heavy cracking clays with thick, very dark grayish brown, clay topsoils
		Flood plain	0 - 1	Very deep, moderately well to imperfectly drained, dark brown heavy cracking clays with thick, very dark grayish brown clay topsoils and very deep, moderately well to imperfectly drained, very dark brown to brown, sandy cays to sandy clay loams with variable salinity and sodicity levels and very deep, poorly drained, dark brown to very dark brown. stratified and mottled sands and sandy clays

Appendix 2. Detailed Analytical Data Report of the Soil Profiles of Various Sampling Points

Sample Point	Description	horizon	
		Horizon Depth	Description
1.	The Major Parent rocks are hornblende pyroxene granulites and gneiss. A mountainous area with a convex Slope of 49%. Stones occupies 10% and the major Erosion types are Inter-rill/sheet/gully/landslide; The area is Well drained.	Ap 0 - 30 cm Deep	Dominant texture is Sandy Clay with sand particles dominates. Slightly acidic ranging from 5.5 for wet soil to 5 for dry soil particles
		C 30 - 35/50 cm	Sand loamy texture accounts for sand particles to 65%. pH ranging from 5.1 to 6.0 for wet to dry particles respectively
		CR 35/50 - 130 cm	A silt loamy soil with a pH ranging from 5.3 to 6.4
2.	The soil of an area is yellowish brown deep. The soil profile is well divided into three distinct horizons. Steep slope makes erosion a dominant process on the area and less deposition effects Sandy clay texture is the main texture.	Ap 0 - 5 cm	The shallowest horizon. Natural vegetation and moisture activities accounts for the moderate pH ranging 6.0 to 6.4 for dry and moist soil particles respectively
		BCt 5 - 30/35 cm	moderate pH ranging 6.1 to 6.4 for dry and moist soil particles respectively
		CB 30/35 - 50 cm	pH ranging 6.0 to 6.5 for dry and moist soil particles respectively

Continued

3.	The major composition of the soil is Banded muscovite biotite sediments and superficial sands. Isolated hills make up the dominant landform of an area. 80% slope accounts for the shallow with only two horizons on the soil profile. The soil well drained and slightly weathered rocks.	Ah 0 - 10 cm	Sand clay loam texture with a very variant pH ranging from acidic dry particles 4.4 to an alkaline moist 7.2
		CR 10+ cm With a slightly weathered rock.	This horizon is dominated by hardpan rock making it challenging to determining soil particles
4.	An area is characterised with a very gentle slope making the soil deeper and poorly drained. Parent rock is dark yellowish brown colluvium.	Ap 0 - 10/25 cm	A black moist acidic soil dominates this horizon. The most dominant texture is sandy loam
		BAt 10/25 - 32 cm	Slightly acidic horizon as neighboring horizons ranging from 5.4 to 4.
		Bt 32 - 76 cm	A dark brown soil suggesting warm temperature. A sandy clay loam texture.
		BCt 76 - 160 cm	A slightly acidic soil with pH ranging from 5.0 to 6.1. A brown moist sandy clay loam soil
5.	Biotite gneiss-pyroxinegranulites rock makes up a parent rock. Most dominant landforms are mountainous 55% slope accounts for landslides and erosion activities.	Ap 0 - 40 cm	Sandy clay loam textured soil with dark colour suggesting organic content and warm temperature. A deep topsoil
		BC 40 – 75/100 cm	A dark yellowish brown soil, slightly lower pH ranging 6.4 to 5.2. The moist dominant texture is Sandy clay loam
		C 75/100 - 170 cm	A yellowish brown moist acidic soil. The most dominant texture is sandy loam
6.	Colluvium rock makes up a parent rock. Landforms are mountainous with slope 65% making an area prone to erosion and rock outcrops. Soil profile is dominated by the sandy clay loam texture	Ap1 0 - 12/26 cm	A dark brown
		Ap2 40/50 – 100/105 cm	A dark yellowish brown deep soil. Soil is slightly acidic
		Bw 40/50 – 100/105 cm	A dark yellowish brown deep soil. Soil is slightly acidic
		CR 100/105 - 170 cm	A very dark greyish brown deep soil. Soil is slightly acidic
7.	The major landform is Colluvium and the soil is located in mountainous areas. 21% slope accounts for the erosion activities in an area. Cultivation activities by human are the main cause of the increased soil depth for this dark greyish brown soil.	Ap 0 - 50 cm	A sandy clay loam soil texture. The soil is very porous due to the presence of many fine roots. Slightly lower pH value ranging from 5.2 to 4.5.
		Bt 50 - 100 cm	A dark greyish soil with a clear separation with the underlying horizon. A sandy clay loam of a partially weathered quartz and feldspar minerals
		C 100 - 150 cm	A structure less massive rock structure made up of saprolite. pH value ranging from 5.9 to 5.1

Continued

8.	A colluvium made lower slope soil feature. 9% slope accounts for the less erosion soil, moderate drainage and a well deep soil.	Ap 0 - 50/60 cm	A very dark brown soil with medium sub angular rock particles suggesting slightly weathered soil. Slightly acidic soil ranging from 6.0 to 5.1 pH value. Most dominant texture is sandy clay loam
		BCt1 50/60 - 90/100 cm	A yellowish acidic moist soil. sandy clay loam soil texture
		BCt2 90/100 - 160 cm	A size of feldspar and mica fragments suggesting a partial weathered rock particle. Higher pH ranging from 5.4 to 6.3
9.	A mountainous landform with mud clay colluvium over pyroxene granulites parent rock. A complex middle slope of 32% accounts for the severe erosion and well drainage system.	Ap 0 - 10 cm	A dark reddish brown soil suggesting warm temperature. A slight varied soil pH ranging from 6.4 to 4.9
		Bt1 10 - 30 cm	A hard a dry dark red clay soil. Clear separation with the underlying horizon
		Bt2 30 - 80 cm	A clay textured soil which is very friable moist. Lower pH value (5.7-4.3)
		Bt3 80 - 150 cm	A red moist slightly weathered clay soil with a very variant pH ranging from 6.1 to 4.6
10.	Soil made of a mud clays colluvium over pyroxene granulites parent rock. A middle slope of 32% accounts for the well drainage system and inter-rill, rill, gully erosion activities on the topsoil. A variant of colour particles ranging from red to dark red and dark brown.	Ap 0 - 6 cm	Very shallow topsoil suggesting dominant erosion activities. A dark brown soil with a sandy clay texture
		Bt1 6 - 30 cm	A dark red clay soil. Many fine porous with a low pH value of 5.9 to 4.5
		Bt2 30 - 85 cm	A red moist horizon with clay texture a very fine pores suggesting organic activities
		C 85 - 150 cm	A strong brown sandy loam soil. A structure less and massive feature. pH value ranging from 6.2 to 4.8.
11.	Soil particles originated from colluvium mainly mud clays derived from hornblende pyroxene granulites and micaceous gneisses. Hilly landforms with an upper middle slope class 15%. The soil is very deep and a well-drained A surface characteristic of a rock outcrop.	Ap 0 - 5 cm	A moist sand clay soil with pH ranging from 5.8 to 5.1
		Bt1 5 - 31 cm	A hard dry clay soil with a medium root activities
		Stone-line 31 - 39 cm	A line of gravels and stone features made of of fresh angular quartz
		Bt2 39 – 92/116 cm	A hard dray sandy clay red soil with a medium pores activities
		BC 92/116 - 145 cm	A red soil with a sandy loam texture. A slightly weathered quartz and feldspars fragments with a very slight root activities

Continued

12.	Landforms classified as Strongly dissected ridge crests and slopes. Soil particles made of Horblende pyroxene granulites with some banded pyroxene granulites. Erosion dominated surface activities. Deep soil ranging from strong brown to dark brown soil.	Ap 0 - 15 cm	A very dark brown soil suggesting a warm temperature. Medium porous structure suggesting medium root features
		Bt 15 - 55 cm	A strong brown fine porous clay soil. pH value ranging from 5.8 to 4.7
		Bts1 55 - 120 cm	A reddish brown clay soil. Very fine pores suggesting root activities
		Bts2 120 - 200 cm	A reddish brown soil with a plastic clay texture. A constant pH of 5.4 for moist and dry particles.
13.	A dominant landform classified as alluvial fan. Soil particles made of Colluvium derived from horblende pyroxene granulites. The soil is well drained very deep and a slight convex slope of 10%. Yellowish red to deep red soil clays soil dominate an area.	Ap 0 - 20 cm	A dark brown topsoil. A weak fine to medium soil blocks with very porous suggesting root activities. pH value ranging from 6.7 to 5.5
		BAt 20 - 42 cm	A yellowish red clay soil with medium soil blocks
		Bts1 42 - 55 cm	A yellowish red clay soil with medium soil blocks
		Bts2 55 - 75 cm	A red soil dominated with a course clay soil blocks
		Bts3 75 - 212+ cm	Major features are medium to course weak angular blocks suggesting slight weathered soil. Slight acidic horizon with pH ranging from 5.5 to 4.3
14.	Soil made of sediments from Banded muscovite biotite and superficial sands. The dominant landform is alluvial fan with a lower convex slope of 6%. A soil is reddish brown very deep and a well-drained.	Ah 0 - 15 cm	A loamy sand soil which is slight hard dry. Color ranging from yellowish red to reddish brown. pH ranging from 6.9 to 5.4
		BA 15 - 35 cm	A reddish brown soil with a loamy sand texture
		Bw1 35 - 75 cm	A dark reddish brown soil with a sand clay loam soil
		Bw2 75 - 160+ cm	A slight varied pH varying from 7.7 to 4.5 A dark brown soil with a sandy clay texture
15.	A low slope (3%) area characterized with nearly flat crest on a peneplain landforms. A deep soil with deposition activities due to low slope with colluvial deposits. The area is excessively drained with pale brown to yellow sand deposits on the topsoil.	Ah 0 - 10 cm	A very porous moist loose sand texture soil. A very low pH value (3.9-4.9) signaling acidic condition
		AC 10 - 40 cm	A pale brown porous moist sand textured loose grains. Diffused boundary with the following horizon.
		C1 40 - 120 cm	A yellowish brown sand moist. Very porous and a medium root activities
		C2 120 - 150 cm	Reddish yellow moist soil. A porous structure less grains with few moderate quartz fragments

Continued

16.	A moderately shallow soils with slight sheet erosion and cullovial deposits. Gneiss constituents the mother rock, almost flat crest on a peneplain landforms on the middle slope (1%). Brown sandy clay loam texture topsoils.	Ah 0 - 15 cm	A dark reddish brown sand clay loamy soil characterized with moderate fine sand granules. A pretty neutral pH value ranging from 7.9 to 7.1
		Ah 0 - 15 cm	A dark reddish brown sand clay loamy soil characterized with moderate fine sand granules. A pretty low pH value ranging from 6.4 to 5.2
		Bw1 30 - 45 cm	A dark reddish brown sand clay loamy soil characterized with medium sand blocks and course pores. A pretty low pH value ranging from 5.9 to 4.5
		Bw2 45 - 55 cm	A dark reddish brown sand clay loamy soil characterized with medium sand blocks and fine pores. A pretty low pH value ranging from 5.9 to 4.8
17.	A middle slope area with flood plain as the dominant landform. Soil particles originating from mixture of alluvial and coluvial deposits. It is a dark brown imperfectly drained and a very deep soil.	Ahg 0 - 15 cm	A black sand clay loam soil consists of the course to fine angular sandy blocks. pH value ranging from 6.3 to 5.3
		ABg 15 - 48 cm	A black sand clay loam soil consists of the course to fine angular sandy blocks. pH value ranging from 6.4 to 5.6
		Bwg1 48 - 79 cm	A very dark brown sand clay loam soil consists of the course to fine angular sandy blocks. pH value ranging from 6.4 to 5.6
		Bwg2 79 - 150 cm	A dark brown sand clay loam soil consists of the course to fine angular sandy blocks. A pretty high pH value ranging from 7.2 to 6.3
18.	A flat terrain surface with a middle slope of 0.5% accounting for the deposition activities. Alluvio-coluvium is the parent rock in form of Alluvio-coluvial deposits. The soil is well stratified, deep and imperfectly drained. Brown clay soil deposits dominates.	Ap 0 - 12 cm	A very dark brown soil with very fine pores. Clay texture pH value ranging from 6.9 to 6.4
		C 12 - 30 cm	A dark brown sand clay textured soil with fine to medium course pores pH value ranging from 6.9 to 6.3
		2C 30 - 48 cm	A structure less and massive dark reddish brown soil with sand clay loam texture pH value ranging from 6.4 to 6.1
		3C 48 - 95 cm	A dark reddish brown clay soil with medium to fine pore structures. pH value ranging from 6.7 to 6.1
		4C 95 - 110 cm	A dark brown clay soil. pH value ranging from 6.7 to 5.9
		5C 110 - 140+ cm	A dark reddish brown soil with a clay texture. Massive and structure less Very porous soil ranging from fine to medium pores.