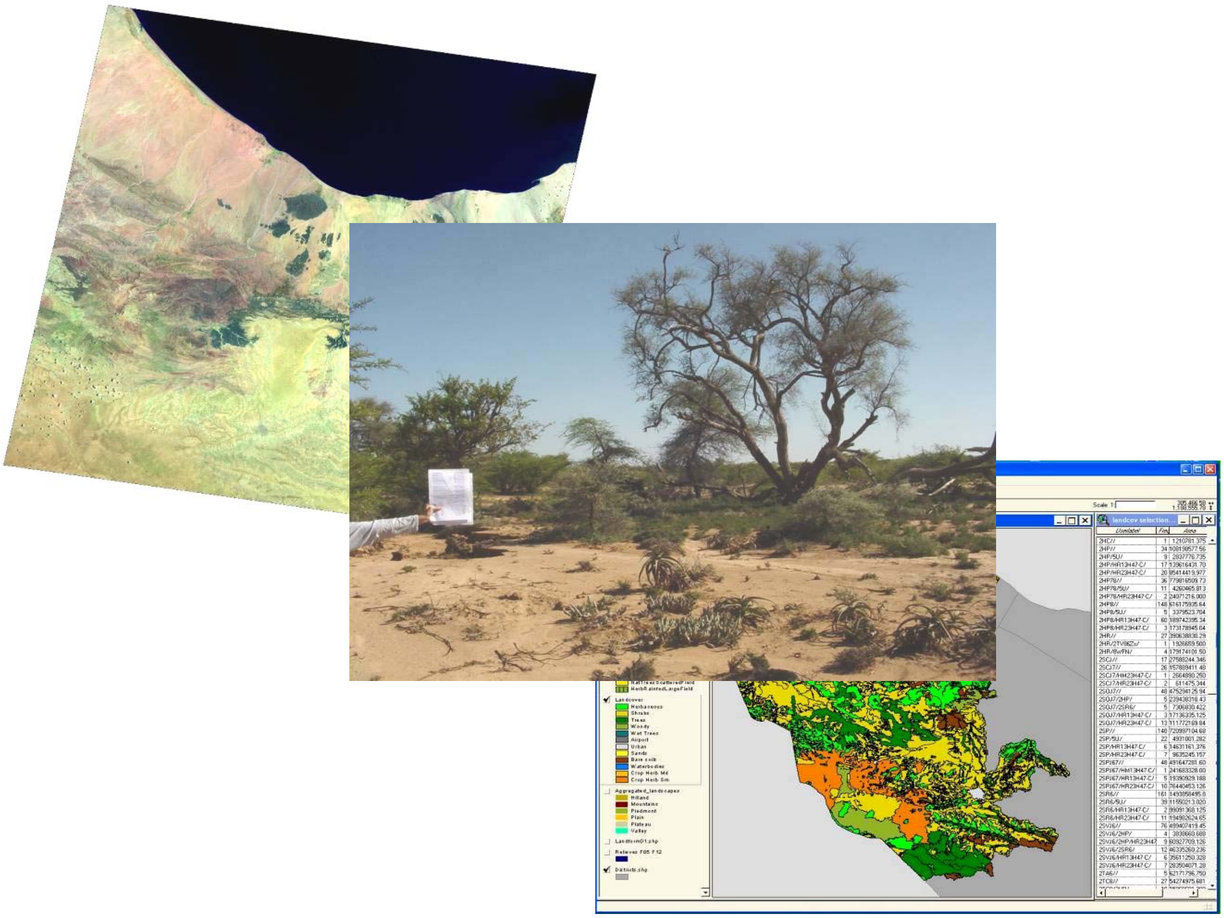
Field Survey Manual

Landform – Soil - Soil Erosion - Land Use - Land Cover



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INTRODUCTION

This Field Survey Manual has been produced by the SWALIM (Somalia Water and Land Information Management System) Land Team as a guide to concepts and tools in carrying out field land resource surveys. It is intended for use in both **Somaliland** and **Southern Somalia**, the two main foci areas of the present SWALIM Project. However, it may be used by any professional and/or institution dealing with land resource inventories.

Land resource topics covered in this manual are:

- Landform;
- Soil;
- Soil erosion;
- Land cover; and
- Land use.

The above foci were chosen due to their pertinence to the primary SWALIM project objectives:

1) Natural resources inventories as a development baseline and
2) Land suitability assessment of land resources.

This manual incorporates the accumulated knowledge of many experts with technical expertise in and experience of Somalia.

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1 LANDFORM MAPPING

1.1 Conceptual basis of landform surveys

To fully understand all actions involved in field data collection, it is important to focus on a few key concepts.

The primary objective of the landform mapping process is to *enable progressive zooming onto features or formations on the Earth's surface*, from the largest landscape unit/s progressively downwards to medium units and finally to the smallest and/or finest units. Satellite images and digital elevation models (DEM), allow a vertical view of the land that can be manipulated and used as a basis of analysis for a wide range of criteria.

Two important concepts are:

- landform subdivisions are made on an hierarchical basis
- landform types or formations are derived from soil forming factors

The terrain classes or landforms adopted here follow a hierarchical geopedologic approach to landform mapping, suitable for a progressive zooming approach.

Three main categories may be distinguished:

A. **LANDSCAPE** or first order terrain class, represents the biggest hierarchical unit;

B. **RELIEF** or second order terrain class, represents the middle hierarchical unit;

C. **LANDFORM** or third order terrain class represents the smallest hierarchical unit.

A. The *Landscape*, or first-order terrain class, is defined as a large area characterised either by a repetition of similar relief-types or an association of dissimilar types. On average, landscapes involve areas 10-100 km in width and relief limits between 100-1,000 m. Landscapes are greatly influenced by distribution of the main geological units and tectonics (e.g. valley, plain, peneplain, plateau, piedmont, hill and mountain).

B. The *Relief*, or second-order terrain class, represents the morphology of the Earths' surface as determined by a combination of geological structure (lithology and tectonics), morphogenetic processes and specific morphoclimatic conditions (e.g., cuesta relief type, pediment, alluvial fan, fluvial terrace, and talus slope). On average, relief will involve dimensions tens of kilometres in width and hundreds of meters in relief.

C. The *Landform*, or third-order terrain class, represents features of the Earth's surface determined more by morphogenetic and climatic processes than geology. On average, landforms have dimensions ranging from hundreds of square meters to several square kilometres in area and between tens to hundreds of meters of relief. They are the smallest landscape unit/s and examples might include the different parts of a slope (summit, shoulder, backslope, footslope, toe-slope), or erosional/depositional features such as rills, gullies, backswamps and coastal dunes.

The most suitable observation points from which to obtain a general overview of a landscape/relief/landform catena are elevated areas overlooking surrounding surface features. The fewer obstacles there are between you and the object/s you need to describe (high trees, hills, buildings, etc), the better the results of the terrain class characterisation will be.

The main diagnostic considerations used to distinguish between different terrain class units are:

- *topography*: shape and direction of slopes, shape and size of topographic elements.
- *slope angles*: the angles that a slope makes with the horizontal plane. It is important to recognise the areas where slope angles change, as it may be possible to distinguish different portions with different slope angles that determine different processes and landforms along the slope itself.
- *size and shape of terrain classes*: it is important to note the size, shape and orientation of terrain classes.
- *drainage patterns*: these are directly affected by the underlying geology and the evolution of the terrain class. Similar drainage patterns tend to overlay similar terrain classes.
- *drainage density*: this quantitative parameter can be extracted from topographic maps and may also be evaluated in the field. It gives direct information on the permeability and degree of fracturing of underlying rocks.
- *surface geological conditions*: these include both lithological and tectonic features such as rock types, strength, faulting, degree of weathering and fracturing. Apart from creating the parent materials for soils, they guide formation of the different terrain class, acting as conduits for morphogenetic processes.
- *colour, tone, pattern and texture:* these visual parameters may also be used in the field. The main difference between their use in the photo-interpretation exercise and in the field is that in the field you do not have a synoptic view of the land. Areas with homogeneous colour, tone, pattern and texture tend to underlie homogeneous terrain classes.

In order to identify and map Landscape, Relief and Landform/s, attention has to be paid to recognising *differences* or *discontinuities* between two or more homogeneous adjoining features. A terrain class unit is a three-dimensional object and thus, if possible, it should be observed from different viewpoints. Be aware of the effect of shadows on perspective and estimations of dimension and distance.

Due to the scale of the work (1:50,000, 1:100,000) and differences between classification and description, once in the field it will be necessary to recognise very small variations in the landforms. The most important activity is to recognise zones where an almost homogeneous unit's characteristics change. This means that you must identify its limits within the surrounding, different units.

During this process it must be remembered that the smallest object or unit to focus on (minimum mappable unit, or M.M.U.) must be larger than 200x200 m. This implies that you do not need to look for discontinuities and/or homogeneity in land surface features smaller than 40,000 m^2 or 4 ha.

This does not imply that you have to discard observations on the smallest features if they can help you in identifying some landform/relief/landscape units, but you should not map them if they are smaller than the M.M.U.

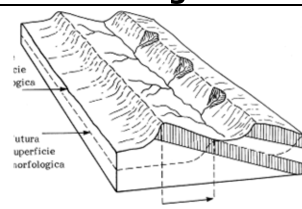
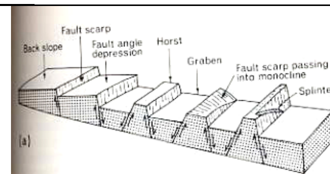
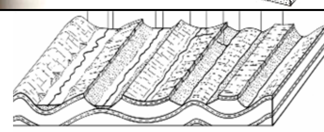
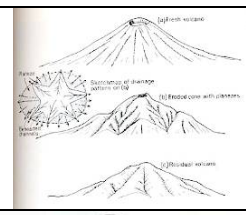
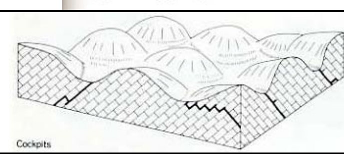
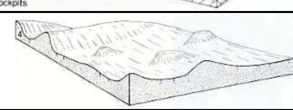
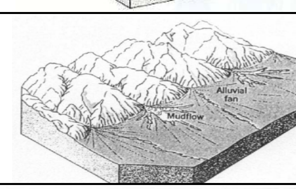
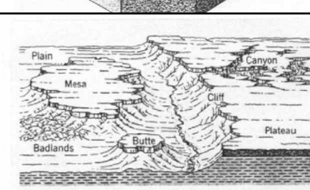
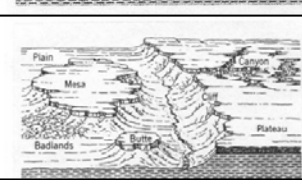
Classifications of landscape and relief are made using two different complementary methods:

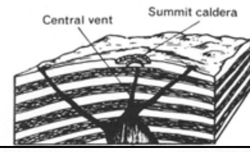
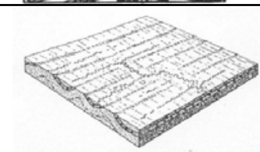
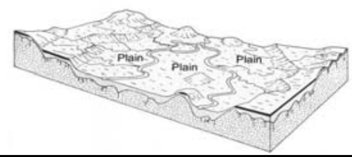
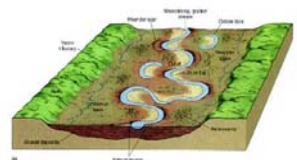
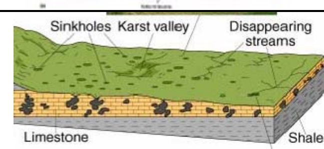
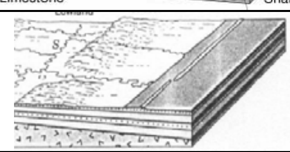
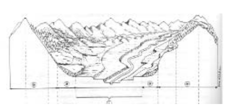
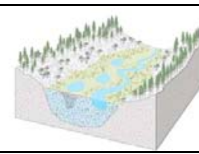
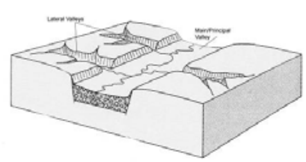
1) *Landform map validation*: making visual observations from an elevated observation point, you should complete the relevant form with reference to the four cardinal points, as explained in the form section

2) *Land cover field sampling quadrat characterisation*: within the land cover field sampling quadrat, you should be able to extract the average land surface feature characteristics following the points in the form

LANDSCAPE: Large area of land characterised either by a repetition of similar relief-types or an association of dissimilar types.

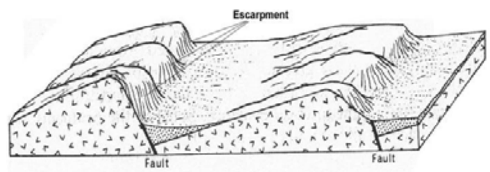
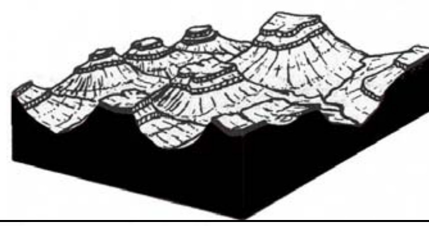
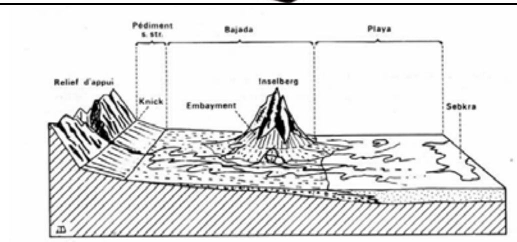
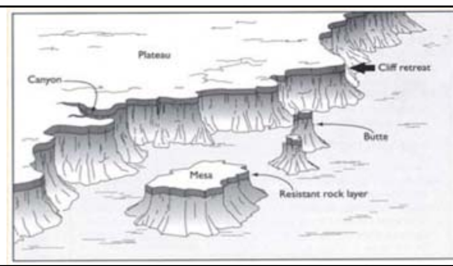
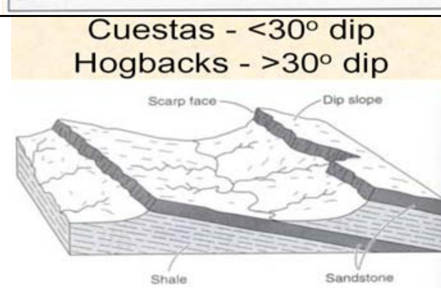
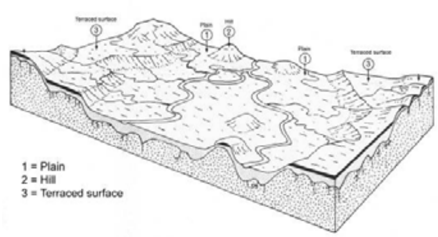
Fig. 1.1 - Landscape classes

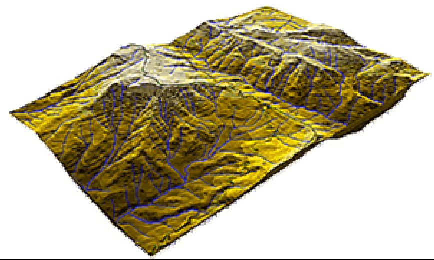
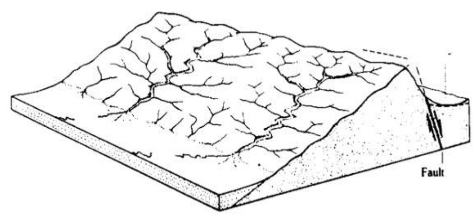
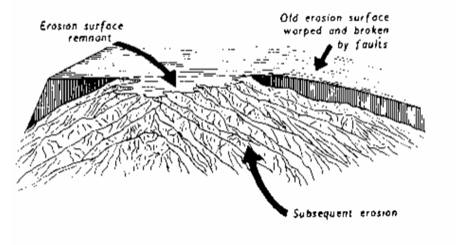
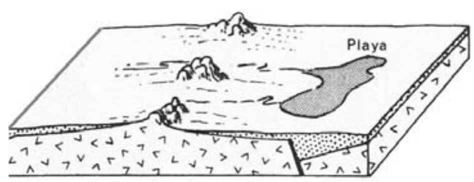
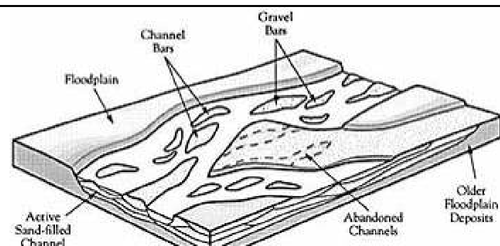
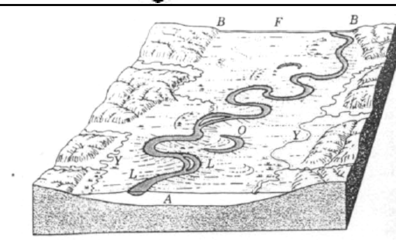
Code	Description	Example from drawings or block diagrams
Mou	Mountain	
MoB	Block mountain	
MoF	Fold mountain	
MoV	Volcanic mountain	
Hil	Hills	
HiD	Dissected hills	
Pie	Piedmont	
Pta	Plateau	
PtD	Dissected plateau	

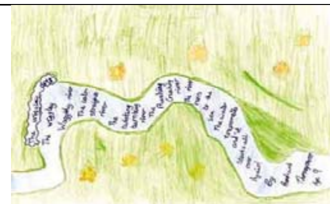
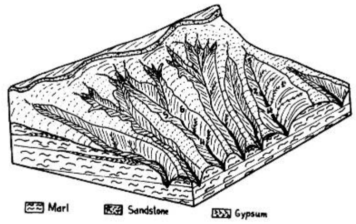
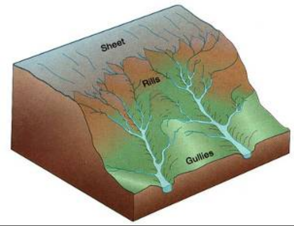
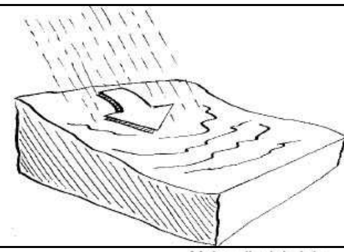
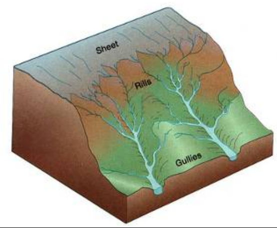
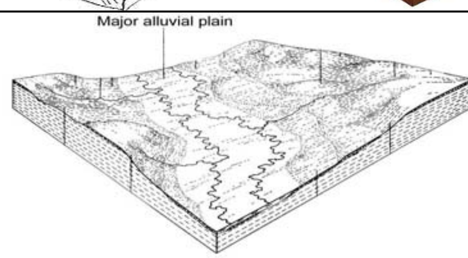
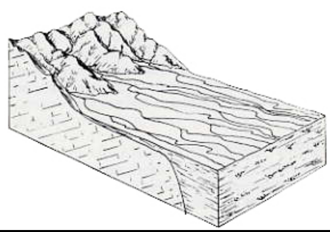
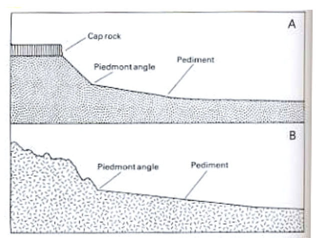
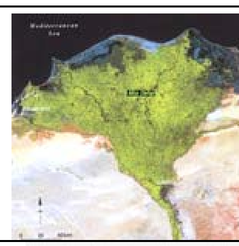
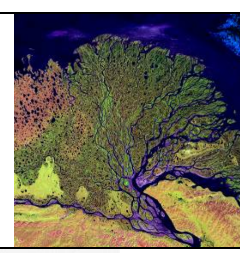
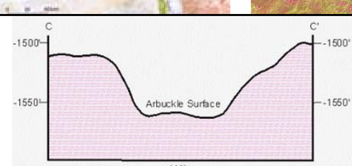
PtV	Volcanic plateaux/shield	
Pen	Peneplain	
Pln	Plain	
PlA	Alluvial plain	
PlK	Karst plain	
PlC	Coastal plain	
PlD	Dissected/incised plain	
Vay	Valley	 
VaL	Lateral valley	

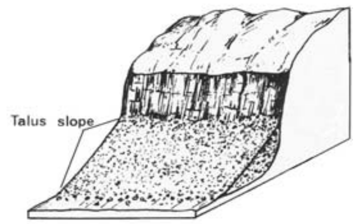
RELIEF: Morphology of the earth's surface determined by combinations of topography and geological structures, as well as specific morphoclimatic conditions or morphogenetic processes (e.g., glacis, fan, terrace, delta).

Fig 1.2 - Relief types

Code	Description	
S08	Escarpment	
S15	Depression	
S16	Dissected ridge	
S24	Inselberg	
S26	Mesa	
S27	Hogback	
S29	Hill	

S30	Hill complex	
S31	Ridge	
S32	Planation surface	
S33	Denudational slope	
S34	Slope	
S35	Denudational surface	
E05	Playa	
F04	Braided river plain	
F05	Meandering river plain	

F06	Straight river plain	
F09	Gully/rill erosion surface	 
F10	Sheet erosion surface	 
F12	Alluvial plain	
F13	Depression	
F14	Pediment	 
F15	Dissected pediment	
F16	Delta	  
F17	Flat floor valley	

G08	Talus slope	
C03	Sandy coast	
A02	Town, industrial district	

1.2 Forms on landforms, terrain and topography

The forms that follow require the use of landform descriptors, as each has a different approach to the others. Landform concepts are specialised and require significant preparation to allow effective evaluations to be made.

The general approach to site description involves creating a framework which zooms from a broad scale down to detailed site characterizations.

The required descriptions and the relevant forms to fill in, cover two different aspects:

1. Validation of the landform map form – Form LNF-A
2. Landform characterisation of the land cover field sampling quadrat – Form 6-B

Different observation points are used from which to describe the landform and the land cover field sampling quadrat.

A. General Landform observations - form LNF-A

<u>For this activity use form LNF-A</u>

In making observations for validating landforms, follow these steps:

1. Find the most elevated panoramic viewpoint within the area that you wish to observe.
2. Carefully observe the landforms around you, turning a full 360° in order to view all of the main landform types surrounding your viewpoint.
3. Using a compass, identify north.
4. Take photographs as described in "5.3.3.3 Taking photographs", starting from the north.
5. Starting from north, move in a clockwise direction and fill in the landform form, describing what you see.
6. Complete the form LNF–A.
7. Make use of sketches, pictures, colours and any annotations, considerations and/or tools that you find useful.

Form field explanations

Date, time, name and place

- DATE OF DESCRIPTION: enter the day in which you are making the observation (DD/MM/YYYY).
- HOUR OF DESCRIPTION: put in the hour of the day in which you are making the observation. Indicate if it is a.m. or p.m., crossing out the inappropriate one.
- SURVEYOR'S NAMES: enter your name/s.
- LOCATION: using topographic maps or other maps you are carrying, enter the name of the closest town, village or significant physical feature.

Coordinates

- X (LONGITUDE EAST): using a GPS, obtain the exact value of the X coordinate in UTM format (6 digits plus 2 decimal digits)
- Y (LATITUDE NORTH): using a GPS, obtain the exact value of the Y coordinate in UTM format (7 digits plus 2 decimal digits)
- ELEVATION: using an altimeter obtain and enter the elevation of the observation point

Weather conditions

- CLOUDINESS: tick a cloudiness condition listed here
- WIND CONDITIONS: tick a wind speed listed here
- VISIBILITY: tick a visibility option listed here
- TEMPERATURE: if you have a thermometer, enter the value shown

Sketch: draw the landscape you see in front of you, remembering to always indicate north, east, south or west.

Landscape: referring to the field manual, enter the correct code and description of the landscape/s you see to the north, east, south and west. If the landscape is characterised by several elements in different perspectives (foreground, background, etc.) you may choose more landscapes, indicating which perspective they belong to.

Relief type: with reference to the field manual enter the correct code and description for relief type/s you see to the north, east, south and west. If the relief type is characterised by more elements in different perspectives (foreground, background, etc.) you may choose more relief types, indicating which perspective they belong to.

Landform: Referring to the field manual, enter the correct code and description for the landform/s you can see looking to the north, east, south and west. If the landform is characterised by more elements in different perspectives (foreground, background, etc.) you may choose more landforms, indicating which perspective they belong to.

Photographs: enter the numbers of the pictures you are taking; procedures to remember when taking pictures are given in the manual.

Annotations: use any useful annotations on the character of the landscape, relief type and/or landform you are describing.

B. Detailed landform observations – Form LNF-B

For this activity use the form LNF-B

Describe in detail the landform parameters of each site (landform observation points, land cover field sampling quadrat and soil sampling transects), following these steps:

1. Find the highest point inside the land cover field sample quadrat and determine if it allows a general overview of the quadrat. If not, find another elevated observation point that allows you to clearly see surface features within it.
2. Carefully observe the landforms around you, focusing on the field sample quadrat and turning a full 360° in order to obtain an overview of the land surface features both inside and outside of the quadrat.
3. Identify north, using a compass.
4. Take photographs as indicated in chapter "5.3.3.3 Taking photographs", starting clockwise from north.
5. Starting from north, move in a clockwise direction and complete the landform form, describing what you see.
6. Fill in Form 6-B, focusing on the land cover field sampling quadrat.
7. Make use of sketches, pictures, colours and any other annotations, considerations and/or tools that you find useful.

Form field explanations

Landscape: with reference to the field manual, enter the correct code and description for the landscape that best represents the land cover field sampling quadrat.

Relief: with reference to the field manual, enter the correct code and description for the relief type that best represents the land cover field sampling quadrat.

Landform: with reference to the field manual, enter the correct code and description for the landform that best represents the land cover field sampling quadrat.

Slope angle: using a gradiometer (or evaluate from a distance) measure slope angle and choose ONE of the seven slope angle classes. Note that all values are given as percentages.

Slope length: measure (or evaluate from a distance) the maximum slope length within the land cover field sampling quadrat and choose ONE of the five slope length classes. Note that all values are in meters.

Slope aspect: using a compass, determine the average slope aspect of the land cover field sampling quadrat and choose ONE of the five slope aspect classes. Note that all values are in degrees.

General position: observing the average location slope of the land cover field sampling quadrat, choose one of the three options (1, 2 or 3).

Specific position: in this section, give a more detailed characterization of the slope than the previous one.

If in the section General Position you have chosen the number 1 – TOP, refine your observation using the 1-1, 1-2 or 1-3 options.

If in the section General Position you have chosen the number 2 – SLOPE, refine your observation using the 2-1A (rectilinear profile & concave plan), 2-1B (convex profile & concave plan), 2-1C (concave profile & concave plan), 2-2A (rectilinear profile & straight plan), 2-2B (convex profile & straight plan), 2-2C (concave profile & straight plan) or 2-3A (rectilinear profile & convex plan), 2-3B (convex profile & convex plan), 2-3C (concave profile & convex plan) options.

If in the section General Position you have chosen the number 3 – PLAIN, refine your observation using the 3-1 (Plain), 3-2 (plateau), 3-3 (narrow valley floor), 3-4 (wide valley floor), 3-5 (terraced system valley) options.

Form Progressive Number:

____

LANDFORM – LNF- A

GENERAL LANDFORM OBSERVATIONS

DATE OF DESCRIPTION: …………………………..
HOUR OF DESCRIPTION:………………..a.m./p.m.
SURVEYOR'S Names: ……………………………….
…………………………………………………………..
LOCATION: …………………………………………...
…………………………………………………………..
…………………………………………………………..
…………………………………………………………..
…………………………………………………………..

GPS Progressive Number: ____________
X (longitude East):
……………..……………………………
Y (latitude North):
…………………………………………..
Elevation (m a.s.l.): ……………………

WEATHER CONDITIONS:

CLOUDINESS	**WIND CONDITIONS**	**VISIBILITY**	**TEMPERATURE**
□ Sunny	□ No wind	□ Optimal visibility	
□ Partly cloudy	□ Moderate wind speed	□ Partly foggy	°C:…...............
□ Cloudy	□ Windy	□ Foggy	
□ Rainy	□	□ Totally foggy	
□ Stormy			

Notes:…….
…….

SKETCH DRAWING OF THE SITE SURROUNDINGS (always enter the directions N, E, S, W)

Landscape

CODE	DESCRIPTION	NORTH	EAST	SOUTH	WEST	NOTES
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	

Relief type

CODE	DESCRIPTION	NORTH	EAST	SOUTH	WEST	NOTES
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	

Landform

CODE	DESCRIPTION	NORTH	EAST	SOUTH	WEST	NOTES
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	
		□	□	□	□	

Pictures:
North: ______________________________
East: ______________________________
South: ______________________________
West: ______________________________
Notes:..

Annotations: ....

....

....

LANDFORM – LNF-B

DETAILED LANDFORM OBSERVATIONS

LANDSCAPE/RELIEF TYPE/LANDFORM OF THE SPECIFIC SITE

Landscape

Code	Description	Annotation

Relief type

Code	Description	Annotation

Landform

Code	Description	Annotation

SLOPE ANGLE, to be measured carefully with the gradiometer (SUUNTO) (choose **ONE** of the following classes)

	Value	Description	Code
□	0-2%	Level	LE
□	2-4%	Very gently sloping	VG
□	4-8%	Sloping	GS
□	8-16%	Moderately sloping	MS

	Value	Description	Code
□	16-30%	Strongly sloping	SS
□	30-50%	Very steep	VS
□	>50%	Extremely steep	ES

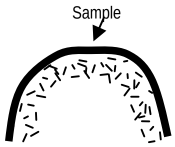
SLOPE ASPECT, to be calculated with a compass (choose **ONE** of the following classes. North is 0°)

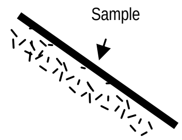
	Value	Description	Code
□	--	Flat or almost flat	FLT
□	--	Variable	VAR
□	338° - 22°	North-facing	N
□	23° - 67°	North-east facing	NE
□	68° - 112°	East-facing	E

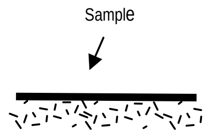
	Value	Description	Code
□	113° - 157°	South-east facing	SE
□	158° - 202°	South-facing	S
□	203° - 247°	South-west facing	SW
□	248° - 292°	West-facing	W
□	293° - 337°	North-west facing	NW

GENERAL POSITION

Looking at the diagrams below, choose **ONE** of the three following main positions in respect to the slope:



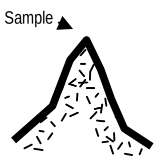


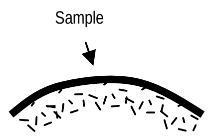


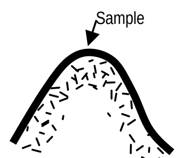
□1 - on TOP of a relief □2 - on a SLOPE □3 - on a PLAIN

SPECIFIC POSITION:

If in “General Position” **you have chosen 1** (TOP of a relief) then distinguish between the following “TOP OF RELIEF” SUBTYPES, looking at the scheme below choose **ONE** of the three following options:

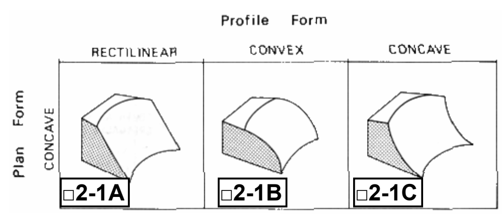


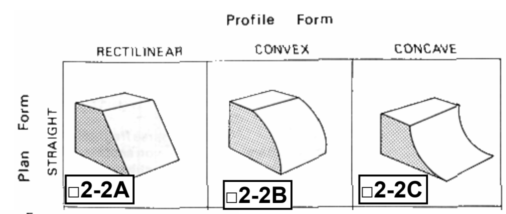


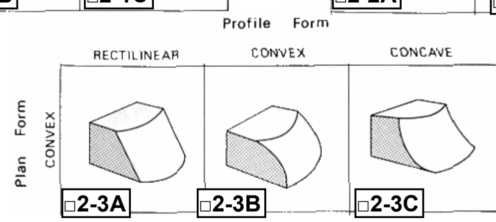


□1-1 HORN □1-2 ALMOST FLAT □1-3 SMOOTH

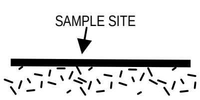
If in “General Position” **you have chosen 2** (SLOPE) then distinguish between the following “SLOPE” SUBTYPES, looking at the scheme below choose **ONE** of the six following options:

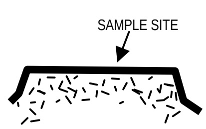


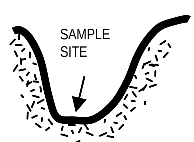


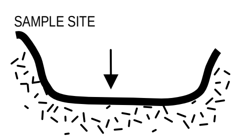


If in “General Position” **you have chosen** 3 (PLAIN) then distinguish between the following “PLAIN” SUBTYPES, looking at the scheme below choose **ONE** of the six following options:

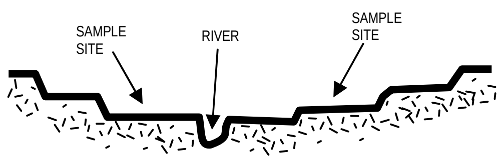








□3-1 PLAIN VALLEY □3-2 PLATEAU □3-3 NARROW VALLEY □3-4 WIDE



□ 3-5 TERRACED SYSTEM VALLEY

LANDSCAPES (first-order land-surface features - glossary for the northern area of study)

Code	Description	Definition
Mou	Mountain	A feature of the earth's surface that rises high above the base and generally has steep slopes and a relatively small summit area. Mountains can be isolated features or arranged in systems. Successions of mountains (mountain ranges or mountain systems) are generally closely related in position, orientation and geologic features. They are an elevated, rugged, deeply dissected portion of land characterised by significantly greater height in relation to lower-lying surrounding areas, sometimes reaching 1,000s of metres a.s.l.. They result in localised differences in climate, drainage, soils, flora and fauna.
MoB	Block mountain	A mountain originating through tectonic **faulting**, specifically vertical faulting. The resulting primary landforms are long and well-preserved escarpments, long straight features, fault lines or fault valleys and/or high relief .
MoF	Fold mountain	A mountain originating through tectonic **folding**. The resulting primary landforms are anticline and syncline valleys, usually with gentle flanks and the development of flat irons, antecedent river valleys, long and well preserved escarpments and fault lines or fault valleys.
MoV	Volcanic mountain	A mountain originating through **volcanic** activity. The resulting main landforms are cones or cone-shaped relief, or remnants of same. A generally high and intense degradation takes place on the slopes of young volcanoes. A characteristic centrifugal drainage pattern develops on their tops.
MoR	Residual mountain	The remains of bigger mountains created through chemical dissolution and disintegration of rocks. They are usually found in arid climates where weathering of rocks is stronger than in middle latitudes**.** They are strongly influenced by the nature of the underlying rock.
Hil	Hill land	A land surface feature characterised by strong relief rising straight from plains or surrounding areas, usually not exceeding a height of about 300 m. It is a prominence smaller than a mountain and like a mountain can be isolated (see the relief type Hill) or in complexes (see the relief type Hill complex). It has uneven summit heights, separated by a relatively dense hydrographic network.
HiD	Dissected hill land	A hill land that has undergone a deeply fluvial incision leaving a rougher topography than the more gently undulating hill land.
Pie	Piedmont	Any sloping surface at the foot of more elevated landscapes such as plateaux, hills or mountains. Also an area of gentle slopes and low relief flanking an upland area. The term is commonly applied to assemblages of planar alluvial surfaces flanking an area of mountains or rocky desert uplands.
Pta	Plateau	An extensive flat or almost flat surface found in upland regions, considerably elevated above the

		adjacent landscape and limited by an abrupt descent scarp on at least one side. It may also be a volcanic plateau, formed by successive eruptions of very fluid basic lava from a large number of linear or fissure vents in the crust. As successive eruptions take place, with little explosive action, very mobile basaltic lava spreads out over preceding flows. Eventually, lava depth may be 100s of meters thick, completely covering the original landscape. Vertical jointing in the basalt causes the plateau edges to be very abrupt and where rivers have dissected the plateau, valleys tend to be steep-sided gorges. "Steps fault platform" is a term used to indicate a broad landform with irregular features produced by step faulting. Plateaus can be volcanic in origin, but upland features with level summits can also be found in sedimentary and metamorphic formations. Plateaus often consist of horizontally-bedding rocks, and vary in size from sub-continental features such as the Deccan plateau in India, to small mesas in the American south-west.
PtD	Dissected plateau	A plateau that has experienced deep fluvial incision/s, leaving a rougher topography than the almost flat plateau. Valleys and hills can develop by this process.
PtV	Volcanic plateaux/shield	A hill or mountain formed by eruption of molten rock from a central opening or vents in the earth's crust. Lava edifices are built by successive lava flows. The size and the shape of a shield are primarily determined by types of material/s ejected. Lava viscosity depends on the % of silica. Silica content between 20-60% acid rock (e.g. rhyolite) is extremely viscous and immobile. Less than 20 % of SiO_2 (e.g. trachyte) is fairly viscous and unable to flow far before solidifying, while basalt is very fluid and mobile). Large quantities of free-flowing basalt can build up a broad shield volcano by being able to flow for long distances before solidifying. The basalt volcano is generally a large accumulation of basic lava with gently sloping sides, often flat-topped and usually low in height relative to a large basal diameter. Some of these shields represent residual landforms called calderas, which are large rounded depressions resulting from the violent eruption and destruction of the upper part of a volcano. Calderas are also created by subsidence; major eruptions, by reducing the magma supply, leave a huge chasm beneath a volcano. The weight of the overlying cone becomes too great, faults develop and it collapses. Many calderas probably result from a combination of both explosions and subsidence. The slopes of these edifices can be deeply dissected by radial valleys. Erosion first develops on the upper slopes, when triangular facets of the original volcano (called planezes), may remain on the lower slopes. Eventually the planezes are also destroyed.
Pen	Peneplain	Gently undulating area characterised by a series of rounded or elongated low hills, with summits of similar height separated by a dense, reticular hydrographic network. They form either by dissection of a former plain or plateau, or by down-weathering and flattening of an originally rugged

		land surface.
Pln	Plain	An extensive, generally broad tract of land, flat or gently sloping, unconfined, low-lying with low relief intensity (varying up to 10 m) and gentle slopes (generally <3%). They can occur around mountain/hill bases, along primary river valleys or along coastlines.
PlA	Alluvial plain	Plains derived through fluvial activity, characterised by extensive alluvial deposits. Usually without well-developed drainage network/s. They have very low slopes and are some 100s to 1,000s meters wide.
PlK	Karst plain	Plains derived mainly through chemical dissolution of limestones and salty rocks (gypsiferous rocks) under specific climatic conditions. They tend to have no surface drainage and karstic features such as dolines, poljes (karst windows), etc. often occur.
PlC	Coastal plain	Plains generated by the activity of ocean or sea movements: they can be either erosional (erosion of a rocky coast gives rise to a flat rocky platform, erosion of a dune system gives rise to almost flat sandy surface, etc.) or depositional (accumulation of sand or gravel).
PlD	Dissected /incised plain	Very gently sloping land marked by intense erosive cutting with a well-developed drainage network.
Vay	Valley	Elongated, flat land portion intercalated between two bordering, higher relief zones (e.g. piedmont, plateaux, hill or mountain). Primary origins can be linked to fluvial/erosion activities, but weathering is also an important factor in their development.
VaL	Lateral valley	A tributary fluvial valley leading to a main valley, usually with a sharp junction (angle close to 90°) to the main valley.

RELIEF TYPES (second-order land surface features - glossary for the northern area of study)

Code	Description	Definition
S08	Escarpment	A fault scarp (or escarpment) is a steep, exposed slope where the land falls from a higher to lower level. Usually escarpments can be caused by vertical displacement of the earth's surface along fault lines. Some are clearly defined while others are less evident, especially if weathering and vigorous erosion has taken place on softer rocks. It forms a linear extensive straight or sinuous steep slope.
S15	Depression	An elongated trough or depression bounded by inward-facing scarps along faults. Depressions can vary in width, with flat (or almost flat) bottoms.
S16	Dissected ridge	An elongated, narrow, steep-sided elevation of the earth's surface. Its crest and slopes are cut by water running in channels and it contains a number of slope faces and peaks.
S24	Inselberg	Inselbergs (German - meaning 'island mountain') are steep-sided residual hills, knobs or mountains, generally rocky and bare, rising abruptly from an extensive lower land erosion surface and some surrounded by gentle rock pediments. They vary in shape and size, from small hills less than 100 m high to much higher elevations.
S26	Mesa	A steep sided plateau of rock, in horizontally bedded rocks, surrounded by a plain.
S27	Hogback	A long ridge of rock dipping steeply on both sides, the exposure of a stratum of hard rock which has been tilted until the original horizontal beds are almost vertical.
S29	Hill	An isolated and well-defined landform with a gently undulating summit, gently inclined to precipitous slopes. The drainage network varies from fixed, shallow erosional stream channels to very wide-spaced drainage. Erosion by wash and creep occurs continuously on their slopes and, in some cases, by landslides. Their relief intensity is usually not greater than 300 m.
S30	Hill complex	A complex of adjoining hills, as defined above.
S31	Ridge	An elongated, narrow, steep-sided elevation of the earth's surface. It has a single crest, which may have a more or less constant elevation, or may contain a number of peaks.
S32	Planation surface	A term commonly used to describe a flattish plain resulting from erosion. It is usually a very gently sloping surface and can be incised by rivers or fractures.
S33	Denudational slope	A slope on which there is clear evidence of erosional processes through active canalised running water, or through landslides, creep, etc.
S34	Slope	The flank of a mountain, hill, hill complex, ridge, etc. on which it is not possible to recognise any of the detailed features adopted here. Its slope and relief intensity can vary significantly.
S35	Denudational surface	An almost flat surface on which there is clear evidence of erosional processes through active canalised running water, or through landslides, creep, etc.
E05	Playa	A closed depression in a dryland area that is periodically inundated by surface water. The term is

		also used to refer to the salty flat surface that may occupy such a depression. Terms such as pan, chott, and kavir are used for the same features.
F04	Braided river plain	A plain with a river whose flow breaks into a number of interlaced branches that divides and rejoins.
F05	Meandering river plain	A plain where a sinuous winding river flows.
F06	Straight river plain	A plain where an almost straight river flows.
F09	Gully/rill erosion surface	A gully is a steep-sided trench or channel, often several metres deep, cut into poorly-consolidated bedrock, weathered sediment or soil. A gully is deeper and longer than a rill. Rills are very small ephemeral channels that often form in sub-parallel sets on sloping agricultural land in response to intense runoff events. They are also common on steep and unprotected surfaces such as road and other earth embankments. Rills may be cm-dm in width and depth, but rill lengths may reach 100s of meters.
F10	Sheet erosion surface	A surface where soil material is being/has been stripped from a relatively broad area such as a field or hillside, to a uniform depth without the incision of drainage channels as large as gullies.
F12	Alluvial plain	A fan-shaped deposit formed by a stream either where it issues from a narrow mountain valley onto a plain or broad valley, or where a tributary stream joins a main stream. It forms a cone radiating downslope from where the stream leaves the source. The coalescing of many alluvial fans forms a depositional piedmont that is commonly called bajada.
F13	Depression	A depression caused by fluvial incision/erosion where fluvial erosion-transport-sedimentation is the main morphogenetic process.
F14	Pediment	A term defined as a smooth concave upward erosion surface, typically sloping down from the foot of a highland area and graded to either a local or more general base level. It is an element of the piedmont belt, which may include depositional elements, such as fans and playas. The pediment excludes such depositional components although an alluvial cover is frequently present. It is broadly synonymous to the French term *glacis*. Coalescent pediments form pediplans.
F15	Dissected pediment	A pediment cut by numerous fluvial incisions (sometimes very deep) or by fracture/fault planes that give rise to a dissected pediment topography.
F16	Delta	Accumulation of river-borne sediment deposited at the coast where a river enters a receiving body of water such as an ocean, lagoon, estuary or lake. Deltas result from the interaction of fluvial and marine forces and their development involves the progradation of river mouths and delta shorelines, producing a sub-aerial deltaic plain surmounting delta front deposits which have accumulated to seaward.
F17	Flat floor valley	A small valley whose floor is flat or almost flat, usually occurring in the upper parts of catchments and normally, but not always, without permanent drainage and often cultivated. Its downslope limit is indicated by an abrupt change of slope.
G08	Talus slope	An accumulation of mostly angular clasts lying at an

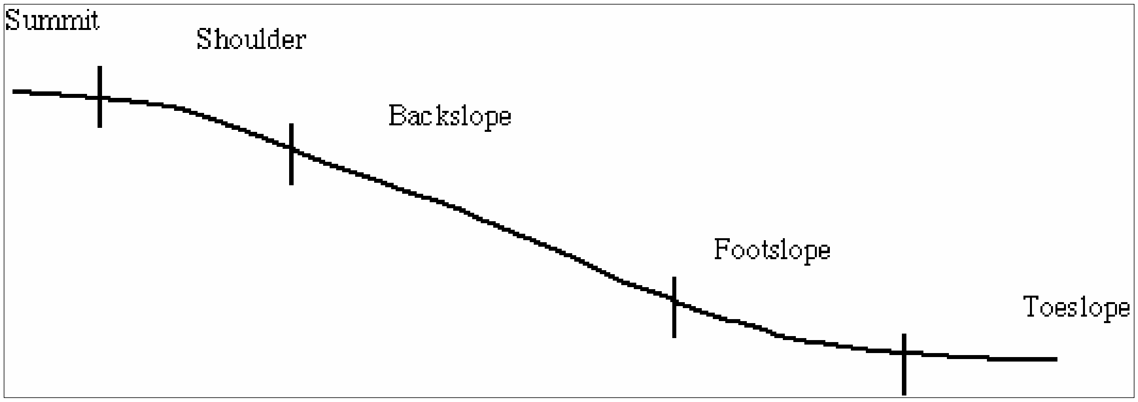
		angle of about 36° beneath an exposed free rock face or cliff. The primary cause of deposition is rock-fall, but other processes such as debris flow may contribute to their development. The largest clasts occur at the base of the slope.
C03	Sandy coast	Or beaches, are accumulations of sand deposited by waves and longshore current/s along marine shores.
A02	Town, industrial district	An area occupied by residential and/or industrial buildings, usually with roads present and may have railway/s as well. It has to be clearly visible on satellite imagery.

LANDFORMS (third-order land surface features - glossary for the northern area of study)

Code	Description	Definition
F02	Rill	A small ephemeral channel, often forming in sub-parallel sets on sloping agricultural land in response to intense run-off events. They are also common on steep and unprotected surfaces such as road and other earth embankments. Rills may be cm-dm in width and depth, but rill lengths may reach 100s of meters.
F03	Gully	A steep-sided trench or channel, often up to several metres deep, incised into poorly consolidated bedrock, weathered sediment or soil. The agent of gullying is the ephemeral flow of running water. A gully is deeper and longer than a rill.
F05	River levee	A broad, long-crested ridge running alongside a floodplain stream or intertidal inlet, composed generally of coarse sand or silt sediments deposited by floodwaters as they overtop channel banks.
F06	Floodplain	Relatively flat alluvial landform, constructed generally by a river flow regime and subject to flooding. Floodplains commonly flank a clearly-defined river channel, but may also occur in valleys without channels while others form downstream of channels.
F07	Terrace	Former floodplain with inactive or barely active erosion and aggradation, because deepening or enlargement of the stream has lowered the level of flooding. Terrace elevation on active floodplains can vary from a few meters to 100s of metres. There can be paired and unpaired fluvial terraces along the main river/alluvial plain.
F09	Depression	A land surface lower than the surroundings due to fluvial erosion. It is normally sub-circular or elliptical in shape and maintains a well-developed drainage network. It can be assimilated by a small basin catchment.
F14	Upper pediment	The upper part of a pediment, recognizable by the presence of an abrupt change in slope between the lower and middle parts.
F15	Middle pediment	The middle part of a pediment, recognizable by the presence of an abrupt change in slope between the upslope Upper pediment and the downslope Lower pediment.
F16	Lower pediment	The lower part of a pediment, recognizable by the presence of an abrupt change in slope from the upslope Middle part of pediment.
X01	Summit	Refer to figure at base of page
X02	Shoulder	Refer to figure at base of page
X03	Backslope	Refer to figure at base of page
X04	Footslope	Refer to figure at base of page
X05	Toe-slope	Refer to figure at base of page
X06	Upper slope	The upper part of a slope, marked by a clear change in slope angle along its length. It is used when it is not possible to distinguish all five distinctions of a slope.
X07	Lower slope	The lower part of a slope, marked by a clear change in slope angle along its length. It is used when it is not possible to distinguish all five distinctions of a slope.

X08	Slope complex	A slope where it is not possible to distinguish any of the previous two systems (5 different tracts or even 2 tracts)
X09	Crest	The uppermost part of a relief, ridge or hill, showing a long and sometimes sharp shape. It can also be almost flat, but its length is always longer than its width.

Figure 1.3 - Ruhe's slope model



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2 SOIL SURVEY

2.1 Introduction

This chapter will support soil surveyors with theoretical and practical issues regarding the soil survey that the SWALIM Project is carrying out as part of their activities in Somaliland and Southern Somalia.

It provides technical information to soil surveyors describing and classifying soil profiles in the field, using a Soil Form (form for field data collection) as well as guidance in the process of describing soil properties under the FAO system. The references supporting this document are FAO (1990, 2006), IAO (2005) and the authors' experience.

The soil manual is divided into two parts:

i. Description of the soil surface; and

ii. Soil profile description.

2.2 Description of the soil surface

2.2.1 Profile and transect code

The profile number is an identification code that facilitates retrieval of the soil profile description from the data storage system. The use of the code is mandatory in the strategy of the Land Resources Survey. The transect code should be located on the map provided to the surveyor for use while in the field.

2.2.2 Date of description

The day, month and year of the description are indicated to show future users the age of the data. The date of the description is given as dd/mm/yy (6 digits), e.g. 15 May 2006 is coded as 15/05/06.

2.2.3 Surveyor(s)

The names and initials of the person/s conducting the soil profile description and sampling are noted, to allow acknowledgment by future users of the data and also for future tracking of data.

Example: Ahmed Jama (A.J.)

2.2.4 Location

The location of the soil profile is described in terms of distance from (in kilometres) and direction to the nearest permanent feature, such as a village, market, hill, dam or school or name of a farm. Administrative units such as locality, district, region and country are also given.

2.2.5 Coordinates

The coordinates of the point where the soil profile is being described should be recorded by Global Positioning System (GPS), using the same coordinate format as the available maps.

2.2.6 Landform Unit

During the soil survey, the soil and landscape will be identified in relation to the soil description site. The soil surveyor will have a landform map generated through the Geopedological approach. In the field, the surveyor should write the landform code used on the landform map and also describe the landform characteristics where the soil profile is located.

> Example: Pie/F14/F14: Pie = Piedmont, F14 = Pediment, F14 = Upper pediment. As this data is taken from the preliminary landform map, the surveyor should describe the landform where the soil profile is located.

2.2.7 Lithology

As a major soil forming factor, it is important to describe the parent material from which the soil developed. The surveyor should identify the lithology and refer to the classes that are presented in Table 2.3 (adapted from SOTER, ISRIC, 2005).

2.2.8 Surface humidity

Surface humidity is an external characteristic of a soil surface that is influenced by atmospheric conditions. It is important because it expresses the moisture status of the area itself and influences soil properties and behaviour. Soil surface humidity levels are qualitative and based on technical observation by the soil expert with reference to Table 2.1 (below).

Table 2.1 - Surface humidity classes (FAO, 1990)

Code	Description
D	Dry
M	Slightly moist
S	Moist
W	Wet

2.2.9 Soil drainage class

This property relates to the internal drainage of soil, which is dependent on the physical properties of the soil itself. After carrying out the soil profile description and describing the physical soil properties we'll be able to properly judge the internal drainage of the soil. However, when we are describing general aspects of the soil, we need to make a qualitative opinion about the natural soil drainage capacity, where assessment of the soil profile is based on general appearances such as soil colour. For example, pale colours express that a soil is well- or excessively drained. Dark colours such as greyish, suggest a poorly-drained or permanently saturated condition. The surveyor can also consider the soil texture variability in the profile. Table 2.2 shows soil drainage classes.

Table 2.2 - Soil drainage classes (FAO, 1990)

Code	Description
0	Very poorly drained (always saturated)
1	Poorly drained (saturated for long periods every year)
2	Imperfectly drained (saturated for short periods)
3	Moderately well-drained (rarely saturated)
4	Well-drained (never saturated)
5	Somewhat excessively drained
6	Excessively drained

Table 2.3 - Lithological groups and types (adapted from SOTER, ISRIC, 2005)

Major class	Main group		Rock type		Definition
	Code	*Description*	*Code*	*Description*	
Igneous (I)	**IA**	**Acid**	**IA1**	Granite	A coarse-grained intrusive igneous rock containing at least 65% silica. Quartz, plagioclase feldspar and potassium feldspar make up most of the rock and give it a fairly light colour. Granite has more potassium feldspar than plagioclase feldspar. Usually with biotite, also hornblende.
			IA3	Syenite	Intrusive equivalent of trachyte, usually containing the minerals orthoclase, microcline, small amounts of plagioclase, one or more mafic minerals (esp. hornblende) and little to no quartz. With an increase in quartz content it grades into granite.
			IA4	Rhyolite/dacit e	Extrusive rock, typically porphyritic and commonly exhibiting flow texture, with phenocrystals of quartz and alkali feldspar in a glassy to cryptocrystalline groundmass. Rhyolite is an extrusive equivalent of granite. Dacite is a fine-grained extrusive rock with the same general composition as andesite but with less calcic plagioclase and more quartz.
	II	**Intermediate**	**II2**	Diorite/diorite -syenite	Intrusive igneous rock made of plagioclase feldspar and amphibole and/or pyroxene. Similar to gabbro, not as dark, less iron and magnesium.
	IB	**Basic**	**IB1**	Gabbro	A dark, coarse-grained intrusive igneous rock. Consists of calcium-rich plagioclase, with amphibole and/or pyroxene, is chemically equivalent to basalt.
			IB2	Basalt	A dark, fine-grained, extrusive (volcanic) igneous rock with low silica content (40% - 50%), but rich in iron, magnesium and calcium. Generally occurs in lava flows, also as dikes. Makes up most of the ocean floor and is the most abundant volcanic rock in Earth's crust.
			IB3	Dolerite/ diabase	A dark, fine-grained igneous rock, consisting mainly of dark pyroxene surrounding light feldspar crystals.

Table 2.3 cont. - Lithological groups and types (adapted from SOTER, ISRIC, 2005)

Major class	Main group		Rock type		Definition
Igneous (I) *(continued)*	**IP**	**Pyroclastic**	**IP1**	Tuff/tuffite	A term for all consolidated pyroclastic rocks (tuff) that can also contain detrital material (tuffite).
			IP2	Volcanic scoria/breccia	Very bubbly (vesicular) basalt or andesite. Both scoria and pumice develop their bubbly textures when escaping gas is trapped as lava solidifies. Scoria is more dense and darker than pumice.
			IP3	Volcanic ash	
			IP4	Ignimbrite	Rock formed by the widespread deposition and consolidation of ash flows and nuées ardentes.
Metamorphic (M)	**MA**	**Acid**	**MA1**	Quartzite rock	Hard, somewhat glassy-looking rock made up almost entirely of quartz. Metamorphosed quartz sandstone and chert are quartzites
			MA2	Gneiss, migmatite, granulite	Coarse-grained, foliated metamorphic rock that commonly contains alternating bands of light and dark-coloured minerals (gneiss). Is a "mixed rock", which forms in one of two ways. Metamorphic rock may be heated enough to partially melt, but not completely. The molten minerals re-solidify within the metamorphic rock, producing a rock that incorporates both metamorphic and igneous features. Migmatites can also form when metamorphic rock experiences multiple injections of igneous rock that solidify to form a network of cross-cutting dikes (migmatite).
			MA3	Slate, phyllite (pelitic rocks)	A compact fine grained metamorphic rock with slatey cleavage and hence can be split into slabs and thin plates. Most slates have been formed from shale.
			MA4	Schist	Metamorphic rock usually derived from fine-grained sedimentary rock such as shale. Individual minerals in schist have grown during metamorphism and are easily visible to the naked eye. Schists are named for their mineral constituents - for example, mica schist is conspicuously rich in micas such as biotite or muscovite.

Table 2.3 cont. - Lithological groups and types (adapted from SOTER, ISRIC, 2005)

Major class	Main group		Rock type		Definition
Metamorphic (M) *(continued)*	**MB**	**Basic**	**MB**	Basic metamorphic	
			MB1	Slate, phyllite (pelitic rocks)	A very fine-grained, foliated metamorphic rock generally derived from shale or fine-grained sandstone. Phyllites are usually black or dark grey; the foliation is commonly crinkled or wavy. Differs from less re-crystallized slate by its sheen, produced by barely visible flakes of muscovite (mica).
			MB2	Schist (green)	A schistose metamorphic rock whose green colour is due to the presence of chlorite, epidote or actinolite
			MB3	Gneiss rich in ferro-magnesium minerals	
			MB4	Metamorphic limestone (marble)	A metamorphic rock made of calcium carbonate. Marble forms from limestone by metamorphic recrystallization
			MB5	Amphibolite	A rock made up mostly of amphibole and plagioclase feldspar. Although the name amphibolite usually refers to a type of metamorphic rock, an igneous rock composed dominantly of amphibole can be called an amphibolite too.
			MB6	Eclogite	A granular rock composed essentially of garnet and sodic pyroxene. Rutile, kyanite and quartz are typically present.
	MU	**Ultrabasic**	**MU1**	Serpentinite, greenstone	A metamorphic rock derived from basalt or chemically equivalent rock such as gabbro. Greenstones contain sodium-rich plagioclase feldspar, chlorite, and epidote, as well as quartz. The chlorite and epidote make greenstones green.

Table 2.3 cont. - Lithological groups and types (adapted from SOTER, ISRIC, 2005)

Major class	Main group		Rock type		Definition
Sedimentary (S)	**SC**	**Clastic**	**SC1**	Conglomerate, breccia (consolidated)	A sedimentary rock made of rounded rock fragments such as pebbles, cobbles and boulders in a finer-grained matrix. To be named a conglomerate, some of the constituent pebbles must be at least 2 mm (about 1/13th of an inch) across. Rock made up of angular fragments of other rocks held together by mineral cement or a fine-grained matrix. **Volcanic breccia** is made of volcanic rock fragments, generally blown from a volcano or eroded from it. **Fault breccia** is made by breaking and grinding rocks along a fault.
			SC2	Sandstone, greywacke, arkose	Sedimentary rock consisting mostly of sand-sized grains.
			SC3	Siltstone, mudstone, claystone	A very fine-grained sedimentary rock formed from mud (mudstone).
			SC4	Shale	Sedimentary rock derived from mud. Commonly finely laminated (bedded). Particles in shale are usually clay minerals mixed with tiny grains of quartz eroded from pre-existing rocks. **Shaley** means "like" shale or having some shale component, as in shaley sandstone.
	SO	**Organic**	**SO1**	Limestone, other carbonate rock	Sedimentary rock made mostly of calcite (calcium carbonate). Limestone is usually formed from shells of once-living organisms or other organic processes, but may also form by inorganic precipitation. A magnesium-rich carbonate sedimentary rock. Also, a magnesium-rich carbonate mineral ($CaMgCO_3$) (dolomite)
			SO2	Marl and other mixtures	Unconsolidated earthy deposits consisting chiefly of an intimate mixture of clay and calcium carbonate, usually including shell fragments and sometimes glauconite.
	SE	**Evaporites**	**SE1**	Anhydrite, gypsum	The commonest sulphate mineral, frequently associated with halite and anhydrite in evaporites, forming thick, extensive beds.
			SE2	Halite	Native salt rock (NaCl) occurring in massive, granular, compact or cubic crystalline forms.

Table 2.3 cont. - Lithological groups and types (adapted from SOTER, ISRIC, 2005)

Major class	Main group		Rock type		Definition
Unconsolidated rocks (U)	**US**	**Sedimentary**	**US1**	Unconsolidated undifferentiated sediments	
	UR	**Weathered residuum**	**UR1**	Bauxite, laterite	A grey, yellow or reddish-brown rock composed of a mixture of various aluminium oxides and hydroxides, along with free silica, silt, iron hydroxides and clay minerals. If it is highly aluminous it is called laterite.
	UF	**Fluvial**	**UF1**	Sand and gravel	A detrital particle smaller than a granule and larger than a silt grain, having a diameter between 0.06 - 2 mm (sand). If larger than 2 mm it is gravel.
			UF2	Clay, silt and loam	A detrital mineral particle of any composition having a diameter ≤0.004 mm (clay) or between 0.004 - 0.06 mm (silt) or a soil composed of a mixture of clay, silt, sand and organic matter (loam).
	UL	**Lacustrine**	**UL1**	Sand	A detrital particle smaller than a granule and larger than a silt grain, having a diameter in the range of 0.06 - 2 mm.
			UL2	Silt and clay	Loose particles of rock or mineral (sediment) between 0.002 - 0.06 mm in diameter. Silt is finer than sand, but coarser than clay.
	UM	**Marine and estuarine**	**UM1**	Gravel	A detrital particle with a diameter larger than 2 mm.
			UM2	Sand	
			UM3	Clay and silt	
	UC	**Colluvial**	**UC1**	Colluvial	
			UC2	Slope	
			UC3	Lahar	
	UE	**Aeolian**	**UE1**	Sand	
	UA	**Anthropo-genic**	**UA1**	Redeposited natural material	
			UA2	Industrial/ artisanal deposits	
	UU	**Unspecified**	**UU1**	Clay	
			UU2	Loam and silt	
			UU3	Sand	
			UU4	Gravely sand	All sedimentary particles larger than two mm are classified as gravel, subdivided into pebbles, cobbles, and boulders.
			UU5	Gravel, broken rock, blocks	
			UU6	Other	

2.2.10 Presence of salts

The degree of salinity (salts) at the surface may be described in terms of cover and thickness. Extent and thickness should be estimated visually, based on the ranges given in Table 2.4 below.

Table 2.4 – Salt Characteristics

SALTS *(FAO, 2006)*					
COVER			THICKNESS		
Description	*%*	*Code*	*Description*	*mm*	*Code*
None	0	0	None		N
Low	2-15	1	Thin	<2	F
Moderate	15-40	2	Medium	2-5	M
High	40-80	3	Thick	5-20	C
Dominant	>80	4	Very thick	>20	V

2.2.11 Presence of surface cracks

Surface cracks develop in shrink-swell clay-rich soils after drying out. The width (average or maximum) of cracks at the surface is indicated in centimetres. The average distance between cracks may also be indicated in centimetres. The classes given in Table 2.5 below may be used.

Table 2.5 - Presence of cracks

CRACKS *(FAO, 1990)*					
WIDTH			DISTANCE		
Description	*cm*	*Code*	*Description*	*m*	*Code*
Fine	<1	F	Very closely spaced	<0.2	C
Medium	1-2	M	Closely spaced	0.2-0.5	D
Wide	2-5	W	Mod. Widely spaced	0.5-2	M
Very Wide	5-10	V	Widely spaced	2-5	W
Extremely wide	>10	E	Very widely spaced	>5	V

2.2.12 Surface sealing

Surface sealing is used to describe crusts that develop at the soil surface after the topsoil dries out. These crusts may inhibit seed germination, reduce water infiltration and increase runoff. The attributes of surface are the consistence, when dry, and thickness of the crust as per table 2.6.

Table 2.6 – Surface sealing

ATTRIBUTES OF SURFACE SEALING *(FAO,2006)*				
Thickness			**Consistence**	
Description	**mm**	**Code**	**Description**	**Code**
None		N	Slightly hard	S
Thin	<2	F	Hard	H
Medium	2-5	M	Very hard	V
Thick	5-20	C	Extremely hard	E
Very thick	>20	V		

2.2.13 Slope gradient

The slope gradient refers to the slope of the land immediately surrounding the site. It is measured using a clinometer aimed in the direction of the steepest slope. Where clinometer readings are not possible, field estimates of slope gradient should be matched against calculated gradients from contour maps.

Table 2.7 contains the different slope classes to be recorded in terms of actual, measured value.

Table 2.7 – Slope gradient classes

SLOPE GRADIENT CLASSES *(FAO, 2006)*		
Class	**Description**	**%**
1	Flat	0-0.2
2	Level	0.2-0.5
3	Nearly level	0.5-1.0
4	Very gently sloping	1.0-2.0
5	Gently sloping	2-5
6	Sloping	5-10
7	Strongly sloping	10-15
8	Moderately steep	15-30
9	Steep	30-60
10	Very steep	>60

2.2.14 Soil erosion

In describing soil erosion, emphasis should be given to accelerated or human-induced erosion. It is not always easy to distinguish between natural and accelerated erosion as they are often closely related. Human-induced erosion is the result of irrational use and poor management, such as inappropriate agricultural practices, overgrazing and removal or overexploitation of the natural vegetation.

Main category

Erosion can be classified as water or wind erosion (Table 2.8), and include off-site effects such as deposition; a third major category is mass movements (landslides and related phenomena).

Area affected

The total area affected by erosion and deposition is estimated following the classes defined by SOTER (FAO, 1995) as per Table 2.8.

Degree

It is difficult to define classes of the degree of erosion that would be equally appropriate for all soils and environments and that would also fit the various types of water and wind erosion. Four classes are recommended Table 2.8, which may have to be further defined for each type or combination of erosion and deposition and specific environment.

Table 2.8 – Slope gradient classes

SOIL EROSION (FAO, 2006)					
Classification per category		**Area affected**		**Degree**	
Description	**Code**	**%**	**Code**	**Description**	**Code**
No evidence of erosion	N	0	0	Slight: some evidence of damage to surface horizons. Original biotic functions largely intact.	S
Sheet erosion	WS	0-5	1	Moderate: clear evidence of removal of surface horizons. Original biotic functions partly destroyed.	M
Rill erosion	WR	5-10	2	Severe: surface horizons completely removed and subsurface horizons exposed. Original biotic functions largely destroyed.	V
Gully erosion	WG	10-25	3	Extreme: substantial removal of deeper subsurface horizons (badlands). Original biotic functions fully destroyed.	E
Tunnel erosion	WT	25-50	4		
Deposition by water	WD	>50	5		
Water and wind erosion	WA				
Mass movement (landslides)	M				
Wind erosion or deposition	A				

2.2.15 Microrelief

Microrelief or micro-topography refers to natural or artificial differences in height over short distances. Some of the microtopographical features show gradual transitions. (See Table 2.9)

Table 2.9 – Slope gradient classes

MICRO-RELIEF *(FAO, 1990)*	
Description	**Code**
No micro-relief. Surface is nearly level	LE
Low Gilgai. Height difference <20cm (within 10m)	GI
Medium Gilgai. Height difference 20-40cm (within 10m)	GM
High Gilgai. Height difference >40cm (within 10m)	GH
Termite or ant mounds	TM
Animal tracks	AT
Animal burrows	AB
Low hummock. Height difference<20cm	HL
Medium hummock. Height difference 20-40cm	HM
High hummock. Height difference >40cm	HH
Shifting sands	SS
Terracettes	TS
Ripples	RI

2.2.16 Flooding

Floods are important events when describing a site. Visual analysis and local knowledge should be used for describing the frequency of floods.

Table 2.9 – Slope gradient classes

FLOODING *(FAO, 1990)*	
Frequency	**Code**
Annually	A
Biannually	B
Daily	D
Every 2-4 years	F
Monthly	M
Rare	R
Every 5-10 years	T
Weekly	W
Not know	R

2.2.17 Rock outcrops

Exposures of bedrock may limit the use of modern mechanized agricultural equipment. Rock outcrops should be described in terms of percentage surface cover, together with additional relevant information on the size, spacing and hardness of the individual outcrops.

Table 2.10 lists the recommended classes of percentage of surface cover and of average distance between rock outcrops (single or clusters).

Table 2.10 – Classification of rock outcrops

CLASSIFICATION OF ROCK OUTCROPS (FAO,2006)				
Surface cover			**Distance between rock outcrops**	
Description	**%**	**Code**	**Distance(m)**	**Code**
None	0	N	>50	1
Very few	0-2	V	20-50	2
Few	2-5	F	5-20	3
Common	5-15	C	2-5	4
Many	15-40	M	<2	5
Abundant	40-80	A		
Dominant	>80	D		

2.2.18 Surface stoniness

Soil surface stoniness, from fine gravel to large boulders, is important as its presence can limit types of land use. The surveyor should visually estimate the coverage and size of stones. For estimation of coverage, refer to Figure 2.1. Table 2.11 gives parameters for estimating stoniness.

Table 2.11 - Surface stoniness

SURFACE STONINESS *(FAO, 2006)*					
COVERAGE			SIZE		
Description	%	Code	Description	cm	Code
None	0	N	Fine gravel	0.2-0.6	F
Very Few	0-2	V	Medium gravel	0.6-2	M
Few	2-5	F	Coarse gravel	2-6	C
Common	5-15	C	Stones	6-20	S
Many	15-40	M	Boulders	20-60	B
Abundant	40-80	A	Large boulders	60-200	L
Dominant	>80	D			

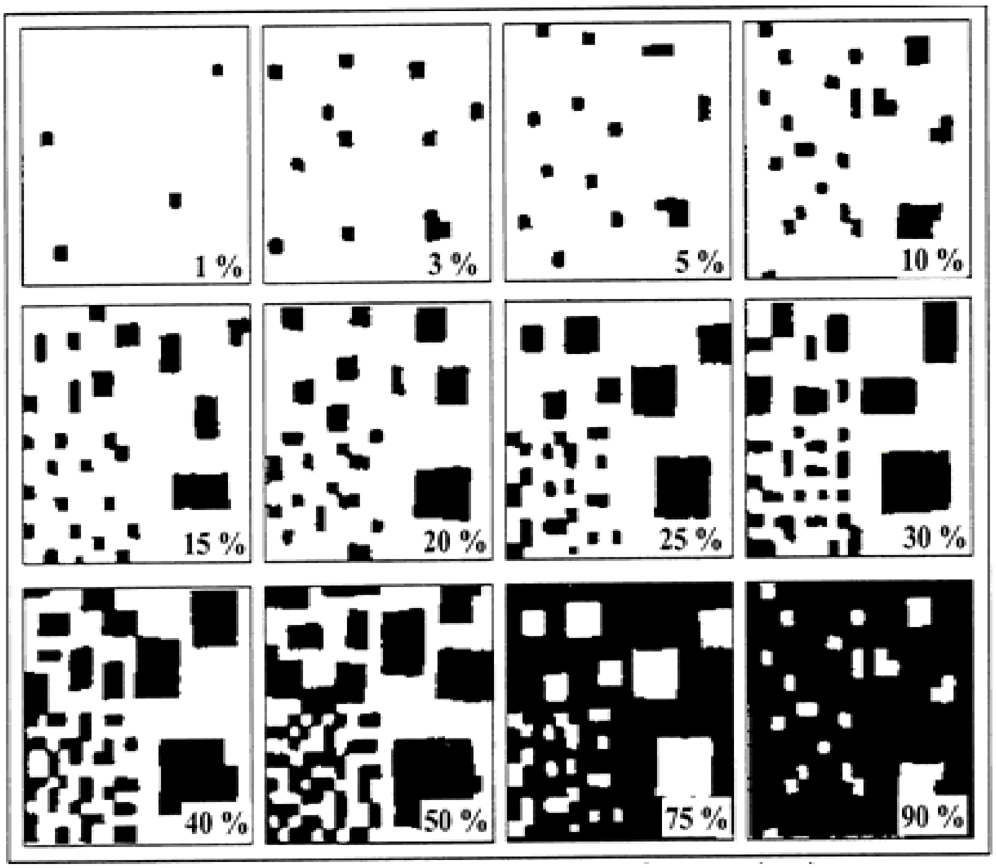

Figure 2.1 - Chart for estimating proportions (stoniness, rock fragments, nodules, mottles)

2.2.19 Soil profile drawing

In this section you'll find an empty profile drawing where you may draw your own profile, showing the existence of the horizons, their depths and their principal characteristics. Remember that these forms are a key source of data for future soil mapping activities and their applications. The surveyor will have to draw an accurate representation of the soil profile in the field.

2.2.20 Transect sketch

Under this section, the right part of the form has an empty space that should be filled by a transect sketch. Since the sampling scheme is based on transects, the surveyor must specify the location of the profile along each transect. This profile location will show the landform position and its physical characteristics. An example is shown below (Fig. 2.2).

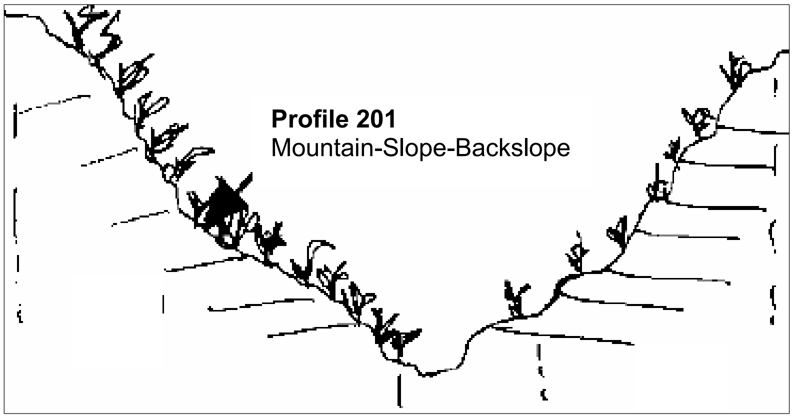

Figure 2.2 - Example of a transect

2.2.21 World Reference Base (WRB) soil classification

The soil profile description provides us with an understanding of the properties, soil-forming processes and subsequently a general idea of the soil we are dealing with. Consequently, we also need to classify the soil. The World Reference Base for Soil Resources system (WSB, FAO, 2006) shall be used for this. This system defines soil properties in terms of diagnostic horizons and characteristics, which should be accurately measurable and observable in the field.

The WRB system consists of two hierarchical levels. The first corresponds to the Reference Soil Groups and the second to the sub-divisions, or qualifiers, of the Reference Soil Groups.

At the Reference Soil Groups level, classes are differentiated mainly according to the primary pedogenetic process that has produced the characteristic soil features. Thirty Reference Soil Groups exist at this level.

Soil horizons, properties and materials are intended to reflect features which are widely recognised as occurring in soils and which can be used to describe and define soil classes. After defining the Reference Soil Group we move to the subdivision at the lower level, a qualifier that is a specific soil characteristic representing that soil.

Each survey team will be provided with a WRB classification key to be used in classification of each representative soil profile. A list of the two hierarchical levels is then provided with an example on how to use them.

Example of how to classify a soil: Soil data from the profile description will be used to classify the soil. The relevant data are:

- A subsurface clayed horizon
- Cracks are present along the surface
- There are slickensides along the peds

- A reddish colour of the B horizon with a Munsell hue of 7.5.YR and a chroma, moist, of more than 4

Using the above criteria we shall try to classify the soil using the key for the Reference Soil Groups on page 13 of the WRB key. We start by first comparing the data we have with the data needed for each soil group. Following this procedure, we shall see that all our criteria match those of *Vertisols*, so our soil belongs to this Reference Soil Group. Of course, to determine this we should go through the whole key, first defining what we mean by a *vertic* horizon, for example, under the key.

Now we need to find the specific classifier or modifier (second-level) characterising this soil. To do so we refer to the priority listing of lower-level units of Reference Soil Groups on page 76 of the WRB. There we'll see all the possibilities for our Vertisols. Our task is to identify each classifier, definitions of each of which are found between pages 19-75. After reviewing the possibilities, we find that the only modifier present under our data is the one related to the soil colour *Chromic*.

Therefore, we find that our soil corresponds to *Chromic Vertisols*.

Table 2.12 - WRB soil classification system

GROUPING CRITERIA	SPECIFIC SOIL PROPERTIES & CHARACTERISTICS	REFERENCE SOIL GROUPS
Organic soils	Organic soils formed of incompletely decomposed plant remains. They are characterised by a thick soil horizon that is rich in organic material.	HISTOSOLS
Mineral soils with strong human influence.	Soils that occur whenever human activities have resulted in profound modifications or burial of the original soils through removal or disturbance of surface horizons.	ANTHROSOLS
	Soils whose properties and pedogenesis are dominated by their technical origin. They contain a significant amount of artefacts (something in the soil recognizably made or extracted from the earth by humans), or are sealed by technic hard rock (material created by humans, having properties unlike natural rock).	TECHNOSOLS
Soils with limited rooting due to shallow permafrost or stoniness	Ice affected soils. Mineral soils formed in a permafrost environment. Cryogenic processes are the dominant soil-forming processes.	CRYOSOLS
	Soils characterised by their shallow depth (<30cm) over hard rock, generally of R horizon and soils that are extremely gravely and/or stony. The most undeveloped soil. Typical soils of mountainous areas.	LEPTOSOLS
Soils influenced by water	Soils with *vertic* horizon and cracks in the surface. Smectite content with shrinking and swelling properties. Usually located in deposition landscapes like lake bottoms.	VERTISOLS
	Soils on alluvial deposition which show stratification or other evidence of recent sedimentation.	FLUVISOLS
	Soils with a presence of sodium in excess of calcium, due either to saline groundwater or to the parent material.	SOLONETZ
	Saline soils formed when evapotranspiration exceeds rainfall, or where salts are present in the parent material.	SOLONCHAKS
	Soils with *gleyic* properties, resulting in soils with internal drainage problems. Prolonged saturation of soils by groundwater in the presence of organic matter results in the reduction of iron. Located in alluvial lowlands.	GLEYSOLS
Mineral soils set by Fe/Al chemistry.	Soils developed in volcanic ash, tuff, pumice and other volcanic ejects of various compositions.	ANDOSOLS
	Acidic soils with a bleached eluviation horizon over an accumulation horizon of organic matter with aluminium and/or iron.	PODZOLS
	Soils characterised by the dominant presence of an iron-rich mixture of clay and silica (plinthite) that irreversibly hardens into ironstone concretions and pans on the exposure.	PLINTHOSOLS
	Soils with a *nitic* horizon and a deep accumulation of clay.	NITISOLS
	Extremely weathered soils, characterised by the presence of kaolinitic clays and oxides of iron and aluminium. They have a *ferralic* horizon.	FERRALSOLS
Soils with stagnating water	Soils characterised by a coarse-textured layer abruptly overlying a deeper horizon with considerably more clay.	PLANOSOLS
	Soils with a perched water table showing redoximorphic features caused by surface water. Stagnosols are periodically wet and mottled in the topsoil and subsoil,	STAGNASOLS

	with or without concretions and/or bleaching.	
Accumulation of organic matter, high base status	Soils with a *mollic* horizon. It has a very dark, deep, humus- and nutrient- rich topsoil.	CHERNOZEMS
	Soils with a *mollic* horizon, rich in organic matter and characterised by an accumulation of calcium carbonate in the subsoil.	KASTANOZEMS
	Soils with a *mollic* horizon having a base saturation of more than 50%.	PHAEOZEMS
Accumulation of less soluble salts or non-saline substances	Soils with *gypsic* or *petrogypsic* horizon.	GYPSISOLS
	Soils with a *calcic* or *petrocalcic* horizon. It means high calcium carbonate content.	CALCISOLS
	Soils with a *duric* or *petroduric* horizon.	DURISOLS
Soils with a clay-enriched subsoil	Base-poor soils with a bleached eluviation horizon tonguing into a clay-enriched subsurface horizon.	ALBILUVISOLS
	Soils with high cation exchange capacity and an *argic* horizon with mixed clay mineralogy.	ALISOLS
	Red and yellow soils developed on old land surfaces. They have an *argic* horizon with a base saturation of <50%.	ACRISOLS
	Soils characterised by clay migration from the surface horizon to an accumulation horizon at some depth and a rich nutrient status.	LUVISOLS
	Soils having an *argic* horizon and low cation exchange capacity but high base saturation percent.	LIXISOLS
Relatively young soils or soils with little or no profile development	Soils in which organic matter has accumulated within the mineral surface soil (in most cases with low base saturation) to the extent that it significantly affects the behaviour and utilization of the soil.	UMBRISOLS
	Sandy soils of: desert areas, beach ridges, inland dunes and areas with highly weathered sandstone. There is an absence of significant soil profile development.	ARENOSOLS
	All soils, part of the less developed soils, pass this stage in the development process. These soils are characterised by moderate weathering and absence of clay immigration. They should show a *cambic* horizon.	CAMBISOLS
	Little soil development due to the very cold climate in which they occur or to the steep slopes on which they form. Typical soils of mountainous areas.	REGOSOLS

2.3 Soil profile description

Soil description is carried out in a soil profile dug at a location specified in the sampling scheme and also based on field experience in recognising soil types in the landscape. Our soil sampling scheme is based on the catena concept, in which predefined soil transects will be sampled and described. The exact position/s where to dig the profile/s relate to the landform map on which the different soil types should be described. Once the profile is ready to be described, place the tape measure and the ID number next to the profile and take a photograph of it.

2.3.1 Taking a photograph

One of the most important tasks when describing a profile is to take a photograph of it. After completion of fieldwork, many tasks will be performed to help define the final soil classification, including mapping activities. Having a photograph of each profile is necessary because we can use them constructively together with the field soil data and the soil lab results. Apart from the field data, the only other available source of information will be the soil photograph. A soil photograph should be taken when the profile wall is free from shadows and should also contain a ruler or tape measure and the Profile ID to reference the profile photograph to the form.

2.3.2 Soil sampling

Once the soil profile description is complete, we need to take samples for soil laboratory analysis. Take 200 gm of soil from each horizon in each profile. A suitable plastic bag will be available for the soil sample and this must be labelled according to the ID profile. Special tags will be available for it.

2.3.3 Horizon

The *soil horizon* refers to a layer of soil material approximately parallel to the land surface that is physically, chemically and biologically distinguishable from neighbouring layers (horizons). Layers of different kinds are identified by symbols, consisting of one or two capital letters for the master horizons (and/or transitional horizons) and lower case letter suffixes for subordinate distinctions, with or without a figure suffix (to indicate specific of master horizons and layers).

a) ***Master horizons***

Master horizons are represented by the capital letters O, A, E, B, C, and R, which are the symbols to which other soil characteristics are added to complete the soil description. Currently, seven master horizons and layers are recognised and these are described below. In this section, you should fill in the form with the horizons you find in the field. Be as specific as possible in naming the horizon.

Table 2.13 - Soil master horizon list

Horizon	Description
O	Layer dominated by organic material, formed from accumulation of un-decomposed or partially decomposed litter, such as leaves, twigs, mosses and lichens at the soil surface (either on mineral soil or organic soil). **O** horizons are not saturated with water for prolonged periods.
A	Mineral horizon formed either at the surface or below an **O** horizon, in which all or much of the original rock structure has been obliterated and which is characterised by one or more of the following: - an accumulation of humified organic matter intimately mixed with the mineral fraction and displaying properties characteristic of E or B horizons; - properties resulting from cultivation, pasture, or similar kinds of disturbance; - a morphology different from the underlying B or C horizon, resulting from processes related to the surface.
E	Mineral horizons in which the main feature is loss of silicate clay, iron, aluminium, or some combination of these, leaving a concentration of sand and silt particles and in which all or much of the original rock structure has been obliterated.
B	Horizons formed below A, E or O horizons, in which the dominant features are obliteration of all or much of the original rock structure, together with one or a combination of the following: - alluvial concentration (alone or in combination) of silica clay, iron, aluminium, humus, carbonates, gypsum or silica; - evidence of removal of carbonates; - residual concentration of sesquioxides; coating of sesquioxides that make the horizon notably lower in value, higher in chroma, or redder in hue than the overlying and underlying horizons without apparent illuviation of iron; - alteration that forms silicate clay or liberates oxides or both, that forms a granular, blocky, or prismatic structure if volume changes accompany changes in moisture content; - brightness.

C	Horizons or layers, excluding hard bedrock, that are little-affected by pedogenetic processes and lack properties of **O, A, E,** or **B** horizons. Most are mineral layers, but siliceous and calcareous layers such as shells, coral and diatomaceous earth are included. The material of **C** layers may be either like or unlike that from which the solum presumably formed. This horizon may have been modified without showing evidence of pedogenesis. Plant roots can penetrate **C** horizons, which provide an important growing medium.
R	Hard bedrock underlying the soil.

*b) **Transitional horizons***

There are two types of transitional horizons: those with properties of two master horizons superimposed and those with two properties separate (FAO, 1990). Example: AE, EB, BC, etc.

Table 2.14 - Transitional horizons

Horizon	Description
Two capital letters such as AB,EB, BE and BC	Horizons dominated by properties of one master horizon but having subordinate properties of another.
Two capital letters separated by a slash(/) such as E/B, B/E, B/C or C/R.	Horizon in which distinct parts have recognisable properties of two kinds of master horizons.

Letter suffixes (FAO, 1990)

A lower-case letter may be added to the capital letter to qualify the master horizon designation. Suffix letters can be combined to indicate properties which occur concurrently in the same master horizon, e.g. Ahz, Btg, Ccs, etc. Normally not more than two (2) suffixes should be combined. In transitional horizons, no suffixes are used unless they apply to the horizon as a whole, e.g. BCk.

The following table show the symbols used for the horizontal suffixes (modified from FAO, 2006).

Table 2.15 - Horizon suffixes

Suffix	Short Description	Used for
a	Highly decomposed organic matter	H and O horizons
b	Buried genetic horizon, (e.g. Btb)	Mineral horizons
c	Concretion and nodules (e.g. Bcs, Cck)	Mineral horizons
d	Dense layer (physically root restrictive)	Mineral horizons, not with m
d	Diatomaceous earth	L horizon
e	Moderately decomposed organic material	H and O horizon
f	Frozen soil	Not in I and R hor.
g	Stagnic conditions	No restriction
h	Accumulation of organic matter (e.g. Ah)	Mineral horizons
i	Slickensides	Mineral horizons
i	Slightly decomposed organic material	H and O horizon
j	Jarosite accumulation	No restriction
k	Accumulation of pedogenic carbonates (e.g. Cmk - marking a petrocalcic horizon within a C horizon)	No restriction

m	Strong cementation or induration (pedogenetic, massive)	Mineral horizons
n	Pedogenic accumulation of exchangeable sodium (e.g. Btn)	No restriction
o	Residual accumulation of sesquioxides (pedogenetic)	No restriction
p	Ploughing or other human disturbance (e.g. Ap)	No restriction, E,B or C as Ap
q	Accumulation of silica (e.g. Cmq - marking a silicate layer in a C horizon)	No restriction
r	Strong reduction (e.g. Cr)	No restriction
s	Illuvial accumulation of sesquioxides and organic matter (e.g. Bs)	B horizons
t	Illuvial accumulation of silicate clay (e.g. Bt)	B and C horizons
u	Urban and other man-made materials	H, O, A, E, B and C
v	Occurrence of plinthite	No restriction
w	Development of colour or structure in B (e.g. Bw)	B horizons
x	Fragipan characteristics (e.g. Btx)	No restriction
y	Pedogenetic accumulation of gypsum (e.g. Cy)	No restriction
z	Pedogenetic accumulation of salts more soluble than gypsum (e.g. Az or Ahz)	No restriction
@	Evidence of cryoturbation	No restriction

c) Vertical subdivisions

Horizons or layers designated by a single combination of letter symbols can be subdivided using Arabic numerals which follow all the letters. For example, a C horizon having successive horizons can be shown as C1, C2, C3, etc. and if the lower part is gleyed and the upper part is not, it can be designated as C1-C2- Cg1- Cg2 or C- Cg1-Cg2-R.

2.3.4 Lower boundary

The lower boundary of each horizon should be described in terms of depth in centimetres. For example if the horizon A has its lower limit at 28 cm, you should write 28 in this field.

2.3.5 Boundary

A soil horizon refers to a layer of soil material almost parallel to the surface ground, differing from bordering layers in physical, chemical and biological properties. The horizons reflect different boundary features which should be identified in terms of distinctness and topography. The major horizon boundary types are shown in Fig 2.3 below.

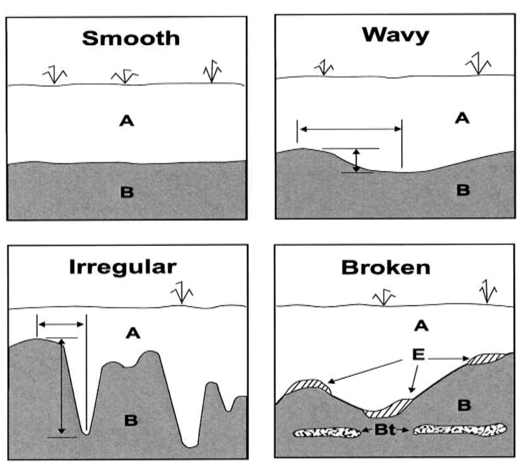

Figure 2.3 - Horizon boundary distinction

Table 2.16 describes the options for describing the boundary distinction and topography of the boundary.

Table 2.16 - Horizon boundary distinction

BOUNDARY (FAO, 1990)				
Distinction (mm)			*Topography*	
A	Abrupt	0-2	S	Smooth (nearly plane surface)
C	Clear	2-5	W	Wavy (pockets less deep than wide)
G	Gradual	3-15	I	Irregular (pockets more deep than wide)
D	Diffuse	> 15	B	Broken (discontinuous)

2.3.6 Moisture status

This property refers to the moisture status of each horizon. Its determination is by visual observation and also by feeling the soil itself to determine if it is dry, moist or wet. The details are given in Table 2.17.

Table 2.17 - Moisture Status

MOISTURE STATUS	
D	Dry
S	Slightly moist
M	Moist
W	Wet

2.3.7 Colour (moist or dry)

Soil colour reflects the soil matrix of each horizon and it is recorded in moist and dry conditions using the notations for *hue*, *value* and *chroma* as given in the Munsell Soil Color Charts (Munsell, 1975), which you will be provided with. *Hue* is the dominant spectral colour (red, yellow, green, blue and violet), *Value* is the lightness or darkness of colour ranging from 1 (dark) to 8 (light) and *Chroma* is the brightness or strength of colour ranging from 1 (pale) to 8 (bright). If the soil moisture is dry, you can identify the colour in dry and moist conditions, whereas if the soil is moist, you identify the colour under moist status only. The procedure is to take a sample of the soil horizon and then try to identify the general *Hue*. Finally, proceed to identify the *Value* and *Chroma*.

Figure 2.4 - Munsell Soil Colour Chart and an example of how to use it

Soil colour is considered a diagnostic property because its identification can be assessed in terms of the general quality and condition of the soil itself.

Note for classification purposes

Intermediate colours should be recorded where desirable for the distinction between two soil horizons and for purposes of classification and interpretation of the soil profile. Intermediate hues (important for qualifiers, such as Chromic or Rhodic, and for diagnostic horizons, such as cambic) that may be used are: 3.5, 4, 6, 6.5, 8.5 and 9 YR. For example, when 3.5 YR is noted, it means that the intermediate hue is closer to 2.5 YR than 5 YR; 4 YR means closer to 5 YR, and so on.

If values and chromas are near diagnostic limits, rounded-off figures should not be used, but accurate recordings should be made by using intermediate values, or by adding a + or a -.

Important diagnostic hues, values and chromas are:

- Abrupt changes in colour not resulting from pedogenesis → lithological discontinuity.
- Redder hue, higher value or higher chroma than the underlying or an overlying layer → cambic horizon.
- Hue redder than 10 YR or chroma ≥ 5 (moist) → ferralic properties, Hypoferralic and Rubic qualifier.
- Hue 7.5 YR or yellower and value ≥ 4 (moist) and chroma ≥ 5 (moist) → Xanthic qualifier.
- Hue redder than 7.5 YR or both hue 7.5 YR and chroma > 4 (moist) → Chromic qualifier.
- Hue redder than 5 YR, value < 3.5 (moist) → Rhodic qualifier.
- Hue 5 YR or redder, or hue 7.5 YR and value ≤ 5 and chroma ≤ 5, or hue YR and value ≤ 5 and chroma 5 or 6, or hue 10 YR or neutral and value and chroma ≤ 2, or 10 YR 3/1 (all moist) → spodic horizon.

- Hue 7.5 YR or yellower or GY, B or BG; value ≤ 4 (moist); chroma ≤ 2 (moist) → puddled layer (anthraquic horizon).

- Hue N1 to N8 or 2.5 Y, 5 Y, 5 G or 5 B → reductimorphic colours of the gleyic colour pattern.
- Hue 5 Y, GY or G → gyttja (limnic material).
- Chroma < 2.0 (moist) and value < 2.0 (moist) and < 3.0 (dry) → voronic horizon.
- Chroma ≤ 2 (moist) → Chernozem.
- Chroma ≤3 (moist) and value ≤ 3 (moist) and ≤ 5 (dry) → mollic and umbric horizon.
- Value and chroma ≤ 3 (moist) → hortic horizon.
- Value ≤ 4 (moist) and ≤ 5 (dry) and chroma ≤ 2 (moist) → plaggic horizon.
- Value > 2 (moist) or chroma > 2 (moist) → fulvic horizon.
- Value ≤ 2 (moist) and chroma ≤ 2 (moist) → melanic horizon.
- Values 4 to 8 and chroma 4 or less (moist) and values 5–8 and chromas 2–3 (dry) → albic horizon.
- Lower value or chroma than the overlying horizon → sombric horizon.
- Value ≥ 3 (moist) and ≥ 4.5 (dry) and chroma ≥ 2 (moist) → aridic properties.
- Value ≤ 4 (moist) → coprogenous earth or sedimentary peat (limnic material).
- Value 3, 4 or 5 (moist) → diatomaceous earth (limnic material).
- Value ≥ 5 (moist) → marl (limnic material).
- Value ≤ 3.5 (moist) and chroma ≤ 1.5 (moist) → Pellic qualifier.
- Value ≥ 5.5 (dry) → Hyperochric qualifier.

2.3.8 Rock fragments

Rock and mineral fragments (> 2mm) are described according to abundance, size and shape. The abundance class is limited to or corresponds with the ones for surface coarse fragments and mineral nodules and the 40% boundary coincides with the requirement for the skeletic phase. This is an important attribute that will be useful for the soil survey interpretation and classification. Table 2.18 is a guide for filling the form. This attribute is visible and requires that you consult Fig. 2.1 for the abundance field.

Table 2.18 - Horizon boundary distinction

ROCK FRAGMENTS (FAO, 2006)							
ABUNDANCE			**SIZE (cm)**			**SHAPE**	
Code	Description	%	Code	Description	mm	Code	Description
N	None	0	F	Fine gravel	2-6	F	Flat
VF	Very Few	0-2	M	Medium gravel	6-20	A	Angular
F	Few	2-5	C	Coarse gravel	20-60	S	Subrounded
C	Common	5-15	S	Stones	60-200	R	Rounded
M	Many	15-40	B	Boulders	200-600		
A	Abundant	40-80	L	Large boulders	>600		
D	Dominant	> 80					

2.3.9 Texture

Soil texture is a key soil property because most of a soil's physical properties depend on it. It is determined by the ratios of mineral particles finer than 2 mm and the proportions of sand, silt and clay that it contains. The particle sizes we use are defined by an international system, while the soil texture classes have been established by FAO, 1990. Soil texture determination will be carried out both in the field and the laboratory. In the field, the soil surveyor determines a soil texture class through feel, based on his/her personal experience. For a more accurate assessment, the flowchart below can be used, which follows a soil texture determination method based on the ratio of each component (sand, silt and clay) based on touch. For soil laboratory analysis, soil samples will be used.

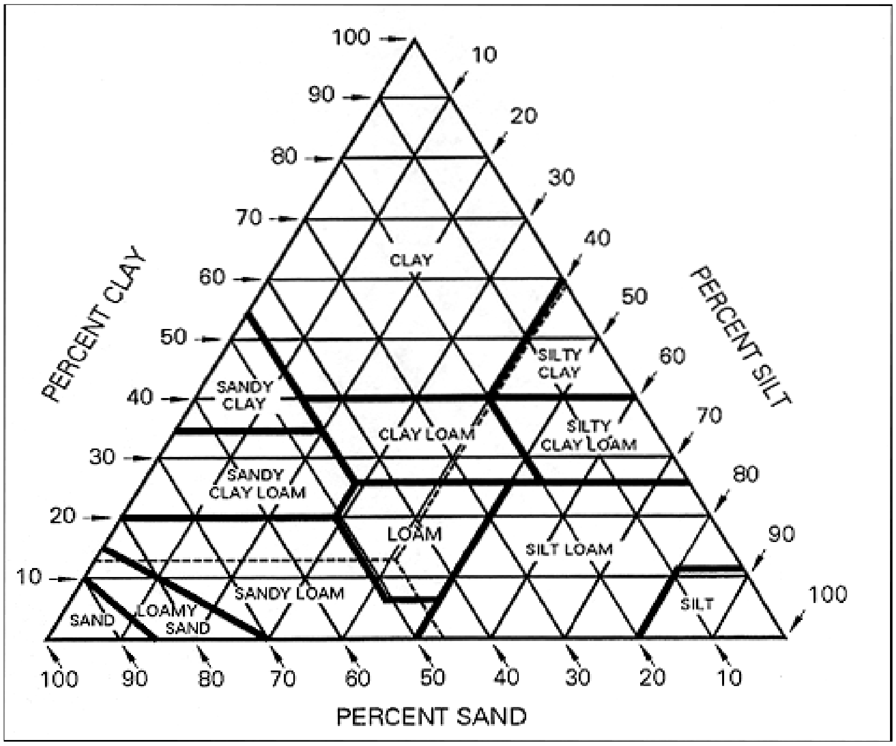

Figure 2.5 - Soil Texture Triangle for quantitative soil texture determination

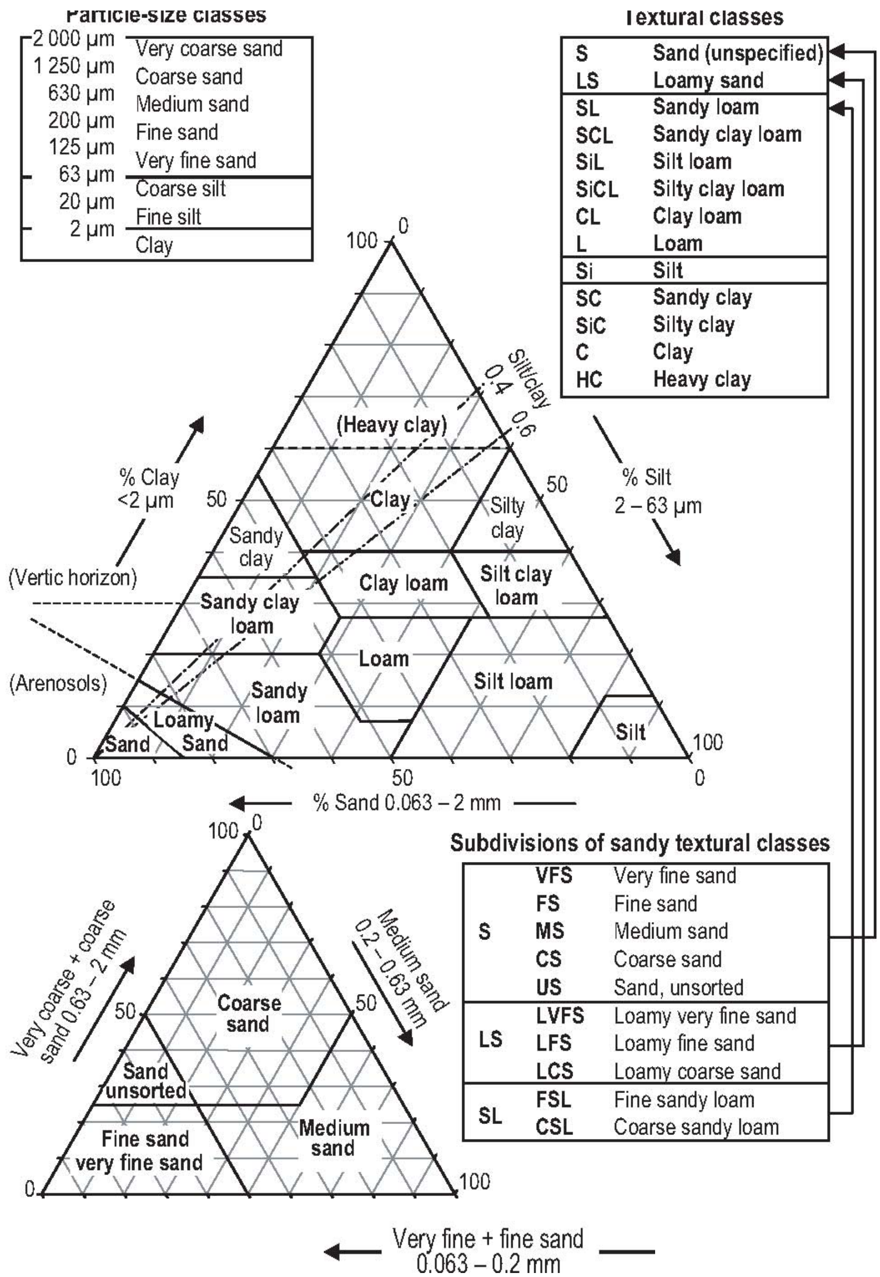

Figure 2.6 - Simplified guide for field assessment of soil texture (source FAO 2006)

2.3.10 Soil structure

Soil structure refers to the natural organisation of primary soil particles into soil aggregate units resulting from pedogenic processes. Each individual unit of soil structure is called a ped. Each aggregate is separated from adjoining aggregates by surfaces of weakness or voids (Soil Survey Staff, 1951).

Take a sample of undisturbed soil in your hand and examine its structure, which will be described according to the type, grade and size of aggregates. The type of structure refers to the shape and arrangement of peds, e.g. prismatic, sub angular blocky, etc. For identifying soil structure you can refer to Figs. 27a and 27b which illustrate soil structure types.

Soil structure *grade* refers to the degree of development and distinctiveness of peds, e.g. weak, moderate and strong.

Weak
Aggregates are barely observable in place and there is only a weak arrangement of natural surfaces of weakness. When gently disturbed, the soil material breaks into a mixture of few entire aggregates, many broken aggregates, and much material without aggregate faces. Aggregate surfaces differ in some way from the aggregate interior.

Moderate
Aggregates are observable in place and there is a distinct arrangement of natural surfaces of weakness. When disturbed, the soil material breaks into a mixture of many entire aggregates, some broken aggregates, and little material without aggregates faces. Aggregates surfaces generally show distinct differences with the aggregates interiors.

Strong
Aggregates are clearly observable in place and there is a prominent arrangement of natural surfaces of weakness. When disturbed, the soil material separates mainly into entire aggregates. Aggregates surfaces generally differ markedly from aggregate interiors.

***Soil structure size** class* is a measurement of the smallest dimension of the aggregate, e.g. fine (thin), medium and coarse (thick).

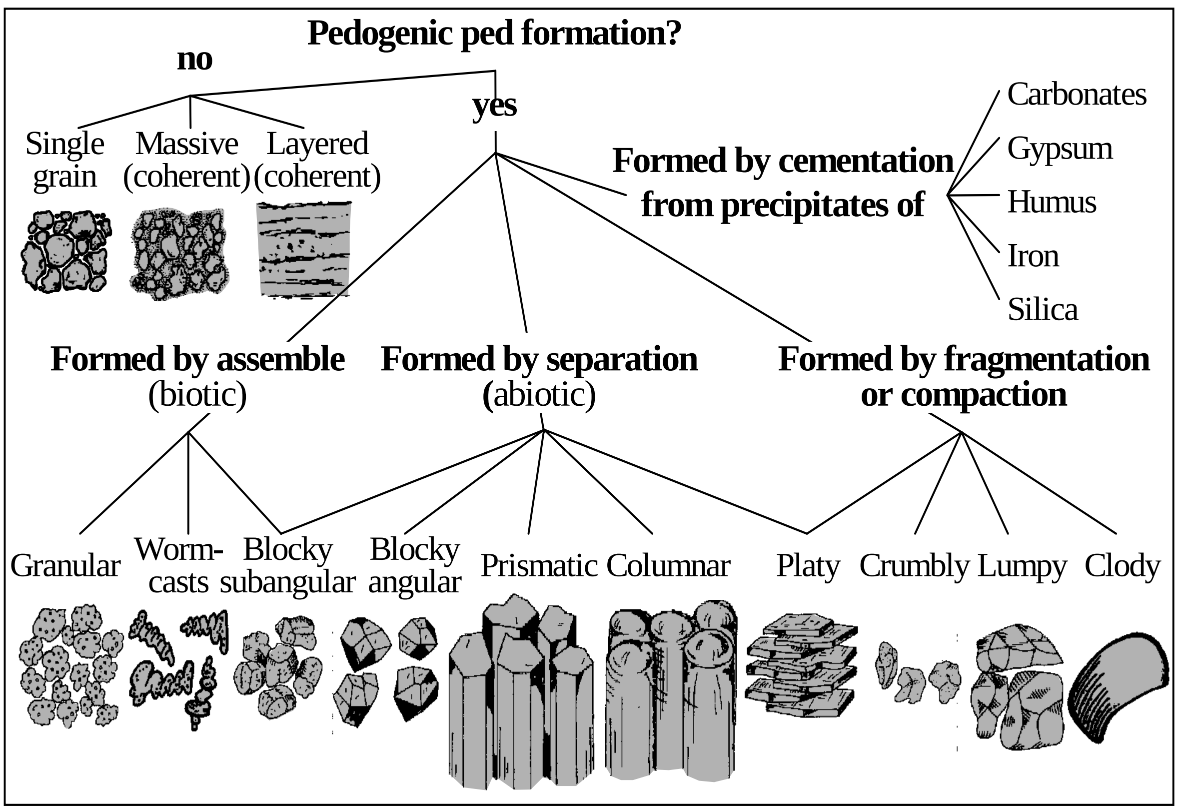

Figure 2.7a - Soil structure types (source FAO 2006)

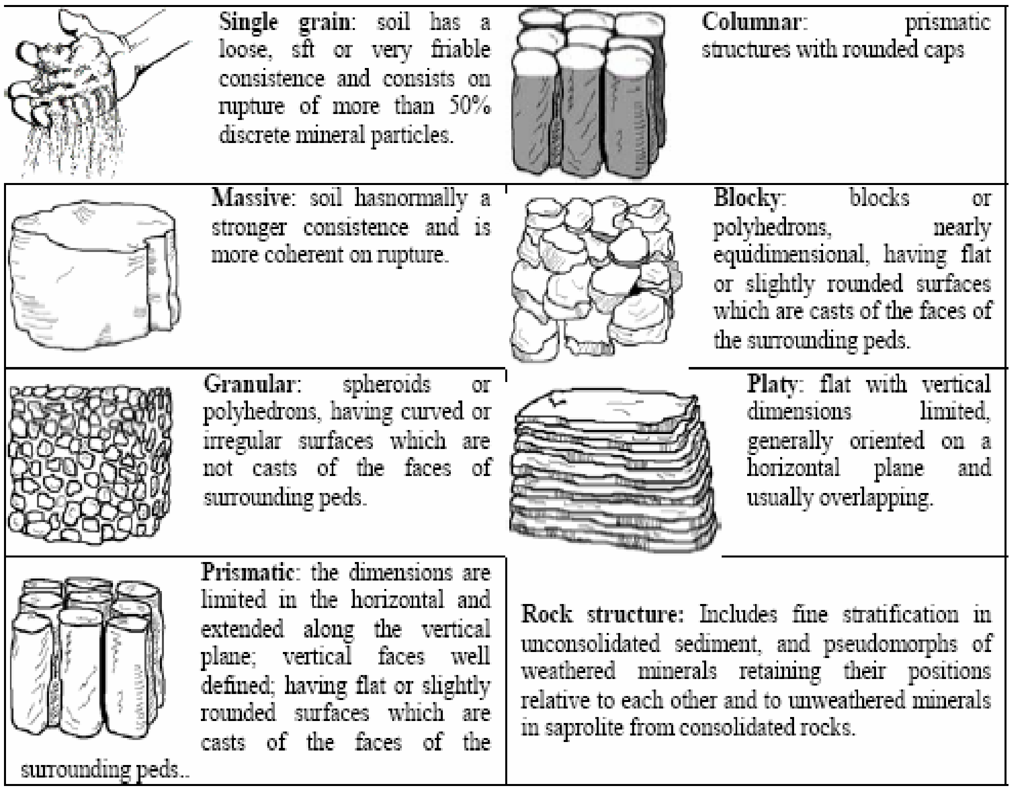

Figure 2.7b - Soil structure types

The following table should be used for filling in the soil structure types, size and grade.

Table 2.19 - Soil structure classes

SOIL STRUCTURE *(FAO, 2006)*										
TYPE OF STRUCTURE				**SIZE**					**GRADE**	
Description				**Code**	**Description**	**Granular/ Platy**	**Prismatic/columnar**	**Blocky/crumbly**	WE	Weak
SG	Single grain	SB	Subangular blocky	VF	Very fine/thin	< 1	< 10	< 5	MO	Moderate
MA	Massive	AS	Angular and subangular blocky	FI	Fine/thin	1-2	10-20	5-10	S	Strong
GR	Granular	SA	Subangular and angular blocky	ME	Medium	2-5	20-50	10-20		
PR	Prismatic	W	Wedged shaped	CO	Coarse/thick	5-10	50-100	20-50		
CO	Columnar	PL	Platy	VC	Very Coarse/thick	> 10	> 100	> 10		
AB	Angular Blocky	CR	Crumbly	EC	Extremely coarse	-	-	-		

2.3.11 Calcium Carbonate (CaCo3)

Carbonates in soils are either residues of parent material or the result of neo-formation (secondary carbonates). The latter are concentrated mainly in the form of soft powdery lime, coatings on peds, concretions, surface or subsoil crusts or hard banks. The presence of calcium carbonate ($CaCO_3$) is established by adding some drops of 10% HCl to the soil. The degree of effervescence of the resulting carbon dioxide gas is indicative of the amount of calcium carbonate present. In many soils, it is difficult to distinguish in the field between primary and secondary carbonates.

Table 2.20 - Calcium Carbonate classes

CLASSIFICATION OF CARBONATE REACTION IN THE SOIL MATRIX *(FAO, 2006)*			
Class	**Description**	**%**	**Code**
Non calcareous	No detectable visible or audible effervescence	0	N
Slightly calcareous	Audible effervescence but not visible	0-2	SL
Moderately calcareous	Visible effervescence	2-10	MO
Strongly calcareous	Strong visible effervescence. Bubbles form a low foam	10-25	ST
Extremely calcareous	Extremely strong reaction. Thick foam forms quickly	>25	EX

2.3.12 pH

Soil pH expresses the activity of the hydrogen ions in the soil solution. It affects the availability of mineral nutrients to plants as well as many soil processes. In the field, soil pH will be determined using the colorimetric charts that are provided to the soil survey team. pH measured in the field is rarely precise and is intended only to give a first idea about soil characteristics for its classification.

Take a small soil sample and put it into the pan hole and then aggregate the solution to it. After 2 minutes you should get the reaction colour that should be compared to the pH colour chart and then identify the correspondent soil pH.

Figure 2.8 - Field soil pH kit

2.3.13 Roots

The presence of roots in each horizon of the soil profile is assessed visually in terms of abundance (expressed in the number of roots per decimeter²) and size (diameter).

Table 2.21- Presence of roots

ROOTS (FAO, 2006)						
ABUNDANCE				**SIZE**		
Description	**<2 mm**	**>2mm**	**Code**	**Description**	**mm**	**Code**
No roots	0	0	N	Very fine	<0.5	VF
Very few	1-20	1-2	V	Fine	0.5-2	F
Few	20-50	2-5	F	Medium	2-5	M
Common	50-200	5-20	C	Coarse	>5	C
Many	>200	>20	M	Very fine and fine		FF

2.3.14 Coatings

This section describes clay or mixed-clay illuviation features, coatings of other composition (such as calcium carbonate, manganese, organic or silt), reorientations (such as slickensides and pressure faces), and concentrations associated with surfaces but occurring as stains in the matrix ("hypodermic matrix"). All these features are determined with the naked eye or with the aid of a 10x hand lens and are described visually and by contact according to their abundance, contrast, nature, and location. They are mostly present in a clayed horizon. The next table should be used to assist in their description.

Table 2.22 - Presence of coatings

COATINGS (FAO, 2006)						
ABUNDANCE			**LOCATION**		**NATURE**	
Description	**%**	**Code**	**Description**	**Code**	**Description**	**Code**
None	0	N	Pedfaces	P	Clay	C
Very few	0-2	V	Vertical pedfaces	PV	Clay and sesquioxides	CS
Few	2-5	F	Horizontal pedfaces	PH	Clay and humus (organic matter)	CH
Common	5-15	C	Coarse fragments	CF	Pressure faces	PF
Many	15-40	M	Lamellae (clay bands)	LA	Slickensides, non intersecting	S
Abundant	40-80	A	Voids	VO	Slickensides, partly intersecting	SP
Dominant	>80	D	No specific location	NS	Slickensides, predominantly intersecting	SI
					Shiny faces (as in nitic properties)	SF

2.3.15 Mottles

Mottles are spots or blotches of different colours or shades of colour interspersed with the dominant colour of the soil. They indicate that the soil has been subjected to alternate wetting (reducing) and drying (oxidizing) conditions. The mottles should be visually identified at every horizon in the profile. Most of the time mottling varies in colour with the respective colour horizon. After defining the abundance, size and boundary of the mottles with reference to Table 2.23, you should identify their colour. The Munsell Soil Color Chart should be used for this.

Table 2.23 - Presence of mottles

MOTTLES (FAO, 1990)								
ABUNDANCE			**SIZE**			**BOUNDARY**		
Description	**%**	**Code**	**Description**	**mm**	**Code**	**Description**	**mm**	**Code**
None	0	N	Very fine	<2	V	Sharp	0-0.5	S
Very few	0-2	V	Fine	2-6	F	Clear	0.5-2	C
Few	2-5	F	Medium	6-20	M	Diffuse	>2	D
Common	5-15	C	Coarse	>20	C			
Many	15-40	M						
Abundant	>40	A						

The colour contrast between mottles and soil matrix can be described as:

Faint (F): the mottles are evident only on close examination. Soil colours in both the matrix and mottles have closely related hues, chromas and values.

Distinct (D): Although not striking, the mottles are readily seen. The hue, chroma, and value of the matrix are easily distinguished from those of the mottles. They may vary by as much as 2.5 units of hue or several units in chroma or value.

Prominent (P): The mottles are conspicuous and mottling is one of the outstanding features of the horizon. Hue, chroma and value alone or in combination are at several units apart.

2.3.16 Voids (porosity)

Voids include all empty spaces in the soil. They are related to the arrangement of the primary soil constituents, rooting patterns, burrowing of animals or any other soil-forming processes such as cracking, translocation, leaching, etc. The term void is almost equivalent to the term *pore* but the latter is often used in a more restrictive way and does not, for instance, include fissures or planes. Voids are described in terms of *type*, *size* and *abundance.* Table 2.25 and 2.26 is a guide.

Porosity

The porosity is an indication of the total volume of voids discernible with an x10 hand-lens measured by area and recorded as the percentage of the surface occupied by pores (Table 2.24).

Table 2.24 - Presence of voids

POROSITY (FAO 2006)		
Code	**Description**	**%**
1	Very low	<2%
2	Low	2-5
3	Medium	5-15
4	High	15-40
5	Very high	>40%

Table 2.25 – Type of voids

TYPE OF VOIDS		
Code	**Name**	**Description**
I	Interstitial	Controlled by the fabric, or arrangement, of the soil particles, also known as textural voids. Subdivision possible into simple packing voids, which relate to the packing of sand particles, and compound packing voids, which result from the packing of non-accommodating peds. Predominantly irregular in shape and interconnected, and hard to quantify in the field.
B	Vesicular	Discontinuous spherical or elliptical voids (chambers) of sedimentary origin or formed by compressed air, e.g. gas bubbles in slaking crusts after heavy rainfall. Relatively unimportant in connection with plant growth.
V	Vughs	Mostly irregular, equidimensional voids of faunal origin or resulting from tillage or disturbance of other voids. Discontinuous or interconnected. May be quantified in specific cases.
C	Channels	Elongated voids of faunal or floral origin, mostly tubular in shape and continuous, varying strongly in diameter. When wider than a few centimetres (burrow holes), they are more adequately described under biological activity.
P	Planes	Most planes are extra-pedal voids, related to accommodating ped surfaces or cracking patterns. They are often not persistent and vary in size, shape and quantity depending on the moisture condition of the soil. Planar voids may be recorded, describing width and frequency.

Table 2.26 - Presence of voids

VOIDS (FAO, 2006)					
SIZE			**ABUNDANCE (nr/dm2)**		
Description	**mm**	**Code**	**Description**	**<2mm**	**>2mm**
Very fine	<0.5	V	None (N)	0	0
Fine	0.5-2	F	Very few (V)	1-20	1-2
Medium	2-5	M	Few (F)	20-50	2-5
Coarse	5-20	C	Common (C)	50-200	5-20
Very coarse	20-50	VC	Many (M)	>200	>20

2.3.17 Cementation and compaction

The occurrence of cementation or compaction in pans or otherwise is described according to its nature, continuity, structure, agent and degree. Compacted material has a firm or stronger consistence when moist and a close packing of particles. Cemented material does not slake after 1 hour of immersion in water.

Structure

The fabric or structure of the cemented or compacted layer may be described as follows:

Platy: the compacted or cemented parts are plate-like and have a horizontal or subhorizontal orientation.

Vesicular: the layer has large, equidimensional voids that may be filled with uncemented material.

Pisolithic: the layer is largely constructed from cemented spherical nodules.

Nodular: the layer is largely constructed from cemented nodules or concretions of irregular shape.

Continuity

The structure of the cemented or compacted layer may be described as follows:

Broken: the layer is less than 50 percent cemented or compacted, and shows a rather irregular appearance

Discontinuous: the layer is 50-90 percent cemented or compacted and in general shows a regular appearance.

Continuous: the layer is more than 90 percent cemented or compacted, and is only interrupted in places by cracks or fissures.

Table 2.27 - Presence of Cementation or Compaction

CEMENTATION AND COMPACTION (FAO, 2006)					
NATURE		**STRUCTURE**		**CONTINUITY**	
Description	**Code**	**Class**	**Code**	**Description**	**Code**
Carbonates	K	Platy	P	Broken	B
Silica	Q	Vesicular	V	Discontinuous	D
Carbonates-silica	KQ	Pisolithic	P	Continuous	C
Iron	F	Nodular	D		
Iron-manganese (sesquioxides)	FM				
Iron-organic matter	FO				
Ice	I				
Gypsum	GY				
Clay	C				
Clay-sesquioxides	CS				
Mechanical	M				
Ploughing	P				
Not known	NK				

2.3.18 Mineral Concentrations

Mineral concentrations cover a large variety of secondary crystalline, microcrystalline and amorphous concentrations of non organic substances as infillings, soft concretions, irregular concentrations (mottles), and nodules of mainly pedogenetically formed materials. Gradual transitions exist with mottles (above), some of which may be considered as weak expressions of nodules. The mineral concentrations are described according to their abundance, kind, size, shape, hardness, nature and colour. Nodules are cemented bodies of various shapes (commonly spherical or tubular) that can be removed as discrete units from soil.

The kinds of mineral concentrations can be:

Concretion: a discrete body with a concentric internal structure generally cemented.

Soft segregation: differs from the surrounding soil mass in colour and composition but is not easily separated as a discrete body.

Nodule: discrete body without an internal organization.

Pore infillings: including pseudomycellium of carbonates or opal.

Residual rock fragment: discrete impregnated body still showing rock structure.

Table 2.28- Presence of nodules

MINERAL CONCENTRATIONS (FAO, 2006)										
SIZE AND SHAPE			**ABUNDANCE**			**KIND AND HARDNESS**		**NATURE**		
Description	**mm**	**Code**	**Description**	**%**	**Code**	**Description**	**Code**	**Description**	**Code**	
Very Fine	<2	V	None	0	N	Crystal	T	Carbonates (calcareous)	K	
Fine	2-6	F	Very few	0-2	V	Concretion	C	Carbonate-silica	KQ	
Medium	6-20	M	Few	2-5	F	Soft segregation	S	Clay	C	
Coarse	> 20	C	Common	5-15	C	Nodule	N	Gypsum	GY	
Rounded		R	Many	15-40	M	Pore infillings	IP	Salt	SA	
Elongated		E	Abundant	40-80	A	Crack infillings	IC	Iron	F	
Flat		F	Dominant	>80	D	Residual crack fragments	R	Manganese	M	
Irregular		I				Other	O	Iron-manganese	FM	
Angular		A				Hard	H	Silica	Q	
						Soft	S	Sulphur	S	
						Both hard and soft	B	Not known	NK	

2.3.19 Biological features

The biological features refer to features of past and present activity of organisms such as plant roots, krotovines, termites, burrows, insect nests, worm casts or burrow of larger animals, including human activity. These activities are described according to their abundance and type**.** Its identification is visual.

Table 2.29 - Presence of biological features

BIOLOGICAL FEATURES (FAO, 1990)			
ABUNDANCE		**KIND**	
Description	**Code**	**Description**	**Code**
None	N	Artefacts	A
Few	F	Burrows (	B
Common	C	Charcoal	C
Many	M	Earthworm channels	E
		Pedotubules	P
		Termite or ant channels and nests	T

2.4 Bibliography

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SWALIM

PROFILE AND TRANSCECT CODE

SOILS

DESCRIPTION OF THE SOIL SURFACE

DATE OF DESCRIPTION:

SURVEYOR:

LOCATION:

COORDINATES

X

Y

Elevation: Slope:

LANDFORM UNIT

According to map:

According to field:

LITHOLOGY

SURFACE HUMIDITY

SOIL DRAINAGE CLASS

SURFACE CRUSTING/SEALING

PRESENCE OF SALTS

PRESENCE OF CRACKS

SURFACE STONINESS

ROCK OUTCROPS

SOIL PROFILE

cm 0

25

50

75

100

125

150

175

200

WRB SOIL CLASIFICATION

SOIL EROSION CLASS:

SOIL EROSION SEVERITY:

SOIL EROSION EXTENT:

LAND USE:

VEGETATION:

MICRORELIEF:

FLOODING:

Draw a transect and the position where your profile is located.

SOIL PROFILE DESCRIPTION

HORIZON	**1**			**2**			**3**			**4**			**5**		
LOWER BOUNDARY															
BOUNDARY	DISTIN		TOPO	DISTIN		TOPO	DISTIN		TOPO	DISTIN		TOPO	DISTIN		TOPO
MOISTURE STATUS															
COLOUR (moist)															
COLOUR (dry)															
ROCK FRAGMENTS	AB	SZ	SH	AB	SZ	SH	AB	SZ	SH	AB	SZ	SH	AB	SZ	SH
TEXTURE															
STRUCTURE	TP	SZ	GR	TP	SZ	GR	TP	SZ	GR	TP	SZ	GR	TP	SZ	GR
$CACO_3$(HCL)															
pH															
ELECTRIC CONDUCTIVITY															
ORGANIC MATTER															
ROOTS	ABUN		SZ	ABUN		SZ	ABUN		SZ	ABUN		SZ	ABUN		SZ
COATINGS	AB	LOC	NAT	AB	LOC	NAT	AB	LOC	NAT	AB	LOC	NAT	AB	LOC	NAT
MOTTLES	AB	SZ	LIM	AB	SZ	LIM	AB	SZ	LIM	AB	SZ	LIM	AB	SZ	LIM
Colour															
CEMENTATION	NAT	ST	CO	NAT	ST	CO	NAT	ST	CO	NAT	ST	CO	NAT	ST	CO
MINERAL CONCENTRATIONS	SZ-SH	AB	K/N	SZ-SH	AB	K/N	SZ-SH	AB	K/N	SZ-SH	AB	K/N	SZ-SH	AB	K/N
VOIDS	TP	SZ	AB	TP	SZ	AB	TP	SZ	AB	TP	SZ	AB	TP	SZ	AB
POROSITY															
BIOLOGICAL FEATURES	ABUN		KIN	ABUN		KIN	ABUN		KIN	ABUN		KIN	ABUN		KIND

3 LAND DEGRADATION

3.1 Coordinates

The coordinates of the point where the soil profile is being described should be recorded using the Global Positioning System (GPS), on the same format of coordinates as on the available maps.

3.2 Surveyor

The names and/or initials of the person/s conducting the soil profile description and sampling are noted, to allow acknowledgment by future users of the data and also for future tracking of data.

Example: Ahmed Jama (A.J)

3.3 Date

The day, month and year of the description are indicated to show future users the age of the data. The date of the description is given as dd/mm/yy (6 digits), e.g. 15 May 2006 is written as 15/05/06.

3.4 Landform unit

Land degradation processes are directly related to the type of landform. It is important that the surveyor can relate the landform code to the one appearing in the map.

3.5 Land cover type

Land cover is also fundamental to land degradation, specifically processes of soil erosion. We need to know under which kind of land cover this site was described. Use the corresponding code found in the land cover map.

3.6 Land degradation types

It is important to make a visual field inspection of the area and determine the types of land degradation present. Check them in the list and write down the one/s you identify. There are certain land degradation types that are not easy to recognise, such as a decline in fertility or presence of soil toxicity, in which case there is no need to cite them and the focus will be on soil erosion.

3.7 Soil erosion classes

Soil erosion is considered as the natural process of removal of topsoil by water and wind. It is a process whose rate may be magnified by human activities (accelerated erosion).

Table 3.1 - Soil erosion classes (FAO, 1990)

Description	Code
No evidence of erosion	N
Water erosion	W
Wind erosion	Wi
Mass movement	M
Badland	B

The soil erosion classes may be defined as:

- ***No evidence of erosion*** - soil surface without evidence of soil removal or transport.
- ***Water erosion*** - the removal of soil particles by the action of water (Figs. 3.2 & 3.3).
- ***Wind erosion*** - removal of soil particles by wind action (Fig. 3.1)

Figure 3.1 - Wind erosion

Figures 3.2 & 3.3 - Gully erosion (top right) and "splash" erosion (right)

- *Mass movement* - the downslope movement of slope material under the influence of the gravitational force of the material itself, without the assistance of moving water, ice or air (Fig. 3.4).

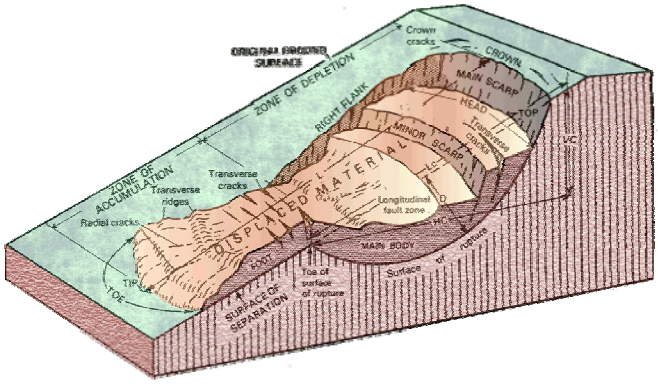


Figure 3.4 - Mass movement

- *Badlands* - are regarded as the archetypal example of the end effects of vigorous water erosion. They can resemble miniature desert landscapes with weirdly shaped hoodoos, steep barren and/or rounded slopes scarred by rills and gullies and a maze of winding channels (Fig. 3.5).

Figure 3.5 - An example of a badland

You should be able to recognise the above classes in the field and note their presence on the form.

3.8 Degree of soil erosion

The degree of soil erosion is a measure of the severity level of the soil erosion process present. Once you have selected the soil erosion class, you should determine if the degree is slight, moderate, severe or extreme.

Table 3.2 - Soil erosion severity classes (FAO, 1990)

Description	Code
Slight	S
Moderate	M
Severe	Se
Extreme	E

- *Slight* - some evidence of damage to the surface; original biotic functions largely intact.
- *Moderate* - clear evidence of removal of soil surface horizons; original biotic functions partly destroyed.
- *Severe* - soil surface horizons completely removed and subsurface horizons exposed; original biotic functions largely destroyed.
- *Extreme* - substantial removal of deeper subsurface horizons; original biotic functions fully destroyed. When this class is present it corresponds directly to a *Badland*.

3.9 Extent of soil erosion

Refers to the extent of soil erosion present in the general area, not only at the site being evaluated. This is useful for characterising the severity of the soil erosion. Refer to the table below for its characterization.

Table 3.3 - Soil erosion extent classes (FAO, 1990)

%	Code
0-5	1
5-10	2
10-25	3
25-50	4
>50	5

3.10 Types of soil water erosion

Since our focus is on soil water erosion, the following classes will be considered.

Table 3.4 - Soil water erosion types

Description	Code
Sheet	S
Rill	R
Gully	G

- *Sheet erosion* - uniform removal of soil in thin layers from sloping land, resulting from sheet or overland flow (Fig. 3.6).

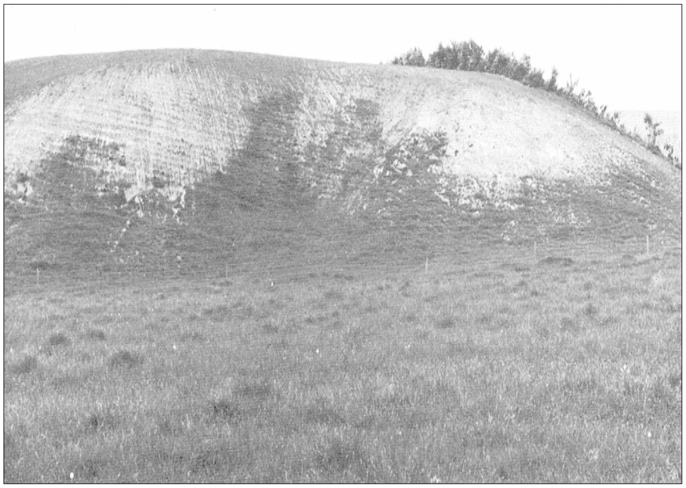
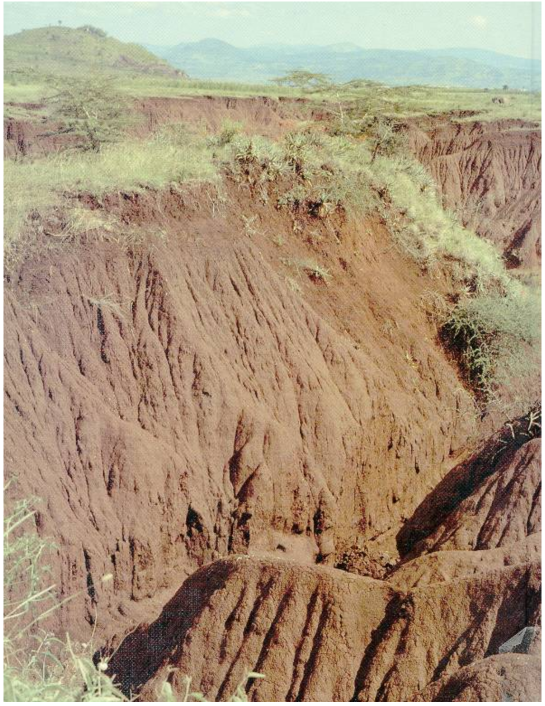


Figure 3.6 - An example of sheet erosion

- *Rill erosion* - detachment and transport of soil by a concentrated flow of water (Figs. 3.7 & 3.8).



Figures 3.7 & 3.8 - Rill formation and rill erosion

Gully erosion - Gully erosion is an advanced stage of rill erosion, in which surface channels have eroded to the point where they cannot be removed by tillage operations. A gully is a deep depression, channel or ravine in a landscape, looking like a recent and very active extension to natural drainage channels (Figs. 3.9 & 3.10).

Figure 3.9 & 3.10 - Gully erosion in Bolivia

3.11 Soil water erosion severity

This will assist in water erosion identification and quantification. First, identify the water erosion type as either sheet, rill and gully erosion. Then, using Table 3.5, try to quantify the extent and severity of the area covered by the identified type of erosion. Determine if the process is slight or extremely severe.

Table 3.5 - Soil water erosion extent and severity degree classes

SOIL WATER EROSION TYPE	Code	SOIL EROSION EXTENT %	Code	SOIL EROSION SEVERITY	Code
Sheet	S	0-5	1	Slight	S
Rill	R	5-10	2	Moderate	M
Gully	G	10-25	3	Severe	Se
		25-50	4	Extreme	E
		>50	5		

3.12 Soil and water conservation practices

It is crucial that a surveyor can visually identify and describe the presence of any soil and water conservation practices. Their identification is important because clues can be obtained about existing soil erosion processes and whether actions are being taken to them. Examples of these practices are: soil bunding, terracing, water harvesting, etc.

3.13 Sketch

The surveyor should make a sketch of the site being described. Additionally, he/she should locate the specific sampling sites where soil erosion measurements are being made (either for sheet, rill or gully erosion), following the fieldwork guides.

3.14 Field form: Pedestals

What are they? A pedestal is a column of soil standing out from a generally eroded surface, protected by a cap of resistant material such as a stone or root. Bunch grasses can also protect the soil immediately under them and create a pedestal-like feature. Pedestals are useful as an indicator of high sheet-erosion rates of the order of 50 or more tonnes/hectare/year.

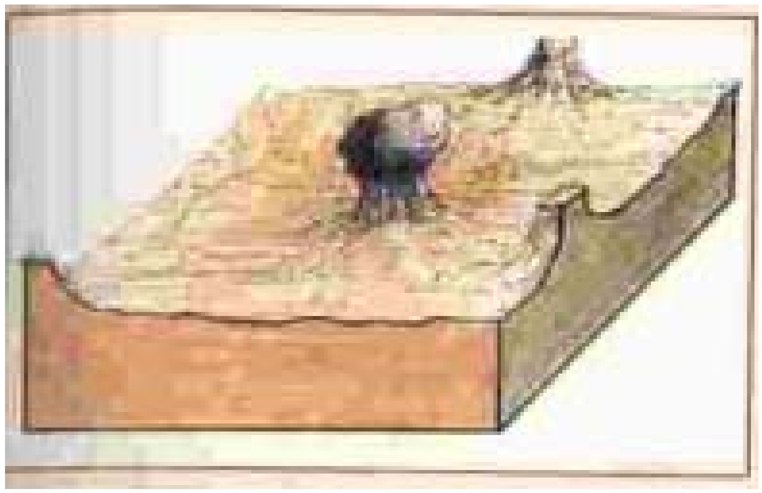


Figure 3.11 - Example of pedestal

How do they occur? Pedestals are caused by rain-splash erosion dislodging soil particles surrounding the pedestal but not under the resistant capping material. The soil particles in the pedestal itself are unaffected because they are protected by a material that harmlessly absorbs the erosive effects of raindrops.

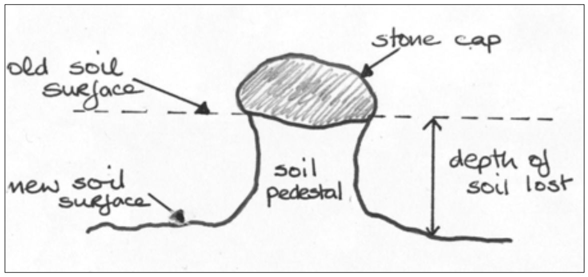


Figure 3.12 - Sketch of soil pedestal capped by a stone (Stocking & Murnaghan, 2000)

How can they be measured? The height of pedestals can be measured using a ruler. Assuming that the pedestal cap was level with the original soil surface when erosion started, make the measurement from the base of the stone or other capping material to the base of the pedestal where it meets the surrounding surface. The difference between the height of the pedestal and the surrounding soil surface represents the soil loss since the soil was last disturbed by tilling or other agricultural practices. If the timing of the disturbance is known, it is possible to estimate a rate of soil loss.

Where possible, a number of measurements should be obtained from different parts of the field. Single pedestals, or a concentration of pedestals in a particular area, are not necessarily indicative of the occurrence of sheet erosion. It is usual to take a large number of pedestal heights and express overall erosion or lowering of the ground surface as an average of these heights. It is recommended to divide the field into a number of small areas or localities of about 1 m^2, and take the maximum pedestal height in each locality.

EXAMPLE OF FIELD FORM: PEDESTALS

Measurement locality	Maximum height of pedestal at locality (mm)
1	10
2	12
3	10
4	15
5	10
6	14
7	14
8	13
9	14
10	11
11	12
12	10
13	10
14	8
15	12
16	13
17	11
18	15
19	17
20	10
Sum of all measurements	241
Average*	AV PED HEIGHT = 12.05

*Rem.: to get average divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) Calculate t/ha equivalent of the net soil loss (represented by the average pedestal height). Using an average bulk density of $1.3 g/cm^3$, a 1 mm loss of soil is equivalent to 13 t/ha.

AV PED HEIGHT (mm)	12.05	x	BULK DENSITY (t/ha)	13	=	157 t/ha

3.15 **Field form: Armour layer** (Stocking & Murnaghan, 2000)

What is it? An armour layer is the concentration of coarser soil particles at the soil surface, that would ordinarily be randomly distributed throughout the topsoil. Such a concentration of coarse material usually indicates that finer soil particles have been selectively removed by erosion.

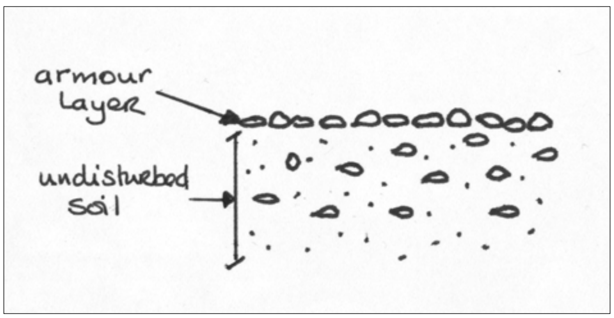


Figure 3.13 - Sketch of armour layer (Stocking & Murnaghan, 2000)

How does it occur? Raindrops or wind detach the finer and more easily eroded soil particles. Water or winds then carry them away from the topsoil surface, leaving behind the coarser particles.

Where does it occur? An armour layer is most likely to form on soils which have both a stony/coarse fraction as well as fine clays, silts and organic matter, following rainfall/severe winds.

How can it be measured? Dig a small hole to reveal the undisturbed armour layer. Using a ruler, measure the depth of the coarse top layer. Where the depth of the armour layer is less than one millimetre, it is best to scrape the stones from a small area about three times the size and then measure this depth and divide by three. This reduces inaccuracies in trying to measure very small depths of stones. Several measurements at different places in the field should be made in order to calculate the average depth of the armour layer.

Figure 3.14 - Measuring the armour layer with a ruler (Stocking &. Murnaghan, 2000)

The approximate proportions of stones/coarse particles in the topsoil below the armour layer are judged by taking a handful of topsoil from below the armour layer and separating the coarse particles from the rest of the soil. In the palm of the hand, an estimate is made of the percentage of coarse particles in the original soil. Again, this estimation should be repeated at different points in the field. The depth of the armour layer is then compared to the amount of topsoil that would have contained that quantity of coarse material. The amount of finer soil particles lost through erosion can then be estimated.

These calculations tell us the quantity of fine particles that have been lost since the soil was last disturbed – for example, since it was tilled or weeded.

EXAMPLE OF FIELD FORM: ARMOUR LAYER

Measurement	Depth of armour layer (mm)	Proportion of coarse material in topsoil
1	0.9	20%
2	1.1	25%
3	1.0	15%
4	1.1	22%
5	0.9	20%
6	1.2	20%
7	0.8	22%
8	0.9	19%
9	1.1	20%
10	1.1	20%
11	1.2	18%
12	1.0	20%
13	0.8	18%
14	0.9	22%
15	0.7	22%
16	1.0	20%
17	1.1	18%
18	1.2	20%
19	1.1	20%
20	0.9	19%
Sum of all measurements	20.0	400%
Average*	AL DEPTH (mm)= 1.0	COARSE % = 20%

* Rem.: to get average divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) First, convert the measured soil loss to its equivalent in metres. In this instance, because the measurements are in millimetres it is necessary to multiply by 0.001.

AL DEPTH (mm) [1.0] x [0.001] = AL DEPTH (m) [0.001]

(2) Calculate the depth of soil required to generate AL DEPTH (m)– this average measured depth of coarse material is 0.001m according to the measurements noted above. The measurements give an estimate of 20% (or $^{1}/_{5}{}^{th}$) for coarse material in the topsoil.

AL DEPTH (m) [0.001] x COARSE % [20% or $^{1}/_{5}{}^{th}$] = TOTAL SOIL(m) [0.005]

(3) Calculate the soil lost

TOTAL SOIL (m) [0.005] - AL DEPTH (m) [0.001] = NET SOIL LOSS (m) [0.004]

(4) Calculate t/ha equivalent of net soil loss – using an average bulk density of 1.3g cm^3. At this bulk density 1mm of soil loss is equivalent to 13 t/ha, so 1m of soil loss would be equivalent to 13,000 t/ha.

NET SOIL LOSS (m)	0.004	x	EQUIV VOLUME PER HECTARE (t/ha)	13,000	=	52 t/ha

3.16 Field form: Rills

What are they? A rill is a shallow linear depression or channel in soil that carries water after recent rainfall. Rills are usually aligned perpendicularly to the slope and occur in a series of parallel rill lines.

Figure 3.15 - Rills in Lesotho (Stocking & Murnaghan, 2000)

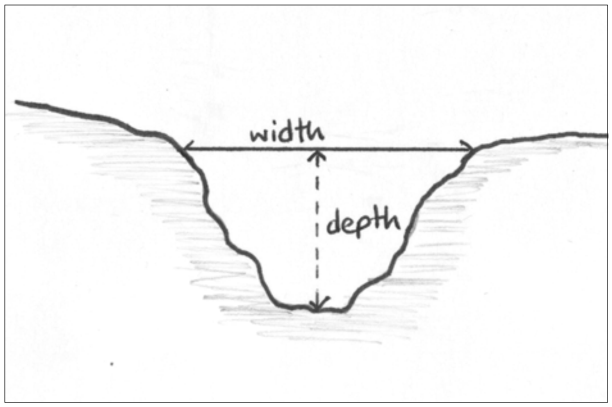
How do they occur? A rill is a product of the scouring action of water in a channel. Runoff is channelled into depressions, which deepen over time to form rills. It is also a means of rapidly draining a small part of a field and efficiently transporting sheet eroded sediment from the rill's catchment. A broadly accepted distinction between rills and gullies, often applied in soil conservation, is that the former can be eliminated using normal agronomic practices (such as ploughing), whereas gullies require specific large interventions such as bulldozers, concrete lining or gabions (rock-filled bolsters placed in gullies to accumulate sediment). Rills tend to occur on slopes, while gullies occur along drainage lines.

Where do they occur? Rills occur on a sloping surface where runoff is prevalent because of land use and lack of vegetation. Typically, rills occur where soil has been disturbed but the surface is left relatively smooth and unvegetated (e.g. after tillage, after building construction and on the sides of earth dams and road embankments). Rills are also likely to form in any slight depression in the soil, so paths, roadways, culverts and tracks made by tillage equipment are at risk of developing into rills.

How can they be measured? The commonest way to assess rills is through the volume of soil that has been directly eroded to create the rill, i.e. the volume of soil now missing because of the rill. This calculation does not include any estimate of the amount of erosion that occurs between rills, i.e. inter-rill erosion, which can be measured using other techniques such as pedestals. The measurement of soil loss from rills assumes that the depression forms a regular geometric shape. Triangular (see Figure 3.16), semi-circular and rectangular cross-sections are most common.

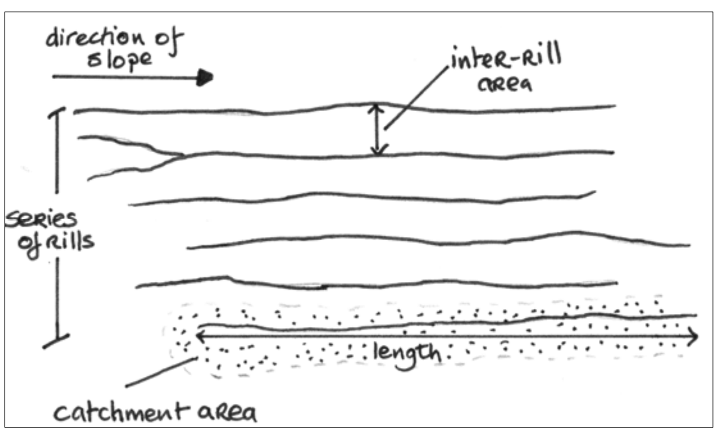
In order to calculate the quantity of soil lost it is necessary to measure the depth, width and length of the rill. A number of measurements of both the width and depth of a rill are required in order to get an average cross-sectional area. This averaging is appropriate, as a rill will not be of a constant width or depth throughout its length. These measurements of average cross-sectional area and length are used to calculate the volume of soil displaced from the rill. If it is known how long it has taken for the rill to form (if, for example the land was last tilled two months or two years ago), then an annualized rate of soil loss can be estimated.

Figure 3.16 - Sketch showing cross-section of a triangular-shaped rill (Stocking & Murnaghan, 2000)



Single rills are rarely found. They usually occur together in the same part of the landscape, each with a contributing runoff area where water passes into the rill. Sediment will be derived that is similarly passed along the rill. The most useful measure of degree of importance of rill erosion is to calculate the volume or mass of soil per square metre of catchment (see Figure 3.17). This can be converted to tonnes per hectare to make the measurement comparable to other estimates of soil erosion.

Figure 3.17 - Series of parallel rills (Stocking & Murnaghan, 2000)



EXAMPLE OF FIELD FORM: RILL

Measurement	Width (cm)	Depth (cm)
1	10	5
2	15	7
3	12	5
4	11	6
5	11	6
6	12	4
7	14	3
8	10	2
9	13	3
10	13	2
11	11	4
12	11	5
13	10	6
14	15	5
15	14	5
16	13	3
17	10	4
18	11	4
19	12	3
20	12	2
Sum of all measurements	240.0	84.0
Average*	WIDTH = 12.0	DEPTH = 4.2
Length of rill (m): 2.50		
Contributing (catchment) area to rill: (m^2) 12.0		

*Rem.: to obtain average, divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) Convert the average width and depth of the rill to metres (by multiplying by 0.01). Thus, an average horizontal width of 12cm is equal to 0.12m and an average depth of 4.2cm is equivalent to 0.042m.

(2) Calculate the average cross-sectional area of the rill, using the formula for the appropriate cross-section: the formula for the area of a triangle (i.e. ½ horizontal width x depth); semi-circle (1.57 x width x depth); and rectangle (width x depth). Thus, assuming a triangular cross-section it is:

½	x	WIDTH (m)	0.12	x	DEPTH (m)	0.042	=	CROSS-SEC AREA	0.00252 m^2

(3) Calculate the volume of soil lost from the rill assuming that the measurements above were taken from a rill measuring 2.5 metres in length.

CROSS-SEC AREA (m^2)	0.00252	x	LENGTH (m)	2.5	=	VOLUME LOST	0.0063 m^3

(4) Convert the total volume lost to a volume per square metre of catchment.

VOLUME LOST (m^3)	0.0063	÷	CATCHMENT AREA (m^2)	12	=	SOIL LOSS (m^3/m^2)	0.000525

(5) Convert the volume per square metre to tonnes per hectare.

SOIL LOSS (m^3/m^2)	0.000525	x	BULK DENSITY (t/m^3)	1.3	x	10,000	=	SOIL LOSS (t/ha)	6.9

3.17 Field form: gully

What is it? A gully is a deep depression, channel or ravine in a landscape, looking like a recent and very active extension to natural drainage channels. Gullies may be continuous or discontinuous; the latter occurs where the bed of the gully is at a lower angle slope than the overall land slope. Discontinuous gullies erode at the upslope head, but sediment themselves at the end of the discontinuity. Hence, several discontinuous gullies may occupy the same landscape depression, their shapes progressively moving upslope. Gullies are obvious features in a landscape, and may be very large (metres wide and deep) causing the undermining of buildings, roads and trees.

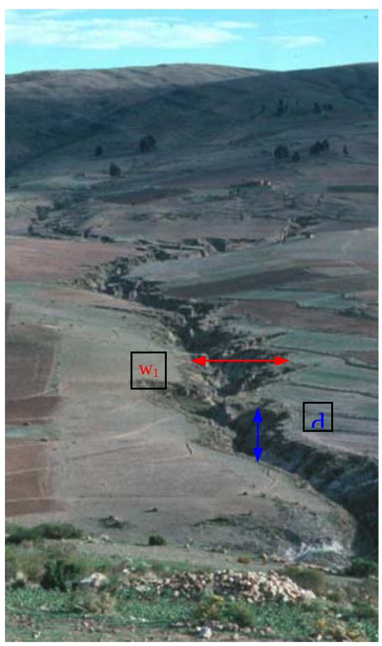


Figure 3.18 - Example of gully (Stocking & Murnaghan, 2000)

How do they occur? A gully is caused by water action. Runoff is channelled into grooves which deepen over time to form a distinct head with steep sides. Gullies extend and deepen in an up-valley direction by waterfall erosion and progressive collapse of their upslope parts; gully sides may collapse by water seepage or undermining by water flow within the gully.

Where do they occur? Several conditions are conducive to gully development. They tend to form where land slopes are long and land use has resulted in loss of vegetation and exposure of the soil surface over a large area so that the land now produces more runoff. They are particularly prevalent in deep loamy to clayey materials, in unstable clays (e.g.

sodic soils), on pediments immediately downslope of bare rock surfaces and on very steep slopes subject to seepage of water and to landslides.

<u>How can they be measured?</u> The measurement of soil loss from gullies is essentially the same as that for rills, except on a larger scale and with a different cross-sectional shape. Gullies usually have a flat floor and sloping sides, and account must be taken of these. In measuring gullies, the estimate being made is of the amount of soil displaced from the area now occupied by the gully furrows. This calculation does not include any estimate of the amount of sheet erosion occurring on the land adjacent to the gully.

In order to calculate the quantity of soil lost it is necessary to measure the depth, width at lip and base and length of the gully. Large gullies could be measured by standard field survey equipment such as a dumpy level, although often a 30-100 m tape and clinometer is sufficient. Measurements of width and depth should be made at a number of points along the gully. If there are big variations in the width and/or depth of the gully, it is best to break the gully into similar sections and calculate the amount of soil lost for each part. These can be summed to give the total amount of soil lost from the gully.

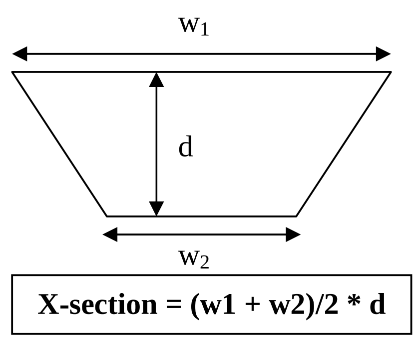


Figure 3.19 - Cross-sectional area of a trapezium-shaped gully (Stocking & Murnaghan, 2000)

EXAMPLE OF FIELD FORM: GULLY

Measurement	*Width at lip(w_1) m*	*Width at base (w2) m*	*Depth m*
1	10.0	4.0	2.1
2	12.0	5.0	2.1
3	11.0	4.0	1.9
4	12.0	6.0	1.8
5	9.0	6.0	2.1
6	9.0	3.0	2.2
7	11.0	5.0	2.0
8	9.0	5.0	2.3
9	10.0	4.0	2.4
10	12.0	5.0	2.2
11	14.0	6.0	2.3
12	9.0	6.0	1.8
13	9.0	4.0	1.9
14	11.0	5.0	1.8
15	10.0	4.0	1.7
16	9.0	5.0	2.0
17	8.0	3.0	2.0
18	10.0	5.0	1.7
19	11.0	6.0	1.9
20	8.0	5.0	1.8
Sum of all measurements	204.0	96.0	40.0
Average*	WIDTH w_1 = 10.2	WIDTH w_2 = 4.8	DEPTH (d)= 2.0

*Rem.: to obtain average, divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) Calculate the average cross-sectional area of the gully, using the formula (w1 + w2)÷2 x d.

½ (AV WIDTH w_1 +AV WIDTH w_2)	½(10.2+4.8)	x	DEPTH (m)	2.0	=	CROSS-SEC AREA	15 m^2

(2) Calculate the volume of soil lost from the gully assuming that the measurements above were taken from a gully measuring 200 metres in length.

CROSS-SEC AREA	15	*	LENGTH (m)	200	=	VOLUME LOST	3,000 m^3

(3) Convert the volume lost to a per metre equivalent, assuming a catchment area of 1 km^2, or 1,000,000 m^2.

VOLUME LOST	3,000	÷	CATCHMENT AREA (m^2)	1,000,000	=	SOIL LOSS (m^3/m^2)	0.003

(4) Convert the volume lost to tonnes per hectare over the whole catchment area.

SOIL LOSS (m^3/m^2)	0.003	*	BULK DENSITY (t/m^3)	1.3	x	10,000	=	SOIL LOSS	39 t/ha

3.18 Bibliography

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LAND DEGRADATION FORM

Coordinates.......................................Surveyor.........................Date..............Landform unit..................................Landcover...

LAND DEGRADATION TYPES

Physical	**Chemical**	**Biological**
soil water erosion	fertility declination	loss of vegetation cover
wind erosion	soil salinity	loss of biodiversity
soil compaction	soil toxicity	
soil crusting		
sedimentation		
stoniness		
urbanization		
waterlogging		

SOIL EROSION AND DEPOSITION

SOIL EROSION CLASSES (FAO, 1990)	**Description**	**Presence**
	No evidence of erosion	
	Water erosion	
	Wind erosion	
	Mass movement	
	Badland	

Erosion degree

Soil erosion extent

SOIL WATER EROSION

Soil water erosion type	**Severity**	**Extent**

Presence of soil and water conservation measures:

Sketch of the measured area:

FIELD FORM: PEDESTALS

Measurement Locality	*Maximum Height of Pedestal in Locality (mm)*
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	
20	
Sum of all measurements	
Average*	AV PED HEIGHT =

*Rem.: to obtain average, divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) Calculate t/ha equivalent of the net soil loss (represented by the average pedestal height).

AV PED HEIGHT (mm)	[ ]	x	BULK DENSITY (t/ha)	[ ]	=	t/ha

FIELD FORM: ARMOUR LAYER

Measurement	*Depth of armour layer (mm)*	*Proportion of coarse material in topsoil*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
Sum of all measurements		
Average*	AL DEPTH (mm)=	COARSE % =

*Rem.: to obtain average, divide the sum of all the measurements by the number of measurements made.

Calculations:

(1)First, convert the measured soil loss to its equivalent in metres.

AL DEPTH (mm) [ ] x [0.001] = AL DEPTH (m) [ ]

(2)Calculate the depth of soil required to generate AL DEPTH (m).

AL DEPTH (m) [ ] x COARSE % [ ] = TOTAL SOIL(m) [ ]

(3)Calculate the soil lost

TOTAL SOIL (m) [ ] - AL DEPTH (m) [ ] = NET SOIL LOSS (m) [ ]

(4)Calculate t/ha equivalent of net soil loss.

NET SOIL LOSS (m) [ ] x EQUIV VOLUME PER HECTARE (t/ha) [ ] = [t/ha]

FIELD FORM: RILL

Measurement	*Width cm*	*Depth cm*
1		
2		
3		
4		
5		
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
20		
Sum of all measurements		
Average*	WIDTH =	DEPTH =
Length of rill (m) =		
Contributing (catchment) area to rill (m^2) =		

*Rem.: to obtain average, divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) Convert the average width and depth of the rill to metres (by multiplying by 0.01).

(2) Calculate the average cross-sectional area of the rill, using the formula for the appropriate cross-section: the formula for the area of a triangle (i.e. ½ horizontal width x depth); semi-circle (1.57 x width x depth); and rectangle (width x depth). Thus, assuming a triangular cross-section it is:

½	x WIDTH (m)		x DEPTH (m)		= CROSS-SEC AREA	m^2

(3) Calculate the volume of soil lost from the rill.

CROSS-SEC AREA (m^2)		x LENGTH (m)		= VOLUME LOST	m^3

(4) Convert the total volume lost to a volume per square metre of catchment.

VOLUME LOST (m^3)		÷	CATCHMENT AREA (m^2)		=	SOIL LOSS (m^3/m^2)	

(5) Convert the volume per square metre to tonnes per hectare.

SOIL LOSS (m^3/m^2)		x	BULK DENSITY (t/m^3)		x		=	SOIL LOSS (t/ha)	

FIELD FORM: GULLY

Measurement	*Width at lip(w_1) m*	*Width at base (w_2) m*	*Depth m*
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
19			
20			
Sum of all measurements			
Average*	WIDTH w_1 =	WIDTH w_2 =	DEPTH (d)=

*Rem.: to obtain average divide the sum of all the measurements by the number of measurements made.

Calculations:

(1) Calculate the average cross-sectional area of the gully, using the formula (w1 + w2)÷2 x d.

½ (AV WIDTH w_1 +AV WIDTH w_2)	½(+)	x	DEPTH (m)		=	CROSS-SEC AREA	m^2

(2) Calculate the volume of soil lost from the gully.

CROSS-SEC AREA		*	LENGTH (m)		=	VOLUME LOST	m^3

(3) Convert the volume lost to a per metre equivalent, assuming a catchment area of 1 km^2, or 1,000,000 m^2.

VOLUME LOST		÷	CATCHMENT AREA (m^2)		=	SOIL LOSS (m^3/m^2)	

(4) Convert the volume lost to tonnes per hectare over the whole catchment area.

SOIL LOSS (m^3/m^2)		*	BULK DENSITY (t/m^3)		x		=	SOIL LOSS	t/ha

4 LAND USE SURVEY

4.1 Introduction

This manual is intended to guide the collection of land-use data, using the SWALIM land-use field data form. Land-use is defined as ''the arrangements, activities and inputs people undertake in a certain land-cover type to produce, change or maintain it''. This definition establishes a direct link between land-cover and the actions of people in their environment (Di Gregorio & Jansen, 2005).

Land-use survey in this case is defined as:

a. the inventory, classification and mapping of present use of the land in terms of cover and function; and
b. the analysis of causes and reasons underlying the present land use situation by means of studies and surveys, in which the land use/unit map could serve as a basis for stratified sampling.

Land-use surveys provide spatially defined information for land management, usually in the framework of rural development planning and decision making.

The following is a step by step analysis of the components of the land use data form and guidelines on its use.

4.2 Date

The day, month and year of the description are indicated to show future users the age of the data. The date of the description is given as dd/mm/yy (6 digits), e.g. 15 May 2006 is coded as 15/05/06.

4.3 GPS coordinates

The coordinates of the point where the soil profile is being described should be recorded by Global Positioning System (GPS), using the same coordinate system as the available maps. The UTM datum is preferred.

4.4 Name of observer

The names and/or initials of the person/s conducting the soil profile description and sampling are noted, to allow acknowledgment by future users of the data and also for future tracking of data.

Example: Ahmed Jama (A.J)

4.5 Local name of the village

This is the name of the village where the interview is taking place.

4.6 Selection of actual land-use

Selection of actual land use will involve assessing and ticking and/or writing down the observed type of land-use. The descriptions of the 11 types are outlined below:

<u>Irrigated agriculture</u> - agriculture with an external source of water other than rainfall, e.g. from main canal/pipe, river or borehole

<u>Rainfed agriculture</u> - agriculture that depends entirely on rainfall

Rainfed fallow agriculture - rainfed agriculture characterised by fallow periods when fields are left without growing crops on them

Nomadic pastoralism - haphazard, extensive grazing characterised by territorial limits

Transhumance pastoralism - seasonal migratory and circuitous grazing patterns

Agropastoralism (semi-sedentary grazing) - land-use where crops are managed together with livestock farming, where herds are taken out daily

Wood collection for charcoal and firewood - land-use involving collection of firewood and burning of charcoal

Grazing and wood collection - land-use where both grazing and wood collection take place

Urban area - urban settlements

Currently without use - idle land with no activities taking place

Other - any other activity on the land other than the ones mentioned above

This information must be collected with reference to the table below:

Table 4.1 - Types of land-use

Check	Type of land Use
	Irrigated agriculture
	Rainfed agriculture
	Rainfed fallow agriculture
	Nomadic pastoralism
	Transhumance pastoralism
	Agropastoralism (semi-sedentary grazing)
	Grazing and wood collection for charcoal and firewood
	Urban
	Currently without use

4.7 Farming system

In this category, selected farming activities include land improvement and mechanisation. Attributes to be assessed are based on characteristic examples of arid and semi-arid lands, focusing on the following:

4.7.1 Land improvement systems

Under this category, the following types must be investigated and checked:

Drainage - land improvement that assists movement of water within the land unit.

Berkade - cemented underground water reservoir for collecting water, primarily from rain.

Borehole - a deep drilled well for exploiting underground water.

Shallow wells - hand-dug well, exploiting the surface water-table.

Terracing - action of dividing slopes into shorter segments or, in some cases, segments of lower gradient in order to intercept and arrest runoff, giving water time to infiltrate the soil.

Soil bunding - earthen dikes or banks along contours, designed both to interrupt water runoff as a measure against erosion and to store water behind the bund to facilitate infiltration, thus increasing soil moisture for plant growth.

Water harvesting - water conservation techniques that preserve runoff water for utilisation.

Other - refers to other types that not mentioned above.

The surveyor will be required to check those land improvements that are present in the unit being surveyed using the table below:

Table 4.2 - Land improvement classes

Check	Land Improvement
	Drainage
	Berkade
	Borehole
	Wells
	Terracing
	Soil bunding
	Water harvesting
	Other

4.7.2 Determination of levels of agronomic input in the present land use system

Agronomic inputs refer to seeds, fertilizers, pesticides, etc. The surveyor shall be required to observe and indicate the levels of material input and categorize them as follows:

Low input - traditional farming methods where no agronomic inputs are undertaken.

Medium input - where farmers follow agricultural extension but have limited technical knowledge and/or capital resources.

High input - modern methods involving advanced technology, high capital resources (fertilizer at levels of maximum economic returns), etc.

The surveyor shall collect this information by ticking whichever is applicable on the table below:

Table 4.3 - Input level classes

	Input Level
	Low input
	Medium input
	High input

4.7.3 Mechanisation

Mechanisation refers to the use of fuel-driven machinery. The surveyor will be required to observe and record what machinery is being used in the area. The listed categories also include the use of animal power and human labour.

4.7.4 Farm management and protection

These include enclosures, fencing and all elements of land improvement which help to increase production. The surveyor is required to observe and record farm management and protection at the observation site.

4.8 Crops

Agriculture involves the production of crops, which are grown in varying sequences and types according to season and the area in question. Under this category, the surveyor is required to address the following aspects:

4.8.1 Indicate the crops as observed in the field

Here the surveyor should list the crops observed in the field during the survey such as those listed in Table 4.4, which is used by ticking whichever crops are applicable:

Table 4.4 - Crop types

	Crop types
	Maize
	Sorghum
	Sesame
	Cowpeas
	Barley
	Vegetables
	Fruits
	Other

4.8.2 Indicate the element of intercropping

Intercropping involves growing two or more crops on the same field, either sequentially or at the same time**.** The surveyor is required to record the presence of intercropping, list the crops that are intercropped and also state the pattern of intercropping, i.e.

Simultaneous - when crops are grown at the same time.

Overlapping - when one crop is grown either after the other is mature or at an advanced stage of growth.

Sequential - when a second crop is grown after the first is harvested.

4.8.3 Indicate the average field size corresponding to the unit

The surveyor will indicate whether fields are small (<2ha), medium (2-5ha) or large (>5ha). He/she must move around in the land-use unit being sampled and estimate the average field size, either in hectares or other appropriate units of area measurement. This information is collected by ticking whichever is applicable on the table below.

Table 4.5 - Classes of farm sizes

	Average Farm Size
	<2 ha
	2-5 ha
	>5 ha

4.8.4 Purpose of crop production

Crops produced are either taken to market for sale, consumed at home, fed to livestock as fodder, or used for other purposes. The surveyor must state the purpose for which the crops are produced in the land-use unit, using the table below.

Table 4.5 - Purpose of crop production

Crop types	Crop use			
	market	consumption	fodder	other
Maize				
Sorghum				
Sesame				
Cowpeas				
Barley				
Vegetables				
Fruits				
Other				

4.8.5 Phenological stage of the crop

During the time of the field survey, crops will be at different stages of development such as growing, flowering, fruiting and/or mature, being harvested or lying fallow. The surveyor will indicate the crop development stage, which is also called the *phenological stage*. The observation will be made for each crop listed, using Table 4.6 to collect phenological data.

Table 4.6 - Crop phenological stage

Crop types	Crop phenological stage				
	start	growing	flowering	fruiting	fallow
Maize					
Sorghum					
Sesame					
Cowpeas					
Barley					
Other					

4.8.6 General crop condition at the time of survey

Various factors determine the health of a crop. Crop condition can be categorised as poor, good or as failed when no harvest is realised. The surveyor will indicate crop condition at the sample site and categorize it according to crop type using Table 4.7.

Table 4.7 - Crop production

Crop type	Crop condition		
	Crop failure	**Poor crop**	**Good crop**
Maize			
Sorghum			
Sesame			
Cowpeas			
Barley			
Other			

4.8.7 The principal limitation

It is important to note the principal cause of a crop failure or a poor crop. The surveyor must indicate any conditions that led to crop failure, which might be either climatic, water related, soil related, cultural or others.

4.8.8 The principal agronomic aspects

These are attributes directly influencing agricultural production, which may vary from crop to crop and between land use units. These aspects are listed below and must be computed for all listed crops. The surveyor shall be required indicate, sometimes with quantities, aspects of each crop listed, such as maize, sorghum, sesame, cowpeas, barley, vegetables, fruits and others.

<u>Acreage under crop</u> - area under the crop, using locally applicable units of measurement.

<u>Type of seed</u> - type/s of seed, such as variety, improved or local.

<u>Type of cropping:</u> cropping patterns, such as simultaneous, overlapping or sequential.

<u>Use of fertilizers</u> - amounts of fertilizer used, in kg/unit area of planted crop.

<u>Manure</u> - usage of manure in quantity/unit area (indicate source of the manure).

Use of pesticides - usage of pesticides in quantity/unit area.

Labour - source and availability of labour at each growing stage, by crop type.

Mechanisation - usage of machinery by type and availability, at each growing stage.

Approximate yield per ha. - production per unit area in last season, by crop type.

The table below should be used to collect this data.

Table 4.8 - Agronomic aspects

Actual crop	Hectarage under crop	Type of seed	Type of cropping	Use of fertilizers	Manure	Use of pesticides	Labour	Machinery	Approx.. yield per ha
Maize									
Sorghum									
Sesame									
Cowpeas									
Barley									
Vegetable									
Fruits									
Other									

4.8.9 Computation of the general crop calendar for the land use system

A detailed crop calendar assists in establishing the effect/s of the previous crop in depleting soil water and nutrients. The surveyor is required to complete a yearly crop calendar, outlining all stages of crop development, i.e. land preparation, planting, mid-season and harvesting., for all the crops listed.

Table 4.9 - Crop calendar

CROP	JILAL			GU			HAGAA			DEYR		
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Maize												
Sorghum												
Sesame												
Cowpeas												
Barley												
Vegetables												
Fruits												
Other												

1	Land preparation
2	Planting
3	Mid-season
4	Harvesting

4.8.10 Farm training in the last 5 years

Farm training improves the technical capacity of farmers. Rural agricultural extension services are an integral component of agricultural production, helping in providing *in situ* training to farmers. The surveyor will indicate the type of training that the farmer may have received in the past 5 years.

4.8.11 Major constraints and opportunities from the farmer's perspective

This involves a semi-structured interview with the farmer, in which the surveyor outlines the constraints and opportunities to agricultural production as seen by the farmer. The surveyor does this through analysis of crop production history using information supplied by the farmer. The surveyor should also establish possible future improvements in agricultural production, taking into account opportunities suggested by the farmer. This data is collected using Table 4.10, below.

Table 4.10 - Table of constraints and opportunities

Constraints	Opportunities

4.8.12 Major constraints and opportunities from a technical point of view

After evaluating the agricultural production system that a farmer uses, the surveyor must make a technical evaluation of all negative issues and also suggest some practical solutions. This is done by listing the major constraints and opportunities from a technical point of view, with reference to Table 4.11.

Table 4.11 - Table of technical constraints and opportunities

Constraints	Opportunities

4.9 Livestock

4.9.1 Type of grazing

The surveyor will indicate the type of grazing occurring at the sample site. Three main grazing types are listed here and include:

Nomadic pastoralism - free-range extensive grazing characterised by territorial limits.

Transhumance pastoralism - the surveyor shall establish this as seasonal migratory and circuitous grazing.

Semi-sedentary (agropastoralism) - systems that include both crops and livestock farming with herds taken out daily.

Other - the surveyor shall indicate the type of grazing other than the ones above.

The procedure involves ticking the applicable grazing type in Table 4.12.

Table 4.12 - Types of grazing

	Types of Grazing
	Nomadic pastoralism
	Transhumance pastoralism
	Semi-sedentary (agropastoralism)
	Other

4.9.2 Animal species present in the system

The surveyor will inventory animal species, by type and breed, observed at the sample site by ticking applicable species in Table 4.13.

Table 4.13 - Types of animal

	Types of animal
	Camel
	Goat
	Sheep
	Cattle

4.9.3 Estimating the number of animals per species

The surveyor is required to provide approximate numbers of domestic animals by species, using information provided by the farmer using Table 4.14 below.

Table 4.14 - Numbers of animals

Species	Approx. number
Camel	
Goat	
Sheep	
Cattle	
Other	

4.9.4 Listing livestock products and their uses

The surveyor should use Table 4.15 to indicate livestock products (such as meat, milk, skin, ghee and cheese) and their use. Other livestock products should also be indicated.

Table 4.15 - Livestock products

Livestock product	Camel	Goat	Sheep	Cattle	Other	Use for livestock product
Meat						
Milk						
Skin						
Ghee						
Cheese						
Other						

4.9.5 General animal condition

Through observation, the surveyor must assess the general health and condition of animals, by type. The observation will be subjective and classified as good, average or bad, using Table 4.16. The surveyor is also required to explain reasons behind bad health, using his/her own expertise in addition to reason/s provided by the farmer.

Table 4.16 - Animal health condition

Species	Condition		
	bad	average	good
Camel			
Goat			
Sheep			
Cattle			
Other			

4.9.6 Quality of forage

Using personal experience and the farmer's assessment, the surveyor must assess forage conditions, listing forage as good, moderate or bad in Table 4.17 and supplying reasons for a bad assessment.

Table 4.17 - Quality of forage

Animal Type	Forage Quality		
	good	moderate	bad
Camel			
Goat			
Sheep			
Cattle			
Other			

4.9.7 Enclosures in rangeland

The surveyor must indicate the presence of enclosures in the rangeland area, indicating in Table 4.18 if enclosures are present or absent and if present, their purpose, destination of products from the enclosures and any problems that may be associated with them.

Table 4.18 - Presence of enclosures

Presence of enclosures	Purpose of enclosures (list)	Destination of produce from enclosures (list)	Do they cause problems? (yes/no) - list if Yes

4.9.8 Water sources for livestock

Source of water for livestock during the different seasons of the year must be indicated. The different seasons used are *Jilal*, *Gu*, *Hagaa* and *Deyr* and observations should be noted on Table 4.19 below. The assumption is that different water sources are used during different seasons.

Table 4.19 - Livestock water sources

	Water Source	Season
	Rivers	
	Boreholes	
	Shallow wells	
	Other	

4.9.9 Distance to nearest watering point

Animal water intake is dependent on food water levels (which varies seasonally), environmental conditions and the condition of the animal, e.g. lactating and young animals have a greater and more frequent need for water. In hot and arid regions, watering may involve animals in long journeys between grazing and water which expends energy and reduces grazing time. The surveyor must indicate distances in kilometres covered by animals to reach watering points in different seasons.

4.9.10 Major constraints and opportunities from pastoralist perspectives

This will involve a semi-structured interview with the pastoralist, outlining constraints and opportunities to livestock production as given by the pastoralist. The surveyor must analyse animal production history given by the pastoralist, establishing possible future improvements in livestock production while taking into account possible opportunities.

Table 4.10 - Table of constraints and opportunities from the pastoralist's perspective

Constraints	Opportunities

4.9.11 Major constraints and opportunities from a technical point of view

After evaluating the livestock production system, the surveyor shall give his technical opinion on all negative issues regarding livestock production and suggest some feasible solutions, listing major constraints and opportunities on Table 4.11.

Table 4.11 - Table of constraints and opportunities from the surveyor

Constraints	Opportunities

4.10 Wood collection (firewood and charcoal)

4.10.1 Charcoal production

Charcoal burning as an alternative livelihood has been extensively practised in drylands, both for export and local consumption and seldom with regard to issues of environmental degradation. Cutting of trees for charcoal burning is selective, such as *Acacia bussei* being preferred over other tree species. To collect data on charcoal burning, the surveyor must select one of two options provided in the data form, i.e. yes or no. Burning of charcoal is given a Yes, whereas absence of burning of charcoal is given a No.

4.10.2 Rangeland degradation through charcoal production

Charcoal burning reduces tree cover and, if not controlled, leads to rangeland degradation through soil erosion, reduction in forage and a reduction in biodiversity. The surveyor should list environmental problems observed to be associated with charcoal production.

4.10.3 Charcoal production and selective tree species

Certain dryland trees such as *Acacia bussei* are preferred for charcoal production. However, other tree species are also cut for the same purpose. The surveyor should indicate what other tree species are being cut for charcoal production by first ticking either Yes or No to indicate whether selective tree cutting is taking place, then listing other tree species that are being cut for charcoal production.

4.10.4 Charcoal burning technique

Charcoal is produced using varying methods, three categories of which are to be evaluated by the surveyor. These are pit/trench kiln, mound kiln and other and should be categorised using Table 4.12. The surveyor should also indicate if charcoal burning involves the use of dead or live trees.

Table 4.12 - Type of charcoal burning technique

	Type of Kiln
	Pit/trench
	Mound
	Other

4.10.5 Current land-use situation

The adverse environmental effects of tree destruction for the burning of charcoal are well documented. Land users always know the preferred areas for charcoal burning, so data on this activity can very rapidly be generated through discussions and observation of indicators such as presence of abandoned or current charcoal kilns, charcoal on trucks and cutting of trees. The surveyor should indicate the current charcoal-burning situation in terms of land-use.

4.11 Bibliography

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de Leeuw, P.N. (1984). Pastoral production systems and land utilization types. **In**: *Proceedings on land evaluation for extensive grazing*. ILRI, Wageningen. p.113-119.

FAO. (1983). Guidelines: Land evaluation for rainfed agriculture. *FAO Soils Bulletin* **52**. Rome.

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Huizing H. (1992). *Land Evaluation.* Lecture Notes for the LE specialization. ITC, Enschede, The Netherlands.

LAND USE FORM

1. Date…………………….

2. GPS coordinates: N………………………………..E…………………………….…

3. Name of the observer…………………………..……………………………………………..

4. Local name of the village or any location………..…………………………………………

5. Select the actual land use:

Check	Type of land Use
	Irrigated agriculture
	Rainfed agriculture
	Rainfed fallow agriculture
	Nomadic pastoralism
	Transhumance pastoralism
	Agropastoralism (semi-sedentary grazing)
	Grazing and wood collection for charcoal and firewood
	Urban area
	Currently without use

Farming System

1. Land improvement systems, please check the ones present in the unit

Check	Land Improvement
	Drainage
	Berkade
	Borehole
	Wells
	Terracing
	Soil bunding
	Water harvesting
	Other

2. Can you determine the level of input in the present land use system?

	Input Level
	Low input
	Medium input
	High input

3. Mechanization: ( ) Yes ( ) No

Type………………………………………………………………………………………………...

4. Is there any form of farm management and/or protection observed?

Yes ( ) No ( )

If Yes, give type:………………………………………………………………………………....................

<u>Crops</u>

1. Can you indicate the current crop(s)? (you can select and describe more than one)

	Crop Type
	Maize
	Sorghum
	Sesame
	Cowpeas
	Barley
	Vegetables
	Fruits
	Other

2. Is there any intercropping activity? Yes ( ) No ( )

If Yes, which crops?

……………………………………………………………………………………………………

……………………………………………………………………………………………………

3. Can you indicate an average field size corresponding to this unit?

	Average Farm Size
	<2 ha
	2-5 ha
	>5 ha

4. Which is the purpose of the crop production?

Crop Type	Crop Use			
	Market	Consumption	Fodder	Other
Maize				
Sorghum				
Sesame				
Cowpeas				
Barley				
Vegetables				
Fruits				
Other				

5. Can you indicate the actual phenological stage of the crop?

Crop Type	Crop Phenological Stage				
	start	growing	flowering	fruiting	fallow
Maize					
Sorghum					
Sesame					
Cowpeas					
Barley					
Other					

6. What is the general crop condition at this time?

Crop Type	Crop Condition		
	Crop Failure	**Poor Crop**	**Good Crop**
Maize			
Sorghum			
Sesame			
Cowpeas			
Barley			
Other			

7. In case of crop failure or poor crop, which is the principal limitation?

Climatic conditions……………………………………………………………………………………………
……
……

Water availability……………………………………………………………………………………………..
……
……

Soil related factors…………………………………………………………………………………………
……
……

Agronomic cultural aspects…………………………………………………………………………………..
……
……
……

Other………..
……
……

8. Can you explain some principal agronomic aspects?

Actual crop	Hectarage under crop	Type of seed	Type of cropping	Use of fertilizers	Manure	Use of pesticides	Labour	Machinery	Approx. yield per ha.
Maize									
Sorghum									
Sesame									
Cowpeas									
Barley									
Vegetable									
Fruits									
Other									

9. Can you make a general crop calendar for this land use system? Give a complete yearly crop calendar.

CROP	JILAL			GU			HAGAA			DEYR		
	Jan	Feb	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov	Dec
Maize												
Sorghum												
Sesame												
Cowpeas												
Barley												
Vegetables												
Fruits												
Other												

1	Land preparation
2	Planting
3	Mid-season
4	Harvesting

10. Have you received any farm training within the last 5 years? Are there any rural extension services?

11. What are the major constraints and opportunities from a farmer's perspective (semi structured interview)? Analyse the crop history by trying to get information from the land users regarding a historical perspective of the lands in terms of production. How is the current situation and what future improvements are possible? What according to you is the best alternative land use in this area?

Constraints	Opportunities

12. Major constraints and opportunities from a technical point of view (your opinion as a technician regarding the negative issues on all aspects and also some feasible solutions).

Constraints	Opportunities

<u>Livestock</u>

1. Which is the type of grazing?

	Type of Grazing
	Nomadic Pastoralism
	Transhumance Pastoralism
	Semi-sedentary (Agropastoralism)
	Other

2. Which are the species present in the system?

	Type of animal
	Camel
	Goat
	Sheep
	Cattle

3. Can you estimate the number of animals per species per household?

Species	Approx. numbers
Camel	
Goat	
Sheep	
Cattle	
Other	

4. Can you list the livestock products and their uses?

Livestock products	Camel	Goat	Sheep	Cattle	Other	Uses
Meat						
Milk						
Skin						
Ghee						
Cheese						
Other						

5. Can you evaluate the general health condition from a physical appearance?

Species	Condition		
	bad	average	good
Camel			
Goat			
Sheep			
Cattle			
Other			

6. If the general condition is down from average to bad, can you explain the principal reasons for it?

7. What, in your opinion, is the quality of the forage for the various animals as listed below (tick)?

Animal	Forage Quality		
	Good	moderate	bad
Camel			
Goat			
Sheep			
Cattle			
Other			

8. Enclosures in the rangeland area.

Presence of enclosures	Purpose of enclosures (list)	Destination of produce from enclosures (list)	Do they cause problems? (yes/no) - list if Yes

9. Which is the water source for the livestock?

	Water Source	Season
	Rivers	
	Boreholes	
	Shallow wells	
	Others	

10. What is the distance to the nearest watering point for the animals (in kilometres)?

- In the rainy season?..
- In the dry season?..

11. What are major constraints and opportunities from a pastoralist's perspective (semi structured interview). Analyse the grazing history by trying to get information from the land users regarding a historical perspective of the lands in terms of livestock production. How is the current situation and what future improvements are possible? What according to you is the best alternative land use in this area?

Constraints	Opportunities

12. Major constraints and opportunities from a technical point of view in regard to livestock production (your opinion as a technician regarding the negative issues on all aspects and also some feasible solutions).

Constraints	Opportunities

Wood collection (firewood and charcoal production)

1. Is charcoal production a common activity in the area?

Yes……………………………………………………………………………………

No…………………………………………………………………………………….

2. Is charcoal production leading to rangeland degradation in this area? List the environmental problems associated with charcoal production.

a)…………………………………………………………………………………………

b)…………………………………………………………………………………………

c)…………………………………………………………………………………………

3. Is the charcoal production activity selective in species?

Yes / No

If yes, list preferred tree species, starting with most preferred tree species.

4. Which type of production method is used?

	Type of kiln
	Pit/trench Mound Other

5. Do they use live or dead trees? (tick)

Yes / No

6. Can you explain the current situation in terms of land use? (This is related to a general overview of the influences of this land use on the landscape. Specify if charcoal is only in some parts of the area or is in all surroundings. Stimulate the pastoralists to sketch the extent of the charcoal burning activity).

5 LAND COVER

The following section focuses mainly on data collection for validating a Land Cover map, but also includes information on landform aspects, soils and land use issues. The aim of this document is to provide suitable training both before the survey and as a fieldwork tool.

The basic steps of a survey are:

- landscape evaluation;
- active selection of suitable observation points; and
- description of the surrounding area.

It is necessary that surveyors are able to distinguish between the different types of vegetation and agriculture in the field, and evaluate them consistently according to the **Land Cover Classification System (LCCS)** adopted.

5.1 Introduction[1]

5.1.1 General principles of land-cover mapping

Land-cover is the (bio) physical cover of the earth's surface, including vegetation and man-made features, as well as bare rock, bare soil and inland water surfaces.

Land-cover mapping is accomplished through interpretation of satellite images, on-screen interpretation of which is done with the help of various mapping software packages to produce polygon-based land cover maps (Fig. 5.1).

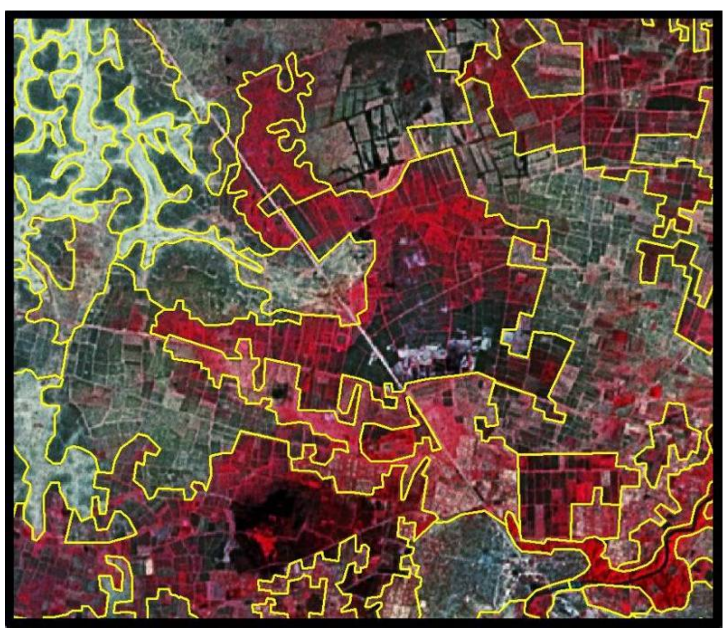


Figure 5.1 - The yellow lines represent polygons drawn onto a satellite image

[1] The Land Cover section of this manual is based on the FAO LCCS manual (Di Gregorio & Jansen, 2005).

Each polygon is labelled with a code indicating the land-cover type that it represents (i.e. 2HC, 2SPJ6, HR57).

The list of all the land-cover classes present in the study area constitutes the 'Legend' of the land cover map (Table 5.1).

Table 5.1 - Preliminary legend for Somalia land-cover: examples of classes and codes created using LCCS.

SOMALIA - PRELIMINARY LEGEND		
LCCOwnDescr	MapCode	LCCLevel
A12-NATURAL AND SEMINATURAL TERRESTRIAL VEGETATION		
Herbaceous terrestrial		
Closed Herbaceous	**2HC**	A2 = Herbaceous
		A10 = Closed >65%
		B4 = 3 - 0.03 m
		C1 = Continuous
Shrubs terrestrial		
General Open Shrubs with Herbaceous from Closed to Open	**2SPJ6**	A4 = Shrubs
		A11 = Open General 65-15%
		B3 = 5 - 0.3 m
		B14 = 5 - 0.5 m
		C1 = Continuous
		F2 = 2nd layer
		F4 = Herbaceous
		F7 = Closed to Open
		G4 = 3 - 0.03 m
A 11-CULTIVATED TERRESTRIAL AREAS AND MANAGED LANDS		
Herbaceous Crop - Irrigated		
Irrigated Continuous Small Fields of Herbaceous crops (single - Rice/Banana - or multiple herbaceous crops)	**HR57**	A3 = Herbaceous crop
		B2 = Small (less than 2ha)
		B5 = Continuous
		D3 = Irrigated
		D9 = Permanent

A polygon can identify one homogeneous land cover type only (single class), or include more than one type up to a maximum of three (mixed unit) when the different land cover types present are too small to be mapped individually (i.e. less than the minimum mappable area[2])

In mixed units, different codes are separated by a slash; the first code on the left indicates the dominant land cover class (Fig. 5.2).

[2] Every thematic map defines a "**Minimum Mappable Area**" or M.M.A. The M.M.A. is the smallest surface that can be mapped, such as a single polygon. Areas smaller than the M.M.A. are not considered. When several un-mappable zones are close to each other they can be grouped together as a polygon. Usually a mixed unit appears like a cluster, or bunch of dots on a different background.

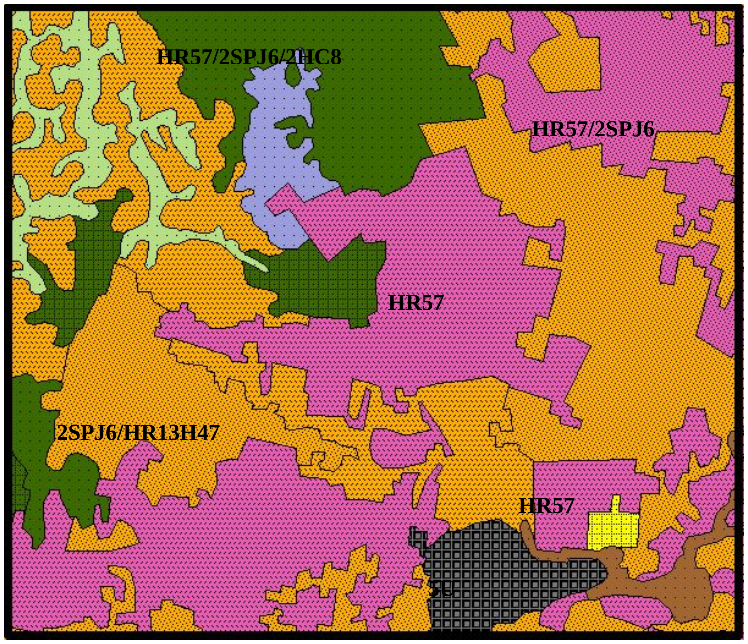


Figure 5.2 - Example of single classes (5U, HR57, 2HC8) and mixed units (2SPJ6/HR13H47, HR57/2SPJ6, HR57/2SPJ6/2HC8)

The actual field boundaries between different land-cover classes or landforms can be either sharp or gradual, but the distinction between different typologies has to be evident. Usually, transitions between different natural vegetation typologies are gradual, while between natural vegetation and agricultural areas they are sharper.

5.2 The survey

The aim of the field survey is to collect ground information through field samples. This phase helps in validating maps derived from satellite imagery analysis. Field data describe the reality on the ground and are collected to confirm or correct the preliminary photo-interpretation.

The areas where field samples will be carried out are identified during the preliminary photo-interpretation. On the map, they are marked by a rectangular sampling quadrat within the polygon to be checked (Fig.5.3). The area marked by each sampling quadrat will be representative for the whole polygon that contains it.

Several criteria are applied during the selection of the quadrates where field samples will be carried out:

Criteria related to the photo-interpretation activity

- the most frequent land cover types
- areas in which there are doubts about the correctness of the interpretation

Criteria related to logistic aspects

- accessibility of the area
- clustering of the field samples

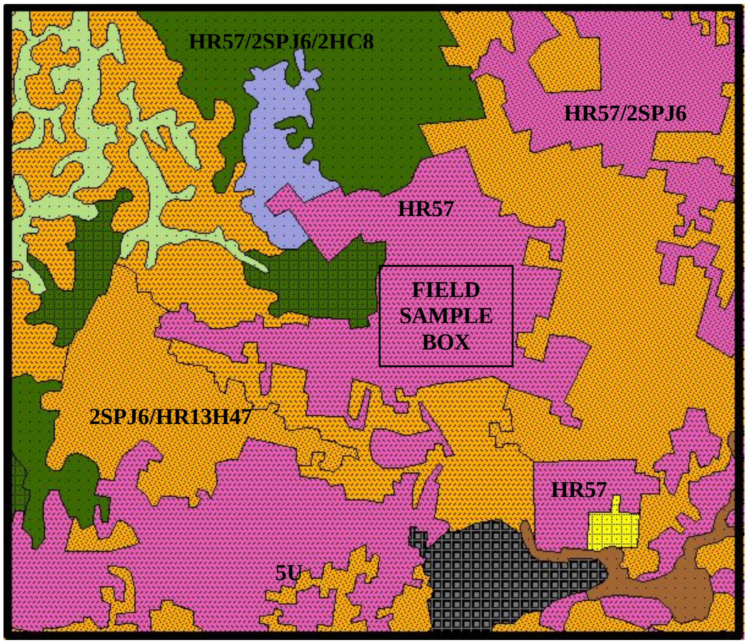


Figure 5.3 - Example of field sample quadrat

5.2.1 Conceptual basis for land cover survey

In order to understand all the actions involved in field data collection, some key concepts must be explained:

5.2.1.1 Difference between classification and description

For *classifying* an object, for example a tree, only those features that allow a clear identification are used:

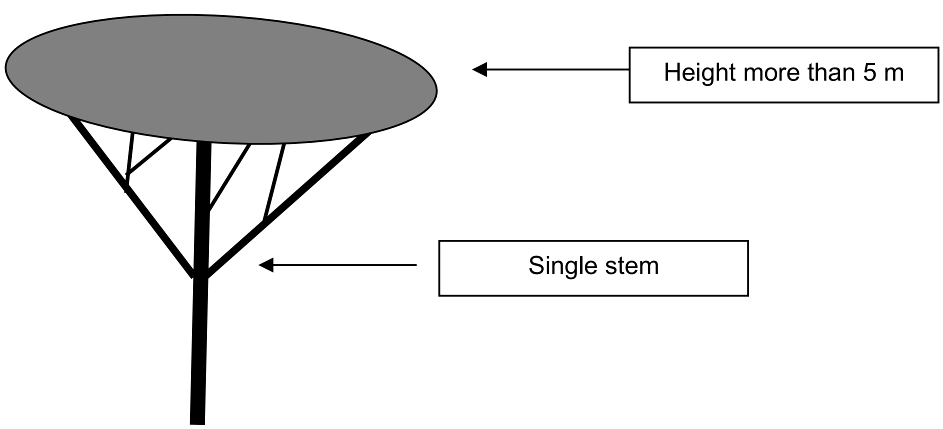


Figure 5.4 - Features of a tree

While for *describing* it, all features may be used:

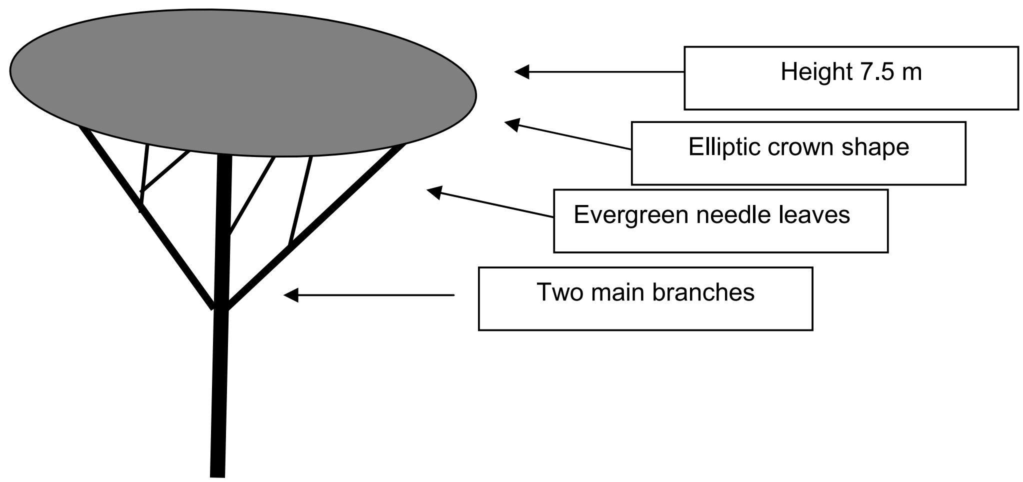


Figure 5.5 – Features used to describe a tree

When conducting a **classification** in order to distinguish different land cover types, only those attributes or characteristics necessary for identifying the main differences between typologies will be considered. These attributes are not expressed by definite descriptions or unique values, but by a range of values.

For each characteristic some thresholds are fixed, grading from one class into another (e.g. plant coverage is referred to as *Very Open* when coverage ranges from 15-40% and *Open* between 40-60%). This allows for the use of a discrete, limited set of classes for a preliminary or general classification of the real cover present in the area where the field sample will be executed.

When conducting a **description** of a land cover type, the unique attributes or characteristics will be collected. Usually the set of characteristics used for a description will not correspond to the ones used for classification, making description more complex. Classification distinguishes land cover types only by allocating them inside established ranges defining each attribute, while description measures the real values of each attribute of a land cover type, providing information useful for performing specific analyses.

A description refers only to a visited site field sample or site. In theory, in the real world, it is impossible to find two places that are identical. In practice, the level of descriptive accuracy attainable is constrained by practicalities and it will be found that two different sites can be matched.

Table 5.2 – Classification and description of a tree.

	CHARACTERISTICS VALUES	**CHARACTERISTICS AMOUNT**
CLASSIFICATION	Within a RANGE	Just enough to make distinctions
DESCRIPTION	The EXACT one (human subjectivity)	All the necessary ones to perform analysis

5.2.1.2 Definition of life form and dominance

All plant formations consist of growth forms distributed within layers or strata, the distinction of which is of fundamental importance when analysing vegetation.

Plant communities are not limited to vertical arrangements into layers; they are also arranged horizontally (i.e. horizontal spatial distribution). Thus, when observing vegetation and considering its growth forms, two factors are fundamental:

- Physiognomy: the overall appearance of vegetation; and
- Vegetation structure: defined as "*the spatial distribution pattern of growth forms in a plant community*" (Küchler & Zonneveld, 1988).

The structure describes the individual layers, usually characterised by the height and density of the respective growth forms.

a) ***Natural and semi-natural vegetation***

Vegetative cover consists of vegetative forms *woody* (trees, shrubs), *herbaceous* (forbs, graminoids) or a combination of both, or consists of *lichens/mosses* (when other life forms are absent). The following definitions and guidelines are extracted from the LCCS manual.

- Woody **-** Perennial plants with stems and branches from which buds and shoots develop. Semi-woody plants are included. Depending on branching symmetry, a distinction is made between trees and shrubs. According to international norms of vegetation classification and mapping, bamboos and tuft plants (palms, tree ferns, etc.) belong to this category and depending on their height, they are classified as either trees or shrubs. This classification is used when vegetation consists of an intricate mixture of different forms (i.e. where trees and shrubs form a closed cover with an upper surface so uneven that no distinct, separate layers can be distinguished). Height ranges from 2 - 7 m.
- Trees - Woody perennial plants with a single, well-defined stem carrying a more or less defined crown and at least 3 m tall.
- Shrubs - Woody perennial plants with persistent woody stems and without any defined main stem, less than 5 m high. Growth form can be erect, spreading or prostrate.

  Guidelines: Height separates trees from shrubs: woody plants higher than 5 m. are classified as trees, while woody plants lower than 5 m. are classified as shrubs. This general rule has an exception: a woody plant with a clear physiognomic tree form can be classified as a tree if the height is less than 5 m., but more than 3 m.

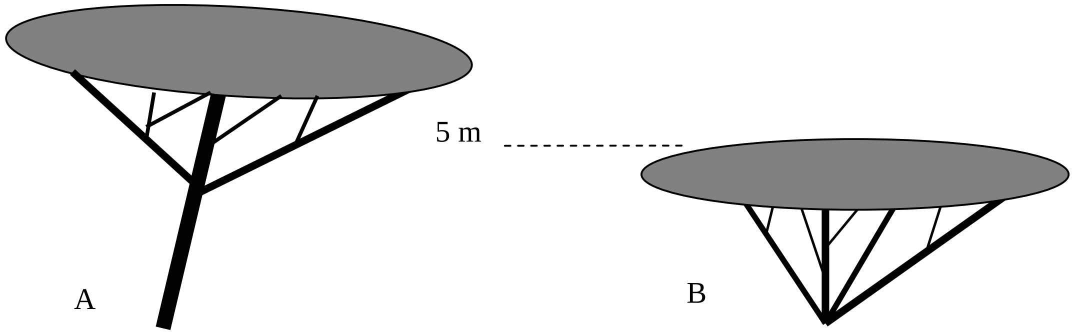


Figure 5.6 - A = Tree life form; B = shrub life form.

- Herbaceous - Plants without persistent above-ground stems or shoots and lacking definite firm structure. There are two categories, depending on physiognomy: *Graminoids* and *Forbs*.

  Guidelines: This layer is used when vegetation is an intricate mixture of different life forms (i.e. forbs and graminoid forming a continuous layer of the two elements).

- Graminoids - All herbaceous grasses and other, narrow-leaved grass-like plants that are taxonomically not grasses. Bamboos are technically grasses, but they are woody and therefore classed with shrubs and/or trees.

  Guidelines: Graminoid vegetation is defined if Graminoids comprise more than 75% of herbaceous coverage. There is no upper height limit; the only condition is plant physiognomy.

- Forbs - All broad-leaved herbaceous plants (e.g. sunflowers, cloves) and all non-graminoid herbaceous plants. Therefore ferns (excepting tree ferns) and very low, non-leafy succulents are included.

  Guideline: Applies where forbs constitute more than 75% of overall herbaceous coverage.

- Rooted - Aquatic plants growing in a substrate, but structurally supported by water.

- Free-floating - defined as un-anchored plants floating freely on the water surface (i.e. formations like common duckweed (*Lemna minor*) or water hyacinth (*Eichhornia crassipes*).

Concerning the concept of *Dominance* two criteria need to be considered:

The main criterion is the **uppermost canopy layer,** meaning that the dominant layer moves downwards from tree canopy, to shrubs, to herbaceous.

This general rule is subjected to a sub-condition of **Cover**. It is only valid if the dominant life form has either a closed or open cover. If the life form is sparse, dominance values indicate another life form with a closed or open cover (Fig. 5.7).

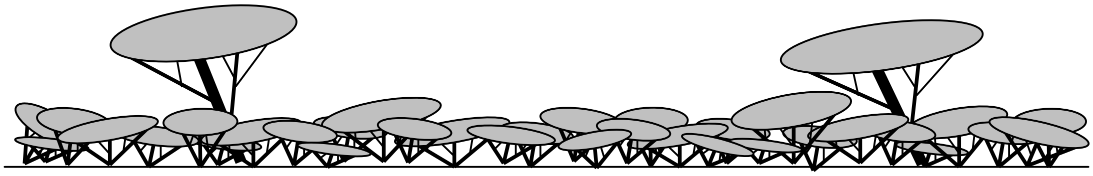


Figure 5.7 - The dominant life form in this example is of closed shrubs, due to sparse tree cover

Stratification describes layering of the vegetation.

For terrestrial vegetation, up to three layers can be described.

For aquatic or regularly flooded vegetation (depending on persistence of water at or near the surface), up to two layers can be described.

b) ***Cultivated and managed areas***

The *Life Form* of a plant is defined by its physiognomic aspect (e.g. tree, shrub, herbaceous, etc.).

For determination of *Dominance* the following rule applies:

The main criterion is the **uppermost canopy layer,** meaning that the dominant layer moves downwards from tree canopy, to shrubs, to herbaceous.

This general rule is subject to a sub-condition of "**marginality**", i.e. the crop should cover at least 15% of the area and/or should return the highest economic revenue (Fig. 5.8).

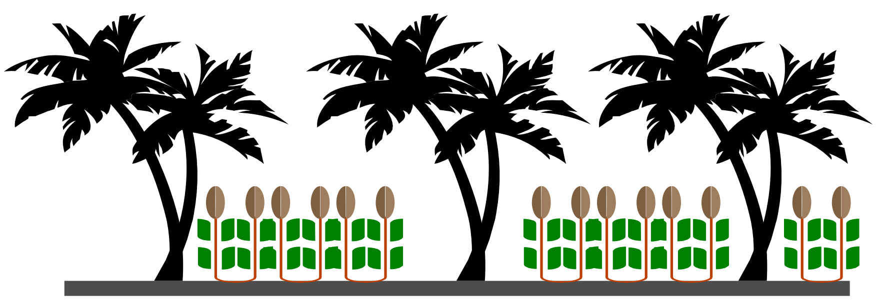


Figure 5.8 - If the cereal crop returns the higher revenue then it is considered as the main crop, although it is not the uppermost canopy layer (from LCCS presentation).

Horizontal *Spatial Distribution* (Fig. 5.9) of the cultivated fields can be divided into:

Continuous: a continuum of more than 50% of cultivated fields

Scattered clustered: percentage of fields is between 20 - 50%

Scattered isolated: percentage of fields is between 10 - 20%

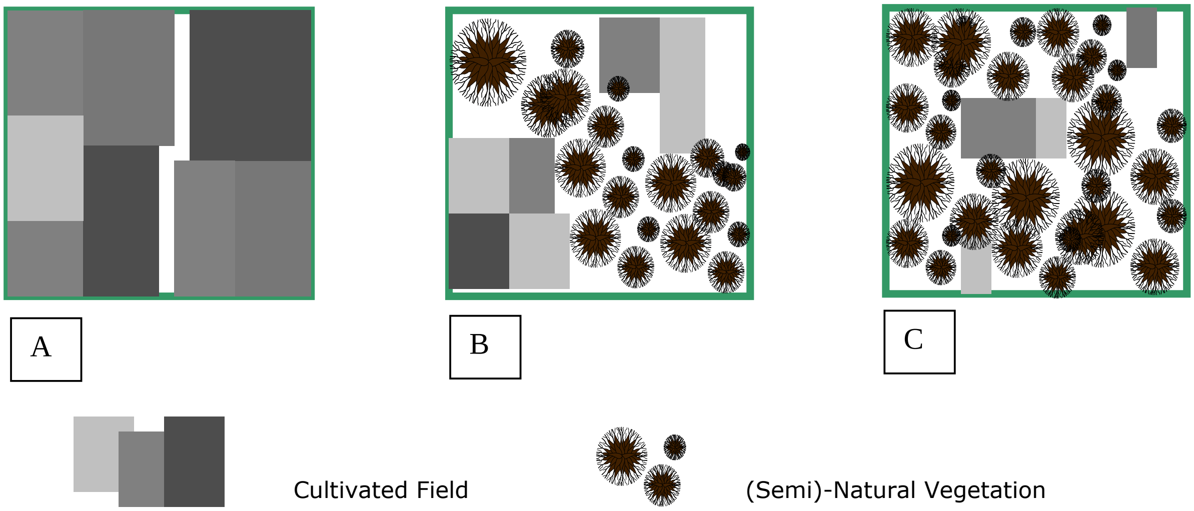


Figure 5.9 - A = Continuous fields; B) = Clustered fields; C) = Isolated fields (from LCCS presentation)

5.2.1.3 <u>Cover</u>

Cover is expressed as a percentage of the total surface area covered by canopy or plant crown. Vegetation cover is evaluated by vertically projecting the crowns to the ground. The cover of each layer is referred to separately, i.e. if three layers are present, total cover could reach 300% (which never happens).

The following is the list of thresholds used in LCCS for each layer. Naturally, a single layer cannot exceed 100%.

0% to 5%	**Absent or scattered**
5% to 15%	**Sparse**
15% to 65%	**Open**
65% to 100%	**Closed**

Guidelines: In the case of trees or shrubs, it is possible to evaluate the percentage of coverage by examining the distances between tree crowns.

1. CLOSED – Trees or shrubs with crowns interlocking, touching or very slightly separated. In the last-named example, the distance between two crowns is not more than 1/6 of the medium crown diameter. The crowns can form an even or uneven closed canopy layer.
2. OPEN – Trees or shrubs with crowns usually not interlocking. The distance between crowns can range from minimal, up to twice the medium diameter. For example when the distance between crowns is equal to the radius of them, the coverage is around 40%.
3. SPARSE – The distance between two crowns is more than double their diameter.

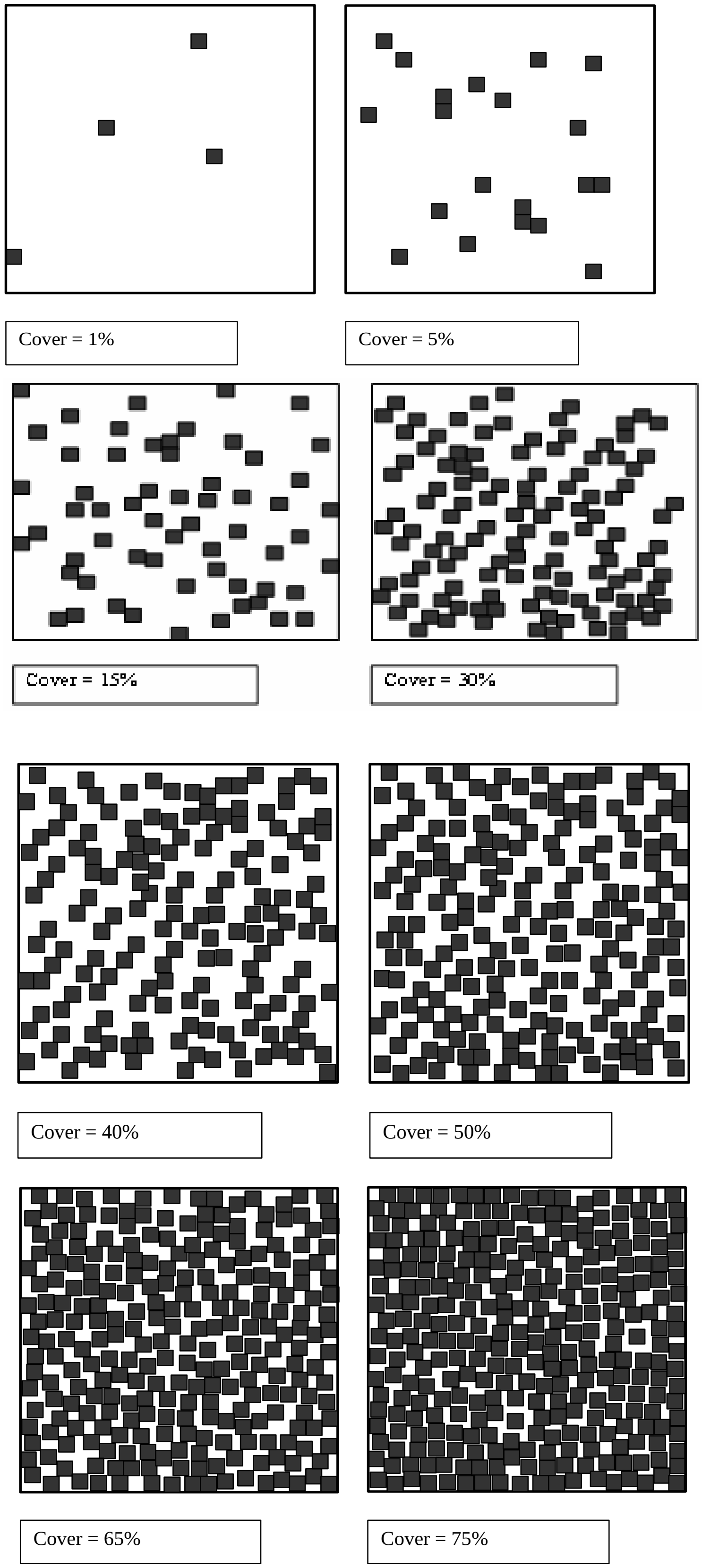
In the case of herbaceous vegetation, it is important to examine the patches of vegetation on the ground. First of all, check if coverage is continuous or fragmented. If continuous, choose closed. If fragmented, apply the already-mentioned thresholds.

For herbaceous vegetation, thickness must also be evaluated following the guidelines below:

Thick:	medium distance among stems < 2 cm
Medium:	medium distance among stems 2-5 cm
Thin:	medium distance among stems > 5 cm

Fig. 5.10 on the following page illustrates some useful examples for estimating percentage cover.

Figure 5.10 - Examples for estimating cover



5.3 Moving towards the sample area

5.3.1 The sampling quadrat (evaluating possible classes inside it)

The survey begins when one enters the sample site, or sampling quadrat. Two coordinates are used to identify the location of the quadrat: one at the upper left corner and another at the bottom right corner. Using a GPS it is possible to identify the location of the quadrat and move inside it.

The evaluation of the sampling quadrat is done following concepts of classification as explained in the previous chapter and to select the most representative class or classes for the area.

Searching for adequate viewpoints as an overview of the area within the sampling quadrat is necessary in order to:

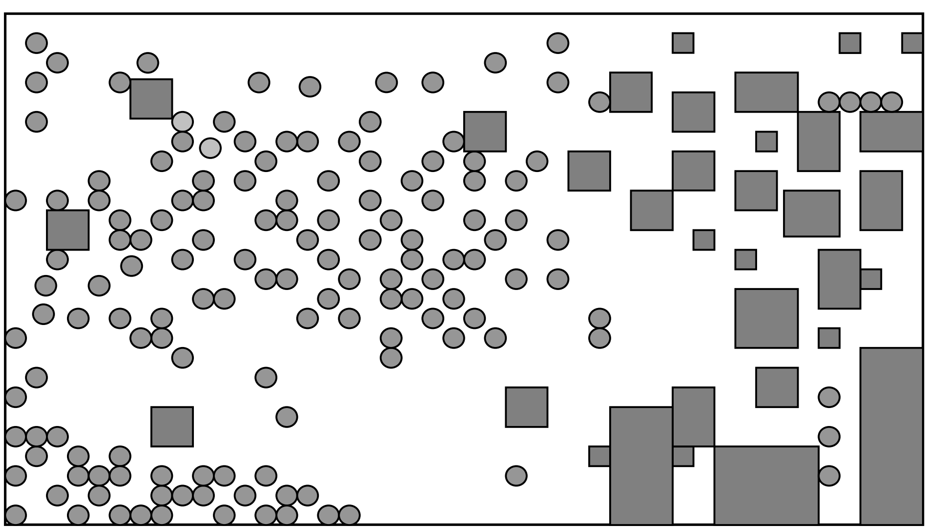
- Identify all classes present in the sampling quadrat (1 - 3 classes);
- Estimate the percentage of the area covered by each class in the quadrat; and
- Identify the most representative site for executing the field sample, for each class.

The difficulty here is to determine the one or more classes present in the quadrat and, in the second case, to determine the boundaries between them as changes in natural vegetation are continuous. As a general rule, it is important to remember that*:*

- A natural vegetation class whose area is less than 20% of the quadrat area, can be ignored.
- The same rule applies to classifying agriculture, when the area is less than 10% of the quadrat area.

In the event that two or more classes are present within the quadrat, the following example may be used as a guideline. It is assumed that the situation inside the quadrat is represented as in Fig. 5.11.

Figure 5.11 - Example of land cover types present in a quadrat. Round shapes represent natural shrubs, geometric shapes cultivated fields and blank spaces, natural herbaceous vegetation.



After having located an adequate viewpoint, it will be possible to identify the classes present in the quadrat (Fig. 5.12).

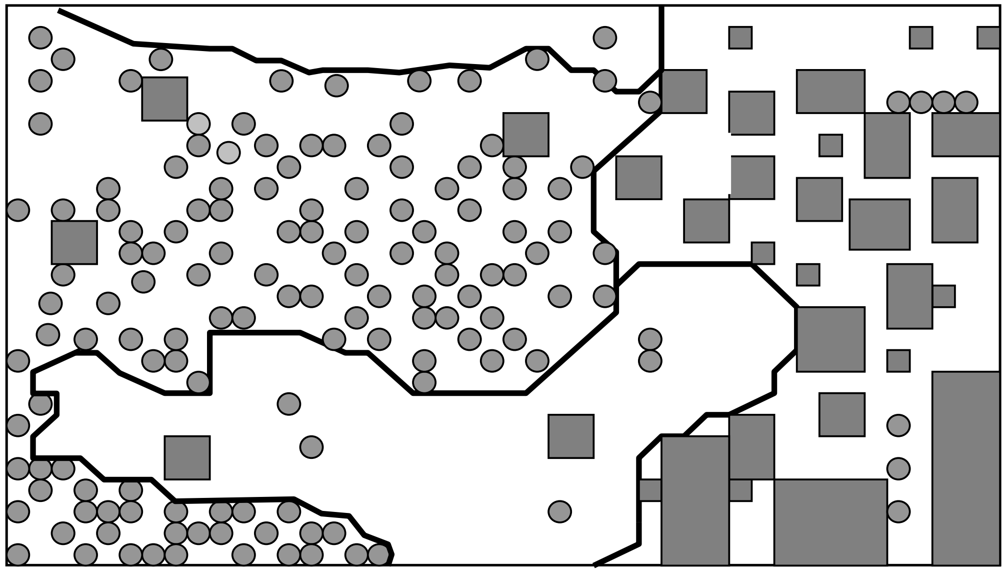


Figure 5.12 - The four classes identified in the quadrat.

In this example it is possible to distinguish:

A = closed natural herbaceous vegetation located in two different areas (A1 and A2).
The total surface is about **25**%.
Field class name: **CH (Closed Herbaceous)**

B = very open shrubs.
The total surface is about **45**%.
Field class name: **VOS (Very Open Shrubs)**

C = herbaceous small fields, rainfed crops.
The total surface is about **30**%.
Field class name: **HeSmRa (Herbaceous Small Rainfed)**

The more representative areas for each class, when executing the field samples, are indicated in Fig. 5.13.

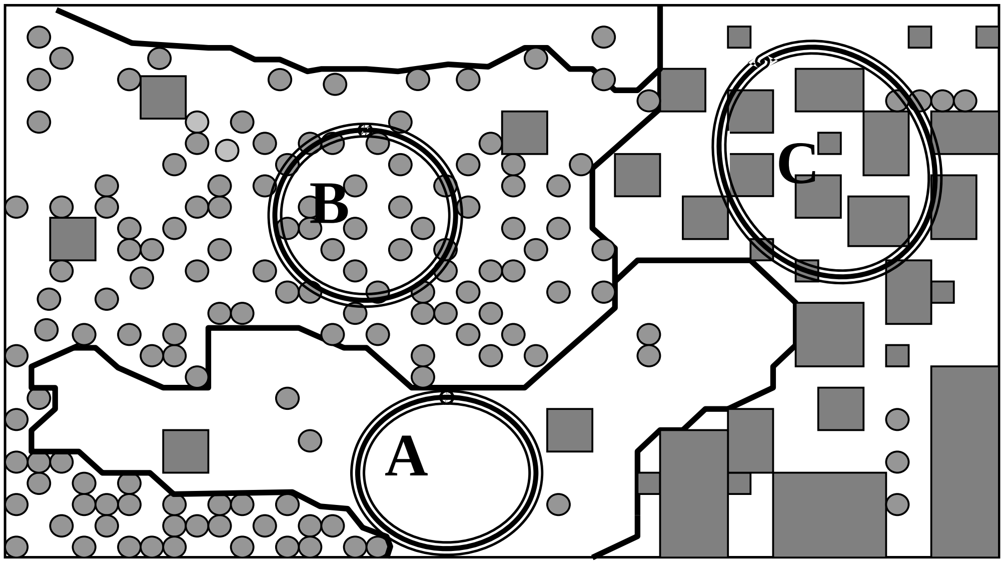


Figure 5.13 - Representative areas for each class in the quadrat indicated with double lined ellipsoids

5.3.2 Layering and main layer

The general classes available for preliminary classification within the sample site are divided between AGRICULTURE and NATURAL VEGETATION, and must be indicated in **Form 1** (see annex Form 1). These classes can form single units, or mixed units of up to three classes. In the case of mixed units, coding starts with the dominant class. All classes (single or mixed) have to be representative of the quadrat.

a) **<u>Agriculture classes</u>**
The following list is adequate:

H-C-R Herbaceous crops rainfed
H-C-I Herbaceous crops irrigated
S-C-R Shrub crops rainfed
S-C-I Shrub crops irrigated
T-C-R Tree crops rainfed
T-C-I Tree crops irrigated

b) **<u>Natural vegetation classes</u>**
The **main layer** defines the class and affects the steps involved in building it. For these reasons it is very important to identify it correctly. Choosing the main layer follows the concept of "**dominance**" based on the "**uppermost canopy**" (see par 5.2.1.2). It means that among layers with the same cover (i.e. all open) the trees are given a higher level in the hierarchy, followed by shrubs and lastly the herbaceous layer.

The shrub layer, for example, can be considered as the main layer only if trees are sparse. If shrubs are also sparse, then the herbaceous layer must be considered as the main layer. If all three layers are sparse, then the trees will be considered to be dominant. If trees are absent and shrubs present, the sparse shrubs will be considered as dominant. If both trees and shrubs are absent, then the sparse herbaceous layer is considered as dominant and the land cover will be considered to be herbaceous. If vegetation is absent (or scattered) the class code to assign will be bare soils.

To facilitate the logical process leading to the final code for natural vegetation, a very simple flow chart has been prepared (see Flowchart 1 on the following page). This diagram should be referred to during the classification of the area. Starting from the upper left-hand box and using general observations, try to find an answer to the question:

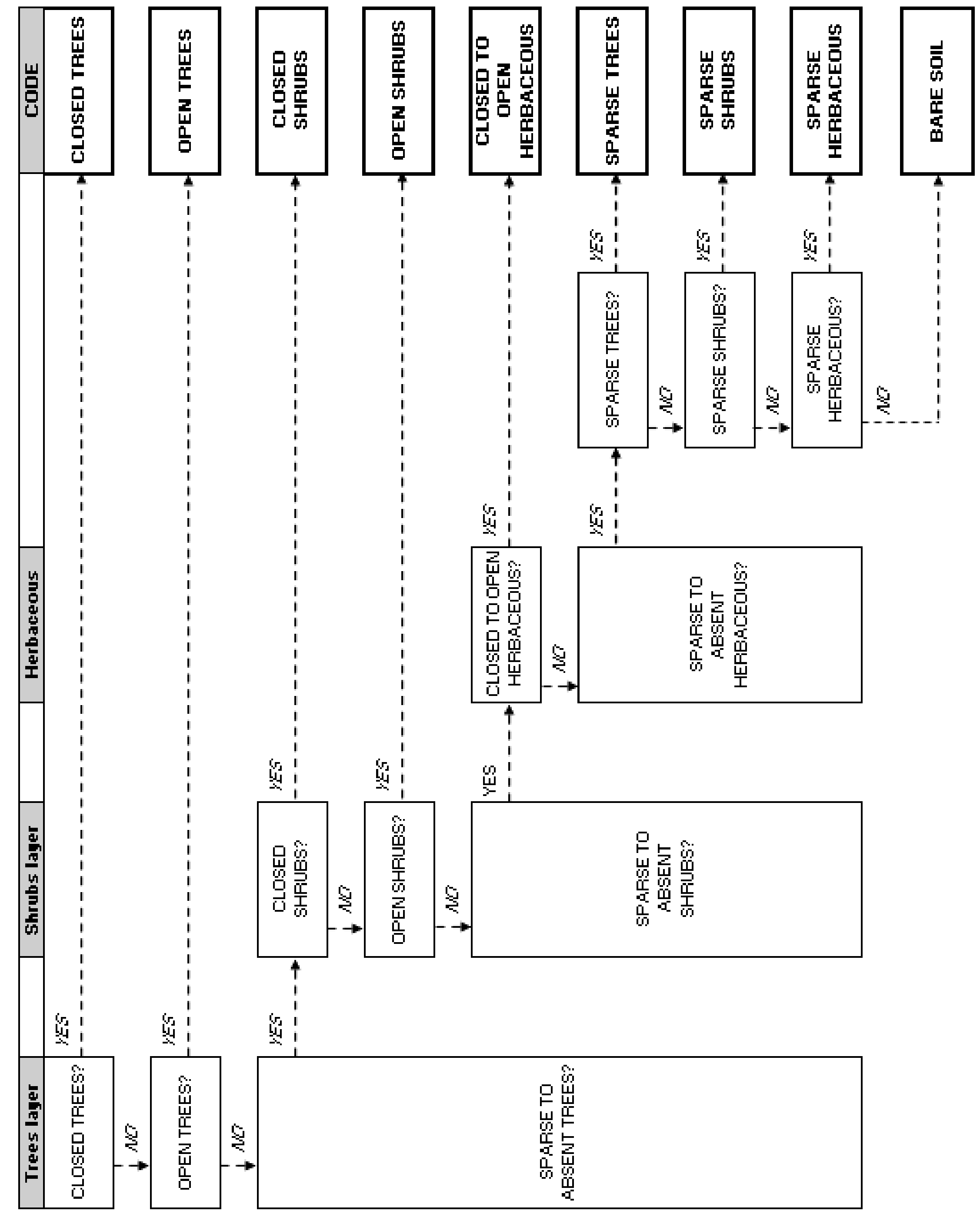
1) "Closed Trees?"

a) If tree coverage is more than 65% the right answer is "Yes", and the process is completed.
b) If tree coverage is less than 65% then the right answer is "No". Follow the corresponding arrow until the question to the second box is reached.

2) "Open Trees?"

a) If tree coverage is between 65 - 15% the right answer is "Yes", and the process is completed.
b) If tree coverage is less than 15% the right answer is "No". Follow the corresponding arrow until the question to the third box is reached.

Continue the selection process following the same rules. It is important that you follow the questions in the boxes until the answer is "Yes" to ultimately find the appropriate "CODE".



Flowchart 1 - Defining the class code on the basis of the dominant layer.

5.3.3 Starting the field sampling

5.3.3.1 Describing each class

The surveyor should stand in the centre of the sampling site (as indicated in the case of the circles in Fig. 5.13). If it is not possible to access the site, the description should be made from outside it, looking in. Choice of a representative point with a good view is important in order to complete the forms effectively.

Field sample data collection is basically descriptive, as it involves noting exactly what is seen. For instance, you are allowed to report the crops you find, or to make visual or assisted estimations according to the forms to be filled (e.g. tree height or plant crown cover).

The first step is to switch on the GPS, ensure adequate reception and lay it down on an open surface, avoiding walking near it and then start the observation.

Before starting to fill in the forms it is important to remember the following points:

- Is the site representative for the class?
- In the case of natural vegetation, is the site influenced by localised human activities? (If what is seen is not representative due to human influence, walk away for about 200 meters to try and avoid such influences).
- Is it possible to see the sample site properly?
- Is what is being seen and described matching with the class previously defined during the evaluation of the quadrat?
- Is the frequency of the field crops sufficient to require description of the crops, or are they so scattered that a natural vegetation class is justified?
- Is the frequency of the crops homogeneously distributed in all the zones identified so justifying a cultivated class, or is it better to split the previously assumed class into two new classes?
- Is the natural land cover around the crop fields enough to require a mixed unit? Or is it distributed in such narrow belts around the crops that the percentage of the farming land is more than the 80%?

5.3.3.2 Filling the form

The forms used for the field data collection are the following:

- **Form LC-1**: "About the quadrat area"
- **Form LC-2**: "General site description"
- **Form LC-3**: "Natural vegetation"
- **Form LC-4**: "Cultivated areas"
- **Form LC-4A**: "Crop list"
- **Form LC-5**: "Bare areas"

The sequence to follow while filling the forms is influenced by the quadrat evaluation.

Each class present in the quadrat (up to three) requires a distinct field sample, with its own site defined by a couple of coordinates (i.e. three field samples are required in a mixed unit with three classes).

For all field sample sites **Form 1** must always be filled, using only one form for all samples in each quadrat.

One **Form 2** is required for each site inside the quadrat.

Form 3, **Form 4** and **Form 5** will be filled according to the class present in the field sample area (natural vegetation, cultivated or bare areas):

- Single Unit of Natural Vegetation……………………………….one copy of Form 3 only.
Only one class of natural vegetation is present in the sample area, for example savannah (dominant herbaceous with sparse trees), or forest (trees only), or shrubland (shrubs only).
In this case only one copy of Form 3 has to be filled.

- Single Unit of Cultivated Area……………………..…………………one copy of Form 4 only.
Only one class of agriculture is present in the sample area, for example irrigated herbaceous crops (single or multiple crops), or rainfed tree crops (single or multiple crop).
In this case only one copy of Form 4 has to be filled.

- Single Unit of Bare Area…………………………….................one copy of Form 5 only.
Only one class of bare soil is present in the sample area, for example sand or soil
In this case only one copy of Form 5 has to be filled.

- Mixed Unit of Natural Vegetation……………………one copy of Form 3 for EACH class.
More than one class of natural vegetation is present in the sample area, for example forest AND savannah, or forest and shrubland.
In this case fill as many copies of Form 3 as there are classes: one form for each class (not more than 3).

- Mixed Unit of Cultivated Area……………………….one copy of Form 4 for EACH class.
More than one class of agriculture is present in the sample area, for example irrigated herbaceous crop AND rainfed tree crops, or rainfed herbaceous crops AND rainfed tree crops.
In this case fill as many copies of Form 4 as there areclasses: one form for each class (not more than 3).

- Mixed Unit of Bare Area……………………………..one copy of Form 5 for EACH class.
More than one class of bare area is present in the sample area, for example bare soil AND bare sand.
In this case fill as many copies of Form 5 as there are classes: one form for each class (not more than 3).

- Mixed Unit of Different Types of Classes. one copy of the related Form for EACH class.
More than one type of class is present in the sample area, for example natural vegetation AND bare soil, or agriculture AND natural vegetation.
In this case one copy of the related form for EACH class present has to be filled: natural vegetation and bare soil = 1 copy of Form 3 and 1 copy of Form 5; agriculture and natural vegetation = 1 copy of Form 4 and 1 copy of Form 3.
In any case, not more than 3 copies.

Form 4A will be used for any one of the crop species of any agriculture class site within one quadrat.

The information collected on the forms will be used to validate the mapping exercise. It is therefore important to carefully check the filled forms for correctness and completeness. This practice allows for corrections to be made, filling accidental gaps and checking for conflicting information in the form while the memory is still fresh.

The filled forms should be detailed, tidy, clear and consistent.

5.3.3.3 Taking photographs

During field sampling, several photographs must be taken. Usually four will be taken from the centre of the site, outwards towards the four cardinal points (Fig. 5.14).

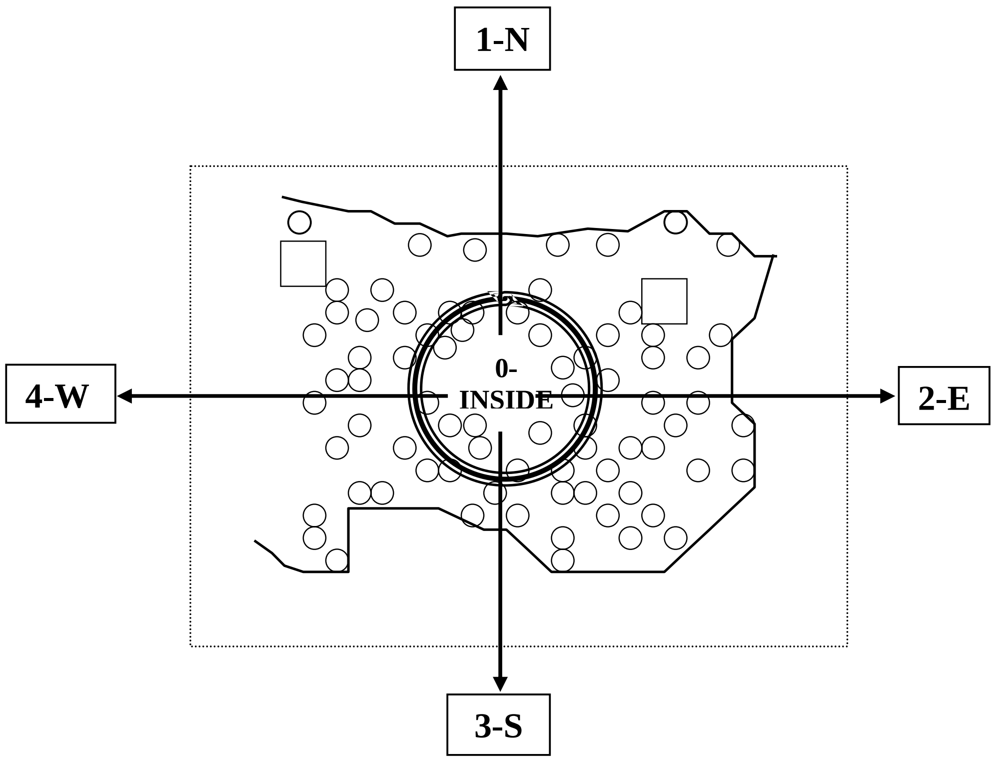


Figure 5.14 - Directions of photographs to be taken from inside the site: point 0

When it is impossible to access the centre of the site, only one photo is required from outside the site, facing towards its centre. What is important is to indicate the direction in which the photograph was taken. The cardinal point from which the picture has been taken must be indicated on the graph on the related form (see Figure 5.15).

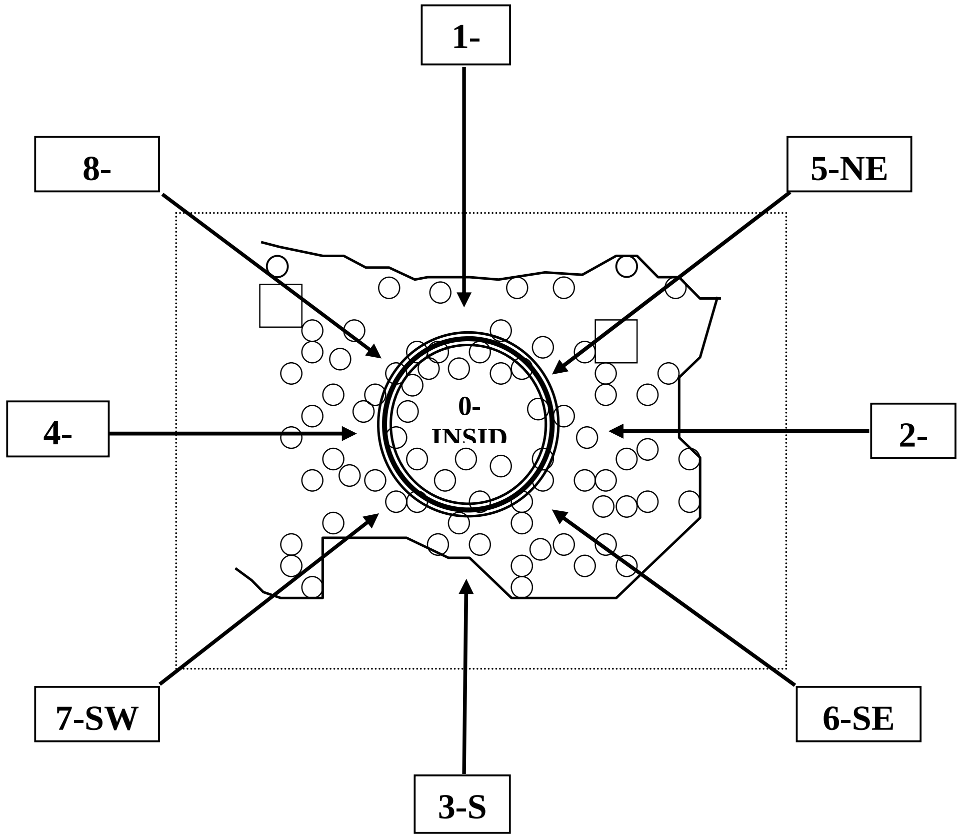


Figure 5.15 - Directions of photographs taken from outside a site (choosing one of the 8 points indicated) towards the inside of the site, point 0.

In the event of very complex or interesting situations, it can be useful to make unplanned stops in order to take a picture. Each stop requires:

- An identification number (to be written on the white board)
- A couple of GPS coordinates
- The direction of shooting as indicated by a compass
- Notes

The above is required in order to allow the identification of the stop. A white board with the identification number must be included in the picture, ensuring it does not take up the whole frame.

Field sample photographs
Photographs taken during field sampling are important. The following suggestions will assist the surveyor in taking pictures.

In order to adequately capture a scene, it is important to stay in the open in at least two of the four photographs. A good compromise is:

- Find an open space that allows reasonable visibility
- Verify that the image is representative of the whole site around the observer.
- Check that the horizon is situated about 1/5 of the way down from the top edge of the photo (Fig. 5.16)
- Ensure that the camera is tilted so as to include all vegetation without cutting it off at the base (Fig. 5.16).

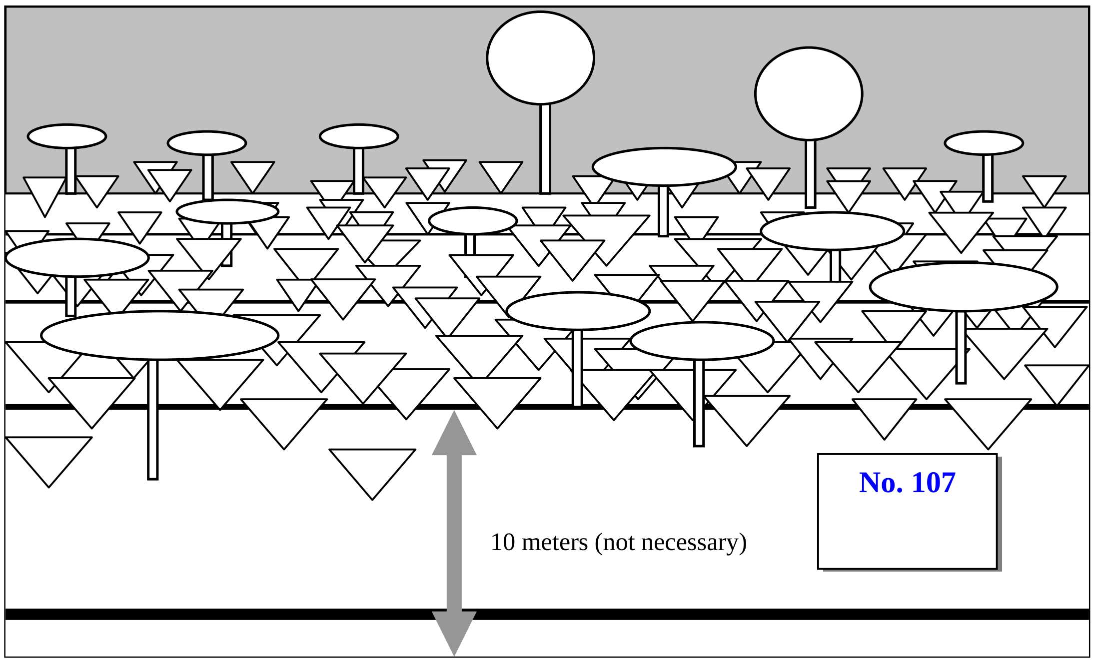


Figure 5.16 - Illustration of very open shrubs (1-2 m height) with emergents (5-7 m height). Note that the "camera" positioning includes the whole crown of the big tree in the middle, but doesn't cut the bottoms off the nearest vegetation.

Stopping point photographs

The same suggestions apply to photos taken at impromptu stopping points. It can be useful to take panoramic photos from suitable viewpoints to illustrate vegetated surfaces, landforms and drainage patterns (Fig. 5.17).

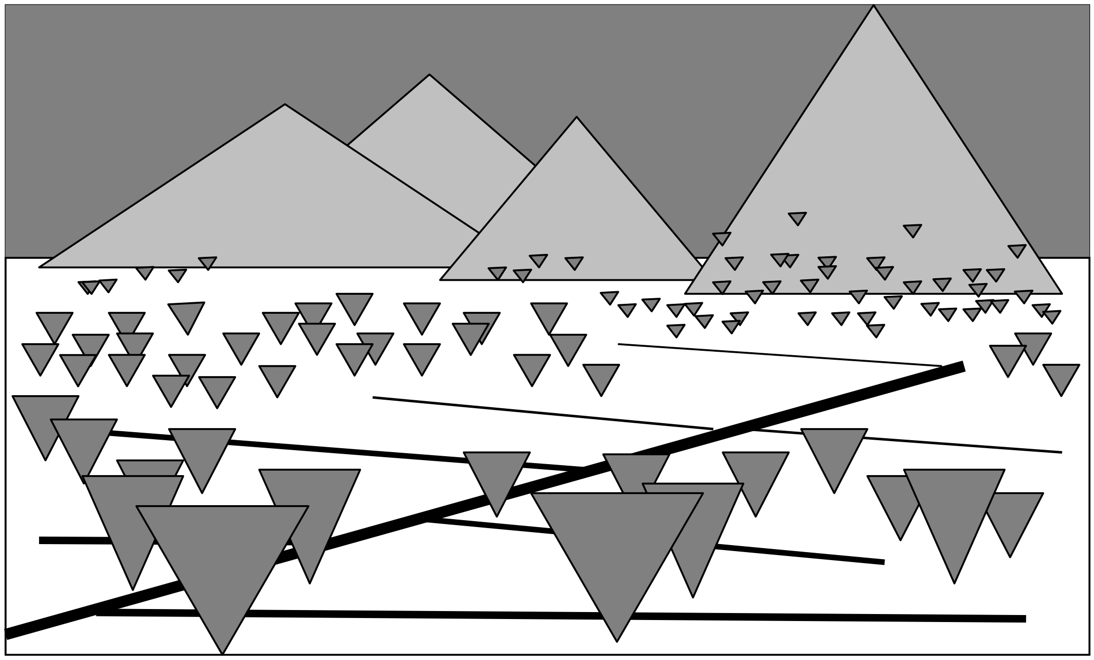


Figure 5.17 - The elements comprising this "stopping point" representation of a photograph are the low plain and mountains landforms, the drainage in parallel channels and the various types of vegetation.

5.3.3.4 Estimating the height of plants

The surveyor will be required to measure the heights of trees and shrubs present on the site. It is important to first directly measure some trees and shrubs and, after looking at the whole area, to estimate the average height of the life forms present.

When estimating a plant's height, it is important to remember that an object's size is reduced in a directly proportional function of the distance. This means that an object twice a given distance away will appear to be reduced in size by half.

- Distortion of the height of an object is a function of the degree of inclination in respect to the viewpoint direction. This means that if the object direction is perpendicular to the direction of view, the real height is visible, otherwise not.
- A human's stereoscopic three-dimensional visual perception allows partial compensation for perspective distortion.

For these reasons it is important to first make direct measurements and then make accurate estimations.

5.4 Forms description and guidelines

5.4.1 FORM LC-1 "About the quadrat area"

This is the first form to be filled, for all the field sample sites. It requires a preliminary scouting of the sample area before being filled. To understand how to evaluate the sample area, please refer to chapter 5.3.

1. **Surveyors**
   Names of the team participants.

2. **Quadrat N°**
   Copy the number from the field sample list.

3. **Sample N° (list all the sites - up to 3).**
   The progressive numbers assigned to the sample site/s.

4. **Land cover types within the quadrat**
   For each type choose an appropriate land cover class from FLOW CHART1 (section 5.3.2).

   Type I (covering the larger part of the quadrat)
   Type II (optional, covering a smaller area)
   Type III (optional, covering the smallest area)

Assign the correct code/s to what is observed within the quadrat (see section 6.3.1), following a process of analysis. Observe the land cover within the quadrat/sample site and identify all meaningful transitions. It is possible to list up to three different classes for mixed units.

For each one:

- Define the most dominant land cover and give it the first code in the mixed unit.
- Check for a final second code:
  - If it is natural vegetation it must constitute more than 20% of the whole quadrat.
  - If it is agriculture then it must constitute more than 10% of the whole area.
- Check for a final third code following the same rules.

Follow the steps in analytical sequence as indicated in the form:

A	vegetated	□	non vegetated	□
B	terrestrial	□	aquatic	□
C	natural	□	agric/infrastr	□
D	land cover class			

After answering questions A, B and C find the class code name to use in D (see section 5.3.2).

5.4.2 FORM LC-2 "About the quadrat area – site general description"

This form provides general information about a single field sample site only. Therefore, it is necessary to have one FORM 2 for each sample made in the quadrat (up to 3 forms).

1. **Sample N°:**
   Write an identifier (progressive number).

2. **Land cover CODE:**
   Write the code of the class observed at the sample site as reported in FORM1.

3. **Field sample coordinates from GPS (Easting; Northing)**
   Write the X and Y coordinates recorded by the GPS (UTM coordinate system is recommended).

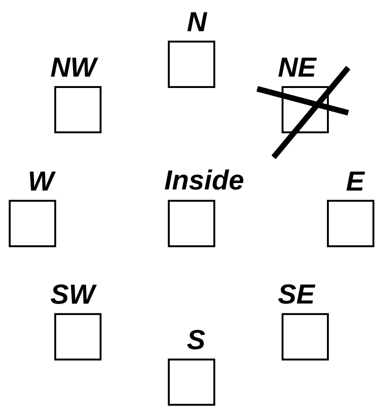
4. **Slope**
   Use a clinometer to determine the average surface slope of the site..

5. **Aspect**
   Use a compass to determine the directions of slope.

6. **Date**
   Write the day, month and year.

7. **Time**
   Write the time.

8. **Check the position of the viewpoint according to the observed (sample) point**
   It is possible that the observer will be unable to reach the site because of obstacles such as a river or rugged terrain.

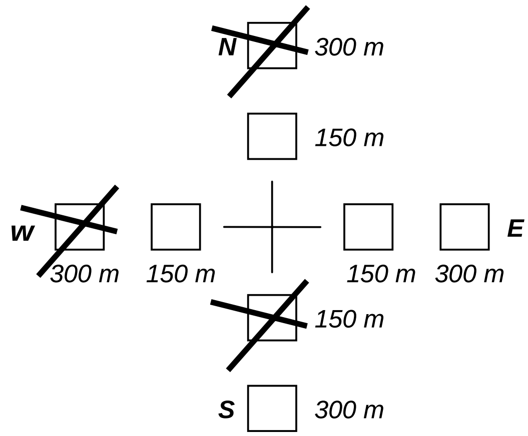


   In the example above, the surveyor was located north-east of the centre of the site. It is not necessary to be exactly in the position shown by the illustration above. It is enough to approximate your position. The most meaningful observations need to be performed from within the sample site.

9. **Distance from the viewpoint to the observed point**
   If you are observing from outside the sample point, you should be able to visually estimate distance to the centre of the site (in metres, kilometres, etc.), as it has to be reported if data was collected from outside the quadrat. You should take only one photo from the viewpoint towards the observed point (the site).

10. **The bearing of the observed point**
    This should be noted only if you are collecting data from outside the sample quadrat, using a compass.

11.Extension of the land cover type from the observed point



In the illustration above, measure the distances from the centre of the site to the boundary where the type of cover (class) you are sampling changes to another one. You can make a visual estimation of the distance. In the above example the sample is:

Towards north	within 300 metres
Towards east	more than 300 metres
Towards south	within 150 metres
Towards west	within 300 metres

It does not matter if you are at position one (the centre of the site) or at a different position - the distance referred to is from the centre of the place you are observing.

5.4.3 "FORM LC-3 "Natural vegetation"

This form is used when you are in a class (code) of natural vegetation. Only one copy of Form 3 can be completed for each site.

If agriculture constitutes less than 80% of the sample site, Form 3 has to be filled.

1. Sample N°:
Write an identifier (progressive number).

2. Land cover CODE:
Write the code of the class observed at the sample site as reported in FORM 1.

3. Seasonality

Seasonality	DRY	GREEN	FLOWERING	FRUITS
TREES	☐	☐	☐	☐
SHRUBS	☐	☐	☐	☐
HERBACEOUS	☐	☐	☐	☐

Select the appropriate phase for each layer. In dry seasons, plants might look dead and be without leaves. They will have green leaves in the rainy season. Flowering and fruiting occur in the green phase (at the beginning and end respectively) but flowers and fruits are not always clearly visible as sometimes they remain small and invisible during this period.

4. Physiognomy

Physiognomy							
LAYER	COVER	HEIGHT	LEAF TYPE			LEAF	
			BROAD	NEED	APHYLL	EVERG	DECID
WOODY			☐	☐	☐	☐	☐
TREES layer 1			☐	☐	☐	☐	☐
TREES layer 2			☐	☐	☐	☐	☐
TREES layer 3			☐	☐	☐	☐	☐
SHRUBS layer1			☐	☐	☐	☐	☐
SHRUBS layer2			☐	☐	☐	☐	☐
HERBACEOUS			Thick ☐	Med ☐		Thin ☐	
GRAMINOID			Thick ☐	Med ☐		Thin ☐	
FORBS			Thick ☐	Med ☐		Thin ☐	

This is the most important table in the form. To understand the meaning of the various layer typologies and how to estimate cover, read section 5.2.1 "Conceptual basis for land-cover survey".

Layers - trees can be subdivided up to 3 minor layers and shrubs up to 2. More layers for one life form must be used only if it is possible to clearly distinguish different levels that are well separated and not in contact with each other. A typical example is the case of a continuous canopy with emergent trunks supporting crowns of bigger plants, i.e. with sparse coverage.

Choosing the leaf type:

Broadleaves = large-surfaced with an almost round shape (e.g.: *Acacia bussei*). Trees and shrubs of the botanical group Angiospermae. Both Evergreen and Deciduous species fall within this category.

Needeleaves = needle-like leaves (e.g.: *Pinus*). Refers to trees and shrubs of the botanical group Gymnospermae.

Aphyllous = includes plants without leaves and plants that apparently do not have leaves (in the common sense). In the first case, photosynthesis takes place through structures such as stems, branches and twigs; in the latter case, the leaves are very short-lived or extremely reduced, to scales or thorns. Characteristic genera are *Casuarina*, *Euphorbia*, *Tamarix* and many others mostly found in arid and semi-arid regions.

Choosing leaf phenology:

Evergreen = leaf life is longer than one year, so the plant is green for the whole year. Usually they are tougher and thicker than deciduous plant leaves. For a layer to be Evergreen, more than 75% of the area must be covered by evergreen vegetation.

Deciduous = perennial plants which are leafless for a defined period of the year. Leaf shedding usually takes place in the dry season.

Thick, Med, Thin – the density of herbaceous vegetation (see chapter 6.2.1)

5. **For herbaceous aquatic only**

For herbaceous aquatic only (choose one box only)	
ROOTED	☐
FLOATING	☐

5.4.4 FORM LC-4 "Cultivated areas"

This form is used when you are in an agricultural class. In case of a single class only one copy of the FORM 4 should be filled at the site.

If agriculture within the sample site is less than 80% of total area, then you should also use FORM 3 to describe the natural vegetation, even if the crops are uniformly distributed throughout the sample area.

If there are two different types of agricultural class within the sample site (for example Herbaceous Crops Rainfed and Tree Crops Irrigated), then FORM 4 should be filled for each one of them.

1. **Sample N°**
   Write an identifier (progressive number).

2. **Land cover code**
   Write the code of the class examined at the sample site as reported in FORM1
3. **Intercropping**

INTERCROPPING (check only one box)

Single crop: ONLY ONE CROP ON THE SAME FIELD	☐
Multiple crops: TWO OR MORE CROPS SIMULTANEOUS	☐
Multiple crops: TWO OR MORE CROPS OVERLAPPING	☐
Multiple crops: TWO OR MORE CROPS SEQUENTIAL	☐

Single Crop
This category refers to a single crop cultivation system, i.e. monoculture. The duration of cover is limited to the harvesting stage.

Guidelines:

1. In the case of annuals or biennials, the crop covers the land for only part of the year or up to two years.

2. In the case of perennials, the crop covers the land throughout the year and is harvested after several years, or part of the crop is harvested every year.

Multiple Crops
These are two or more crops growing in the same field. Crop intensification is both temporal and spatial (vertical and horizontal). No horizontal spatial arrangement of the crops is considered (e.g., rows, strips or no arrangement).

Simultaneous
More than one crop is cultivated at the same time within a defined area. This is often indicated as mixed cropping, where different crops can be intermingled or grown in distinct patterns in the same field.

Guidelines:

1. Mixed annual or biennial crops are cultivated on one piece of land, e.g. legumes are often combined with non-legumes.
2. In the case of perennial crops (trees and shrubs), cash crops are inter-planted during the period of establishment of the main crop. At a later stage the inter-planted crops might be replaced by cover crops.

Overlapping
Planting or sowing one crop into another crop which has reached an advanced growing stage, before the harvesting of the first crop.

Guideline:
This class applies only to crops with briefly overlapping growing periods. An overlap which lasts for the whole cultivation period, such as when annual or biennial crops are planted into a stand of perennial plants, is considered under Simultaneous. An example of crops with an overlapping period is when root crops are planted into a stand of cereals.

Sequential
Cultivation of two or more crops in sequence on the same field within one growing season. The succeeding crop is planted after the preceding one is harvested.

It is not always possible to identify these features at the site. Seek guidance from some nearby farmers if that is the case, or use your knowledge of the area.

4. Irrigation

IRRIGATION (check only one box)		
Not irrigated, rain fed		☐
Post flooding		☐
Surface irrigation		☐
Other - in this case specify		☐
Flooded cultivation only		
Flooded		☐
Waterlogged		☐

Rainfed
Crop establishment and development is completely determined by rainfall.

Irrigated
Any of the several means of supplying an artificial, regular supply of water to crop/s in addition to rainwater. This category is further subdivided into the main irrigation methods:

- Post-flooding
  After rainwater has flooded a field, water that has infiltrated the soil is used intentionally as a water reserve for crop cultivation. Crops use this water reserve for establishment. It is the case of the deshecks.

- Surface Irrigation
  Water supplied to fields forms a water layer that infiltrates slowly into the soil. The field may be wetted completely (borders, basins) or partly (furrows, corrugations). The water layer may be moving during irrigation (flow irrigation) or it may be mainly stagnant (check irrigation).

5. Average field size (ha. or fractions)
Make a visual estimation of the average size of field within the sample site.

6. Spatial distribution

Check the appropriate box.

Bordering fields
Distance between fields < 0.5 times average size
Distance between fields 0.5 – 1.5 times average size
Distance between fields 1.5 – 3 times

This table helps in checking the surface percentage covered by crops (corresponding to the percentage of the observed cultivated class cover). It uses a linear parameter useful in avoiding problems due to perspective, standing close to the ground and observing towards the horizon. The length of the border between two crop fields visible from the surveyor's viewpoint, is compared to the distance between the borders of two contiguous crop fields. Follow the thresholds separating the different ranges. When fields constitute less than 10% of the samle area, they are ignored.

Bordering fields = 100%

Distance = 0.5	average size = 50% threshold
Distance = 1	average size = 30% threshold
Distance = 1.5	average size = 20% threshold
Distance = 2	average size = 15% threshold
Distance = 3	average size = 10% threshold

5.4.5 FORM LC-4A "Crops list"

This page is considered an extension of **Form 4**, but in the case of multiple crops it is required that you use one form for each crop species found.

1. **Sample N°:**
   Write an identifier (progressive number).

2. **Land cover CODE:**
   Write the class code observed at the sample site as reported in FORM1

3. **Dominant , med. importance, marginal**
   Composition of the area and the economic value.

4. **Crop name**
   It is not always possible to see these features directly at the site, in which case it is recommended to seek guidance from nearby farmers if possible. Otherwise, use your knowledge of the area.

5. **Life form**

Life form		*LEAF TYPE*		*LEAF PHENOL*		*PRODUCTS*	
		BROAD	*NEED*	*EVERG*	*DECID*	*FRUIT*	*TIMBER*
TREES	☐	☐	☐	☐	☐	☐	☐
SHRUBS	☐	☐	☐	☐	☐	☐	☐
CEREALS	☐	☐	☐	☐	☐	☐	☐
LEGUMES	☐						
OTHER	☐	*Specify the crop*					

To understand the meaning of the various layer typologies, read Chapter 6.2.

Choosing the leaf type:
Broadleaves = large-surfaced, with an almost round shape.
Needeleaves = narrow leaves, such as pines or casuarina.

Choosing leaf phenology:
Evergreen = leaf lifespan is greater than one year, hence plant is green for whole year. Usually tougher and thicker than leaves of deciduous plants.
Deciduous = all or most of leaves fall during a part of the year.

Crop destination:
Fruits are designated for collection when ripe.
Timber is for logging use.

6. Seasonality

Seasonality			
HERBACEOUS		TREES - SHRUBS	
INITIAL STAGE	☐	LEAFLESS	☐
PLOUGHED	☐	FULL VEGETATIVE	☐
FULL GROWTH	☐	FLOWERING	☐
FLOWERING	☐	UNRIPE FRUITS	☐
UNRIPE FRUITS	☐	RIPE FRUITS	☐
RIPE FRUITS	☐	HARVESTED	☐
HARVESTED	☐		

Herbaceous:
Ploughed = the soil is worked but totally bare.
Initial stage = the young plants are just emerging from the soil.
Full growth = plants have achieved their full potential size, are vigorous and green.
Flowering = flowers are visible.
Unripe fruits = fruits are still green and smaller than the final size.
Ripe fruits = final stage of fruits.
Harvested = fruits or the whole plant has been collected.

Trees and shrubs:
Leafless = the plant is dormant
Full vegetative activity = maximum leaf production has been achieved.
Flowering = flowers are visible.
Unripe fruits = fruits are still green and smaller than their final size.
Ripe fruits = final stage of fruits.
Harvested = fruits have been collected.

5.4.6 FORM LC-5 “Bare areas”

This form is used in areas where vegetation is less than 4%.

1. **Sample N°:**
   Write an identifier (progressive number).
2. **Land cover CODE:**
   Write the code of the class observed at the sample site as reported in FORM1

This form is subdivided into three sections. At least one, but no more than one has to be filled to describe the class.

3. **Consolidated**
   Consolidated bare areas are characterised by the solid, firm consistency of their surface, or by the presence of coarse fragments. These surfaces are impenetrable by a spade or hoe. The surface and coarse materials remain coherent and hard, even when moist.

   In this case specify

Bare rock	
Gravel stones and boulders	
Hardpans	

Bare rock
The rock surface is continuous, except perhaps for a few cracks. The remainder of the area may be covered with shallow layers of soil or isolated pockets of soil, or a mixture of both.

Gravel, stones and boulders
This describes areas where rock or mineral fragments cover the surface. The remainder may be covered by shallow soils. The description of the area can be further subdivided into specific types of coarse fragments if more than 60% of the total area consists of coarse fragments.

The different types of coarse fragments are defined as follows (FAO, 1990):

- *Gravel*: coarse fragments < 6 cm. diameter
- *Stones*: coarse fragments between 6 - 20 cm. diameter
- *Boulders*: coarse fragments > 20 and 200 cm. diameter

Hardpans
Hardpans are soil layers or surfaces that have been indurated due to chemical or physical processes. Their hardness at the surface is irreversible. They form impenetrable layers for water and/or plant roots.

In the context of the Land Cover Classification System, these layers are only described when occurring at the surface:

Ironpan/laterite

Soils rich in iron are irreversibly hardened. Iron is the "cement" and there is little or no organic matter content.

Petrocalcic

The surface of the soil is cemented or indurated by calcium carbonate to the extent that dry fragments do not absorb water and plant roots cannot penetrate.

Petrogypsic

The surface of the soil is cemented or indurated by gypsum to the extent that dry fragments do not absorb water and plant roots cannot penetrate.

4. Unconsolidated

An area covered with materials that are neither solid nor firm. The surface can be penetrated with a spade or a hoe. In this case specify if stones are present:

Bare soil	Stony (5-40%)
Loose and shifting sands	Very stony (40-80%)

- <u>Bare soil and/or other unconsolidated materials</u>
  Unconsolidated materials cover the earth's surface as a result of weathering of parent material (including the effects of moisture and temperature) and/or action of macro- and micro-organisms.

- <u>Loose and shifting sands</u>
  Areas are covered by sand. The particles may be moved by regularly by winds, forming distinct patterns.

- <u>Stony</u>
  Between 5–40% of the soil surface is covered with stones. This class can be applied to either of the two preceding categories.

- <u>Very Stony</u>
  Between 40-80% of the soil surface is covered with stones. This class can only be applied in combination with *bare soil and/or other unconsolidated materials*.

5. Dunes

Dunes are defined as low ridges or hillocks of drifted sand, moved mainly by wind. They occur in deserts or along coasts, their formation dependent on the load of sand, strength and direction of wind, nature of the surface on which sand is moved (sand or rock), presence of obstacles and presence of groundwater.

In this case specify:

Barchans — Saturated
Parabolic — Unsaturated
Longitudinal

- <u>Barchans</u>
  Crescent-shaped sand dunes lying transverse to the wind direction, with the 'horns' trailing downwind.
- <u>Parabolic</u>
  Elongated dunes with 'horns' pointing upwind.
- <u>Longitudinal</u>
  Long, narrow symmetrical dunes running parallel to the prevailing wind direction.

These three dune types can occur in two forms:

- *Saturated*
  The area is covered with clustered dunes. This class can be applied to all three types of dunes.
- *Unsaturated*
  The area is covered with dunes occurring in isolation (contrary to the above). This class can be applied to all three types of dunes.

5.4.7 Floristic relieve

Floristic composition is important in classifying the plant populations of a particular habitat. Knowledge of vegetation allows an understanding of environmental conditions affecting land degradation and grazing intensities.

The adopted methodology is a time-effective assessment of the **abundance** and **frequency** of all species in a sample.

Trees and shrubs will be assessed separately from the herbaceous layer, using different methods.

<u>Trees and shrubs</u>
Using a tape measure, measure out one transect of 100 meters. Each round number (1 meter, 2 meters, 3 meters and so on up to 100 meters) is considered as a node. At each of the 100 nodes, check if there is a tree or shrub crown intersecting the tape measure and, if so, assign the corresponding node number to the plant (the closest node to the trunk).

For each species that is selected in this way, the following are required:

1. an identifier in the **species list form**.
2. the name in the **species list form**.
3. the identifier in the box of the corresponding node in the floristic relieve form.
4. assign plant coverage by measuring the length of tape intersecting the crown (under its shadow) and write the measurement (in cm) in the box of the corresponding node in the floristic relieve form.

<u>Herbaceous</u>

Every 20 meters along the tape, measure out one segment of 0.5 m. The tape unrolled several times to reach 100 meters allows defining 5 segments of 0.5 m. each. A transect measuring 25 cm. from either side of the tape measure (i.e. 50 cm.), will be examined.

1. Starting from the first segment (a quadrat of 50x50 cm. from 0 - 0.5 m.) identify all species inside it and note them on the floristic form. Take care to write the correct segment number on the floristic form that corresponds to the appropriate transect segment.
2. For each species, assess coverage expressed in percentage or, using the Braun-Blanquet scale, refer to the segment area.
3. For each species, measure the height in cm.
4. Pass to the next segment from 0.5 - 1 m. and repeat the operation. All the species already found in previous segments are included in the new floristic list form with the same identifier.
5. Complete all the segments until the last (the tenth), repeating the same methodology.

All unidentified species need to be collected and labelled with a piece of masking tape, writing the number of the **Site ID** and the number of the **Species ID** on it. For herbaceous plants, it is important to collect parts of the plant that will help in identification. In the case of woody plants, a small leafy or fruiting branch can be collected to help in identification.

Collected material needs to be preserved in a plant press.

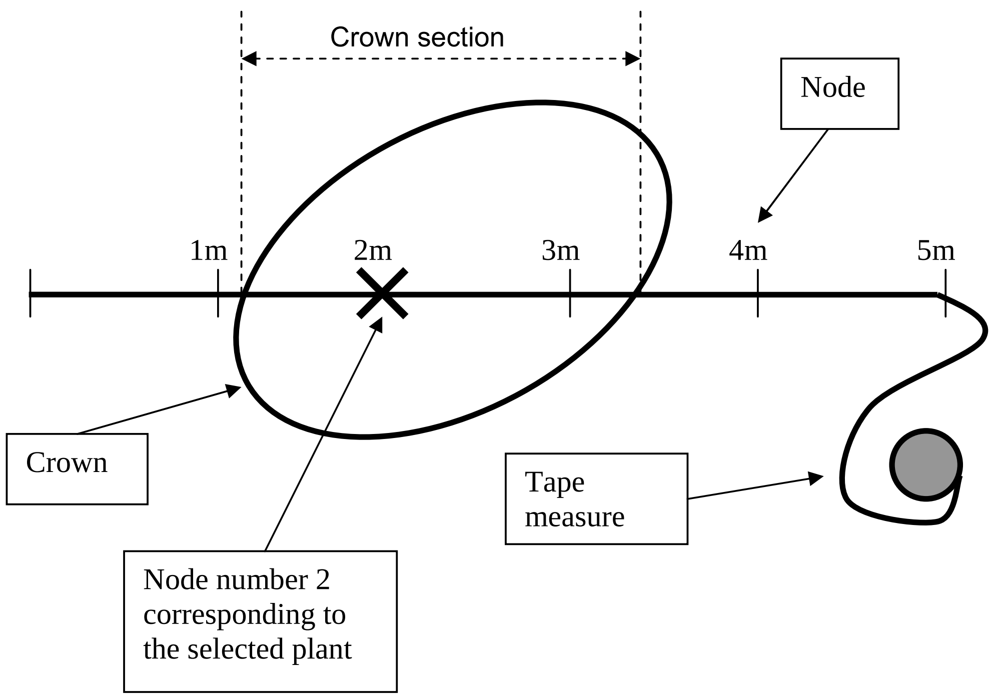


Figure 5.18 - How to select plants and take measurements.

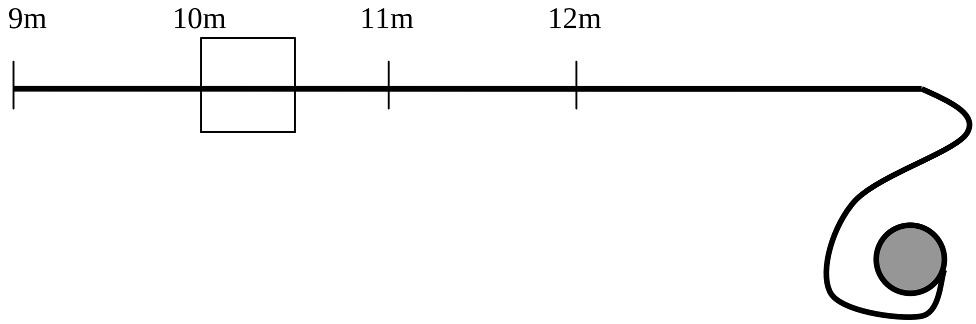


Figure 5.19 - Showing the second 0.5 x 0.5 m² segment, located at the tenth meter.

FLORISTIC RELIEVE																				
Node Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Species Identifier	ID	ID 1	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID	ID
Section Cm	cm	cm 220	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm	cm

FLORISTIC LIST FORM

Species Identifier	Species Name	Tot Crown Section Cm
1	Acacia bussei	

Here is an example of how to fill the floristic relieve and the floristic list form.

Herbaceous	FLORISTIC RELIEVE FLORISTIC LIST FORM	BOX N.________________ SITE N.:________________

Segment N. (from1 to5):_______				
Species Identifier	species Name		Height	Cover

Braun-Blanquet scale:

R	**=**	**rare**
+	**=**	**coverage not measurable**
1	**=**	**coverage < 5%**
2	**=**	**coverage 5% – 25%**
3	**=**	**coverage 25% - 50%**
4	**=**	**coverage 50% - 75%**
5	**=**	**coverage > 75%**

5.5 Bibliography

Di Gregorio, A. & Jansen, L.J.M. (2005). *Land cover classification system: classification concepts and user manual.* Software version 2. FAO, Rome

Di Tommaso, P. (1992). *Geobotanica.* Edizioni CUSL, Firenze, Italy.

FORM 1 "ABOUT THE BOX AREA"

Surveyors:____	
Box N:_______________	
Sample N °(list all the sites made - up to 3):__________________________	

Land cover types within the box

Type I (covering the bigger part of the box)

vegetated	☐	***non vegetated***	☐
terrestrial	☐	***aquatic***	☐
natural	☐	***agric/infrastr***	☐

land cover CODE_______________

Type II (optional covering a smaller area)

vegetated	☐	***non vegetated***	☐
terrestrial	☐	***aquatic***	☐
natural	☐	***agric/infrastr***	☐

land cover CODE _______________

Type III (optional covering the smallest area)

vegetated	☐	***non vegetated***	☐
terrestrial	☐	***aquatic***	☐
natural	☐	***agric/infrastr***	☐

land cover CODE _______________

FORM 2 "SITE GENERAL DESCRIPTION"

Sample N °:_______________

Land cover CODE:_______________

Coordinates from GPS (UTM)

Easting:___________________

Northing:__________________

Slope:____________________________

Aspect:__________________________

Date:______________________

Time:______________________

Location:_________________________

Check the position of the viewpoint according to the observed (sample) point.

IF YOU CAN STAY INSIDE
Samples recorded from outside are partially useful

	N ☐	
NW ☐		NE ☐
W ☐	Inside ☐	E ☐
SW ☐		SE ☐
	S ☐	

If you are not inside only

Distance in meters from the view point to the observed point:__________________

The bearing in degrees of the observed point:________________________________

Extension of the land cover type from the observed point

		N ☐ 300 m		
		☐ 150 m		
W ☐ 300 m	☐ 150 m	+	☐ 150 m	☐ 300 m E
		☐ 150 m		
		S ☐ 300 m		

FORM 3 "NATURAL VEGETATION"

Sample N °:_______________ **Land cover CODE:________________**

Seasonality	***DRY***	***GREEN***	***FLOWERING***	***FRUITS***
TREES	☐	☐	☐	☐
SHRUBS	☐	☐	☐	☐
HERBACEOUS	☐	☐	☐	☐

Physiognomy

LAYER	***COVER***	***HEIGHT***	***LEAF TYPE***			***LEAF PHENOL***	
			BROAD	***NEED***	***APHYL***	***EVERG***	***DECID***
WOODY			☐	☐	☐	☐	☐
TREES layer1			☐	☐	☐	☐	☐
TREES layer2			☐	☐	☐	☐	☐
TREES layer3			☐	☐	☐	☐	☐
SHRUBS layer1			☐	☐	☐	☐	☐
SHRUBS layer2			☐	☐	☐	☐	☐

HERBACEOUS			*Thick* ☐		*Med* ☐		*Thin* ☐	
GRAMINOID			*Thick* ☐		*Med* ☐		*Thin* ☐	
FORBS			*Thick* ☐		*Med* ☐		*Thin* ☐	

For herbaceous aquatic only (choose one box only)

ROOTED	☐
FLOATING	☐

FORM 4 "CULTIVATED AREAS"

Sample N °:______________

Land cover CODE:_______________

INTERCROPPING (check only one box)

Single crop: ONLY ONE CROP ON THE SAME FIELD	☐
Multiple crops: TWO OR MORE CROPS SIMULTANEOUSLY	☐
Multiple crops: TWO OR MORE CROPS OVERLAPPING	☐
Multiple crops: TWO OR MORE CROPS SEQUENTIAL	☐

IRRIGATION (check only one box)

Not irrigated, rain-fed		☐
Post flooding		☐
Surface irrigation		☐
Other in this case specify (sprinkler, etc)		☐

Flooded cultivation only

Flooded	☐
Waterlogged	☐

AVERAGE FIELD SIZE (ha or fractions):	

SPATIAL DISTRIBUTION (check only one box)

Bordering fields	☐
Distance between fields < 0.5 times of average size	☐
Distance between fields from 0.5 to 1.5 per average size	☐
Distance between fields from 1.5 to 3 per average size	☐
Distance between fields > 3 times of average size	☐

FORM 4A "CROP LIST"

Sample N °:_______________ | **Land cover CODE: ________________**

Dominant	☐	*Med importance*	☐	*Marginal*	☐

Physiognomy | **Crop name: ___________________________** | **Crop N.:___**

Life form		**LEAF TYPE**		**LEAF PHENOL**		**PRODUCTS**	
		BROAD	NEED	EVERG	DECID	FRUITS	TIMBER
TREES	☐	☐	☐	☐	☐	☐	☐
SHRUBS	☐	☐	☐	☐	☐	☐	☐
CEREALS	☐	☐	☐	☐	☐	☐	☐
LEGUMINOUS	☐						
OTHER	☐	*Specify the crop type*					

Seasonality

HERBACEOUS		**TREES - SHRUBS**	
INITIAL STAGE	☐	**LEAFLESS**	☐
PLOUGHED	☐	**FULL VEGETATIVE ACTIVITY**	☐
FULL GROWTH	☐	**FLOWERING**	☐
FLOWERING	☐	**UNRIPE FRUITS**	☐
UNRIPE FRUITS	☐	**RIPE FRUITS**	☐
RIPE FRUITS	☐	**HARVESTED**	☐
HARVESTED	☐		

FORM 5 "BARE AREAS"

Sample N °:_______________	**Land cover CODE:________________**

CONSOLIDATED	***YES***	☐	***NO***	☐

If "YES" specify (check one box only)

BARE ROCK	☐
GRAVEL, STONES AND BOULDERS	☐
HARDPANS	☐

UNCONSOLIDATED	***YES***	☐	***NO***	☐

If "YES" specify (check only one box)

BARE SOIL	☐
LOOSE AND SHIFTING SANDS	☐

Both for "bare soil" and "loose and shifting sands" specify (check only one box)

NOT STONY	☐
STONY	☐
VERY STONY	☐

DUNES	***YES***	☐	***NO***	☐

If "YES" specify (check only one box)

BARCHANS	☐
PARABOLIC	☐
LONGITUDINAL	☐