Field Manual for Local Level
Land Degradation Assessment in Drylands

LADA-L Part 2:

Local Assessment: Tools and Methods for Fieldwork

Contents

Foreword

This is Part 2 of the manual for the assessment of land degradation in drylands produced by the LADA project (see Part 1 for project details). This part provides the tools for the Field Assessment. Tools 1 to 6 are for characterisation of the study area and Tools 7 to 14 for conducting the detailed site assessments. The conceptual framework for the approach and recommendations for site selection, sampling, analysis and reporting of the assessment findings are provided in Part 1.

The manual has been developed and piloted in collaboration with the six pilot LADA countries (Argentina, China, Cuba, Senegal, South Africa and Tunisia), however, it is hoped that it will be of much wider use to those conducting land degradation assessments in dryland areas everywhere. For this reason the direct references to the project are kept to a minimum and the wider application of the methods is considered where appropriate.

Section 1 Characterization of the Study Area

1.1 INTRODUCTION AND OBJECTIVES

There are two main objectives:

1. Firstly, to provide an overview of the study area as the context within which land degradation and sustainable land management (LD/SLM) are occurring. The characterisation should enable the team to confirm that the study area is representative of the GAA and/or one of the national level land use systems (LUS) within it.

2. Secondly, the characterisation will provide the team with a rational basis for selecting the location and number sites, along the transects, for the detailed assessments.

Six tools are provided for the characterisation. Several additional activities are required:

- Collect and review **available secondary information sources** where available. A list of recommended secondary information is provided in Annex 2 of Part I of this manual.

- Identify **key stakeholders** and relevant projects and NGOs located in the area.

- A **reconnaissance field visit** ideally before the Focus Group Discussion (FGD, tool 1) with the selected community/ies. A tour (car/bus) with a few key informants will help the team to familiarise themselves with the study area, land uses and the extent and severity of degradation. If this takes place before the FGD it can reveal interesting land resources features and observations for later discussion with the community.

Though tools 1-4 are presented here separately it is logical to combine them as much as possible during the assessment. i.e. in most cases it is sensible to conduct the community discussion and participatory mapping at the same time and to follow these quite soon with the transects.

1.2 TOOLS FOR CHARACTERISATION OF THE STUDY AREA

The following tools are described in this section:

Tool 1: Focus group discussion (FGD)
- guide to the FGD (tool 1a).
- field form for the FGD (tool 1b)
- wealth ranking exercise as part of the FGD (tool 1c)

Tool 2: Participatory mapping of the study area
Tool 3: Transects through the study area
Tool 4: Rapid assessment of vegetation, land use and vegetation degradation
Tool 5: Rapid soil erosion assessment
Tool 6: A protocol for a Rapid Overview Assessment of Water Resources Degradation

Tool 1a Community Focus Group Discussion

Objectives
To obtain information about the range of land-users, their individual and communal management regimes, and the area history. This will help the team gain a better understanding of how the socio-economic and institutional factors influence land user's perception and management of land resources at landscape level. It will also help with interpreting the results from the detailed assessments of land degradation[1].

Expected output
A brief written report (or a section in the study area report) presenting characteristics of the community and its territory, and the linkages with land degradation and sustainable land management. This should highlight any early thoughts on possible indirect and direct causes (driving forces and pressures) of LD/SLM, the impacts on the community and existing responses.

Participants
A small number (6-10) of village elders (male and female together or separately depending on local customs) selected on the basis of their knowledge of the village territory, history and land uses; together with two assessment team members: a facilitator with experience of conducting interviews and a recorder. The recorder will keep a written record and write this up into a field report as soon as possible after the meeting. It is proposed that only 2 of the team members participate to avoid them dominating or intimidating the community members. The other team members need to be fully briefed on the discussion before proceeding with the assessment. This may be followed by a larger meeting called by the local authorities with the community informing them of the assessment objectives and activities also requesting their support as required.

Time required
One hour

[1] The approach draws on the work on sustainable livelihoods (Ellis, 2000) and also on the FAO guide for analyzing local institutions and livelihoods (Carloni, 2005).

Procedure

- Ask for a meeting with the community elders and with representatives of other groups in the society including women, youth and marginal groups.
- Identify a suitable location e.g. inside room, under a tree.
- Introduce participants and outline the meeting objectives.
- Use the questionnaire below to guide the discussion. Try to cover all the areas but allow the participants to provide additional information. Review the questions before conducting the FGD, decide how to ask particular questions, which vocabulary to use to avoid confusion etc.

The rapid reconnaissance visit of the study area recommended in section 1.1 will help the team familiarise themselves with the area and will also help them refine the questionnaire.

Questionnaire

A form (tool 1B) is provided at the end of this section to facilitate recording the findings.

1. What is the population of the whole community? (number of people and/or households)
2. What is the history and pattern of settlement in the area?
3. What are the important land units[2] and land use types (LUT – see Table 1.1, Annex 1 for LUT classification) differentiated by the community, and water sources in their territory?
4. What are the main livelihood/production activities during the rainy/dry seasons (i.e. what are the main things people do for subsistence or to earn a living)?
5. What are the main resources that the community uses for production/livelihoods? e.g. grazing lands, fuel-wood, medicinal plants, dry season water sources.
6. What are the important types of land degradation[3] in the territory? What do you consider are the main causes? What are the main impacts? What are the changes in the last 10 years, in terms of type, extent and degree ?

More details on the causes and impacts of land degradation and resource uses to facilitate the discussion:

7. Is soil erosion or other types of degradation occurring? What are the main causes? What are the indicators the locals use to describe soil erosion/degradation (e.g. soil loss, gully formation (active, under control, inactive), shifting sand dunes, sedimentation, soil accumulation, etc)?
8. Vegetation: Is deforestation occurring in the study area? What is their source of fuel for cooking (and heating)? Have the cover, distribution and quality of vegetation been diminishing? Have the abundance and distribution of palatable species for livestock or invasive species decreased in the area? Since when? Causes? Are rangeland enclosures practiced? Since when? Reasons for establishment? What related problems?
9. Water: What changes (over the last 10-20 years?) have there been in the amount and quality of water resources in the study area? e.g. trends in rainfall amounts and seasonal distribution; changes in levels of water in wells and boreholes; changes in river/ stream flow, changes in water quality (salinity, pollution). Is irrigation water used in agriculture? By whom? Are the community members paying for water? Under what circumstances?
10. Is there any conflict in relation to land and water uses in the area?

[2] A land unit is a distinct type of land characterized by soil type, drainage characteristics, vegetation etc.

[3] In most cases land degradation will be interpreted as soil degradation, so deliberate effort should be made to include vegetation and water resource degradation as well in the discussion.

11. What are the main livelihoods problems/difficulties the faced by rural households? food insecurity? poverty? access to resources? access to markets?
12. Have they experienced drought in the last 10 years?
13. What are the strategies and coping mechanisms adopted during drought or unusual dry years?
14. Are there successful areas where land degradation control, i.e. conservation, restoration and or improvement of land resources were achieved? What were the main sustainable land management (SLM) practices or the different measures to prevent land degradation that were implemented (See Table 1.2, Annex 1 for SLM classification). Were they aimed to improve the productive capacity of the land (e.g. soil fertility, use of water) or for conservation/protection of resources (soil, water, vegetation, wildlife, biodiversity). Indicate for each whether they are the result of an external intervention or a local/traditional practice.
15. If possible, identify any interventions that have addressed wider ecosystem services (e.g. water catchment, carbon sequestration, pest and disease control e.g. tsetse, bilharzia, invasive species control, biodiversity protection and enhancement),etc. What practices were used and what was achieved?.
16. What are the various organizations that affect the way land (including water and vegetation resources) is managed in the community? e.g. informal groups or cooperatives of land-users, NGOs operating locally, private sector investors, local leaders or authorities, government departments or research agencies, etc. The effects might be positive or negative.
17. What are the main informal and formal systems of tenure and rights to access land resources (crop land, pasture land, forest and water) in the community? How do they influence land degradation, conservation or improvement?
18. How do laws, rules and regulations concerning land resources affect the extent of land degradation and/or conservation? The effects might be positive or negative.
19. What other major social divisions (apart from poverty/wealth) that exist in the community (e.g. religious or caste groupings, pastoralists or settled farmers, irrigators or rainfed farmers) that affect the differential access people have to resources and/or the ways in which they manage their land?

Tool 1b Field Form for the Community Focus Group Discussion

Study area or community name: _____________Name of record keeper _____________
Date of discussion__________

1. Population:____

2. History, migration and pattern of settlement:

____
____
____

3. Land units, land use types and water sources in the study area

Land Units (biophysical)	Land use types (includes management practices)	Water Sources

4 & 5. Main livelihood/productive activities during rainy and dry seasons, and associated resource uses

Livelihood Activities	Season R- Rainy D- Dry B- Both	Resources used G- Grazing lands; M- Medicinal plants W- Wild food; W- Water sources F- Forest/tree; O- Other
1. 2. 3. 4. 5. 6.		

6. Important types of land degradation in the study area, their causes, the impacts, and changes in the last 10 years.

Land degradation			
Types	Causes	Impacts	Changes (trend)
1. 2. 3. 4. 5. 6.			

For more details on soil, vegetation, water and socio-economic aspects of land degradation:

7. Indicators and causes of soil erosion perceived by the community

Locally perceived Indicators	Causes of Soil degradation

8. State of natural vegetation

Vegetation Indicators	Changes/Trends	Causes
Deforestation		
Distribution of Vegetation		
Quality of grazing lands		
Abundance of palatable species		
Presence of invasive species		
Bush encroachment		
Other:		

9. Range enclosures

Presence of range enclosures	High	Few	None
When and Why? Main reasons for establishment			
What problems do they cause?			

10. Changes and causes of water quantity and quality

Water	Changes (trends)	Causes
- Quantity - Rainfalls - Surface - Irrigation - Wells/groundwater -		
- Quality - Drinking water - Irrigation -		

Who practices irrigation in the community?

____

Are community members paying for:
- drinking water?____
- watering animals?____

11, 12, 13 & 14 Livelihoods problems and coping mechanisms

Main livelihoods problems:
1.
2.
3.

Presence of conflict(s)?____
Food Insecurity?____
Poverty?____
Drought?____

Main coping mechanisms and strategies:
1.
2.
3.

15. Sustainable land management practices for land degradation control or land restoration

SLM practices	Reasons for implementation	When, and by whom	Results

16. Importance of organizations influencing sustainable land management at local level (Importance: H- High, M-Medium, L-Little, and Influence: + or -)

Organizations (specify)	Influence on SLM
Informal group:	
Cooperative of land users	
NGO local/international	
Private sector	
Local leader	
Government authorities	
Research agencies	
Other:	

17. Main informal and formal systems of tenure and rights to access land resources in the community

Land tenure system	Details	Influence on SLM
- Ownership - Allocation - Share - Rent - Communal -		
Access right system	Details	Influence on SLM
- Cropping lands - Grazing lands - Forest Lands - Water -	-	-

18. Effects of laws, rules and regulations concerning land resources on land degradation and/or conservation/SLM

Laws, rules & regulations	Effects on land degradation/conservation
- - - -	-

19. Major social divisions affecting community members' access and management of natural resources e.g. poverty/wealth status, religious or caste groupings, pastoralists or settled farmers, irrigators or rain-fed farmers)

Social divisions	Effects on access and management of natural resources
- - - -	

Following the community focus group discussion, the group could be divided in two, one conducting the wealth ranking, and the second the territory mapping. (to the extent possible involve representatives of different social groups- male, female, ethnic and age groups)

Tool 1c Wealth Ranking

This wealth-ranking exercise can be completed after the community focus group discussion if some participants still have time available. Alternatively it can be completed later that day or the next day with 3-4 community members.

The relative wealth[4] status, or level of well being, of individuals in the community will be an important factor in determining their views and behaviour in relation to the land resources they use directly and the resources in the study area. Both the extent to which people are responsible for LD/SLM and are affected by the impacts of LD/SLM are strongly linked to their wealth status. For this reason it is necessary to categorize the household/livelihoods in the community using a simple wealth ranking exercise.

The first step is to identify with the community members a set of key indicators for the three (relative) wealth groups: better-off, medium, poor. These should be reliable local indicators that distinguish households in the community, for example farm size, number of livestock, size of household, type of house, off farm employment, financial assets/ indebtedness, education level, social capital, etc. The indicators representing the three wealth groups should be recorded and agreed upon using a flip chart. For example in a rangeland area, number of livestock could be cattle 0 to 10 for poor households, 10 to 100 for medium and more than 100 for the better-off and so forth.

These simple wealth ranking indicators should be subsequently used to rank those households selected from the livelihoods interviews in section 2.1.

These indicators of wealth will accompany the work in the field (key informants) and will be further used as reference to weight the capital assets in the household livelihoods assessment to identify different household profiles.

[4] Wealth in a relative and broad sense, not just the financial assets of the household.

Tool 2 Study area Mapping

Objective

To provide a graphical representation of the study area of the community.

Expected output

An annotated map

Participants

Few (4-5) community members who have participated in the focus group discussion

Time required

1 hour

Materials/preparations required

Any available visual aids such as LADA national land use and degradation maps, aerial photographs, satellite images, more detailed maps etc. that will facilitate discussion.

Procedure

i) Help the people get started but let them draw the map by themselves.
ii) Sit back and watch (what is drawn first, what features are drawn large or small, what parts of the map generate discussion among the map drawers and onlookers).
iii) Once the map is drawn, ask questions about what is shown, prompt for more information and take notes of the issues to follow-up on in subsequent interviews.
iv) Make a permanent (paper) record and a photograph to take away (the original should stay with the community), including names of the map drawers.

Guidance on map content

Prompt the group to provide missing information, The map should show/locate:

- Boundaries of the study area
- Main areas for settlement , roads and markets
- Important land units and land use types differentiated by the community such as cropping lands, grazing lands, forest, wetland, etc and use this to find out/discuss differences in quality of soils, pasture, water sources etc..
- Water sources in the territory such as river, pond, well, borehole, etc
- Types and locations of key resources located outside the community boundaries but used by community such as communal pastures and water sources.
- Areas of land degradation (soil, vegetation, degraded water resources)
- Areas of successful land degradation control/sustainable land management.

This type of information will be important for locating the position of the transects and selecting the sites for the detailed assessments.

Community maps can be used to present the range of land resources (soil, water, vegetation, etc.) or specific resources. For example, in Figure 1, land-users distinguish several land units in terms of soil types. The map makes it possible to estimate the relative importance of the soil types in terms of area and percent of cropped fields. To distinguish soil types farmers pay special attention to visible aspects of the soil, such as colour and vegetation and characteristics that have direct management implications, such as ease of ploughing (this is influenced by the texture of the topsoil and rainfall). Remember to clearly show the legend /key for the different symbols used.

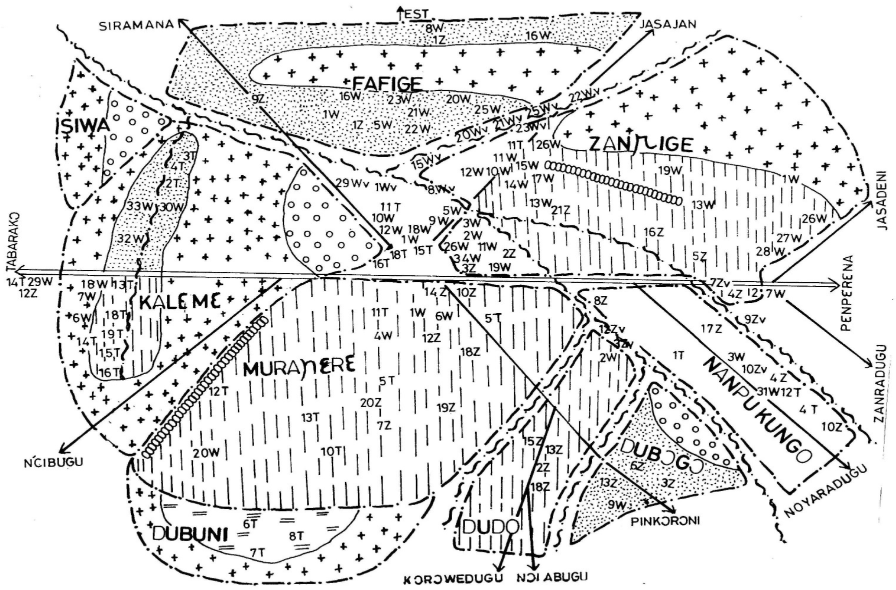


Figure 1. A community territory map drawn by villagers (taken from Defoer et al., 2000)

The community map may show that land degradation is especially severe in certain areas. This can be used to discuss any land use planning, legislation, local bye-laws/regulations or other interventions that have happened or that may be considered, along with constraints to their implementation.

If available, the community mapping can be complemented by use of high resolution satellite images (such as "Quickbird") or lower resolution Google Earth images of the geographical assessment area. With only very limited manipulation such images could be used to cross-check (with community members) and supplement the completed hand-drawn study area map.

The community map and transect diagram (see Tool 3) can be used to stimulate debate about the types, degree, extent and trend of land degradation in the study area, as well as the effectiveness of, or the need for, interventions to address degradation/ restore or improve land resources, for example:

- communal erosion control works to protect uplands from further degradation,
- control of bush burning to safeguard vegetation cover and biodiversity,
- grazing management/control to allow restoration of pasture/range,
- improved crop and/or livestock rotations to restore soil fertility,
- control of settlement expansion to prevent loss of productive lands,/crop expansion into fragile lands or wetlands, control of irrigation and drainage to prevent over exploitation of limited water supply, or loss of wetlands and their functions.

This discussion with the community could raise further valuable information and could provide incentives to the community for improved land resources management.

Tool 3 Transect

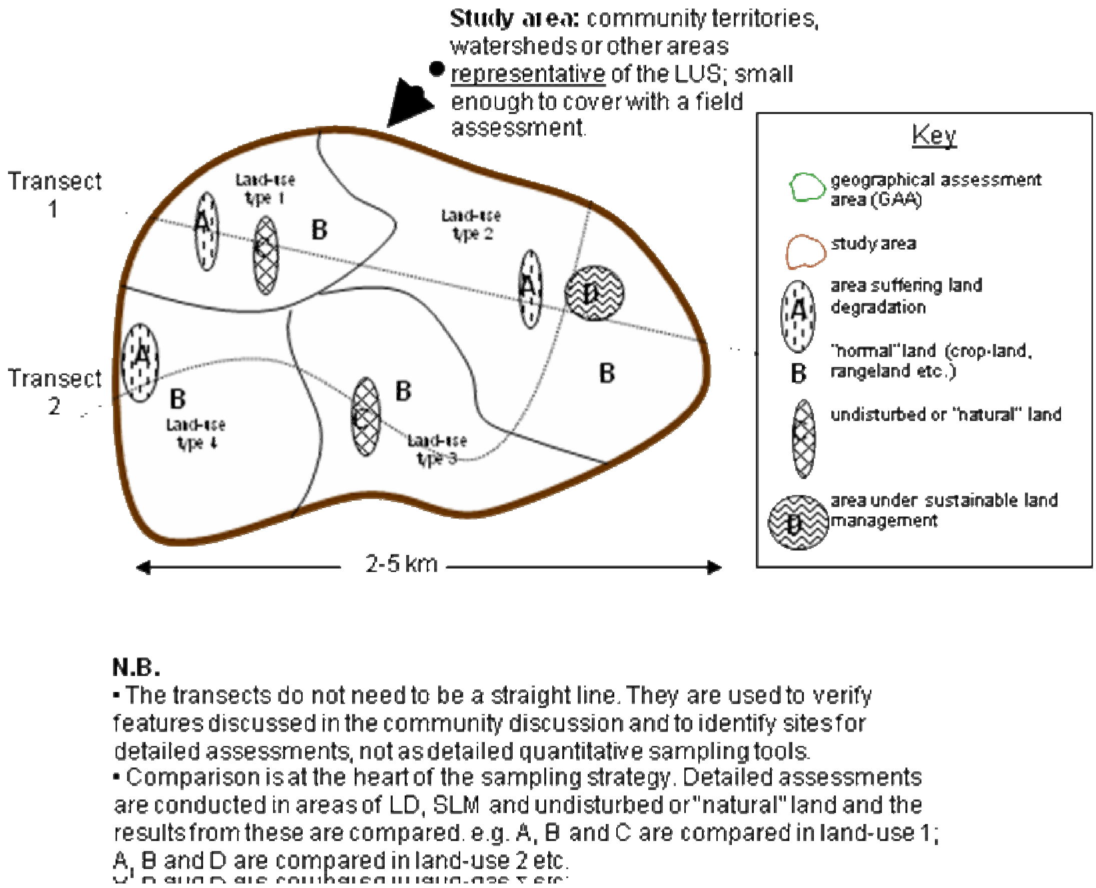


Figure 2 Hypothetical study area marked with two transects cutting across the main LUTs and land units and representative areas showing land degradation and SLM

Introduction

Transects are used here used to verify features discussed in the community discussion and to identify sites for detailed assessments, not as quantitatively robust sampling tools.

1-3 transects per study area is recommended to capture most of the land resource and LD/SLM features of interest in the area. The decision on location and number of transects should be made after the community discussion and mapping and build on information collected during those exercises (Tools 1 and 2). They should if possible cut across the major LUTs and different land units (see box 1 in Part 1 for definitions of LUS, LUT, land unit etc.) or, in the case of a very uniform landscape, cut across an area with as much variation as possible in land-user type and management practice. Some socio-economic criteria can also be used in identifying representative transect sites, such as population density, change in settlement pattern (e.g. due to refugee camps, policy for centralised villages). Final selection of the location and start and end points of the transects takes place in the field through observation and discussion with community leaders.

The length of each transect will depend on the variation in terrain and land type but are often 2-5 km in length. In some cases, two or three short transects may be better than a single long one for capturing sites of interest within the study area.

As it is not being used to sample quantitatively the transect width is not fixed but is effectively the land easily visible to the naked eye as one walks along it. It will be shorter and narrower in areas under complex and intensive land-use, or in forest, than in extensive pasture or open savannah, because of the time required to record information.

The land resources (vegetation, soil, water) can be investigated to some extent during the transect walk but the important thing is to gain a broad appreciation of type and variation across the site, to "ground-check" features discussed in the FGD and to select a few "key" sites for the more in depth and time consuming detailed site assessments.

Objectives

i) To support the area characterization exercises, particularly the mapping (Tool 2) by identifying/verifying key land forms and LUTs. In addition, capturing additional detail on water, vegetation and soil features and wider/off-site effects of land use pressures (e.g. deforestation, overgrazing, burning, encroachment of wetlands and drylands) and resource degradation, e.g. downstream impact of runoff and sediment deposition, landslips, wind erosion etc.

ii) To help locate sites for the detailed vegetation and soil assessment.

Expected outputs

The transect exercise generates information that feeds into the study area mapping, study area report and aids location of subsequent detailed assessments. The transect diagram, in conjunction with the site map and photos, also facilitate subsequent analysis with the community of reasons for certain land uses and management practices (i.e. direct causes as well as root causes or driving forces) and provides a permanent record of the state of the study area at the time of the study, and the location of assessment sites.

Participants

The local team should be accompanied by local persons/"informants", both men and women, with knowledge of land use changes, of vegetation species and their uses (local names), if possible the same group or a sub-group of those involved in Tools 1 and 2.

Materials/preparations required

- Note-taking materials (paper and clipboard)
- Map and/or aerial photo and/or satellite image to help locate the transect and to locate key features and boundaries
- GPS to record locations and altitude (of major changes in land use/vegetation, landform and soil and suggested detailed assessment sites)
- Digital camera
- Compass
- Abney level or clinometer to take slope and tree height measurements
- Tape measure to measure distances
- Machete to cut through thickets
- A spade
- Plastic bags to take any samples (vegetation, insect pests)

Time required

Three to four hours per transect.

Procedure

1. Identify key informants (both men and women) who are knowledgeable (especially in identifying local plant and indicator species) and willing to assist (e.g. identified with the help of community leaders and through the focus group discussion).

2. Identify the transect route with community members (using community and conventional maps, aerial photos, satellite images):

– to cut across major land use types and land units (terrain, soil);
– to capture variation in land users and management practices; and,
– to capture variation in socio-economic variables (population, farm size,…etc.),.

3. Discuss with the local informants and list the different factors to be drawn on the transect (land use, crop and livestock management, trees, soil, natural vegetation, water, etc.), problems and opportunities as perceived by the community.

4. Walk along the transect route with local informants (the start and end points to be identified by observation in the field). The actual length and width should be specified on the recording form.

5. Record altitude (m) and GPS readings (coordinates) at each main change in LUT or land unit and to identify and locate (GPS) sites along the transect (plots, fields, areas of pasture etc.) for the detailed land degradation assessments.

6. Where the transect crosses a road, river or other infrastructure or administrative border (e.g. protected area) the GPS reading should also be noted as this helps to compare ground observations with satellite imagery (Google earth etc) and facilitates subsequent monitoring.

7. To help with selection of sites for the detailed assessment the digging of many, rapid, "one spadeful" holes is encouraged to both provide a rapid overview of soil types, anthropogenic impacts, soil-vegetation relationships, and to aid location of subsequent detailed assessment sites.

8. The rapid vegetation, erosion and erosion assessment tools (Tools 4-6) are designed to be used at appropriate points along the transects.

9. It is important to take notes and, where possible, photographs of the following aspects:

- characteristics of the land unit and land-use type: what terms/criteria do farmers use to distinguish land units? (soil type/colour, slope, drainage, productivity, etc.); relate these characteristics to the position in the terrain and proximity to households;
- slope and aspect – in each new land unit crossed record the average slope using the clinometer/abney level (taking care to use either degrees ° or percentage % throughout - do not mix them); with the compass, record the compass bearing of the slope, see note on aspect below
- dominant land use type (LUT), presence of planted trees, pasture, density of homesteads/farms, size of the farms;
- major land constraints (such as steep slopes, shallow soils, stoniness, water-logging, salinity, sodicity, etc);
- land degradation features (gully, sheet or rill erosion, deposition, rock or laterite exposure, bush encroachment, deforestation)
- vegetation type, see Table 3 below: (natural/planted species, type, composition, dominant species) and management of trees and grazing lands (e.g. tree coppicing, burning, etc.)
- indicator plant species (of soil/land quality; invasive species; useful wild species)
- crops (annual/perennial species for food, fibre, fruit, etc.) and management practices (rotations; intercropping, tillage, weeds, residues/mulch, fallow land);
- livestock type and management practices (grazing, watering points, kraaling, pasture burning, livestock movements, etc.);

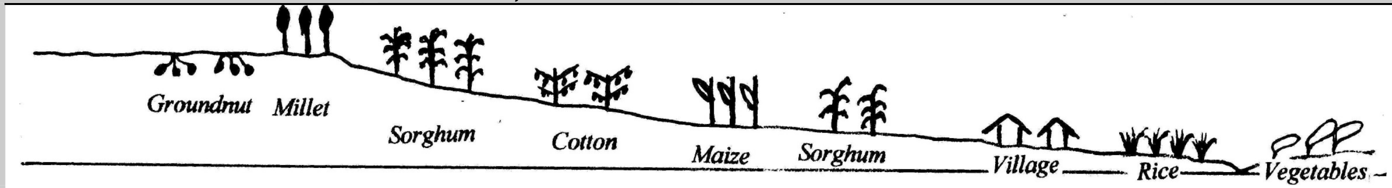
- water resources (natural drainage pattern rivers/springs, sources, wetlands; and investments- wells, boreholes, livestock watering troughs, piped water, etc.)
- human management factors and constraints (settlement pattern, farm size, fragmentation, communal lands, etc.)
- soil and water conservation measures (terraces, bunds, tied ridges, agroforestry practices) and investments in conservation/SLM (e.g. dams, irrigation, water harvesting, afforestation, catchment management, watering points etc.)
- landscape diversity (spacing of features such as trees, woods, field borders, live fences, fallow land) and biodiversity conservation

10. Local informants can be prompted during the transect walk to provide further information on changing land use, management practices (if possible note if the land users are small, medium or large farmers/herders). This could include information on actions by individuals, communities or authorities; conflicts; successes in conservation / SLM (e.g. improving productivity, extent of adoption of improved practices, and by which land user types); constraints (e.g. labour, lack of tenure security); opportunities known but not tried and reasons).

11. Collect specimens of indicator plants in plastic bags, (or in a plant press, if available) for later identification with specialists (botanists, foresters, pasture specialists, ecologists, entomologists etc.). Record the local names of these.

12. Draw a rough transect diagram and, if possible, cross-check it immediately with key informants to verify it is a good representation. Then return to the field team's "office" and complete the transect diagram, or matrix, with details as shown in Figure 3. Show proposed sites for the detailed site assessment on the diagram,. This should be verified with local informants over the next days and agreement reached on where exactly to carry out the detailed assessments (see section 3).

Figure 3 Example of a transect diagram or matrix [5] including information on land degradation type, extent and control measures.

LUT Characteristics	Land Use Types (LUT)			
	Annual crops, grazing mix	**Annual crop land, grazing mix, trees**	**Annual crops, grazing mix**	**Annual crops**
Record where the transect crosses a road, river or other infrastructure or border (e.g. protected area)				
GPS location (from start to end)	XXX – YYY	XXX - YYY	XXX - YYY	XXX - YYY
Altitude (from start to end)	XXX – YYY	XXX - YYY	XXX - YYY	XXX - YYY
Average slope (in degree or %)	XX	XX	XX	XX
Soil • **Soil texture** • **Soil colour** • **Soil fertility (G, M, P)**	• Gravel, sand • Red	• Sand, loamy-sand • Red to brown	• Sandy loam to loam • Brown to black	• Clay • Black
Hydrology and water sources			• 1 well and 1 borehole in the village	Small river (dries up in some dry seasons)
Major constraints (biophysical and human	• Low moisture	• Erosion risk	• Soil adhesion; land difficult to prepare • Drying	• Water logging • Weeds • Land difficult to prepare
Major crops + livestock	• Sorghum, millet, groundnut	• Sorghum, millet, cotton, groundnut	• Maize, cotton, sorghum	• Rice, vegetables • Small herd of cattle
Vegetation • **Type and cover** • **Main species** • **Indicator species**	Poor cover, few trees • *Combretum sp., Burkea africana* • ……….	Negligible ground cover • *Vitellaria paradoxa*, small *Parkia biglobosa* ……….	Healthier vegetation • Large *Parkia biglobosa*, and *Vitellaria paradoxa, Daniellia oliveri*	Hydrophilous plants: • *Terminalia macroptera* • *Mitragyna inermis*
Land degradation features (specify also extent and severity)	Drought prone	Soil erosion – rills/gullies	Soil erosion – rill/sheet	• Water logging, • water pollution, • sedimentation
Land degradation control/ restoration practices (specify extent and effects)	Mulching on some fields	Contour tillage demo Planted grass strips/trees some fields –less erosion	None	None
Farm/field sizes/ fragmentation, borders etc.	•	•	•	•
Potential improvements	• Runoff/Erosion control	• Application of manure • Runoff/Erosion control	• Limit use of mineral fertiliser	• Mechanical and chemical weeding
Selected sampling sites (GPS reading	XXX –YYY	XXX –YYY	XXX –YYY	XXX –YYY

[5] Bunning, adapted from Defoer, 2000, from southern Mali

Figure 3 above shows an example transect diagram and Table 1 below summarises the range of information that can be observed during the transect walk and recorded on the transect diagram[6]

Table 1 Transect indicators and information.

THEME/ISSUE	INDICATOR
GENERAL LAND USE and RESOURCE QUALITY	
Predominant Land Uses	• Type and level of intensity • Number and extent of main land use types
TOPOGRAPHY	
Type and slope	• % of steep, undulating, flat land • Average slope per specific LUT • Extent of rock outcrops- non productive land
Slope aspect	• Direction of the slope (compass bearing)
LAND AND WATER RESOURCES QUALITY AND DEGRADATION	
Soil erosion (large features)	• Presence and spacing of gullies (ravines) • Land slumping or landslides
Vegetation cover, type (see Table 3 below), structure and relation with degradation	• % of bare soil (ground cover - natural, crop and weeds) • Type of vegetation: % annuals, perennials, shrubs, tree canopy • Cover quality (low, medium, high) • % Tree canopy cover • Degradation severity (low, medium, high) • Degradation extent (low, medium, high)
Topsoil colour, texture and structure in relation to land use	• Colour (red-yellow-brown-black, mottled) • Texture (sandy - loamy- clayey) • Surface hardness (crusting or lateritisation) • Evidence of large soil clods (compaction) • Organic matter decline (soil colour differences within a soil type)
Indicators of soil salinity	• Indicator plants (specify which) • Whitish salt deposits
Watershed management soil & water conservation, water use for livestock/crops	Observable measures and % of area (e.g. protection of hill crests, water sources, contour farming, alley cropping, stone lines, bunds, terraces, livestock tracks to water source, water harvesting type, etc.)
Water source and use	• Type (river, ephemeral stream, spring, well, borehole, dam/pond, trough) • Use for household. livestock, all year/dry season) • Access (distance /time to reach)
Quality of water	• Sediment load of rivers/lakes • Pollutants • Aquatic weeds
Irrigation and water storage techniques	• Type (dam, tank, roof, gravity-fed) • Size/surface area (volume/extent) • % households
CROP-LIVESTOCK SYSTEMS	
Grazing system	• % communal grazing • % extensive/intensive systems • Livestock types • Livestock management/feeding (free grazing, fenced, tethered, stall-fed, cut and carry, improved pastures)

[6] Bunning, 2006, extract from Methods for conduct of baseline studies for the Kagera transboundary agro-ecosystem management project in Tanzania, Uganda and Rwanda

THEME/ISSUE	INDICATOR
	• Type/quality of sheds, stalls, kraals etc
Crops and crop-livestock associations	• Crop types and diversity (number of species, mixes, rotations) • % land area • Previous land use/crop (1 or 2 years) • Evidence of crop-livestock integration (use of manure for crops, of crop residues for feed/fuel) • Uses (% for food. fodder, sale)
CROP-LIVESTOCK SYSTEMS cont.	
Health/Productivity	• Crop health (good, moderate, poor) • Livestock health (weight/ body condition good, moderate, poor) • Herd size and composition • Visible pests/diseases
Fallow	• % of the land • Fallow type (natural/ improved quality)
Loss of biodiversity	Loss of socio-economically important • tree species and uses • other plant species and uses • plant varieties and uses • domestic animal breeds and uses • wild animal species and uses Crop/livestock uniformity (% local/improved seed; range of local/improved breeds)
Soil Management	• % are cultivated • % area under conservation agriculture (zero tillage , permanent cover) • Tillage type (% hand, oxen, tractor)
Invasive species, Weeds and pests	• Serious invasive species • Weed severity in crops/pasture (high, medium, low) • Pest severity in crops/pastures (high, medium, low)
Burning of organic materials	• Extent of burning (% area) • Evidence of severe burning (tree damage etc)
Wild animal species	• Evidence of wild pigs, rabbits, rodents, snakes, vultures, birds, etc. Damage from wild species (high, medium, low)

Types of agroforestry	• Technique and extent % area (e.g. alley cropping, contour planting, improved fallow, scattered)
	• % of tree cover
	• Types and number of tree species (indigenous and introduced)
	  ○ combined with crop systems
	  ○ combined with pasture systems

Pasture/Range degradation	• Pasture composition (good, moderate, poor; % shrubby/ • herbaceous species; • Evidence of grazing on preferred/less desirable species (% palatable, thorny, poisonous) • % useful compared to less valued species (positive and negative trends) • Evidence of damage to trees, shrubs, pasture • Extent/severity of trampling/overgrazing damage (tracks on stream banks/ steeplands/ water sources, soil compaction)
Grazing corridors	• Presence and size • Management /degradation
Livestock disease control	Evidence of communal dips, cattle crushes etc

Tool 4 Rapid Vegetation/Land Use Assessment

There are two stages of the vegetation assessment: A rapid assessment of vegetation and land use is conducted as part of the Characterisation of the Study Area. Thereafter a more detailed vegetation assessment need to follow at selected sites in the study area

The rapid assessment enables the team to obtain an overview of vegetation patterns and degradation between different land units (i.e. protected, well managed vegetation with little evidence of degradation and/or under inappropriate land use or poor practices that are resulting in degradation).

The vegetation and land use assessment should include the identification of vegetation /land use type, and a rapid assessment of the vegetation cover, vegetation composition and species diversity, plant health or quality, especially in terms of grazing quality in pasture and rangelands.

The results from this assessment should enable the team to develop some initial ideas on the relationship between vegetation and land degradation, in particular, effects of vegetation degradation on erosion, soil fertility, productivity and the water cycle.

Tool 4.A. Vegetation Type.

During the study area characterization, for each land unit identified on the community map and along transects, the natural vegetation type and land use should be recorded and classified using the system in Table 2.

Table 2 Major *land use types* and sub-types (adapted from WOCAT 2008)

Land use type	***Land use subtype and codes***
Cropland: *Land used for cultivation of crops (field crops, orchards).*	• ***Ca: Annual cropping:*** *land under temporary / annual crops usually harvested within one year, or maximum of two years (e.g. maize, paddy rice, wheat, vegetables, fodder crops)* • ***Cp: Perennial (non-woody) cropping:*** *land under permanent (not woody) crops that may be harvested after 2 or more years, or only part of the plants are harvested (e.g. sugar cane, banana, sisal, pineapple)* • ***Ct: Tree and shrub cropping:*** *permanent woody plants with crops harvested more than once after planting and usually lasting for more than 5 years (e.g. orchards / fruit trees, coffee, tea, vineyards, oil palm, cacao, coconut, fodder trees)*
Grazing land: *Land used for animal production*	• ***Ge: Extensive grazing land:*** *grazing on natural or semi-natural grasslands, grasslands with trees / shrubs (savannah vegetation) or open woodlands for livestock and wildlife* • ***Gi: Intensive grazing/ fodder production:*** *improved or planted pastures for grazing/ production of fodder (for cutting and carrying: hay, leguminous species, silage etc) (Not including fodder crops such as maize, oats, which are classified as annual crops, see above)*
Forests / woodlands: *land used mainly for wood production, other forest products, recreation, protection.*	• ***Fn: Natural forests:*** *woods/forests composed of indigenous trees, not planted by man including riverine forests* • ***Fp: Plantations, afforestation, woodlots:*** *forest stands established by planting or/and seeding in the process of afforestation or reforestation, (including plots and wider belts (Wind-/shelterbelts)* • ***Fo: Other:*** *e.g. selective cutting of natural forests and incorporating planted species*
Mixed: *mixture of land use types within the*	• ***Mf: Agroforestry:*** *cropland and trees* • ***Mp: Agro-pastoralism****: cropland and grazing land (including seasonal*

Land use type	***Land use subtype and codes***
same land unit.	*change between crops and livestock)* • ***Ma: Agro-silvopastoralism:*** *cropland, grazing land and trees (including seasonal change between crops and livestock)* • ***Ms: Silvo-pastoralism:*** *forest and grazing land* • ***Mo: Other:*** *other mixed land*
Water bodies: *used for food production*	• ***Wa: Natural and artificial waterbodies:*** *inland natural lakes, permanent and seasonal rivers and streams, and ponds used for aquaculture and fishing*
Other land use:	• ***Oi: Mines and extractive industries, quarries,*** • ***Os: Settlements, infrastructure networks:*** *roads, railways, pipe lines, power lines* • ***Ow: Waterways, drainage lines, canals, ponds, dams built by humans*** • ***Oo: Other: bare lands, wastelands, deserts, glaciers, swamps, recreation areas, etc***

In some cases mosaics of land uses are found e.g. mixtures of forest and savanna or savanna and agriculture.
For all the subsequent indicators, Steps 2-4, where possible, for each land use, comparisons should be made with a benchmark site that is protected or under good management.

Tool 4.B. Assessment of the Overall State of Vegetation Degradation.

A rapid visual assessment of vegetation/land use type, vegetation cover, structure and species composition, can be undertaken through the reconnaissance visits and transects. At this stage, we should be able to make an initial hypothesis of the effects of degradation (type and severity; high, medium, low), protection or restoration, e.g. resistance to/extent and severity of erosion, water regulation (infiltration, runoff), soil structure (organic matter, rooting) and productivity. This will help in selecting the sites for detailed investigations.

Table 4 can be used as a basis for the vegetation overview using simple scores of the state of degradation (extent and severity), negative (-, --, ---) or positive (+, ++, +++). Any descriptive information on trends and effects in terms of productivity or effects on water supply or other ecosystem services or livelihoods should be captured from discussion with the land users /informants during the initial reconnaissance visit and transect walk.

NB There may be some overlap between the land use types, for example, i) vegetation in pasture and rangelands comprises grasses, shrubs and scattered trees, with in some cases a high tree density e.g. wooded savanna; ii) grazing may take place in forest/woodland and in cropland after the harvest; ii) crops may be under agroforestry practices.

Table 3 Indicators of degradation by land use type [degradation status scores (-, --, ---) or (+, ++, +++)].

Indicators of degradation by land use type	Status of Degradation	Trends in Degradation	Degradation Effects
Grass/rangeland degradation			
Reduced vegetative cover by living plants			
Reduced protective ground cover by litter and plant residues			
Decline in species diversity			
Change in composition (grasses; other herbaceous species – annuals and perennials)			
Loss of beneficial trees and shrub species (forage, soil fertility, fuelwood, shade, etc)			
Increase in relative area of bush and shrubs			
Reduced plant vigour and biomass production			
Reduced forage production and livestock carrying capacity			
Increase in undesirable plant species (invasive, poisonous, non-palatable)			
Forest/woodland degradation			
Reduced tree density and canopy cover			
Reduced protective ground cover by herbaceous undergrowth			
Reduced protective ground cover by litter and plant residues			
Decline in species diversity			
Reduced height and diameter of trees and shrubs (biomass)			
Reduced number/share of economically valuable trees/shrubs (for timber, poles, firewood, fruits, medicines etc)			
Increased plant mortality/reduced natural re-growth			
Reduced/Loss of native species due to competition by invasive (alien) species or planting with exotic species			
Degradation of vegetation resources within croplands			
Reduced numbers/density of beneficial trees/shrubs in fields or boundaries (forage; soil fertility, fuelwood, wild foods, medicines)			
Reduced effectiveness of windbreaks/shelter belts in croplands (die back, harvesting, non-replacement)			
Reduced harvested species diversity and associated increase in pests and diseases			
Reduced plant vigour and biomass due to soil fertility decline			
Increase in weeds/invasive species that are hard to control			

Tool 5 Qualitative Soil Erosion Assessment (Status, Type, Severity)

A qualitative estimate of the severity of existing erosion can be obtained for the various land units designated on the study area map and/or identified through aerial photos or satellite images and the initial transect walks. This initial rapid assessment of soil erosion is conducted through the use of simple visual indicators that can be observed during field inspection of the main land use types - cropland, grassland and forest/woodland. It can help relate the main management practices to degradation extent and severity.

The following visual parameters could be used for assessing qualitatively the state and severity of soil erosion in the course of a transect walk and subsequently at sample sites.

Table 4A State of Erosion

Active Erosion	One or more of the following conditions apply: • evidence of recent sediment movement; • sides and/or floors of rills and gullies are relatively bare of vegetation; • sand dunes have little vegetative cover and show scouring on the windward side and deposition on the leeward side
Stabilised	One or more of the following conditions apply: • no evidence of recent sediment movement; • sides and/or floors of rills and gullies are revegetated; • sand dunes well vegetated with very few bare areas from which soil could be removed by the wind.
Partly Stabilised	Localised evidence of active water and/or wind erosion; but part of the eroded area shows evidence of stabilisation and partial revegetation.

Table 4B Splash Erosion

Splash Erosion Not apparent	No obvious signs of splash erosion but evidence of minor splash erosion may have been masked by for instance recent tillage.
None	No visual indicators of splash erosion.
Slight	• Some visual evidence of splash erosion from the presence of soil particles having recently been splashed up onto the stems and undersides of the leaves of crops. • Some signs of surface sealing due to the impact of raindrops. • Any surface crust is thin and easily broken.
Moderate	• Clear signs of splashing having thrown soil particles into the air with a moderate coating of soil on stems/undersides of the leaves of crops. • Clear signs of surface sealing due to the impact of raindrops. • A surface crust up to 1 cm in thickness and moderately easily broken.
Severe	• Clear evidence of the wholesale splashing of soil particles into the air from the presence of a distinct coating of soil on the stems and undersides of the leaves of crops. • Obvious surface sealing due to the impact of raindrops. • A hard surface crust of over 1 cm in thickness.

Table 4C. Sheet Erosion

Sheet erosion Not apparent	No obvious signs of sheet erosion but evidence of minor sheet erosion may have been masked by for instance recent tillage.
None	No visual indicators of sheet erosion.
Slight	• Some visual evidence of the movement of topsoil particles downslope through surface wash • No evidence of pedestal development. • Only a few superficial roots exposed.
Moderate	• Clear signs of the transportation and deposition of topsoil particles downslope through surface wash. • Some pedestal development but individual pedestals no more than 5 cm. in height. • Some tree, grass and/or crop roots exposed within the topsoil. • Evidence of topsoil removal but no subsoil horizons exposed.
Severe	• Clear evidence of the wholesale transportation and deposition of topsoil particles downslope through surface wash. • Individual pedestals over 5 cm in height • Extensive exposure of tree, grass and/or crop roots • Subsoil horizons exposed at or close to the soil surface.

Table 4D Rill Erosion

(A rill is a small channel less than 30 cm deep which can be completely smoothed out by cultivation with animal or machine drawn implements, although traces (depression lines within the field) may remain where all cultivation is done by hand).

Rill erosion	
None	No rills present within the field.
Slight	A few shallow (< 100mm depth) rills affecting no more than 5% of the surface area.
Moderate	Presence of shallow to moderately deep rills (<200mm depth) and/or rills affecting up to 25% of the surface area.
Severe	Presence of deep rills (up to 300mm depth) and/or rills affecting more than 25% of the surface area.

Table 4E Gully Erosion.

(A gully is a channel 30 cm or more deep. It forms a physical impediment to cross-slope movement, of animal or machine drawn farm implements and cannot be smoothed out during normal cultivation).

Gully erosion None	No gullies present within the field.
Slight	A few shallow (<0.5m depth) gullies affecting no more than 5% of the surface
Moderate	Presence of shallow to moderately deep gullies (0.5-1.0 m depth) and/or gullies affecting 5 - 25% of the surface area.
Severe	Presence of deep gullies (>1m depth) and/or affecting > 25% of the surface

Table 4F Stream bank Erosion.

(Occurs along the side of banks of rivers/streams and contributes directly to the sediment load of the river system. Can be severe during floods when large volumes of water are flowing at great speed).

Stream bank erosion None	• Stream bank has close to 100% vegetative cover and no active erosion • Little if any signs of undercutting on the outer bends of meanders and little active deposition of sediment on the inside.
Slight	• Limited loss of vegetative cover (>80% cover remaining) and only slight erosion on the mid to upper portion of the stream bank. • <5% of outer bends of meanders over a 1km stretch show active undercutting of only the lower portion of the bank and some deposition of sediment on the inside.
Moderate	• Moderate loss of vegetative cover (50-80% remaining) and slight to moderate erosion on the mid to upper portion of the stream bank. • 5-15% of the outer bends of meanders over a 1km stretch show active undercutting that may extend into the mid portion of the bank and moderate deposition of sediment on the inside.
Severe	• Severe loss of vegetative cover (<50% remaining) and moderate to severe erosion on the mid to upper portion of the stream bank. • >15% of the outer bends of meanders over a 1km stretch with active undercutting extending to the upper portion of the bank on the outer bends of meanders and heavy deposition of sediment on the inside.

Table 4G Mass Movement

(Relatively large down-slope movement of soil and/or rock e.g. landslides, slumps, earth flows and debris avalanches. Described for relatively large land units, e.g. watersheds, not for individual fields)

Status

Active Mass Movement	Landslide scars clearly visible with sharp boundaries and less than 10% vegetation cover within the landslide area.
Stabilised /Inactive	Landslide scars still detectable but no longer with sharp boundaries and with greater than 50% vegetation cover within the land slide area.
Partly Stabilised	Landslide scars clearly visible; vegetation cover 10-50% of the landslide area

Severity

Mass movement None	No evidence of mass movement (no signs of land slides, or mass slumping)
Slight	Isolated events of mass movement, small in size and/or affecting less than 0.1% of the total area.
Moderate	A moderate number of individual mass movement events, small to moderate in size and/or affecting up to 1% of the total area.
Severe	Significant number of mass movement events, may be, large in size and/or affecting over 1% of the total area.

Table 4H Wind Erosion

Wind erosion includes both the removal and deposition of soil particles by wind action and the abrasive effects of moving particles as they are transported.

In areas with extensive loose sandy material wind erosion can lead to the formation of mobile sand dunes that cause considerable economic losses through engulfing adjacent farm land, pastures, settlements, roads and other infrastructure.

In farmland areas wind erosion occurs when soil is left bare of vegetation, and the topsoil has been reduced to a fine tilth, as a result of cultivation.

It also occurs in overgrazed grassland areas that have lost their protective vegetative cover, and in forest/woodland areas following the cutting of trees and shrubs, and in particular following the removal of the leaf litter and herbaceous ground cover.

The risk of wind erosion is highest in spring, prior to the onset of the summer rains, due to the combination of strong winds, dry topsoil, poor vegetative ground cover, and a lack of leaves on the trees in the windbreaks planted to protect croplands.

Wind erosion None or not apparent	No obvious visual signs of wind erosion but evidence of minor wind erosion may have been masked by for instance recent tillage.
Slight	• Some visual evidence of the movement by wind of soil particles within individual fields. • No evidence of wind scouring but a few superficial roots exposed. • Deposits of wind blown soil at field margins or where the winds progress has been obstructed under 2 cm thickness. • Little accumulation of wind blown soil in drainage ditches. • Only a light covering of wind blown material on roads and minor accumulation in settlement areas.
Moderate	• Clear signs of the transportation and deposition of soil particles by wind, some scouring but no more than 5 cm in depth. • Some tree, shrub, grass and/or crop roots exposed within the topsoil • Deposits of wind blown soil at field margins or where the winds progress has been obstructed between 2-5 cm thickness. • Moderate accumulation of wind blown soil in drainage ditches.

	• Moderate covering of wind blown material on roads and accumulating in settlement areas.
Severe	• Clear evidence of the wholesale transportation and deposition of soil particles by wind. • Extensive scouring with individual scours over 5 cm in depth • Extensive exposure of tree, shrub, grass and/or crop roots. • Subsoil horizons exposed at or close to the soil surface. • Drainage ditches filled with wind blown soil. • Elsewhere original soil surface buried beneath at least 5 cm of wind blown soil. • Wind blown material accumulating deep enough on roads and in settlement areas to have a negative impact on transport and living conditions.

Tool 6 Rapid Overview Assessment of Water Resources Degradation

As with tools 4 and 5 this rapid water resources assessment is designed to be carried out with the transects as part of the study area characterization.

Review of secondary material

It is particularly important to review relevant secondary data and existing studies on water resources in the study area have been. (See Part 1 section 3.3 for a list of types of material for review).

1- Secondary information on water resources and climatic conditions and trends in the geographical assessment area (GAA) and the study area. *Collect and review this before the field assessment, emphasising the current situation and recent trends (last 10-20 years) where possible*. Table 5 in section 3.3 of Part 1 lists common sources of useful secondary information.

During the transect walk/reconnaissance visit the following should be rapidly assessed visually and in discussion with accompanying land-users:

- Water availability: types, number and size of water resources/bodies
- Water quality (e.g. polluted, saline, etc)
- Water uses: types (human consumption, livestock, agriculture, industry)
- Water resources management over the last decade including: water conservation and harvesting activities;
- Water policy and institutional aspects, i.e. water allocation, water rights and water conflicts. Most of these issues are also covered community focus group discussion (Tool 1a), and household interview (Tool 7).

Off-site impacts of water resources use.

These can operate in either direction:

a. Does local land use and management (vegetation, soil and water) in the study area affect water resources in off-site/neighbouring areas? (select from list below or note additional impacts)

b. Does land use and management outside the study area affect the water resources in the study area? (select from list below or note additional impacts)

Table 5 Off-site impacts of water resources use

Off-site impacts
- Floods during extreme events/ rainy season - Sediment deposition/accumulation and dust storm - Contamination by airborne pollutants (e.g. from industry, mining, urbanization) affecting vegetation, soil or water - Surface water availability during dry seasons/ spells, droughts, (e.g. river flows, lake levels, dams, ponds, etc.) - Ground water/ subsurface water availability - Water-logging - Salinization - Drinking water quality - Industrial water quality - Agricultural water quality - Other (specify)

c. What are the human and natural causes of off-site impacts ?
Identify the relevant causes and rank them in order of importance starting with the most important)

Table 6 Causes of off-site of water resources use

Human induced causes	Natural causes
– Soil management (improper management of the soils) – Crop and rangeland management (improper management of annual, perennial (e.g. grass), shrub and tree crops. – Deforestation and removal of natural vegetation (incl. forest fires) – Over-exploitation of vegetation for domestic use: – Overgrazing – Industrial activities and mining – Urbanisation and infrastructure development – Discharges (point contamination of surface and ground water resources, or excessive runoff in neighbouring areas) – Release of airborne pollutants (urban/ industrial activities) – Disturbance of the water cycle leading to accelerated changes in the water level of ground water aquifers, lakes and rivers – Over-abstraction / excessive withdrawal of water: (for irrigation, industry, etc.)	– Change of seasonal rainfall – Heavy/extreme rainfall (intensity and amounts) – Windstorms / dust storms – Floods – Droughts – Topography and effects on runoff, river flow regimes) – Other natural causes (landslides, volcanic eruptions, earthquakes, highly fragile/ susceptible natural resources, etc.)

– Other human induced cause (specify)	

Section 2 Interviews with Selected Households and Local Informants

2.1 Introduction and OBJECTIVES

One of the objectives of this assessment is to deliver an improved understanding of how socio-economic, cultural and institutional factors influence land-users' views and management of their land resources. The objective of the livelihoods[7] component of this manual is to deliver this understanding. There are many examples from dryland areas showing that providing land-users with technical options for more sustainable land management can be useful but it is rarely enough on its own to change behaviour significantly in the long-term.

Particularly with poor land-users in marginal areas (common in the drylands) there are many factors relating to resource and market access, institutional and policy environment (e.g. rights and tenure) and the characteristics of poverty itself that influence the perspective land-users have on his/her land resources. These factors can enhance or constrain their ability to practice sustainable land management, or land degradation control or rehabilitation, often much more than their knowledge of land degradation processes or options for "improved" management.

This part of the manual provides tools for assessing the household level "livelihoods" context within which land degradation is occurring and the extent to which land-users are attempting to address land degradation. A good livelihoods analysis should reveal the institutional and socio-economic drivers that lead to land degradation and also appropriate responses at the policy level for the different groups of land user in a community.

This analysis should be conducted with at least 20 households responsible for managing the land assessed under the detailed bio-physical assessments.

2.2 TOOLS FOR LIVELIHOODS AND KEY INFORMANT INTERVIEWS

Tool 7.1 Household livelihoods interview

Objectives
To capture livelihoods-related information that will improve LADA-L pilot countries' understanding the role socio-economic and institutional factors play in affecting the ways in which people view and manage their land resources.

Participants
Household head on his/her own or with other household members (depending on who is around/available).
An experienced facilitator to guide the discussion and a recorder from the LADA-L team.

Preparation
The interviewers should look through the questions and consider the most appropriate language to use. Particularly with technical terms, those involved in the interviews should agree on how to phrase and (if necessary) explain key expressions.

Time
One (1) hour

Questionnaire

This questionnaire aims to be short and to focus on the socio economic and institutional issues most related with sustainable resource use and land degradation in the context of LADA-L. It is important to try to capture “trends” and for this reason many questions ask about changes in time (10-20 years). Also, a single question might lead to a line of follow-up questions and discussion that uncover the full explanation for a problem or perspective on land management. Finally, it is very important that the local assessment team of each pilot country review it and add any additional questions relevant to the local context.

A form is provided at the end of this tool to facilitate recording of the findings.

1. Natural capital

It will usually be necessary to ask separately about soil, vegetation and water resources as the term “land” is likely to be interpreted by land-users as soil.

1.1 Activities: What is the seasonal calendar of different activities that household members are engaged in? (Construct a table identifying what they do by month associated with rainfall.)

1.2 Water resources: What are the main water sources (pipe, reservoir, water point, spring, well, borehole, dam)? When are they available/used? What are the water uses (drinking, livestock, irrigation)? What are the main constraints and problems linked to water resources (distances, prices, safety, and quantity)? What changes have occurred in uses, quality and access to over the last 10 years?

1.3 Land resources: How many hectares of farm land do they have? Does the household own them? If not then on what basis is it being used? (ownership, rental, share arrangement, open-access, allocation). How does this (ownership) situation change in time? Grazing land: Does the household own its grazing land(s)? If not then on what basis is it being used? (ownership, rental, share arrangement, open-access). How far is it from the home? Has this (ownership) situation changed in the last 10 years?

1.4 Household uses of each crop types?

1.5 Livestock: How many livestock do the household own (by type: cattle, sheep, goats, camels)? Have livestock numbers changed in the last 10 years?

1.6 Vegetation resources: For what activities does the household use the vegetation and forest resources? What are the main constraints and problems with vegetation resources (access, use, quality etc)? Have any of these changed in the last 10 years?

1.7 General changes in activities and practices: Has the household made changes in his/her cultivation practices/rangeland management over the last 10 years?

***2.* Land degradation**

What are the causes and impacts of land degradation in the land managed by the household? N.B important to ask not just about the immediate cause but to ask questions that get to the root cause (driving force/indirect pressure).

2.1 What is the quality of your cropping lands, grazing lands, forested lands and water resources? What are the changes/trends?

2.2 Types land degradation: soil loss by runoffs or wind, gully, loss of soil fertility, reduced amount of vegetation in the grazing lands, reduced quality of the grazing, loss of palatable species, etc

2.3 Why? What are the direct and indirect causes?

2.3 What specific impacts does land degradation (reduction of income, diminution of food production, less products to sell, reduction of construction materials, more time spend on farming/grazing/fetching water, need more inputs/fertilisers, out migration, etc) have on the household?

2.4 How have land degradation and its effects changed over the last 10 years?

2.5 Have attempts been made to control land degradation? If yes, for which reason? If no, why not?

i.e. what are the obstacles – they might be technical but more just as likely to be economic or institutional (e.g. related to land tenure, policy, markets etc.)

2.6 Is there interest in trying land degradation approaches not currently used? If yes, which ones?

3. Financial capital and production *(Income/year shouldn't be asked to respect privacy)*

3.1 How does the household earn cash? (crop and/or livestock sales, remittances, fishing, forest products, off farm activities, business, and processing food like honey/cheese)?

3.2 How much does the household rely on each one (importance of each)? Have there been significant changes in household income in the last 10 years?

3.3 What is the income used for (main things)?

3.4 Are the yields decreasing, constant or increasing over the last 10 years?

3.5 Has the use of inputs/fertilisers changed over the last 10 years?

3.6 Are they benefiting from subsidies, extension services, payments, food aids or other support (project or government), and/or using micro-credit, cooperative bank or borrowing money from relatives? If yes, why and when? Any changes in the last 10 years?

4. Vulnerability context

4.1 What crises has the household have faced (drought, food insecurity, crop failure, livestock loses, natural disaster, health problem, war/conflict, migration, indebtedness, etc.) and how have these affected the way they use soil, water, vegetation and forest resources?

4.2 Which months are the most difficult in access to food, grazing, fodder and/or water?

4.3 What have been the main changes in the landscape and living conditions over the last 10 years (trends in livelihoods)?

4.4 In his/her opinion, what are the main problems in the area? What things would they like to change or improve?

5. Physical capital

5.1 How is access to markets and service infrastructure (health centre, school, farming cooperative, water points) in terms of road networks and distances? Has there been any change in the last 10 years?

5.2 What useful service or infrastructure is missing or not accessible and why?

5.3 Does the household have access to vehicles, machinery (including farming equipment) and other goods? What are the terms of access: ownership, hire, sharing, etc. Have there been any changes in the last 10 years?

6. Policies, institutions and processes

6.1 Who controls or makes decisions about how to use or access communal natural resources (water, grazing lands, and forest)? Has there been any change in the last 10 years?

6.2 Are there any laws, rules and regulations (formal and informal) that affect how the household manages its land resources? Has this changed in the last 10 years?

7. Social capital

7.1 Do any household members belong to a local association, committee, producer association, women's group, NGO, or any social group? Since when?

7.2 What are the benefits of being part of the group(s)?

7.3 Do they have access to new information/knowledge on natural resource management and marketing of agricultural products? If yes, by who?

8. Human capital and household composition

8.1 Number of household members? Children? Migrants?

8.2 What is the educational level of the household head and children? Has he/she/they received any training?

8.3 What is the approximate age of the household head? *(Can be estimated without asking if too sensitive)*

(<20, 20-30, 30-40, 40-50, 50-60, >60)

It is important that the notes are written up as soon as possible after the interview, the same day to avoid misinterpretation.

Tool 7.2 Field Form for Household Livelihoods Analysis

1. Natural capital

1.1 Calendar of Farming/Herding Activities by Seasons in relation to Rainfalls

Activity	**Months** ***(or by seasons in local terms)***											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Rainfalls H-High L-Low N-None												

Activity codes: Cropping: 1- Land preparation, 2- Planting, 3- Growing, 4- Harvesting 5-Herding:

1.2 Type of water source available, uses, constraints and changes in the last 10 years

Water Sources	**Use/available during which months?**	**Used for** D- Drinking, I- Irrigation, L- Livestock	**Need access rights or payment** (Yes/No)	**Constraints** P-Price D- Distance S- Safety Q- Quantity	**Changes**
Borehole					
Well					
Dam/ Reservoir					
Rivers					
Pipe					
Other:					

1.3 Household land resources, terms of utilisation, and changes in the last 10 years

Household land use types	**Area of land (ha)**	**Terms of utilisation** O- Ownership R- Rental S- Share C- Communal A- Allocation	**Changes**
Cropping 1:			
Cropping 2:			
Cropping 3:			
Pastures			
Natural grazing lands			
Forest/Woodlands			

Who is responsible for forest management (natural and planted trees)?
Natural:____
Planted:____

1.4 Household uses of each crop types

Crop Types	**Crop Uses**			
	Market	**Consumption**	**Fodder**	**Other**
Hay				
Vegetables				
Fruits				
Other				

1.5 Livestock number by species, details and/or changes in the last 10 years

Animal Species	**Approximate numbers**	**Details/ Changes**
Cattle		
Goats		
Sheep		
Camel		
Other:		

1.6 Vegetation resource(s) used by the household for different activities

Activities	Resources used			
	Land	Water	Trees/Forest	Natural Vegetation
Grow crop				
Fetch water/ water animals				
Wild food				
Fuel wood				
Feed livestock				
Other:				

1.7 Main constraints, problems, changes in vegetation resources in the last 10 years

Constraints	Resources				Changes
	Land	Water	Trees/Forest	Natural Vegetation	
Access					
Use					
Quality					
Other:					

1.7 General changes in activities and practices: Has the household made changes in his/her cultivation practices/rangeland management over the last 10 years?

____
____
____
____
____

2. Land degradation

2.1 Quality assessment of the conditions of different land resources and changes

	Cropping Lands	Grazing Lands	Forested Lands	Water Resources
Quality				
Changes/Trends				

2.2, 2.3 & 2.4 Types of land degradation, causes, impacts and changes

Land degradation types/(problems)	Causes (Direct Pressures)	Root Causes (Driving forces)	Impacts (I)	Changes in last 10 years (Trend)

Examples of land degradation*: soil loss by runoffs or wind, gully, loss of soil fertility, reduced biomass in the grazing lands, reduced quality of the grazing, loss of palatable species, etc*

Example of impacts*: reduction of income, diminution of food production, fewer products to sell, reduction of construction materials, more time spent on farming/grazing/fetching water, need more inputs/fertilisers, out migration, etc*

2.5 Measures/Interventions currently used to control land degradation- sustainable land management and specific conservation /degradation control measures

SLM /conservation	What for	When	By whom	Obstacles to scale up

Potential conservation/SLM measures/interventions that are known but not currently implemented

Potential conservation/SLM measures	Obstacles to implement

3. Financial capital and production

3.1, 3.2 & 3.3 Sources and importance of each household income, their use and changes in the last 10 years

Income sources	Order of priority	Use for?	Changes
Crop production			
Livestock production			
Remittances			
Fishing			
Forest products			
Off farm employment			
Business			
Processing Food (e.g. honey, cheese, etc.)			
Other:			

3.4 & 3.5 Changes in yield, inputs and practices in the last 10 years

Crop Production	Changes (Trend)
Yield	
Fertilizers/Inputs	
Practices/Machinery	

Record yields and fertilizer uses per year if available/known by household.

3.6 Forms of aid received to support agricultural activities

Forms of aid	Why	When	By whom	Changes
Subsidies				
Extension services				
Payments				
Food aids				
Micro-credit Project/program				
Cooperative bank loan				
Borrowing money from relatives				

4. Vulnerability context

4.1 Crises faced by the household in the last 10 years, and impacts/effects on natural resources and land management

Crises	When	Impacts on Natural Resources/ Land management
Drought		
Food insecurity		
Crop failure		
Livestock losses		
Natural disaster		
Health problem		
War/conflict		
Migration		
Indebtedness		
Other:		

4.2 Period with shortage or limited/difficult access to natural resources

Shortage/Limited access	Month(s)
Food	
Grazing	
Fodder	
Water	
Other:	

4.3 Main changes in the landscape and living conditions in the last 10 years (trends)

Changes in landscape
1.____
2.____3.______
____

Changes in Livelihoods:
1.____
2.____3.______
____

4.4 Main problems in the area
1.____
2.____
3.____

5. Physical capital

5.1 Changes in services/infrastructures access in the last 10 years

Services/ Infrastructure	**Access** G- Good M- Medium P- Poor	**Distance (or time)**	**Changes**
Market			
Medical centre			
School			
Farming cooperative			
Extension/research			
Water points			
Main town/city			
Other:			

5.2 Services/infrastructures not accessible or missing and explain why

Services/ Infrastructure	**Not accessible**	**Missing**	**Why**
Market			
Medical centre			
School			
Farming cooperative			
Extension/research			
Water points			
Main town/city			
Other:			

5.3 Vehicles and farming equipment used by the household and changes in 10 years

Household's goods	**Term of access** (O-own; R rent; S share)	**Changes**
Car		
Motorcycle		
Bicycle		
Farm tools		
Tractor		
Donkey/bull/horse		
Other:		

6. Policies, institutions and processes

6.1 Decision makers who control access and use of communal resources and changes in the last 10 years

Communal Resources	Decision makers	Changes
Water		
Grazing lands		
Trees/Forests/woodlands		
Other:		

6.2 Formal and informal laws and rules affecting land/resources management and changes in the last 10 years

Laws, rules, regulations	F- Formal I-Informal	Effects on natural resources and land management	Changes

7. Social capital

7.1, 7.2 & 7.3 Household's membership of associations and benefits

Associations	Since when	Direct Benefits [1]	Access to new information [2]
Local group			
Producer associations			
Womens' groups			
NGO			
Social/religious groups			
Water committee/ users association			
Other:			

Codes for Benefits B- Borrowing money; T- Technical support; S- Share equipment; M- Micro-credit; F- Food processing facilities; T- Transport to market; A- Access to natural resources; C- Community integration; O- Other

Codes for Access to new information:: S- Seeds; C- Conservation agriculture; L- Land degradation control measures, R- Rangelands management M- Marketing; O- Other (specify)

8. Human capital and household composition

8.3 Age range of household head

Age of household head	
<20	
20-30	
30-40	
40-50	
50-60	
>60	

8.2 Composition of family members

Family	Number
Total members	
Active workers	
Children	
Migrants	

8.1 Educational level and training of family members

Family	Educational level	Training on conservation/SLM
Head		
Mother		
Children		

Tool 8 Key informant interviews on LD/SLM

Results emerging from the community focus group discussion, household livelihoods interviews and other parts of the assessment should be used by the team to cross-check or discuss further with specific individuals using key informants interviews. These need to be flexible and the questions posed according to the issues requiring further discussion.

In particular, it will be important at some point to discuss aspects of sustainable land management with land users and with officials from land and forestry offices. These individuals may offer plausible explanations for particular observations or behaviour. The team should decide on the local resource persons/informants who should be interviewed through semi-structured interviews during the assessment. An example of how such an interview could be structured is provided below

To conduct with land users and community key informants along the transect walk in order to understand the reasons why land users do not invest to maintain land productivity and ecosystem services.

1. How is the quality of the soil, vegetation and water resources?

2. Have you experienced any change, lower yields, change in grazing species composition?

3. What is done to remedy this/these change(s)? What are the methods used to improve soil fertility, to reduce erosion? Have you adopted new practices and/or changed your management patterns?

If Yes:
4. Is the measure used is to prevent, reduce degradation or rehabilitate degraded lands?
5. Who introduced the practice? (land user, extension officer, project)
6. What is the effectiveness of the new/traditional practices? (+, neutral or –)
7. Is the practice labour demanding or costly to implement? Does it need special material, expertise or maintenance?
7. What is the % of farmers and/or herders using these practices?
8. What are the advantages and disadvantages or the practice?

If no:

10. What are the constraints that impede adoption of sustainable land management practices/conservation measures? e.g. Insecurity of tenure, seasonal migration, land shortage, lack of capital, labour unavailability.

Identify the sustainable land management practices implemented by land users to maintain land productivity and ecosystem services, using Table 7

Table 7 Sustainable Land Management Practices

Land Degradation Problem	Sustainable Land Management Practice	Conservation effectiveness +, neutral or -	Benefits of SLM practice	Utilization by land users in the geographical assessment area %	Constraints to Adoption

Constraints: No perception of land degradation
No incentives to adopt SLM practices (e.g. insecurity of tenure, seasonal migration, etc)
No capability to remedy (e.g. land shortage, labour unavailability, lack of capital)

Section 3 Selection and detailed assessments of sites

3.1 SELECTING SITES FOR DETAILED ASSESSMENT

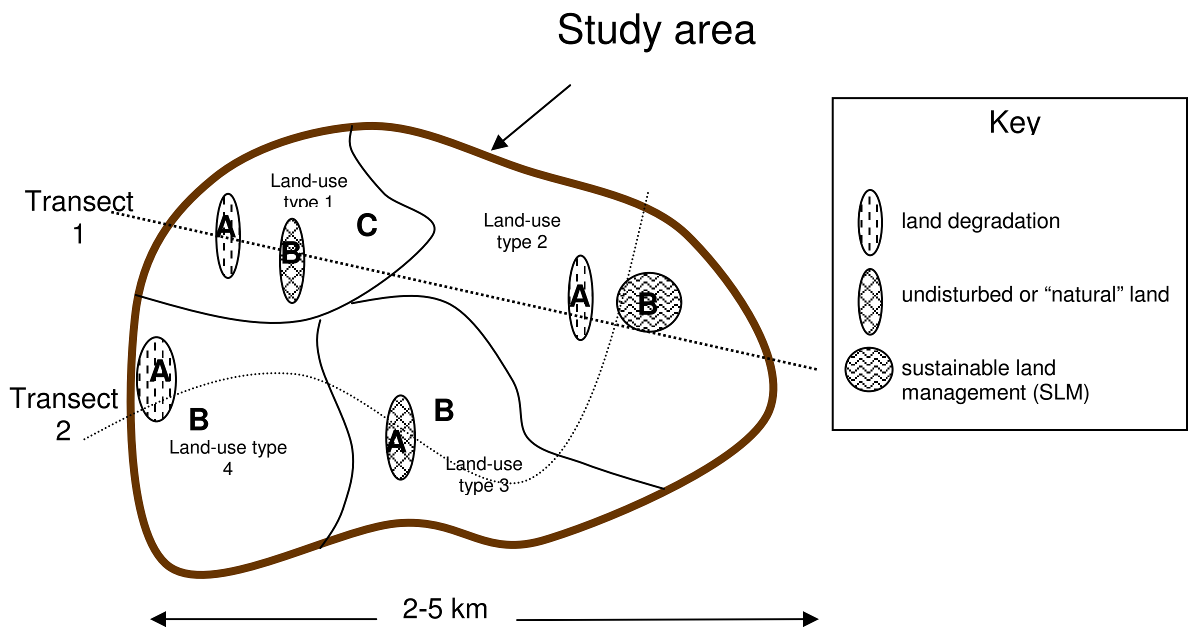
The transects (Tool 3 and Fig 2 above) conducted as part of the characterization activity in combination with the information obtained from the community group discussion are recommended as the main tools for identifying sites/plots for the detailed biophysical and socio-economic assessments described in the following sections of this manual. The importance of comparative sampling has been stressed, typically each sampling site will consist of:

- two or more plots (i.e. fields areas of rangeland) for comparative assessments of above ground indicators of vegetation cover, health and composition, land degradation, soil quality and productivity
- the household(s) responsible for managing these plots.

Some examples of useful comparisons that might be made are:

- side by side comparisons of plots where there is visible land degradation in one but not in the other;
- side by side comparisons of plots with differences in conservation/restoration measures/management practices (e.g. grazed vs non-grazed; no till vs conventional cultivation) that impact on LD/SLM;
- untouched (natural) areas compared with areas under some form or land-use and/or suffering from land degradation (e.g. cultivated field vs adjoining tree line);
- a comparison of agricultural ground with relatively “untouched” adjoining tree or fence lines;

It is important to select plots that are relatively close to each other if valid comparisons are to be made, as sites far apart may differ in soil type and other qualities that will affect susceptibility of the land to degradation and the impact of the degradation on measured properties.



N.B.
t need to be a straight line. They are used to verify features discussed in the
ın and to identify sites for detailed assessments, not as quantitatively robust

ɘ heart of the sampling strategy. Detailed assessments are conducted in areas of
ırbed or “natural” land and the results from these are compared. e.g. A, B and C
ɟ-use type 1, A and B are compares in land-use type 2 etc.

Figure 4 (same as Figure 2) Hypothetical study area marked with two transects cutting across the main LUTs and land units and representative areas showing land degradation and SLM

Figure 4 represents a hypothetical study area and some possible sampling scenarios using this methodology . The study area has been selected because it is representative of the LUS and it contains 4 different LUTs. In the area under LUT 1 it is possible to find severe land degradation (A) close to an area where the status of the land resources can be described as undisturbed or “natural“ (B). A and B are both within a larger area of normal land use (i.e. not particularly degraded: the usual situation in the area). In LUT 1 it would be useful to conduct assessments in A, B and C as comparisons between all of these are meaningful. In area B the vegetation and soil resources are close to their original condition. The B/C comparison gives an impression of the change in these resources caused by the prevailing land-use since the land-use began. The A/C and A/B comparisons will reveal the extent of any additional change in these resources caused by the observed land degradation. This clustered sampling approach relying on comparison is a type of “spatial analogue” sampling[8].

Similar comparisons are possible within the other LUTs.

[8] This is a type of “spatial analogue” method. It may not be relevant everywhere (e.g. some areas are under natural vegetation because they are inherently different: infertile or shallow soil etc) but can be useful in giving an integrated estimate of the impact of land-use on the land resources over the period since the land was first used.

N.B. Depending on what is being assessed there should be some replication of the detailed measurements made at each site. i.e. the soil, vegetation etc. should be characterised in at least 2-3 sites within each of A, B and C. With some indicators replication will be more difficult but effort should be made to carry it out wherever possible.

Thus, the total number of samples in the study area illustrated in Figure 2 will be at least 24 plots for biophysical assessment. The livelihoods interviews should conducted with as many as possible of those responsible for managing these assessed sites – perhaps 6-8 individuals in this case, though numbers will vary. If there is need for more replication or the study area is particularly complex requiring many LUTs and different forms of LD/SLM then the sample number will increase.

Once the field/plot locations and the land-users have been identified the characterization and detailed assessment can begin.

The following sections of the manual provide the tools and methods for assessment of soil erosion, vegetation, water and production constraints. This is the main section where the biophysical state (in DPSIR language) of the land resources are assessed.

3.2 SITE DESCRIPTION AND HISTORY

This section collects descriptive information on the sites (fields/plots) that will be subjected to the detailed assessments. As there will often be two or possibly more sites managed by a particular land-user it is important to collect separate information for each.

Depending on the location and the LUT the sites may be arable fields, areas under pasture or perhaps under shrub or woodland (e.g. if these locations are important for livestock grazing).

Two tools are provided:

Tool 9: Interview with land-user
Tool 10: Site photo and or sketch

Tool 9 Interview with land-user

It is important to understand the characteristics, management and environmental history of the sample sites. Discussions with farmer/advisor/local expert are most important. The best location for this interview is in the field, next to the plots/sites of interest.

RECORD all possible information as this is the basis of interpreting subsequent observations and measurements.

These include items of management and environmental history, past information and trends over the last 5 -10 years and current information (not all factors are relevant depending on land use):

- land uses changes (ha) - increase/decrease in crop, pasture, range, forest, other
- livestock grazing system (seasons, free/tethered/fenced/kraaled),
- access rights (owner, communal area, lease, etc)
- pasture improvements (seeding, removal invasive species etc)
- forest (type, health, yield - above or below expectations)
- crops (type, health, yield - above or below expectations)
- land preparation/tillage: type, direction and depths
- power: hand, animal, tractor (size)
- presence of minimum or no till (and for how many years/seasons)
- crop residues (kept in field, removed – partially or totally, etc)
- fertilization (and response to) – organic (includes manures) and mineral
- other soil ameliorants applied, for example lime, gypsum
- land levelling (and if in specific areas of the site)
- rainfall (recent and historical), for example “very wet at last harvest”
- water for domestic and agricultural use:
    - Are additional water resources besides rainfall used (rivers, streams, boreholes, etc.)?
    - Are there problems with availability of water, flooding, water quality?
    - Are there difficulties in accessing water (perhaps prohibited by rules or laws or ownership issues)?
- Have there been changes (in the last 1, 5, 10 years) in quality, quantity, access?
- attempts at introducing “best” or altered practices
- land degradation observations – location, type, history, apparent causes

This is a “check-list” rather than a fixed list of questions. Ask additional questions and/or explore additional areas if raised during discussion and relevant. It is important to probe on trends and changes when appropriate e.g. changes in land degradation and people’s perceptions of its effects or the extent to which land-users engage with conservation/SLM.

N.B. Although the objective of this interview is to provide contextual and management information to accompany the land degradation assessment it is important that the household livelihoods interview (Tool 7) builds on this interview and does not duplicate it. Ideally, therefore, the record of this interview should be available to those carrying out the livelihoods interview and at least one member of the LADA-L team should be involved in both.

Tool 10 Site photo and sketch

This is required as it is important to get an overview of and record the environmental and management context in which the land degradation is being assessed and the juxtaposition of the various degradations and susbsequent observation/measurement locations. There are several advantages from doing this with the land-user:

- it is a good “ice-breaker” and engages the land-user in a positive way;
- it immediately identifies and records the land units recognized by the farmer, distinguished by biophysical type or land use;
- it provides a baseline from which to identify the precise locations of subsequent measures/observations of such things as vegetation types, soil quality (where the holes were dug), etc.

Site photographs are recommended: eg record the landscape across the site as well as the soil surface (looking down from above – i.e. from head-height). Sketches made by the land-user in discussion with the LADA-L personnel are also very useful as they provide valuable information on the perspective of the land-user on their land. The areas on the site sketch need only be approximate. The most important aspects to include are:

- the spatial arrangement of the site and differentiated land units within the area;
- features of the land unit with the homestead, roads, rivers, fences and other important resources (e.g. forest, wetland);
- observations on key biophysical aspects such as slope, soil, rocks, water features, conservation features
- land degradation features and prominent indicators such as gullies, soil crusting, crops suffering severe nutrient deficiency, area of burned pasture/forest land etc.
- an initial record of the land user’s assessment of limitations of each land units and how this has changed over time.

An example of a site sketch map of an arable area is provided in Figure 5.

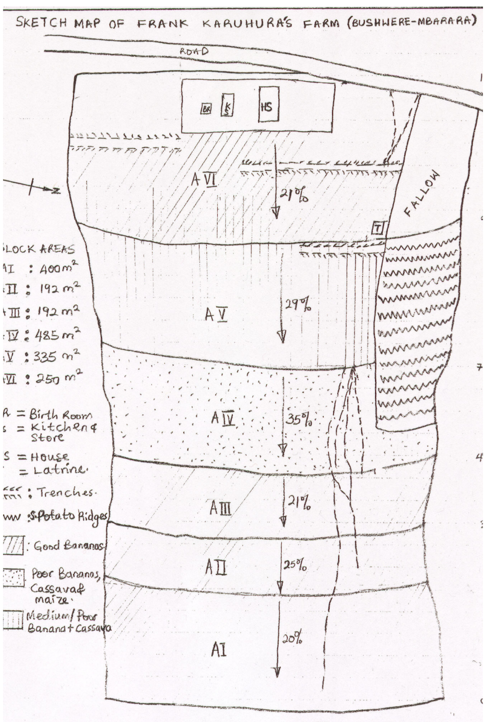


Figure 5. Sketch map of a farm in Bushwere, Uganda. (M.A. Stocking)

The site sketch map should be used to identify the sites for sampling soil and conducting the below ground soil quality assessments. Sample sites should be marked on this map and their location recorded by GPS.

3.3 DETAILED ASSESSMENT OF SOIL EROSION

The detailed assessment of soil erosion is conducted in each of the detailed assessment sites by repeating the use of tool 5 used for the study area characterisation and where possible through the use of comparative (adjoining) plots using the following tools:

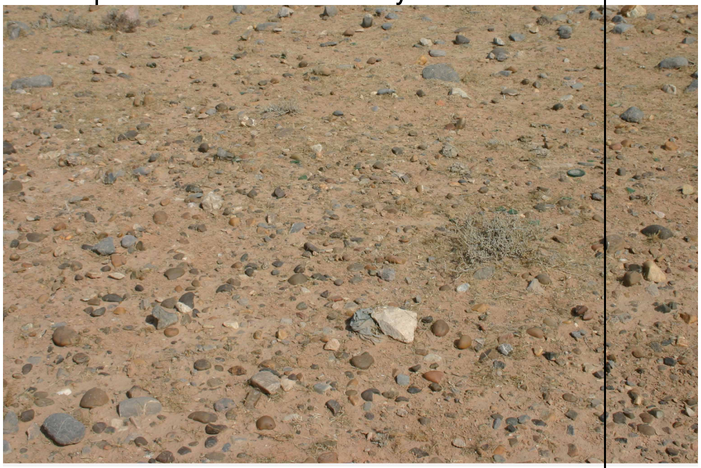
- **Tool 11.1** Soil erosion validation using Qualitative Visual Indicators
- **Tool 11.2** Support Tools for Assessing the Severity of Water and Wind Erosion
  - **11.2.1** Measuring Plant/Tree Root Exposure
  - **11.2.2** Measuring a Tree Mound
  - **11.2.3** Measuring the Armour Layer
  - **11.2.4** Measuring Soil/Sand Build Up Against Barriers
  - **11.2.5** Assessing the Selective Removal and Redistribution of Fines (Enrichment Ratio)
  - **11.2.6** Assessing Reduction in Soil Depth Due to Erosion

Tool 11.1 Soil erosion validation using visual indicators on detailed assessment sites

During the transect walks, a qualitative estimate of the state and severity of erosion is conducted (see Tool 5) in each of the identified land use types, reflecting land use - cropland, grassland, forest /woodland - and changes in management practices and in biophysical features (land units). These same visual erosion indicators are further validated on each of the selected sites for detailed investigations alongside the assessments of soil, vegetation degradation and effects on productivity. Figure 6 shows some common erosion features.

Figure 6 Photos and sketches showing different types of erosion

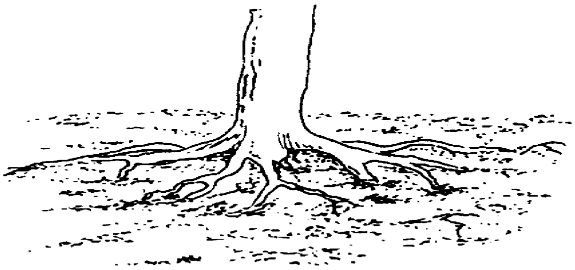
Development of an Armour Layer



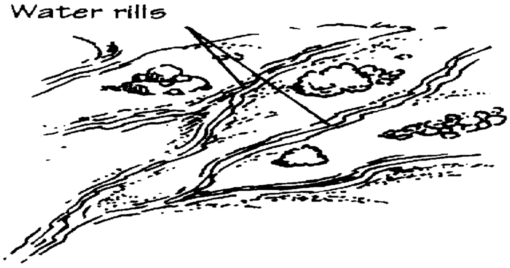
Accumulation of coarse stony material on the soil surface due to the selective removal of the finer particles by a combination of water and wind erosion.

Wind Scouring

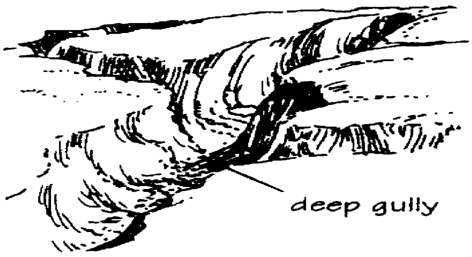
Localised scouring of the topsoil as a result of wind erosion



SHEET EROSION



RILL EROSION



GULLY EROSION

(Source Vukasin et al. 1995)

Tool 11.2 Support Tools for Assessing the Severity of Water and Wind Erosion

A number of measurements can also be made to estimate the severity and rate of soil erosion by water and wind, see tools 11.2.1 to 11.2.6 below. These have been selected (from Stocking and Murnaghan, 2001) as being the most appropriate for a rapid assessment.

Tool 11.2.1 Measuring plant/tree root exposure

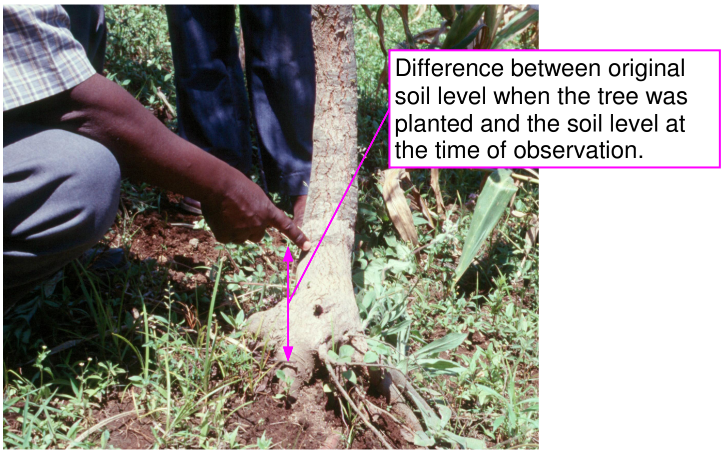


Figure 7 Tree root exposure, Vietnam

Indicator: The presence of exposed roots can therefore be used as an indicator for assessing the extent and severity of soil loss.

Process: When soil particles are removed by water or wind, the roots of trees, and other plants, may become exposed as erosion lowers the overall soil level.

Method: Close inspection of the lower portion of the tree trunk or plant stem may reveal a mark indicating the level of the original soil surface. By measuring the vertical difference between this mark and the present soil surface an estimate can be made as to how much soil has been lost[9] (Figure 7). In the case of lateral roots away from the stem, the upper surface of the most exposed roots is usually taken as the former soil surface. In the case of an annual crop this will provide an estimate of how much has been lost within one growing season. For perennial crops and plantations/woodlots the soil loss estimate would cover the period from when the crop/tree was planted. In areas of degraded natural vegetation it may not be so easy to relate the measured soil loss to a particular number of years, however, interviews with local land users may reveal the approximate date when soil erosion was first observed to be taking place.

Estimating the average soil loss: Where root exposure is evident at different places in the field, a number of measurements should be taken to assess the average soil loss. However, given that there may not be sufficient standing plants/trees in a particular field this may not always be possible. In which case an average estimated soil loss will need to be extrapolated from those sites where measurements can be taken. The figures should also be cross checked with other erosion indicators to determine, whether the estimated soil loss is realistic.

[9] 1 mm of soil loss is equivalent to 13 t/ha where the bulk density is 1.3 g/cm^3 (Stocking & Murnaghan 2001).

Caution and common sense should be used when basing the extent and severity of soil loss on root exposure alone, as:

- Differences in root exposure may reflect different erosion processes (for example, stem-flow and rain-splash) occurring in the same field.
- Roots and stems may act as an obstacle to runoff and may cause channelling of erosive water flows, thus increasing the soil loss around the obstacle, or it may slow down the surface flow, allowing deposition to occur. Likewise they may trap and allow the accumulation of windblown material. Therefore, extrapolated soil losses, calculated solely by reference to plant/tree root exposure, may be either overstated or understated.
- Some plants have a tendency to heave themselves out of the ground as they grow, thereby giving a spurious impression of high soil loss. This effect is often indicated in stony soils, especially where larger platy fragments occur. Look for evidence in the alignment of stones as tree growth may force a rearrangement of stones so that they become tilted, with the raised end nearest to the trunk. The aerial roots of maize plants can also be deceptive.
- Tree roots may expand in diameter as the tree grows, so roots running parallel to the soil surface may rise to/above soil level, giving the impression that there has been more erosion than there has been.

Tool 11.2.2 Measuring a tree mound

Indicator: Tree mounds can be used as another visual indicator of the occurrence and severity of sheet erosion. They refer to the situation where the soil under a tree canopy is at a higher level than the soil in the surrounding area. A tree mound has approximately the same diameter and shape as the overhanging tree canopy (Figures 8a and 8b).

Process: If tree mounds are present then this can be taken as an indication that there has been more erosion away from the tree than near it, the surface of the mound representing an earlier soil level. The assumption is that the erosive impact of the raindrops has been absorbed by the tree canopy, with the eroding power of the raindrops having been reduced before they reach the ground surface, with consequently less soil being dislodged. In contrast, soil unprotected by a tree canopy is subject to the full force of the raindrops, so that soil particles are dislodged (splash erosion) and are transported downslope in runoff (sheet erosion). Tree mounds therefore occur where a tree provides good, continuous, protection to the ground surface. The tool was originally developed for estimating erosion rates in Kenya in a semi-arid zone characterised by extensive gently sloping plains, with occasional trees dotting the landscape, notably the ant-gall Acacia (*A. drepanalobium*).

Method: Measurements involve comparing the level of the soil surface under the tree with the level in the open. The difference in height between the soil surface under the tree and in the surrounding area provides a proxy indicator of the amount of soil loss that has occurred during the life of the tree (the life of the tree being estimated by talking with local key informants). It is recommended that such measurements are recorded for a range of trees of different sizes and ages. The estimated erosion rates can then be grouped according to bands of progressively older time periods to see if there is any difference in calculated average erosion rate. Typically, in the East African case, the longer the time period, the lower was the average annual erosion rate. This suggested that annual erosion rates have increased in recent historical times as grazing pressures have increased.

Caution and common sense should be used when basing the extent and severity of soil loss on tree mounds alone, as:

- Mounds around the base of trees, shrubs and other plants may have been caused by factors other than erosion. For example, termite mounds are commonly found around trees and shrubs. In addition, the trunks of trees may act as a barrier to the transport of sediment resulting in deposition. Organic matter may build up under trees, especially where leaf litter accumulates or livestock shelter.
- Some trees may lift the soil around them as they grow, thus giving natural mounds and an appearance of higher levels of soil loss than may actually exist.
- Because the tree canopy size changes as the tree grows, the tree mound will not be at a constant height above the level of the surrounding soil. Thus, it is important to take measurements at different points from the edge of the mound towards the tree trunk.
- Wind-borne sediment can be slowed or trapped by trees and shrubs, falling to the ground surface underneath the leaf canopy. Such material increases the difference between the surface beneath the tree and beyond but it bears no relation to the original soil level and may have been transported from far off.

Figure 8a: Tree mounds

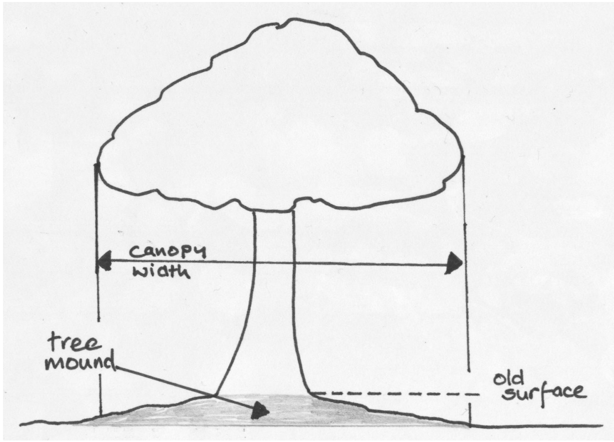


Figure 8b Sketch of tree mound

Tool 11.2.3 Measuring the Armour Layer

Indicator: An armour layer is the concentration, at the soil surface, of coarser soil particles that would ordinarily be randomly distributed throughout the topsoil (Figures 9a and 9b).

Process: Such a concentration of coarse material usually indicates that finer soil particles have been selectively removed by erosion. Raindrops or the power of the wind detach the finer and more easily eroded soil particles. Then water or wind carries them away from the topsoil surface, leaving behind the coarser particles.

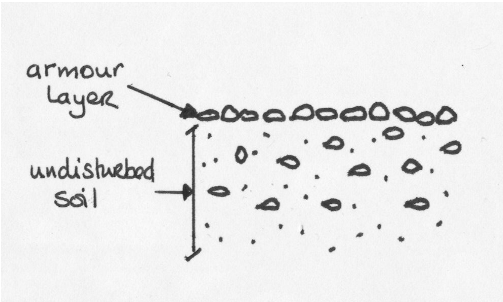


Figure 9a. Sketch of armour layer

Figure 9b Measuring armour layer using a ruler, Sri Lanka

Method: The armour layer can be measured by digging a small hole to reveal the depth of the coarse top layer. Several measurements at different places in the field should be made in order to calculate the average depth of the armour layer. The approximate proportion of stones/coarse particles in the topsoil below the armour layer is 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 that have been lost through erosion can then be estimated.

Potential for Error:

- Stones on the surface may arise for other reasons, such as the exhumation of a concentration of stones in the subsurface soil.
- As well as the erosion process itself, repeated shallow tilling of the soil, especially in weeding operations, may concentrate more stones near the surface

Tool 11.2.4 Measuring Build Up Against Barriers

Indicator: The build up of eroded material against a barrier is a measure of the movement of soil across the field rather than loss from the field.

Process: Where the transport of eroded material is halted by an obstruction, the particles suspended in the runoff may be deposited against the obstruction as the water slows. This results in a build up of sediment against the barrier.

Method: The volume of soil trapped behind the barrier can be calculated by measuring the depth of the soil deposited and the area over which it is deposited. Where the build up is against a continuous barrier such as a fence or hedge the measurement will give an approximation of soil loss from the field.

Figure 10 Build up of soil behind a Gliricidia hedge, Sri Lanka

Estimating soil erosion: The amount of soil accumulated behind a barrier represents a build-up over time. The annual rate of soil loss from a hillside can be arrived at by dividing the quantity of accumulated soil by the number of years that a barrier has been in existence.

Potential for Error:

- The calculations do not differentiate between sediment that results from in-field erosion and sediment that results from erosion further upslope and outside the immediate field, which may lead to an overestimation of the soil loss per field.
- Not all materials transported in runoff will be deposited at a barrier. The speed, volume and direction of runoff all influence the level of deposition. Therefore, the estimated soil loss may be understated by the amount of soil carried beyond the barrier.
- Tillage techniques may increase the soil depth behind barriers, particularly where conservation techniques such as terracing have been introduced to lessen the effect of slope. This tillage erosion is also called 'plough' erosion, because farmers often scrape soil downhill when they cultivate.
- If the slope was convex before the barrier was constructed, the estimate of soil loss will be understated as it assumes a linear slope.

Tool 11.2.5 Assessing the selective removal and redistribution of fines

Indicator: Comparison between the higher levels of nutrients to be found in the areas where the fines are deposited, and the nutrients in the area from which they have been eroded, is referred to as the enrichment ratio.

Process: Wind and water erosion can selectively remove the finer soil particles and lighter organic matter, both of which contain relatively higher levels of nutrients than the coarser mineral deposits left behind. The effect of this selective erosion process is to progressively reduce the inherent fertility of the remaining soil. When the finer particles are deposited downstream or downwind then they will enrich the location in which they settle. This may just be a local redistribution within the same field, for instance where sediments are trapped by cross slope barriers or against field boundaries, or transported further and accumulate in drains, valley floors, local reservoirs and ultimately the sea.

Method: This type of erosion is normally assessed by measuring the quantity of nutrients found in the deposited sediment and comparing this to the quantity in the original soil from which the material was eroded. For the purposes of making a quick field assessment the proportions of finer soil particles can be used as a proxy measure, as these are closely related to nutrient levels and in themselves are also good variables for assessment of enrichment. This involves taking equal quantities of soil from the eroded and the depositional locations, and visually observing them in the palm of the hand so as to estimate the proportion of coarse material to fine material in both samples. This should be repeated a number of times.

Estimating the redistribution of fines also known as the enrichment ratio. The average percentage of fine materials in both the enriched soil and the eroded soil should then be calculated. The enrichment ratio is the ratio comparing the percentage of fine particles in the enriched soil, to the percentage of fine particles in the eroded soil. It should also be possible to quickly identify by hand texturing the different samples whether the selective removal and subsequent deposition of fines is taking place within a field.

Tool 11.2.6 Assessing Reduction in Soil Depth Due to Erosion

Indicator: Estimating the reduction in soil depth due to soil erosion

Process: Soil depth is the vertical depth of soil from the surface down to weathered rock, or other impermeable barrier such as a stone-line or hardpan. The depth of soil material above weathered rock is a product of climate, which determines the rate of chemical breakdown of rocks, and the type of rock. Some rocks break down more quickly than others. The specific depth at any one site is determined by the balance between natural forces of removal of topsoil (sometimes called geological erosion – occurs at a rate of less than 1 tonne/ha/year) and the formation of new soil in the subsurface. The faster the rate of weathering and the more susceptible the rocks are to breakdown, the deeper is the soil. Deep soils are not necessarily more fertile, because they may contain layers of highly weathered and nutrient-deficient clays.

Accelerated erosion due to human activities can be expected to reduce the overall soil depth as soil will be lost at the surface at a faster rate than it can be created from the weathering of the rock. In areas where soil depth is naturally no more than 0.75-1.00 metre in depth any significant reduction in soil depth due to erosion will have severe consequences for plant growth (due to reduced rooting depth) and therefore levels of production within the affected croplands, rangelands or woodlands.

Method: In assessing the extent to which soil depth has been reduced by soil erosion, the ideal situation is to be able to compare the soil profile in an area where there has been little, or no, soil erosion with the soil profile in an area of the same soil type where erosion is taking place. The aim is to determine the typical depth, colour, texture and structure for each of the topsoil (A), upper subsoil (B) and lower subsoil (C) horizons for the non eroded soil profile, and to compare these with the profile in the eroded area. The depth, colour and texture of each horizon can be quickly sampled for a number of locations using a soil auger. These should be complemented with the occasional soil pit in which the structure can also be more easily assessed. The main purpose of this exercise is to assess how much of the topsoil has been lost (ie. the comparative reduction in depth of the topsoil (A) horizon). In the most severe cases the original topsoil (A) horizon may have been completely removed so that what is currently the topsoil is derived from the exposed subsoil (B and in extreme cases C) horizon. Loss of topsoil is the most critical aspect associated with the reduction in soil depth due to erosion, as this is where most of the available plant nutrients and organic matter are located. Visual inspection of the colour, texture and structure of the soil at the surface will reveal the extent to which the subsoil has been exposed by erosion. Due to its lower organic matter content the subsoil is usually paler in colour than the topsoil, and except in the case of sandy soils, will usually be slightly heavier in texture and often exhibit some difference in structure.

3.4 ASSESSING SOIL PROPERTIES

The tools in this section are taken from the VS-Fast methodology (McGarry, 2007) and selected VSA methods of Shepherd (2000). Emphasis with VS-Fast is on the assessment, both tactile/qualified and quantified, of soil physical condition conducted during field visits. The critical set of indicators used are robust yet rapid approaches to measuring soil characteristics. The measures are designed to be reproducible and quickly learned. Additionally, as they are field methods they provide immediate indications of soil quality, quickly interpretable for farmers and land owners present during testing. They are included in this methodology as they generate quantitative data on soil quality and condition, and provide guidelines for scoring and ranking the results to enable comparisons between soil at the detailed assessment sites. A core set of indicators are proposed in this section, assessing the following soil characteristics:

- basic descriptive information on the soil sample (depth, texture, structure, colour, layering)
- aggregate size distribution
- soil crust
- tillage and other pans
- biota (particularly earthworms and roots)
- slaking and dispersion
- pH
- water infiltration
- organic carbon
- soil and water salinity

Scoring

Guidelines are provided for scoring each of these and weighting/integrating the scorings into two measures of soil quality, one based on visual observations (Tool 12.1) and the other based on the soil measurements (Tool 12.2). Score-cards for recording the VS-fast information and data from Tools 12.1 and 12.2 are included at the end of section 3.4.

For consistency and comparability it is important to conduct the complete set of core measurements at all selected detailed assessment sites. If not then the scores cannot be combined to give the integrated scores of quality. Additional measurements can be taken and other indicators used to assess the soil where appropriate or preferred locally.

SITE SELECTION

The procedures for selecting and describing the sites for detailed assessment have been outlined in the above sections. The following observations and measurements are based on the examination of an excavated spade-ful of soil at a site selected for detailed assessment.

Spade technique, hole size and depth

A spade with a flat (though usually slightly curved) blade is used to remove an intact “block” of soil, commonly up to 30 or 40 cm deep and 25 cm wide from the site under investigation. The soil is left on the blade of the spade for subsequent observations. The spade, with the block of soil on the blade, is commonly “propped-up” on a rock or against a car or fence for description, sketch or photograph. A photograph is recommended.

The soil zones of greatest interest in terms of VS-Fast occur from the soil surface to approximately 40 cm depth. This represents the most important zone for seedbed development, early germination and plant growth, as well as being the zone with the greatest potential for negative impacts on water infiltration, soil carbon losses, etc from soil compaction and erosion (both wind and water).

TOOL 12.1 SOIL VISUAL INDICATORS

Seven visual indicators of soil quality, determined on the excavated soil block with supporting information from the soil surface around the excavated pit, are recommended for the core LADA-L assessment.

- **Soil depths**
- **Texture**
- **Structure (tillage pan, aggregate size distribution)**
- **Surface crusts**
- **Colour**
- **Earthworms (and other biota)**
- **Roots**

With the exceptions of soil depth, texture and colour, guidelines are provided for the scoring of each of these and the integration of these scorings into a soil quality assessment.

Soil depths

Firstly, using a measuring tape, ruler or stick graduated in centimetres, assess and measure the location of any visible soil layers; in terms of colour, soil structure (see below), root density, etc.

RECORD these depths. A sketch of the soil profile, annotated with depth and principal soil features is recommended.

Texture

Soil texture refers to the relative proportions of sand, silt and clay size particles in a sample of soil.

- Clay size particles are the smallest being less than 0.002 mm in size.
- Silt is a medium size particle being between 0.002 and 0.05 mm in size.
- The largest particle is sand with diameters between 0.05 and 2.00 mm; commonly divided into fine sand (0.05– 0.5 mm) coarse sand (0.5 – 2.00 mm)

Texture has important effects on a wide variety of soil properties, e.g. soil's water holding capacity, aeration and porosity, hydraulic conductivity, compaction potential, resistance to root penetration, nutrient holding capacity (i.e. cation exchange capacity) and resistance to acidification.

Soils that are dominated by clay are called fine textured soils while those dominated by larger particles are referred to as coarse textured soils. Soil scientists group soil textures into soil texture classes (Fig. 11).

Field method:
Texture can be determined in the field by taking one or two table-spoonfuls of soil (from a soil layer of interest) in one hand and adding water, drop by drop, to the soil as it is being worked in the hand until a sticky consistency is reached. The soil is then rolled into a ball and texture determined, through ability to form various shapes from the rolled ball (see Table 8 and Fig. 12).

RECORD the texture class determined, on the field sheet

Fig. 11 Soil texture diagram showing the % of sand, silt and clay in the textural classes

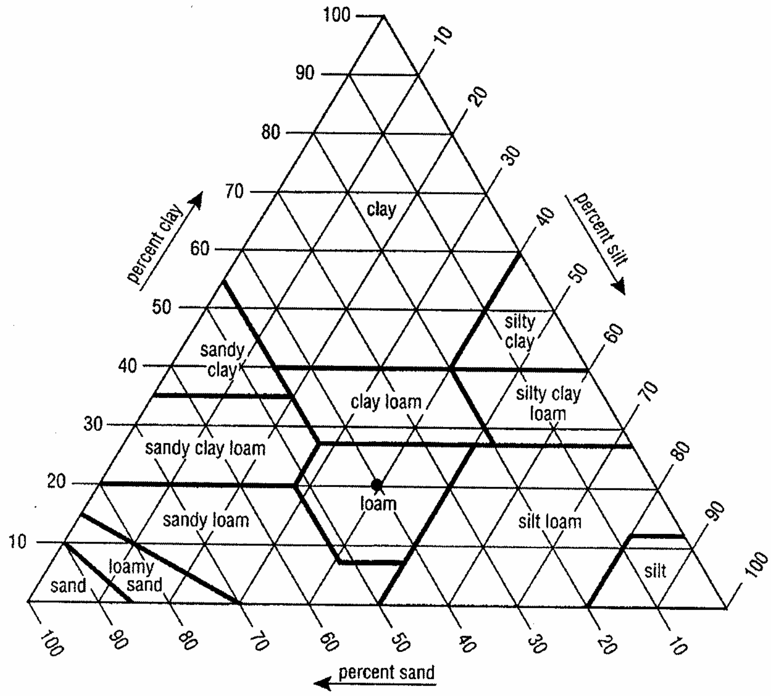
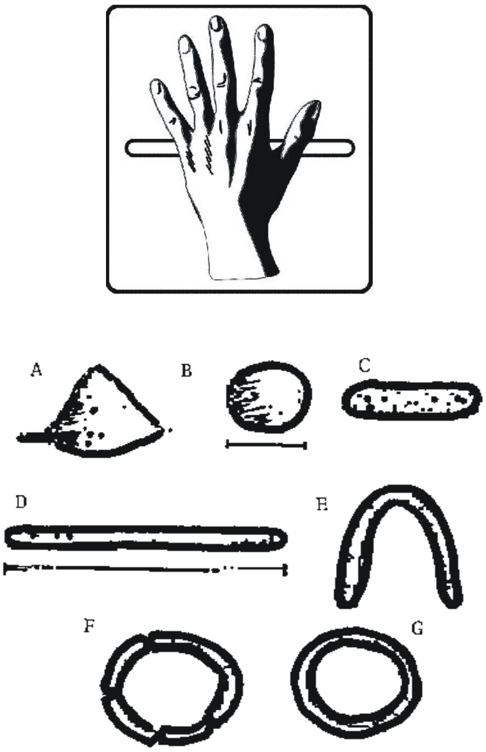


Table 8 To determine the textural class of the soil compare it to the table below and refer to Fig. 12. Source: Rural Development in the Tropics and Subtropics (1989).

Sandy	The soil stays loose and separated, and can be accumulated only in the form of a pyramid	**Figure A**
Sandy Loam	The soil contains enough silt and clay to become sticky, and can be given the shape of an easy - to - take - apart ball.	**Figure B**
Silty Loam	Similar to the sandy loam, but the soil can be shaped rolling it with a small and short cylinder.	**Figure C**
Loam	Contains almost the same amount of sand, silt and clay. Can be rolled with a 6" long (approximately) cylinder that breaks when bends.	**Figure D**
Clayey Loamy	Similar to the loamy, although this one can be bent and be given a U shape (without forcing it) and does not break.	**Figure E**
Fine Clay	The soil can be given the shape of a circle, but shows some cracks.	**Figure F**
Heavy Clay	The soil can be shaped as a circle, without showing any crack.	**Figure G**

Fig.12 The point at which the soil becomes malleable and can be hand-shaped, indicates its texture (use in conjunction with Table 1). Source: Rural Development in the Tropics and Subtropics (1989).



Structure

In the VS-Fast system, the description of soil structure focuses on each of: (a) the presence of “pans” in the soil; these being platy and massive, continuous, horizontal layers; and the (b) description of the size and shape of the soil units, present in the excavated cube of soil and exposed for description by manipulating the cube of soil to facilitate breakages along natural lines of weakness.

a. Tillage and other soil pans
Tillage pans (formed by plough or hoe) and other forms of pans are important negative indicators of soil condition as well as being symptomatic of non-sustainable land management practices. Soil pans are located and described by comparing the lower and upper parts of the excavated spadeful of soil. As an example, the upper layer may be small to medium granular structure, overlying a tillage pan, where the structure is clearly compacted, massive, smeared or "platy" (like large dinner plates).

Tillage pans only occur in cultivated land, either from metal implements working soil or repeated trafficking by tractors; both giving the worst compaction (tillage pan) when conducted in moist to wet soil.

Other types of "pans" can be found in each of grazing and fodder producing lands (e.g. growing perennial grass swards). In these situations the "pan" is commonly on the immediate soil surface, resulting either from surface "trampling" by animal feet (particularly if animals were present in large numbers in moist to wet soil conditions) or from repeated passes of harvesters and balers, cutting and packing animal fodder; again worsened by random (criss-crossing) traffic in moist to wet soil conditions.

RECORD the presence, thickness and degree of development of any pan

Scoring[10] (after Shepherd 2000):

- Good condition (score = **2**): no tillage pan (or any other type of pan), with friable structure and soil pores from topsoil to subsoil
- Moderate condition (score = **1**): firm, moderately developed tillage pan in the lower topsoil (or upper subsoil), or surface pan from animals or repeated traffic. The pan is clearly platy or massive but contains one or more of: areas of better soil structure recorded above or below the pan, cracks or continuous pores through the pan.
- Poor condition (score = **0**): a well developed tillage pan in the lower topsoil (or upper subsoil), or surface pan from animals or repeated traffic. The pan has massive or platy structure with firm to extremely firm consistency and very few or no vertical cracks or pores through the pan.

b. Aggregate size distribution
In order to bring some uniformity to the method of manipulating the soil (on the spade) and to get it to break along natural cleavage planes, Shepherd (2000) has further developed the "drop-shatter" test. In this, a spadeful of soil is dropped three times from a uniform height either onto a plastic sheet (lying on the ground) or into a rectangular shaped "washing-up" basin. If the soil does not completely shatter into individual units, then gentle hand manipulation is used to break the soil along natural breakage lines. Once the soil is broken into its individual aggregates, these are sorted so that the largest are placed at the top and the smallest at the bottom (Fig. 13).

As such, this is a field method of aggregate size distribution. Degraded soil tends to have a greater proportion of coarse and firm structure units than a well structured soil (Fig.13).

[10] Note: that scores in the VS-Fast system are usually 0, 1 and 2, from poor to good. It is possible to score in 0.5 increments where a recorded soil attribute fits between or has components of two scoring classes

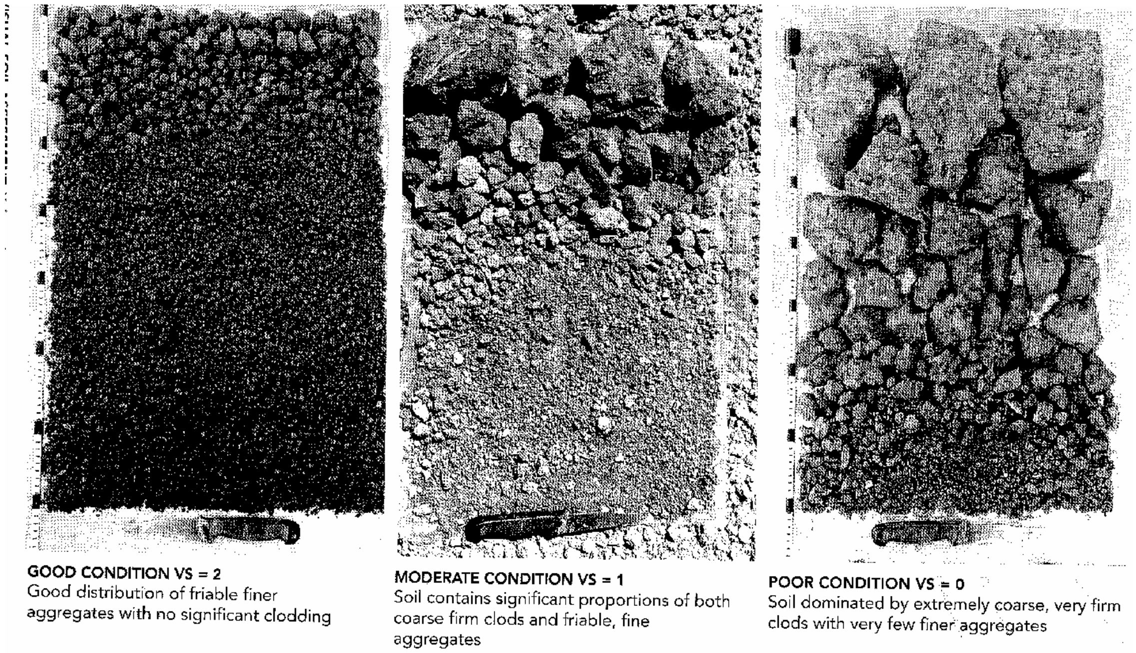


Figure 13. Examples of (left) finely structured soil and (right) coarsely aggregated soils; differentiated using the “drop-shatter” test with subsequent arrangement into coarse – fine aggregate size distribution (from Shepherd 2000).

A problem with this test is the strong interdependency between what is achieved with the “drop test” and the current soil water content. The wetter the soil, the less will be achieved when the soil is dropped. Every effort should be made to conduct comparisons at the same water content. Another problem occurs in sandy soils where the aggregates cannot be sorted by hand due to their inherent weakness (i.e. the structure grade is “weak”).

Scoring (after Shepherd 2000):

- Good condition (score = **2**): good distribution of friable, smaller aggregates with no significant number of clods
- Moderate condition (score = **1**): soil contains significant proportions of both large, firm clods and friable, small aggregates
- Poor condition (score = **0**): soil dominated by large, extremely firm clods with very few small, friable aggregates

Soil crusts

Soil crusts are a soil surface phenomenon, comprising a consolidated layer commonly <10 mm thick that can be separated from and lifted off the soil beneath, on drying. Most commonly regarded as a negative soil feature, in certain circumstances they can have positive effects on soil and landscape health. Crusting is most common in fine textured soils (loams and sands), though clays with low aggregate stability (see stability test below) from high sodium levels and/or low organic matter content can also crust. In such soils, soil crusts impact negatively on soil health through reducing water infiltration (hence increased erosion risk, prolonged water ponding in flat and concave areas, and reduced water storage in the soil) as well as reduced seedling germination. The degree of negative impact increases with both greater crust thickness and continuity (i.e. degree of cracking). Examples of “positive” crusts are so called "Biological" crusts[11] that consist of a hard crust, held together by lichen/moss type materials. These type of crusts are specific to arid, desert areas (e.g. north west China), where their widespread occurrence has a strong positive impact on soil and landscape condition through binding the soil surface, hence greatly reducing wind erosion (specifically wind blown sand).

RECORD observations of surface crusting in the general notes or photograph the surface crust. Observations and scoring are best conducted after a period without rain and on ground that is not cultivated or disturbed by animals.

Scoring

A. Negative crusting:

Refer to the photographs in Figure 14a

- Good condition (score = **2**): little or no surface crusts
- Moderate condition (score = **1**): Crusts present, up to 3 mm thick, broken by cracking
- Poor condition (score = **0**): Crusts present, up to 10 mm thick, continuous with almost no cracking

B. Positive crusting: Biological crusting (only used in arid / desert lands)

Refer to photograph in Figure 14b

- Good (score = 2): almost continuous, surface biological crust, commonly with increased soil surface roughness (pinnacle formation)
- Moderate (score = 1): discontinuous (patchy formation) of biological crust with minimal evidence of pinnacles
- Poor (score = 0): no biological crust present

Figure 14a Soil crust with negative impact

[11] See: http://www.soilcrust.org/

Figure 14b An example of mature biological soil crusts, showing the common "pinnacle" formation. [12]

Soil colour

Soil colour indicates many important soil properties. First and foremost soil colour provides much information on the source material(s) of the soil and the climatic/human factors that have altered the original rocks and sediments to give the current soil condition.

Secondly, soil colour is a strong indicator of current soil water (or aeration) status. Generally, bright colours, and reds and oranges in particular, show good soil aeration and drainage (the iron in the soil is in the ferric (oxidised) state). Dull and grey colours show reduced aeration and a tendency for low-oxygen status and waterlogging. The dull grey/black colours in a waterlogged soil often occur as mottles, ie a secondary colour within the main soil colour.

Thirdly, soil colour may reflect the organic matter status of the soil, particularly useful when comparing the topsoils of long term cropping land with treelines and fencelines. Generally, the darker the soil the greater the organic matter content.

How do I measure the soil colour?

1. Take a lump of soil from the layer/horizon to be described. Break the lump to expose a fresh face (Fig. 15).
2. If the soil is dry moisten the face by adding water drop by drop.
3. Wait for the water to seep into the soil.
4. Now name the soil colour, e.g. red, brown, grey, black, white, etc
5. If a soil has more than one colour. Record a maximum of two and indicate (1) the main (dominant) colour and the (2) secondary colour.
6. *If available*, match the soil with a chip on the Munsell Soil Colour Chart.
   Record the Soil as: Hue/Value/Chroma value and the name of the colour.

[12] From: http://www.soilcrust.org/gallery.htm

RECORD the soil colour(s) on the field sheet.

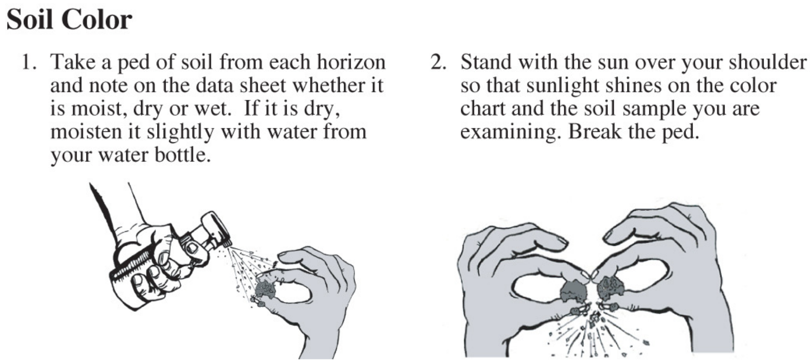


Figure 15 Procedure for determining soil colour in the field (from NASA 2004).

Earthworms (and other soil biota)

Soil biota are usually an indicator of good quality. Earthworms are particularly good indicators as the to incorporate organic matter into the soil and improve aeration with associated improvements in water infiltration and crust prevention. They also increase soil fertility *via* their caste material.

The presence of large numbers of species in good concentrations reflects and integrates many positive aspects of soil condition: good aeration (no waterlogging), structure (no compaction), plentiful food supply (for earthworms, the retained crop residues and stubble) and the lack of disturbance by cultivation (no-till). As such, the presence of biota is a most important, and fortunately in terms of the macro-biota, an easy-to-measure, attribute.

Earthworms are used as indicators here for two reasons:

- they are easily seen and captured and
- they are good indicator species, indicating the presence of a healthy soil biota and a good soil.

Earthworms are rarely found in sandy soils and may only occur in deep soil layers of arid (infrequently wetted) landscapes, hence are a poor indicator species for soil health in such situations. Termites, ants, beetles and collembolan (commonly called “springtails”) are also considered important indicators of good soil condition, as well as causing the development of fertile soils. Ants are known to move and aerate considerable quantities of soil, and termites affect both nutrient pools and the flow of water into the soil through their interconnected galleries. Currently, research is limited[13] on the link between the presence and abundance of ants and selected termite types and their use in monitoring soil condition.

It is important to recognise that all soil biota are seasonal and migratory animals (seeking warmth, food and moisture). Because of this, it may well be that during a soil inspection earthworms (and other soil indicator fauna) are not found but <u>strong evidence</u> of their earlier presence is visible, namely earthworm burrows (large, round and continuous pore spaces) in the soil profile and caste (faecal) material on the soil surface, termite burrows and mounds,

[13] See: http://www.environorth.org.au/windows/all/all_termites.html

buried stores of organic material, etc. In the absence of actually capturing and counting earthworms and other soil fauna, note should be taken of the number and concentration of related soil fauna features.

The assessment team should use local knowledge to decide whether earthworms are the most appropriate animal group to use as an indicator. If not then they should identify a more appropriate gorup to use.

Method:
- While manipulating the soil on the spade blade for soil structure description, pick-out and place to one side all earthworms found in the soil sample.
- Observe the presence (number and size) of earthworm burrows and castes, too.

RECORD earthworm numbers on a 1 m^2 (a square meter) spade depth basis. So if the spadeful of soil is a 20cm cube, that equates to a 1/25 square metre of soil, so multiply numbers of earthworms by 25 to convert to a m^2 basis.

Scoring (after Shepherd 2000):

- Earthworms plentiful (score = **2**) if >8 earthworms counted
- Moderate earthworm numbers (score = **1**) if 4 to 8 earthworms counted
- Few or no earthworms present (score = **0**) if <4 earthworms counted

Quantifying Roots

The development of root systems into the soil are a prime biological indicator of soil and vegetation condition. Where plant root growth is not impeded it will reach its optimal form (root depth, lateral spread, density of roots and root hairs) and optimise uptake of water and nutrients to meet plant demand. However, when root growth is impeded by rocks, hard or compacted soil layers, high groundwater or saturated conditions, nutrient deficiencies, salinity or toxicity, or water shortage, the result will be visibly stunted or deformed roots, that in turn will lead to restricted growth of above ground parts of the plant. Triangulation with other indicators/observations will help identify the precise causes of the root deformations.

The determination of the extent and development of the plant root system is best done:

1. by examining the root system emanating from the sides of the block of excavated soil (on the spade blade), and
2. then, similarly, as the excavated block of soil is manipulated and broken up for soil structure description.
3. these observations can be supplemented with observations of any exposed soil profiles around the site where plant rooting is visible, eg road or drainage cuttings, etc.

Observations (recorded and leading to scoring on the field sheet) will include the following :

- evidence of stunted/deformed roots or acute, sharp changes in root penetration into the soil (the “L” shaped root syndrome, particularly evident in tap rooted crops like cotton and sunflower)
- disproportionate number and concentration of roots in the immediate surface layer, demonstrating that extension into the layers beneath is difficult
- concentration of roots on ploughpans – at the greatest depth of ploughing

- evidence of roots “squashed’ in fissures between strong soil units, demonstrating their inability to penetrate into these units, and acess water/nutrients within, and
- an absence of fine root hairs, or an over-abundance of strong primary roots, showing the difficulty (and hence loss of vigour) experienced by the fine roots, penetrating the soil.

RECORD observations in the general notes on the field sheet or annotate the photograph or soil profile sketch with root shapes and concentrations.

Scoring (after Shepherd 2000):

- Good condition (score = **2**): unrestricted root development
- Moderate condition (score = **1**): limited horizontal and/or vertical root development
- Poor condition (score = **0**): severe restriction of horizontal and vertical root development; presence of “L” shaped roots, over-thickening of roots, or roots squashed between soil units

TOOL 12.2 ASSESSING SOIL PROPERTIES

Five soil properties are measured or assessed in this section. Each is scored and integrated to give a value for the **soil quality assessment**.

- **Slaking and dispersion**
- **Soil pH**
- **Water infiltration**
- **Organic carbon (labile)**
- **Soil and water salinity (electrical conductivity)**

The soil measurements here have been chosen for a combination of simplicity, reproducibility and rapidity; focusing on measures that are directly affected by land management. In some cases assessment teams may wish to carry out more conventional sampling and soil laboratory analysis but these conventional tests are not part of this rapid field assessment.

If possible, the VS-Fast field soil measures and tests should be conducted at the assessment sites. There are two principal reasons for this:

First, it allows an immediate sharing and discussion of findings with land users. Secondly, it is possible to record in a field photograph a site record ofthe pH test (in the porcelain plate) alongside the result of the dispersion test (samples from the same depth in the dispersion dishes) with the soil profile on the blade of the spade. Used in conjunction with Tool 10, the Site Photo and Sketch, this gives an additional lasting record of the site and soil at the time of the assessment.

The one test that lends itself more to "analysis at the end of the working day" is the labile carbon test. With increased proficiency of use, it may be conducted more widely in the field. However, in early days of using these methodologies, to save time, soil samples can be collected (from the same layers or sites where the other measures were conducted) and the test done later in the day, and the information collated into the overall results by the team.

Clearly, not all of the following tests are suitable for all soil types. And the interpretation of the results can also change between soils. For example, rapid hydraulic conductivity, that indicates good soil structure in a clay or loam, is an unattractive attribute in a sand – showing rapid drying of the soil, following rain or irrigation. These possible ambiguities in the results are discussed in the relevant sections below.

Slaking and dispersion; soil stability in water

The inherent ability of a soil, and particularly the soil surface, to withstand the impact of several types of land degradation, principally wind and water erosion, is strongly dependent on the soil's response when wetted.

There are two main types of aggregate collapse when water is added to soil: slaking which describes the breakdown of aggregates into micro aggregates, and dispersion which describes the breakdown of aggregates into the primary soil particles of sand, silt and clay.

The differentiation between slaking and dispersion is most important. Generally, the products of slaking can re-form to produce larger aggregates whereas dispersion into primary particles is irreversible and results in undesirable, massive structure. On the soil surface, dispersed soil appears either as a hard-setting layer (or a surface crust) or as loose fine (white) sand grains. Crusts (see section 12.1) and hard-setting are major impediments to both water penetration (causing rain water to pond on the soil surface with strong potential for erosion) as well as to the germination of seeds. Additionally, fine, loose (dispersed) material on the soil surface has strong potential for wind erosion.

The amount of organic carbon in a soil strongly influences the ability of a soil to maintain aggregation (and not disperse) when wetted. Organic matter binds soil particles together, and particularly in sand and loam soils is the principal material causing aggregation.

The determination of the slaking or dispersive nature of a soil is commonly a laboratory test but an appreciation of the phenomenon can be gained in a short time during soil description in the field (Field et al. 1997).

The procedure is as follows. Drop an air-dried aggregate from the layer under investigation into a dish (e.g. a saucer) or a small clear container (glass or cup) containing water (use rain water or local irrigation water). Ensure the entire aggregate is submerged below the water. After each of 10 minutes and 2 hours (when possible) immersion, a visual judgement is made of the degree of dispersion on a scale of 0 – 4 (Figure 16).

<u>NOTE 1</u> the scoring is the <u>reverse</u> of the Field et al. (1997) scoring, to reflect the fact that the VS-Fast methodology gives a higher score for better conditions.

<u>NOTE 2</u> The following descriptors of the degree of dispersion are more suited to clay rich soils (clays to clay loams) where dispersion of the original aggregate gives an obvious "halo" of dispersed clay. Sandy soils, because they contain less clay do not give such visible clay halos. With these soils greater emphasis should be given to the degree of aggregate breakdown and whether individual mineral grains become visible (sand and silt).

Scoring:

- No dispersion (though the aggregate may fall apart, ie slake) but with no signs of individual mineral grains (score = **4**)
- Slight dispersion, recognised either by a slight milkiness in the water adjacent to the aggregate, and/or the aggregate falls apart with only a few individual mineral grains evident (score = **3**).
- Moderate dispersion with obvious milkiness (score = **2**)
- Strong dispersion with considerable milkiness and about ½ the original aggregate volume dispersed outwards and/or individual mineral grains separated-out and clearly evident (score = **1**).
- Complete dispersion, the original aggregate completely dispersed into clay, silt and sand (individual mineral) grains (score = **0**).

<u>RECORD</u> the score value on the field sheet

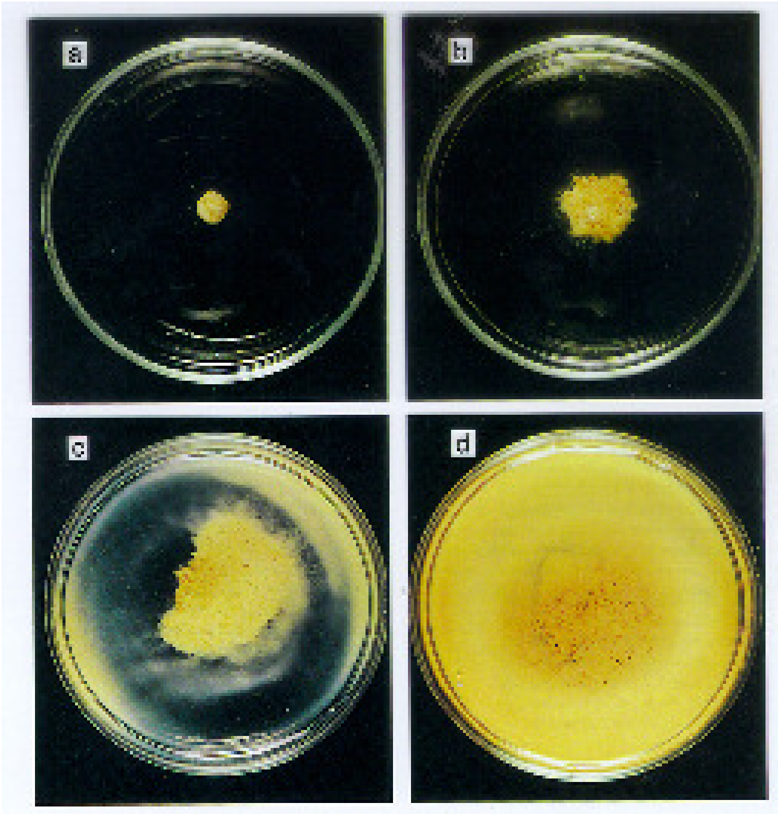


Figure 18 Examples of the nature and the range of dispersion classes in the soil dispersion test for a clay rich soil. Source: McKenzie et al. (1992).

- the aggregate remained intact with no slaking or dispersion [score = 4, A in Fig. 18]
- a slaked aggregate with no dispersion ie no visible individual mineral grains [score = 4, B in Fig. 18]
- the aggregate slaked and moderately dispersed ie evident individual mineral grains [score = 2, C in Fig 18]
- the aggregate completely slaked and dispersed with clearly evident and abundant mineral grains [score = 0, D in Fig 18]

Soil pH

Soil pH measures the molar activity (concentration) of hydrogen ions in the soil solution. It is a negative logarithmic scale, so a decrease of 1 pH unit increases the hydrogen ion concentration ten-fold. At a pH of 7 (neutrality), the activity of hydrogen ions is equivalent to the activity of hydroxyl ions. At pH values less than 7, the soil is acidic, whereas at pH values greater than 7 the soil is alkaline.

In summary, strongly acidic soils can have the following negative characteristics:

- aluminium and/or manganese toxicity,
- phosphorus deficiency,
- calcium and/or magnesium deficiency,
- reduced nitrogen mineralisation because of restricted microbial activity,
- reduced boron, zinc, molybdenum and copper availability.

Strongly alkaline soils can have the following negative characteristics:
- surface sealing and crusting problems due to excessive sodium,
- reduced availability of iron, manganese, zinc, phosphorus and copper,
- reduced microbial activity and reduction in fungal population.

The pH test presented here utilises a “field test kit” developed by CSIRO, Australia. It is the field test kit used by Australian field pedologists (soil surveyors).

The ph kit is used in the VS-Fast system, in preference to other methodologies of determining soil pH such as (electrical) meters, principally as the pH kit provides a visible output – the coloured Barium Sulphate. This visible outcome, therefore, lends itself to the “alignment” procedure mentioned above where the samples from the exposed soil profile are place in the porcelain dish in the correct (depth) order and positioned beside the exposed soil profile for photography. In this way providing a lasting record of pH with the corresponding, visible soil layers / features.

The procedure is as follows:

1. Take a small amount of soil from the centre of a layer of interest. Crumb it up and place onto a white tile or piece of flat plastic.
2. Add some of the black/purple liquid from the Test Kit (this is Universal “Raupach” indicator).
3. Just add enough of the liquid to thoroughly moisten the soil. It is important **not** to flood the soil.
4. Mix the soil and the indicator well together with a plastic or wooden rod (a clean stick or old “biro” pen).
5. Let the mixture sit for two minutes (to let the two react).
6. Using the little “puffer” bottle, gently “puff” a fine layer of the Barium Sulphate powder over the mix. A colour will develop in the powder.
7. Match this colour with the closest match on the Test Kit colour chart.

RECORD the pH value on the field sheet. This is commonly recorded to 0.5 of a unit accuracy.

Water infiltration

A major determinant of the cropping or grazing potential of a soil is the rate and amount of water that can infiltrate either through the soil surface or within the soil profile.

Interpretation of the measured rates of hydraulic conductivity is not a straight forward matter since many inherent and anthropogenic factors influence the result in potentially interactive/additive ways: soil texture, soil surface structure (crusts), organic matter levels, soil biota (can create macropores and channels to the soil surface), etc. However, in this rapid assessment, the prime aim is to gain an indication of water infiltration rate. Hence, infiltration rate is classified as fast, medium, slow and very slow. The two classes “very slow” and “fast” are considered less suitable for most crops/land uses as they indicate drainage problems/waterlogging and moisture unavailability, respectively.[14] Hence, the systems presented here have two “tails”, with low (poor) values at the extremities and larger (good) values in the middle range.

[14] One unique interpretation of the water infiltration rate occurs in paddy (flooded rice) soils where the desired outcome is “very slow” infiltration; hence the scoring system would be reversed in this situation – 0 for “fast” and 2 for “very slow”

The following method has been devised by CSIRO, Australia. The aim was to derive a simple method for the rapid estimation of soil hydraulic conductivity. Simplicity, both in apparatus required and field method, was essential. However, though operationally simple, the method is robust, being firmly based on fundamental, globally tested and accepted soil physical principles.

The method has two variations:

- in the first, the ring is only pressed a short distance (a few millimetres) into the soil surface (this facilitates 3 dimensional flow – where the water can flow both vertically and horizontally into the soil), and
- in the second, the ring is push in to a considerable depth (> diameter of ring), so that the flow is essentially 1 dimensional (i.e. the water mostly flows vertically into the soil).

Where possible, always use the 3-D method as results will be obtained more quickly and the time data is more sensitive to the hydraulic conductivity. The 1-D method is more appropriate when soil cracking or the aggregation of the soil makes it difficult to seal the ring onto the soil without leaks occurring**.**

Field equipment required: a 100 mm (length) x 100 mm (diameter) ring (metal or PVC with a sharpened tip), a container holding exactly 400 ml of water and a watch with a "seconds" hand or digital stopwatch.

The procedure[15][2] is as follows:

1. Select a level area and carefully brush away any loose surface litter. If vegetation is present, clip it close to the soil surface and remove the clippings.
2. Place the metal ring on the soil surface and push it a few mm into the soil to obtain a seal between the ring and the soil surface but ensuring minimal soil disturbance inside the ring.
3. Pre-wet the soil surface in the ring by applying 50 to100 millilitres (mL) of water. This is important, to reduce the initial, commonly rapid and non steady state infiltration component of hydraulic conductivity, termed sorptivity (where the soil absorbs water due mainly to capillary forces rather than gravity). This pre-wetting reduces errors associated with assumptions in the method.
4. After 15 to 30 minutes, add 400 ml of water to the ring; this being equivalent to applying 50 mm water (rainfall or irrigation water). (Note: during this wetting and the pre-wetting the water should not be poured directly onto the soil surface, to minimize changes to the soil surface. One method is to use a squeezable "wash bottle", apply the water to the inner sides of the ring until water ponds on the soil surface, then gently add the remainder of the water to this water surface)
5. Note the time for the water to disappear (infiltrate) into the soil.
6. Tables 6 and 7 allow conversion of the infiltration time to a permeability class for each of the 3-D and 1-D scenarios, respectively.

RECORD whether 1-D or 3-D infiltration was measured and "fast", medium", "slow" or "very slow" rate using the times in Tables 9 and 10.

[15] Parts of the method are common with the same procedure in the SCAMP manual of Moody, P. W. and Phan Thi Cong (2008). See also Moody et al., (in press).

Scoring (from Tables 9 and 10):

- Fast rate (score = **0**)
- Medium rate (score = **2**)
- Slow rate (score = 1)
- Very slow rate (score = **0**)

Table 9 Simple estimation of *K* on the basis of 3-D flow from a pond.

Time for 400 ml of water (volume) to be gone from ring with radius 50 mm.	Hydraulic conductivity - K (mm/hr)	VS-Fast score
< 1 min	> 360 (fast)	0
> 1 min, < 10 min	< 360, > 36 (medium)	2
> 10 min, < 2 hr	<36, > 3.6 (slow)	1
> 2 hr	< 3.6 (very slow)	0

Table 10 Simple estimation of *K* on the basis of 1-D flow from a pond.

[Time for 400 ml of water (volume) to be gone from ring with radius 50 mm.	Hydraulic conductivity - K (mm/hr)	VS-Fast Score
< 8 min	> 360 (fast)	0
> 8 min, < 30 min	< 360, > 36 (medium)	2
> 30 min, <10 hr,	<36, > 3.6 (slow)	1
> 10 hr	< 3.6 (very slow)	0

Soil organic carbon – labile fraction

Most of the functions associated with soil quality are strongly influenced by soil organic matter, especially the small portion that is termed labile or “active” organic carbon.

Most (routine) soil chemical laboratories provide a determination of total soil organic matter or soil organic carbon (SOM and SOC). This is reported as something generally between 0.5% and 7% in soil. These cannot be field tests as they are based either on total (high temperature) combustion of a soil sample or require strong chemical reagents. Another problem is that they are insensitive to management practices because they include recalcitrant (inert) forms of organic matter (such as charcoal) which remain unchanged for decades, regardless of management practices.

Techniques have developed to fractionate carbon on the basis of lability (ease of oxidation), recognising that these sub-pools of “active” carbon may have greater effect on soil physical stability and be more sensitive indicators of carbon dynamics in agricultural systems than total carbon values (Weil et al. 2003). The labile fraction of soil carbon is the component of organic matter that feeds the soil food web and is closely associated with nutrient cycling and other important biological functions in the soil.

Weil et al. (2003) have developed a “field kit method” for the determination of potassium permanganate ($KMnO_4$) oxidisable carbon. The field procedure has been further refined in the SCAMP manual (Moody and Phan Thi Cong (2008); Moody et al., in press). In this test a dilute solution of $KMnO_4$ is used to oxidize organic carbon. Generally, in the course of the experimental procedure the greater the loss in colour of the $KMnO_4$, the lower the absorbance reading will be, hence the greater the amount of oxidisable carbon in the soil.

The method[16] requires a field kit consisting of:

Equipment

- 50 mL graduated disposable plastic centrifuge tubes (internal diameter: 30 mm) with screw-on caps
- plastic rack(s) to hold the tubes vertical
- 5 mL standard teaspoon (equivalent to 5 g ± 0.5 g soil)
- 550 nm wavelength Hach brand pocket colorimeter (or similar)
- 1 mL graduated pipette (plastic, disposable)
- 25 mL dispenser (plastic syringe) or measuring cylinder
- deionised or distilled water
- 1 funnel and cleaned glass wool

Reagents

Analytical grade reagents should be used.

- 0.1 *M* $CaCl_2.2H_2O$
- 33 *mM* $KMnO_4$

Preparation of reagents

- To prepare 0.1 *M* $CaCl_2$ weigh 1.47 g $CaCl_2.2H_2O$ into a volumetric flask and dilute to 100 mL with deionised water.
- To prepare 33 *mM* $KMnO_4$, weigh 5.21 g $KMnO_4$ into a small beaker with 200 to 300 mL of deionised water, heat the solution on a hot plate (optional, no hotter than 60^0 C) and stir until dissolved. Filter the solution through a funnel containing a plug of cleaned glass wool and dilute with deionised water to 1 L in a volumetric flask. Store the solution in an amber glass bottle or in a dark place.

Calibration procedure

The procedure for preparing a calibration curve relating absorbance to labile or "active" carbon is given in Annex 3.

The soil testing procedure is as follows

1. Air-dry 20 g of the soil under investigation (commonly 2 or 3 depths from the 30 cm or 40 cm soil profile on the spade) for 15-30 minutes by laying out on plastic in the sun. In wet / overcast weather, the soil may need to be taken indoors for drying and subsequent analysis.
2. Crumble the soil to approximately 2 mm aggregate size, carefully removing all stones and root and vegetative materials.
3. Add five cc of the crumbled soil with 25 mL of the $KMnO_4$ solution and one mL of the $CaCl_2$ solution (to assist flocculation of the soil particles) in one of the centrifuge tubes, and firmly cap the tube.
4. Shake vigorously for exactly two minutes.
5. Stand upright for 5 minutes, in the plastic rack and protected from direct sunlight.

NOTE: ***The period of time the soil is in contact with the permanganate solution is critical and therefore 2 minutes shaking and 5 minutes settling time should be strictly adhered to.***

6. Pipette-off 1 mL of liquid from the top 1 cm of the "soil sample" solution and dilute in a centrifuge tube to 50 mL with deionised water, ensuring (through repeatedly flushing the contents of the pipette) that all the "soil sample" solution is added to the tube.
7. Zero the colorimeter using deionised water as in the calibration procedure (above)

[16] Parts of the method are common with the same procedure in the SCAMP manual of Moody, P. W. and Phan Thi Cong (2008)

8. Measure the absorbance of the sample (soil) as in the calibration procedure
9. From the standard curve (Figure A3.1, Annex 3), calculate the concentration of KMnO4 (mM) left in the sample after the oxidation period.

NOTE: ***If the absorbance of any sample is less than a reading of 0.4 (on the colorimeter at 550 nm), repeat the extraction using 2.5 g soil instead of 5 g soil. The implication is that the soil is rich in labile organic matter, hence a smaller soil quantity needs to be used to achieve oxidisation by the $KMnO_4$ solution. Calculation of results need to suitably altered, considering only half the soil quantity was used; i.e. the unit "5" in equation - 1 becomes "2.5"***

Calculation:

It is assumed that 1 *M* MnO_4^- is consumed (reduced from Mn^{7+} to Mn^{2+}) in the oxidation of 0.75 mmol or 9 mg of carbon.

So, the amount of labile Carbon in the soil sample (grams of Carbon in a kilogram of soil) is calculated as follows:

$$C(g/kg) = \frac{(Mo - M1)x26x9}{1000x5} \quad \text{----------------- equation (1)}$$

where: *Mo* = initial concentration of $KMnO_4$ (33 *mM*)
*M*1 = concentration of $KMnO_4$ (*mM*) after oxidation (calculated from standard calibration curve: Fig. 19A)
Final volume of $KMnO_4$ solution = 26 mL
Weight of soil = 5 g (or as used)

RECORD the amount of active carbon present (mg/g) using Fig. A3.2 (Annex 3) and refer to table 11 to assess status.

Table 11 Permanganate (33 *mM*) oxidisable carbon contents (g/kg) considered to be low, moderate and high for soils of various textures.*

Soil organic carbon status	Sand	Sandy loam	Loam	Clay loam/Clay
"good"	> 0.2	> 0.28	> 0.36	> 0.4
"moderate"	0.1 – 0.2	0.14 – 0.28	0.18 – 0.36	0.2 – 0.4
"poor"	< 0.1	< 0.14	< 0.18	< 0.24

* Values (mg/g) of labile carbon considered to be "good", "moderate" and "poor" for soils of different textures. The table is taken from Moody and Phan Thi Cong (2008) and the values are based on the analysis of several soils covering a wide range in total organic C.

Scoring (from Table 11 and dependent on soil texture):

- Good organic matter status (score = **2**)
- Moderate organic matter status (score = **1**)
- Poor organic matter status (score = **0**)

The relationship between the measured quantities of labile organic carbon fraction (as determined here) and total soil organic carbon (as commonly required for carbon "trading" and sequestering in consideration of climate change) is not straightforward; being inter-related with soil type, clay content, and climate (organic matter weathering and volatisation).

Soil and water salinity

Salinity is the presence of soluble salts in soils or waters (Shaw and Gordon, 1997). Salinity processes are natural processes, however, human activities can accelerate these, contributing to long term land and water degradation. Salinity becomes a land issue when the concentration of salt adversely affects plant growth or limits plant species selection (to salt tolerant plants) or degrades soil structure (surface crusting and scalding). It becomes a water issue (surface and groundwater) when the potential use of water (for irrigation and human/animal use) is limited by its salt content (Shaw and Gordon, 1997).

Table 12 Assessing salinity using visual indicators in the field

Visual indicators	**Salinity**	**Sodicity**
Plant indicators	– Salt tolerant species e.g couch grass *(Cynodon*) and other halophytes (that tolerate or favour an environment with elevated salt concentrations) – Water stress symptoms in a crop (rolled and/or drooping leaves) even though the soil is wet	– Poorer vegetation than normal, few or stunted plants and trees – Variable height growth in a growing crop and yield variations at harvest – Symptoms of water stress not long after a rainfall or irrigation event.
Soil indicators	– Saline soils often exhibit a fluffy surface – Whitish salt crusts often observed on top of mounds, aggregates or slightly elevated areas in the field when the surface is dry	– Hard-setting surface horizon often observed in soils with a sandy loam topsoil. – Surface crusting. – Soapy feel when wetting and working up for texture assessment. – pH >8.5. – Poor penetration of rain or irrigation water into the soil due to surface crusting – Cloudy water in puddles that may form on the soil surface. – Shallow rooting depth.
Populations of salt-sensitive plants	– Decreased germination rate, slow growth rate, incomplete life cycle (e.g. plants do not flower), diminished abundance, depressed health (e.g. yellowing and stunting of crop or pasture species), greater susceptibility to disease and decreased seed viability.	

Limitations to field assessment of salinity

If the assessment is taking place in years of below average rainfall there may be very little plant germination or growth. The use of plants as salt indicators will be restricted.
Conversely, in years of above average rainfall the full extent of salinity may be underestimated due to the leaching effect. In both cases it is preferable to delay the assessment until favourable climatic conditions return.

Soil and water salinity measurements (Electrical Conductivity)

Salinity in soils and waters can be estimated conveniently from the electrical conductivity (EC) of a soil solution, or directly on a water sample. Many salts dissociate (separate out) to ionic form in water, so the EC of a solution provides a measure of the total concentration of salts (Shaw and Gordon. 1997).

Electrical conductivity is defined as a measure of a solution's ability to conduct electricity, and as such can be used to express salinity levels in soil (a soil extract in water) or water. When salt is dissolved in water the conductivity increases, so the more salt, the greater the EC value. EC is measured by passing an electric current between two metal plates (electrodes) in the solution and measuring how readily current flows (i.e. conducted) between the plates. EC measures the charge carrying ability (i.e. conductance) of liquid in a measuring cell of specific dimensions. It is necessary, therefore, to state the units of both conductance and length in considering EC. EC units vary between institutes and countries but most common is the use of "decisiemen per metre" (dS/m)[17], and commonly at 25°C, as temperature at time of measurement effects result.

Soil salinity generally affects plant growth by increasing osmotic tension in the soil making it more difficult for the plants to absorb water from the soil. Excessive uptake of salts by plants from the soil may also have a direct toxic effect on the plants. Crops vary considerably in their capacity to withstand adverse effects of salinity. Saline water, apart from being unpalatable to humans and stock, can also cause direct damage to crop leaves, depending on the concentration of salts, applied through sprinkler irrigation.

Electrical conductivity (EC) can be measured in the field using a portable EC meter. The Milwaukee® C66 "pen" electrical conductivity meter has been used in LADA assessments to date, as it was found to fulfil many of the requirements of the testing procedure, including operational range (0 to 10 dS/m), waterproof, cost, ease of use, lightweight and being (automatically) temperature compensated.

Methods

The method tests EC on a soil saturation extract (EC_{se}) using a portable field EC meter.

Before measuring EC in the field, ensure that the EC meter has been calibrated against a standard salt solution. The technique is one of manual calibration at 1 point using the small screwdriver supplied with the meter. This procedure is included in the "instruction booklet" provided with each C66 pen, and is as follows:

1. Place electrode into clean water to clean and rinse it
2. Shake off excess water
3. Unscrew the battery compartment cap on the top of the meter
4. Place meter into calibration fluid (commonly used is Milwaukee 1413 μS/m EC solution) until electrodes are covered. (NOTE: pour just sufficient from the bulk container into a small container for this calibration procedure and then discard the solution; ie never re-use the calibration solution or return it to the bulk container)
5. Allow the reading to stabilise and use the small screwdriver supplied with the meter, to turn the small brass screw (the "calibration trimmer") until the readout says 1.41 mS/cm. Note: the Milwaukee C66 pen gives a readout in millisiemens per centimetre (mS/cm). So, these can be read directly as dS/m.

[17] To aid in conversions: 1 decisiemens per metre (dS/m) = 100 millisiemens per metre (mS/m) = 1000 microsiemens per metre (μS/m) = 640 parts per million (ppm) of total dissolved salts (TDS). Note: 640 is a commonly accepted average as the correct factor varies from 530 to 900 depending on the type of salt present and its concentration. Note also, ppm is equivalent to mg/L (milligrams per litre).

6. Replace the battery compartment cap
7. The pen is now calibrated

The technique of determining the EC of a soil sample is as follows:

1. Take 50 to 100 g of soil from the layer(s) of interest (commonly the top and bottom of the spadeful of soil)
2. Remove all stones and organic/vegetative materials
3. Prepare a soil paste by stirring deionised water into the soil in a tube or cup (wide enough to take the tip of the EC probe) until a smooth paste is obtained. An indicator that the correct amount of water has been added is that the "paste" glistens (mirror-like) and just begins to flow. It is important to standardise this wetness "end point" as the value of EC_{se} changes as the concentration of salts changes (with more or less water added).
4. Ensure that the EC meter has been calibrated against a standard salt solution (note: EC is influenced by current temperature conditions, however, if the EC probe is temperature-compensated (as in the case of the Milwaukee C66 as recommended here) there is no need for temperature recording and post-compensation of calibration or solution readings).
5. Carefully insert the EC probe into the soil paste until the electrodes are covered and wait for the EC reading to become steady. Record the reading (exactly as displayed on the wand) in dS/m
6. After reading, remove the probe, wash with deionised water while removing excess soil from around the probes with a soft brush (e.g. toothbrush), ready for the next soil solution.

Salinity (EC_w) in water, whether irrigation, surface or ground-waters can be measured directly by collecting a suitable (fresh, non-stagnant) water sample, ensuring calibration of the meter, placing the EC probe directly into the sample and taking the reading (as displayed on the wand) in dS/m.

The quality of ground-waters is of particular importance in sandy and/or arid areas, where the presence of a shallow (< 2 m depth) and non-saline (electrical conductivity of <1 dS/m) water table can radically improve the potential agricultural productivity. Conversely, the presence of a shallow water table that is saline can be ruinous to almost all land uses and long term sustainability and productivity. Relevant, too, is the measured change in level of such water tables – both short and long term. Important will be determining linkages between the nature and extent of (local) land use changes and the link (if any) with monitored changes in groundwater levels (perhaps information available from local water authorities).

Values of soil and water EC can be related to information on plant salt tolerance and the VS-Fast scoring sheet (Table 13).

Table 13. EC_{se} values, with corresponding plant salt tolerance and VS-Fast class and score, [18]

[18] Corresponding to the plant salinity tolerance classes of Maas and Hoffman (1977) and in accordance with Victorian Resources Online: Salinity Class Ranges and USDA ratings of relative crop tolerance to salinity (ECse = dS/m) (Van Lynden et al, 2004). N.B. in USDA Moderately tolerant crops are very numerous (4-10 dSm) - very wide class, so have used FAO document instead to identify which plants for each category see below.

Soil salinity level EC_{se} range (dS/m)	**Plant salt tolerance grouping**	**VS-Fast score**
"not" saline < 1	• No vegetation appears affected by salinity and a wide range of plants present; • Suitable for salt intolerant crops: o field/horticulture crops: beans-*Vicia faba*; flax; radish; celery; green beans- *Phaseolus vulgaris*, artichoke, carrot, onion seed, strawberry)	**Good = 2**
mildly saline 1 - 2	• Suitable for moderately sensitive crops o field/horticulture crops: e.g. corn (Zea mays); potato, sweet potato, flax, sugarcane, broad bean, mung bean, chickpea, cabbage, eggplant, lettuce, onion, pepper, radish, cherry tomato o forage crops: clover (Trifolium spp.), foxtail (Alopecurus pratensis), orchard grass (Dactylis glomerata), alfafa (*Medicago sativa)*, *Eragrostis spp.*	**Good = 1.5**
moderately saline 2 - 4.5	• Suitable for moderately tolerant corps-those below plus: o field/horticulture crops: peanut, rice, durum wheat, beetroot, broccoli, cucumber, garlic, cowpea, pea, spinach, tomato o forage crops: fescue; *Sesbania, Sirato, Sphaerophys*a Sudan grass, Timothy grass, vetch • Salt tolerant species e.g. sea barley grass often abundant in plant community. • Salt sensitive plants in general show a reduction in number and vigour. • At the upper end of the range, grasses and shrubs may be prominent in the plant community. • No bare saline patches or salt stain/ crystals are evident on bare ground.	**Moderate = 1**
moderately saline 4.5 – 8	• Suitable only for salt tolerant crops (those below plus): o field/horticulture: barley, cotton, sorghum, soyabean, sugarbeet, sunflower, Triticale, wheat (*Triticum aestivum)*, artichoke, squash o forage crops: Bermuda grass, ryegrass, trefoil, purslane • Salt tolerant species begin to dominate the vegetation; all salt sensitive plants are markedly affected. • Plant community is dominated by grasses, shrubs and flat weeds. Legumes are very rare. At the upper end of the range some slightly tolerant species disappear. • Small bare areas up to 1 m2 may be present and salt stain/crystals may be visible on bare soil at the upper end of the range.	**Moderate = 0.5**
strongly saline 8 –12	• Only suitable for very salt tolerant crops o field and horticultural crops e.g. rapeseed/canola; kenaf; rye o forage crops e.g. Alkali sacaton; salt grass; Nuttall alkali grass; Rhodes grass; Canada wild rye; Western wheat grass. • Salt tolerant species only remain unaffected, in salt marshes species like sea barley grass (*Hordeum marinum*) and buck's horn plantain (*Plantago coronopus)* may dominate large areas. • In low rainfall areas trees may show some effects i.e.. dieback. Generally salt tolerant plants do not have high waterlogging tolerance. • Large, bare saline areas may occur showing salt stains or crystals (on some soils a dark organic stain may be visible), or the top soil may be flowery or puffy with some	**Poor = 0**

Soil salinity level EC_{se} range (dS/m)	Plant salt tolerance grouping	VS-Fast score
	plants surviving on small pedestals and the B horizon may be exposed in some areas. • In moderate to high rainfall areas, bare patches may be minimal but vegetation will be dominated by one or two highly salt-tolerant plant species (e.g. Puccinellia, Spurrey, Gahnia). • In higher rainfall regions, where soils may be waterlogged or flooded for considerable periods, plant species may show salt and waterlogging tolerance.	
very strongly saline > 12	• Generally too saline for crops • Halophytic plants (usually 2-3 highly tolerant species) may dominate the plant community e.g Salicornia, Tamarix • Moderately and highly salt tolerant species may show a reddening of the leaves. At the upper end of the range even highly salt tolerant plants may be scattered and in poor condition. • Trees will be dead or dying. • Extensive bare saline areas occur with salt stains and or crystals evident (on some soils a dark organic stain may be visible). Topsoil may be flowery or puffy with some plants surviving on small pedestals and the B horizon may be exposed in some areas.	**Poor = 0**

The implications for different levels of salinity on crops is covered in detail in the FAO Irrigation and Drainage series paper 61 (2002): Agricultural Drainage Water Management in Arid and Semi-Arid Areas. (Available online from ftp://ftp.fao.org/agl/aglw/docs/idp61e.pdf). Some guidance on the implications of different salinity levels for drinking water for humans and animals is given in Table 14.

Table 14 Water quality guidelines (EC_w) for domestic and stock (animals) supply (after Anderson and Cummings (1999)

EC_w range (dS/m)	Usefuleness of water supply
0 – 0.8	- Good drinking water for humans (if no organic pollution and minimal suspended clay) - Generally good for irrigation, though above 0.3 dS/m overhead sprinklers may cause leaf scorch on salt sensitive plants. - Suitable for livestock
0.8 – 2.5	- OK for humans - lower half of range preferred - for irrigation, requires special management including suitable soils, good drainage and consideration of salt tolerance of plants. - Suitable for livestock.
2.5 - 10	- Not recommended for humans. Up to 3 dS/m OK if nothing else available - Not suitable for irrigation. Up to 6 dS/m OK on very salt tolerant crops - >6 dS/m - occasional emergency irrigation OK - for poultry and pig supply < 6 dS/m OK. Other stock < 10 dS/m - > 4 dS/m - causes shell cracking in laying hens.
> 10	- Not suitable for human consumption or irrigation - Not suitable for pigs, poultry or any lactating animals. - Beef cattle can use water up to 17 dS/m and adult dry sheep can tolerate 23 dS/m.

The Field Score Card December 2008

FIELD SCORE CARD

Soil Condition Assessed using VS-Fast Methodolgy

Part A: Soil Visual Descriptors

Date:

Land Use (Current and Past):

Site Location:

Recent Weather Conditions:

Soil Type:

Soil Structure:

Soil Texture:

Soil Colour:

"Walk in" Observations (soil / crop residues):

Soil Profile sketch

Visual Indicator of Soil Quality	**Visual Score (VS)** **0 = Poor Condition** **1 = Moderate Condition** **2 = Good Condition**		**Weighting**	**VS-Fast score**
Tillage pan			x 3	
Aggregate Size Distribution			x 3	
Soil Crusts * * Score for either "negative" or "positive (biological)" crusts	***(negative)*** 2 = no crust 1 = some cracking 0 = continuous crust	***(positive =biological)*** 0 = Poor 1=Moderate 2 = Good	x 2	
Earthworms (or other more pertinent soil fauna)			x 2	
Roots			x 3	
Sum of visual VS-Fast scores				

Soil Visual Assessment	**Sum of visual VS-Fast Scores**
"Poor"	< 7
"Moderate"	7 – 14
"Good"	15 - 26

.

Part B: Field Soil Measurements

Field Measurement	**Actual Value**	**Visual Score (VS)*** **0 = Poor Condition** **1 = Moderate Condition** **2 = Good Condition**		**Weighting**	**VS-Fast Score**
Slaking and Dispersion		(scores: 0-4)		x 1.5	
Soil pH		Not scored		Not scored	-
Water Infiltration ***"negative" = sands*** ***"positive" = other soils***		**(negative = sands)** **0 = fast** **1 = medium** **2 = slow**	**(positive = all other soils)** **0 = slow** **1 = medium** **2 = fast**	x 3	
Organic C – labile fraction				x 2	
Soil salinity (EC)				x 3	
Sum of soil measurement VS-Fast scores					

* These scores not applicable to Slake/Dispersion test, where scores range from 0 to 4 (hence ½ weighting value)

Soil Measurement Assessment	**Sum of VS-Fast Scores**
"Poor"	< 7
"Moderate"	7 – 14
"Good"	15 – 22

Total VS-Fast score (Part A + Part B) scores	
"Poor"	**< 14**
"Moderate"	**14 - 28**
"Good"	**30 - 48**

Other Notes, e.g. Site Photo; Soil Photo or Sketches of soil, pit location…

3.5 VEGETATION INDICATORS AND ASSESSMENT METHODS

Vegetation condition is a key aspect of degradation in grasslands, wood/forest lands and croplands. There are many different ways to assess vegetation, however, the five most important vegetative indicators of degradation identified for this assessment are:

- Reduced vegetation cover (plant and litter);
- Changes in vegetation structure and species composition;
- Decline in species and habitat diversity;
- Changes in abundance of specific indicator species (e.g. that indicate high or low pasture or soil quality, invasive species, or specific land degradation concerns);
- Reduced productivity.

These same indicators are also relevant for assessing SLM and improvements in management practices. As with the assessment of other land resources it is important to supplement and triangulate the data provided by the simple assessment tools with information provided by key informant interviews.

The following tools are provided:

Tool 13.1 Interviews and focus group discussions on vegetation resources.
Tool 13.2 Visual assessment of vegetation status, quality and trends in pasture/ rangeland
Tool 13.3 Assessing vegetation status, quality and trends in forest /woodlands
Tool 13.4 Assessing vegetation condition in croplands

These tools provide a rapid assessment of vegetation. More detail on vegetation assessment is given in Annex 2.

As with the soil assessments, if possible, the local team should be accompanied in the field by the land owner/land users.

Sites: The sites for the detailed investigations and scoring will have been identified during the transect walk and reconnaissance visit of the study area. They need to be representative of the land unit, land use type and management practices. Where possible the vegetation condition of an area/ site should be compared with that of a benchmark - a similar vegetation type taken to be in a good condition that is chosen by the team. Digital photographs should be taken of each site and the benchmark sites.

Equipment: In addition to the standard assessment materials (paper and clipboard; map to help locate the site, key features and boundaries; GPS to record site locations and altitude; and a camera) additional tools that may be required include:
- Machete to cut through thickets;
- Plastic bags and plant press to take any vegetation samples;
- 50m Tape measure (marked at 1m, 2m and 10m intervals) to measure distances;
- A conventional quadrat (see Annex 4 for details);
- Calibrated Aluminium Disk Pasture Meter (optional);
- Abney level for measuring tree height (optional).

Tool 13.1 Interviews and focus group discussions on vegetation resources

Some initial information on vegetation resources will have been obtained from the initial community focus group discussion (FGD, Tool 1). An additional FGD on vegetation resources should be organized with 6-10 established community members. These persons should be experienced in using and managing these resources (e.g. for grazing, cropping, fuelwood and other products). There will be some variation in topics for discussion depending on the local context but some important topics are given here:

Identifying plant indicators (for a pasture area)

1. Has the quality of the grazing land changed over the last 20 years? How and why?
2. What plants show that pasture quality is i) good? or ii) bad? Do they have any particular characteristics?
3. Which plants have appeared in grazing areas that indicate that pasture quality has:

   i) improved? What do they indicate?

   ii) declined? What do they indicate (e.g. unpalatable grazing, overgrazing, annual vs. perennial grasses, etc.)
4. What plants/ species show that soil quality is i) good? or ii) bad?
5. Which plants/species have appeared in grazing areas that indicate that soil quality

   i) has improved? What do they indicate?

   ii) has declined? Do they have particular characteristics (e.g. grow on rocky land or saline soil).
6. Which plants have appeared in croplands that indicate that soil quality/ fertility

   i) has improved? Do they have particular characteristics (e.g. appears after applying fertilizer/manure; grows on red soil etc.)?

   ii) has declined? What do they indicate?

Record up to 3 plant species for each aspect and for each species identified, record the local name and, if possible, its botanical name. Where possible, photograph the indicator plants, and as required collect samples to obtain the botanical/scientific names.

Record sheet for capturing plant indictor species

Common name	Scientific name	What does it Indicate?	Specific qualities, characteristics	Causes/ pressures
1				
2				
3				
etc.				

Checklists of indicator species can be developed within countries/agroecological zones.

Obtaining information on the grazing regime and stocking rate

To back up observations on the grazing regime and stocking rate, further information can be obtained through household interviews with land users and compared with the information obtained on the ground:

7. How many and what type of livestock are supported (No./ha/annum) (this may need estimation of herd size and common grazing area) and what are the trends (e.g. over the last (approx) 10 years)?;
8. What are the main livestock products (milk, meat, hides), yields/annum, and trends?;
9. What are the forage production trends (increasing, stable, decreasing)?
10. What other significant sources of fodder are there?

If possible record any given reasons for the changes. Technical experts may be able to provide information on carrying capacity and recommended stocking rates for specific vegetation types and agro-ecological zones.

Obtaining information on fires and drought risk/resilience and coping/management strategies

Discuss with informants the intensity and frequency of fires and droughts and their effects on vegetation and uses/products.

11. How common are fires (rare, occasional, frequent) are they wild or controlled?
12. How severe is fire damage to the rangeland and forest vegetation (none, low, moderate, severe);
13. What effect (if any) does fire have on species composition in rangelands and forest (e.g. loss of valued species/products, increase in less palatable species, % of non re-sprouting shrubs that do not re-grow after severe fire/drought, etc.)
14. Are there any control measures? (e.g. bye laws, fire breaks or fire committees)
15. How frequent and severe are drought periods? (It may help to draw a timeline)
16. Has drought caused any changes in land-use over the last (approx.) 10 years?
17. Are there any drought coping strategies? (e.g. resilient species, bye-laws on grazing/ livestock/forest management, water harvesting/irrigation).

Obtaining information on laws and regulations that affect vegetation quality

It is common for there to be many formal and informal policies, regulations and arrangements governing access and use of vegetation/forest resources. These should be identified and discussed. Specific questions are not detailed here but potentially interesting discussion points are:

- Areas once heavily utilized may have become protected, preventing the harvesting of forest products, use for grazing etc. What impact has this had on the vegetation and on the land-users livelihoods?
- Customary (informal) regulations may be more significant/effective than formal policies and laws in controlling grazing periods, forest access, etc. Document both formal and informal mechanisms.

Tool 13.2 Visual assessment of vegetation status, quality and trends in pasture/ rangeland

a) Objectives:

i) To compare vegetation status and trends (degradation/improvement) between different units of land (i.e. protected, well managed vegetation with little evidence of degradation and/ or under inappropriate land use or poor practices that are causing degradation).

ii) To identify/verify indicator plants of land degradation, conservation or improvement.

iii) To assess pasture and rangeland in terms of productivity and ecological function and capacity to maintain the range of ecosystem services.

iv) to identify the direct causes of vegetation degradation and the direct effects of SLM practices.

The observations should generate information that facilitates subsequent analysis to identify drivers and wider impacts of LD/SLM on livelihoods and ecosystem services.

b) Visual Indicators and Methods

There is some discussion of the processes of rangelands degradation in section 5.5 in Part 1 of the manual. This understanding helps in identifying appropriate indicators of vegetation status and trends and assessing interactions between vegetation, soil and water resources degradation.

Whilst it is important to understand all major impacts of degradation on ecosystem services, land users (notably the livestock owners and herders) will be most interested in the effects on rangeland productivity and livestock carrying capacity (see point "d" below).

Changes in grass species composition, notably the decline in the percentage and absolute number of desirable (palatable) species, combined with decline in plant vigour leading to lower forage biomass production, will result in the affected rangeland having a reduced livestock carrying capacity. This will have an adverse effect on livestock productivity with livestock owners finding that they can keep fewer animals on a given area of rangeland. The health, condition and breeding success of the animals may deteriorate if livestock numbers exceed the long term carrying capacity of the range.

A set of proposed indicators is outlined below (Table 15) for a visual assessment of pasture/rangeland condition. The proposed scoring needs to be tested and adapted/calibrated for each situation. The findings need to be integrated with those from the soil site assessment (sections 3.3 and 3.4 above).

This list of core indicators is adapted from a list of visual indicators for assessing pasture (veld) condition trend on farms and extensive grazing areas used in South Africa with farmers, extension staff and researchers and repeated yearly. (Roberts,1970; Roberts, *et. al.* 1975; Fourie & Roberts, 1977, as described by Jordaan, 1991). The original list of indicators includes density, basal cover, botanical composition, vigour, and the condition of the soil surface.

These methods are subjective, the accuracy depending on the judgement of the operator, but they need no in-depth knowledge of the pasture and are easily applied. The criteria for calibrating the scoring should be well documented and supported with photographs. This will allow the scoring to be consistently applied by different people at different times, improving their robustness and value for base-line setting and monitoring.

Table 15 Indicators and Classes for assessing pasture/rangeland quality

Issues and Core Indicators		Category
1.	**VEGETATION /LITTER COVER**	
1.1	**Total bare soil/ vegetation cover**	Estimation of % cover- for comparison (using a quadrat or line transect) *NB Cover is of great importance for soil protection from raindrop impact, high temperatures and to reduce runoff volume and rates*
1.2	**Bare spots**	Spots without vegetation. In savannah - 2m or larger - the agreed size may change per ecological zone
	None	None can be seen
	Little	Can be seen, but does not characterise of the area
	A lot	Characterises the area
	Dominating	More bare than covered
1.3	**Litter cover/Surface organic matter**	The more, the better soil surface protection. Gives an indication of moderate grazing practices.
	Dense	Covers soil beneath tufts.
	A lot	Bare soil can be seen
	Little	Seen but no notable cover effect.
	None	None seen
2. VEGETATION QUALITY and COMPOSITION		
2.1	**Vegetation height, diameter and vigour for** perennial species (shrubs, trees) **and** herbaceous species (grasses, legumes)	Growth measurements - height and diameter at breast height (DBh) and growth pattern- e.g. stunted, defoliated) and Vigour measurements - stem diameter, average shoot length and basal shoot diameter. Using representative quadrat or line transects and comparing between well and poorly managed land or protected areas, taking note of time of year and seasonality.
	Good	Vegetation height, diameter and plant vigour compare very well with representative site and is close to optimal considering the seasonality and climatic conditions like rainfall and drought.
	Moderate	
	Poor	
	Very poor	There is a serious reduction in biomass (reduced vegetative production), resulting in stunted and defoliated growth pattern and very little to no plant vigour.
2.2	**Proportion of perennial /annual species**	*Indication of grazing quality and resilience to drought (herbaceous species –lower lignin and higher protein; woody species- higher lignin, lower protein)*
	Dominating	All grasses perennial
	A lot	Single annuals present
	Little	Present but not important
	None	Not seen
2.3	**Proportion (dominance) of useful species**	*This could include: - Ecological functions-canopy cover, deep rooting, resilience to drought, recovery after burning - Palatability-browse/grazing and - Products for human use*
	Dominating	All or most species useful
	A lot	Moderate
	Little	Present –some useful species
	None	Not seen

Issues and Core Indicators		Category
3. ECOLOGICAL INTEGRITY, BIODIVERSITY AND CHANGE DYNAMICS		
3.1	**Proportion of each vegetation strata**	%/proportion of trees, bushes/shrubs, forbs[19], grasses (reflects exploitation and change in habitat)
3.2	**Species that decrease with grazing pressure** (i.e. preferred by livestock) **-**	For each vegetation strata (herbaceous (grasses and forbs); shrubs/bushes; and trees): -Identify preferred species/decreasers - those species that decline with graze/browse pressure e.g. palatable spp. that play an important role in livestock diet (*T.triandra, Panicum.maximum* and *D. eriantha* can be used as key species in South Africa) - Compare with protected sites.
3.3	**Species that increase with grazing pressure** (i.e. resilient to trampling, unpalatable species)	Identify key species that are known to increase with grazing pressure for each vegetation strata including species resilient to trampling (e.g. *Eragrostis* spp. in particular *E. rigidior* can be used as key species in South Africa). Compare with trampled sites; - Key species not regularly utilised by livestock e.g. *E. muticus, C. plurinodis* and *Bothriochloa radicans* ("stinkgrass") in South Africa. Compare with lightly or moderately utilised areas.
3.4	**Poisonous plants**	Identify poisonous plants to livestock. This will differ from area to area. (e.g. In South Africa *examples include Homeria* spp., *Senecio* spp., *Lantana camara*, *Dicapetalum cymosum*, etc.)
3.5	**Alien Invasive or proliferous weed species**	Identify specific alien invasive or weed species that have reduced pasture/range or crop productivity e.g. presence (low, moderate, high) or % cover of *Prosopis, Lantana*, etc
3.6	**Pest damage**	Indicate extent and severity of damage by a) termites - defoliated vegetation and termite nests can be seen, b) rodents, c) locusts, d) other
	None	Not seen.
	Little	Single localities, no real damage.
	A lot	Damage seen, but not over whole area.
	Dominating	Whole area damaged.
3.7	**Damage due to diseases**	Evaluate as in pest damage
3.8	**Bush/shrub encroachment**	A key factor of pasture/range degradation that includes an increase in woody, invasive, unpalatable/toxic species. Too many bushes/trees depress grass production (reduce livestock carrying capacity) and may reduce access to water.
	None / sparse	Trees 30m+ apart.
	Open	Present. Visibility 200m and more.
	Dense	Visibility 50m. People and livestock can still move with ease.
	Very dense	Not easy to penetrate.
3.9	**Deforestation**	Deforestation is the loss of forests, woodlands and savanna areas to other land uses due to overcutting of trees. One consequence of deforestation is soil erosion, which results in the loss of protective soil cover and the water-holding capacity of the soil.
	None	There are no signs of deforestation.
	Some	There are some indications of deforestation, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts.

[19] Forbs are herbaceous flowering plants that are not grasses or grass related (i.e. not grasses, sedges or rushes).

Issues and Core Indicators	**Category**
Moderate	Deforestation is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts.
Severe	Evident signs of deforestation. Changes in land properties are significant, or even beyond restoration, and very difficult to restore within reasonable time limits.
3.10 Biomass decline *	Reduced vegetative production for different land use (e.g. on forest land through clear felling, secondary vegetation with reduced productivity). Depending on the time of year, biomass estimates can be made and compared between poorly and well managed/protected sites to give an indication of reduced vegetation production - trees, grasses, shrubs.
None	There are no signs of biomass decline.
Some	There are some indications of biomass decline, but the process is still in an initial phase. It can be easily stopped and damage repaired with minor efforts.
Moderate	Biomass decline is apparent, but its control and full rehabilitation of the land is still possible with considerable efforts.
Severe	Evident signs of biomass decline. Changes in land properties are significant, or even beyond restoration, and very difficult to restore within reasonable time limits.

* Biomass estimates can be made using simple hand balance in the field. However, dry weights of biomass samples weighed in a laboratory are more accurate and comparable than wet weights in the field.

Once the rapid assessment (Tool 4, carried out as part of the study area characterization) has been conducted the vegetation condition can be scored. The score sheet (Table 16) should be used for each sample site or for each vegetation group identified. The bigger or more variable the area the more observations are necessary to get a representative scoring of range quality. Avoid transition areas and make sure the visual assessment represents all major changes that have occurred in vegetation groups and conditions. Additional indicators, appropriate locally, can be included in the score sheet or they can be used to make a more informed assessment of the existing indicators.

Table 16 Scoring using visual indicators for assessing range quality

Range condition indicator	**Best Class**	**Moderate**	**Poor**	**Worst class**
1.1 Total bare soil	None	Little	Lot	Dominating
1.2 Bare spots	None	Little	Lot	Dominating
1.3 Litter cover / surface organic matter	Dense	Lot	Little	None
2.1 Vegetation height, diameter and vigour	Good	moderate	poor	very poor
2.2 Proportion of perennial/annual species	Dominating	Lot	Little	None
2.3 Proportion of useful species	Dominating	Lot	Little	None
3.1 Proportion of each vegetation strata (grasses, shrubs, bushes and trees)	Dominating	Lot	Little	None
3.2 Species that decrease with grazing pressure	Dominating	Lot	Little	None

Range condition indicator	**Best Class**	**Moderate**	**Poor**	**Worst class**
3.3 Species that increase with grazing pressure	None	Little	Lot	Dominating
3.4 Poisonous plants	None	Little	Lot	Dominating
3.5 Alien invasive or proliferous weed species	None	little	Lot	Dominating
3.6 Pest damage	None	Little	Lot	Dominating
3.7 Damage due to diseases	None	Little	Lot	Dominating
3.8 Bush /shrub encroachment	Sparse	Open	Dense	Very dense
3.9 Deforestation	None	Some	Moderate	Severe
3.10 Biomass decline	None	Little	Lot	Dominating
Score	**5**	**3**	**1**	**0**
Sum of scores				

For each indicator one of the columns is marked. Columns have the following values: column 1 = 5, column 2 = 3, column 3 = 1, column 4 = 0. Sum the number of marks in each column. Multiply it with the value of each column. Sum all to give a total index for each site/paddock. Convert the score to a percentage (score/number of points X 100), and compare to the following:

Table 17 Interpretation of the pasture/range quality scores

Score	**Grassland condition**	**Trend (indicate if it is...)**
100 – 90	Excellent	
71 – 90	Good	Stable
70 - 51	Average	Improving
50 - 31	Bad	Deteriorating
0 – 30	Extremely bad	

This system has been calibrated in South Africa and it may need to be re-scaled in other locations.

c) Management practices

The scoring should be accompanied by a description of reasons for the current vegetation status (cover, composition, ecological integrity, biodiversity etc.) and where available, also the reasons for change dynamics. This should include information gathered from land users/ household interviews on the:

- management and conservation practices in place or missing to ensure sustainable utilization of vegetation resources;
- Direct pressures and socio-economic and bio-physical driving forces or the direct and indirect causes for the current vegetation status (human population, animal numbers, poverty, labour, land tenure/access rights, etc. that lead to clearing, fragmentation or conversion of land etc.);
- A description of land users’ historical, current and future responses to land degradation, policies, legislation and change dynamics related to vegetation.

Some of this information will have already been obtained if the vegetation FGD has taken place.

d) Grazing quality and carrying capacity

Grazed species vary considerably in their response to management practices as well as in their nutritive value and acceptability to livestock. Such variation exists between- and within-species at different times of the year and in the same species growing in different areas.

With regard to pasture and rangeland productivity and effects of livestock, information needs to be obtained from individual key informants and the FGD on livestock **stocking density** and variations throughout the year due to mobility and the potential **carrying capacity**.

Carrying capacity is the potential of an area to support livestock through grazing/ browsing/ fodder production over an extended number of years without deterioration to the overall ecosystem (Trollope et. al. 1990). Carrying capacity is dynamic and influenced by several edaphic and botanical factors (Jordaan 1991). The main factors being climate, soil, topography and veld types (botanical composition, quantity and quality of grazing material) (Fourie *et. al.*,1985).

Carrying capacity can be expressed as **Livestock Units/ha** (LSU/ha = 1/(ha/LSU),
where: 1 LSU = an animal with a mass of 450 kg which gains 0.5 kg per day on forage with a digestible energy percentage of 55% (Meissner *et. al.* 1982; Trollope *et. al*. 1990).

A pasture/rangeland area under assessment, or a specific farm, usually contains several grassland types, each with different plant communities and different micro- climate and soil characteristics. Any carrying capacity analysis should be carried out for each main pasture type. Although mentioned here, this detailed analysis will be beyond the scope of a rapid assessment in most cases. If, however, there is an ongoing programme of measuring climate change or using this as a key indicator of pasture productivity in the region being assessed, the team may want to include these more detailed measurements.

Tool 13.3 Assessing vegetation status, quality and trends in forest /woodlands

The process of forest/woodland degradation is described in section 5.5 in Part 1 of the manual. Table 18 provides some specific indicators and methods that are useful in assessing degradation in forest/ woodlands. This area is not greatly emphasised in this assessment though additional indicators and tools should be added if locally important.

Table 18 Indicators and Methods for Assessing Forest Production Constraints

Indicator	Method/Information source
Changes in Forest land area and intensity of use	Information on changes in forest land area can be obtained from: - time-series aerial photos and satellite images - reports associated with forest inventories and land cover surveys - interviews with local key informants can also provide and back up such secondary information
Vegetation condition and health	Information on the relative impoverishment of forest/woodland areas can be obtained through: - visual inspection of forest condition and - specific vegetation surveys that compare forest/woodland areas that have been subject to different levels of protection, management and utilisation.
Forest production	- Information on changes in the quantity and quality of the products harvested from particular forest/woodland areas can be obtained through community and household interviews. - Different household members may have different information depending on which specific forest products they harvest (in particular women may use forest/woodland resources in very different ways to men).

Drawing from the protocol that is used in the field by the global Forest resources assessment (FAO) it is proposed that condition and productivity of trees in woods/forests and trees outside of forests i.e. in grazing or croplands can be determined and compared with benchmark site with good condition using the following indicators

- Tree /shrub species: record either common/local (specifying local language) or scientific species name for all species if there are few or the three dominant tree species and the three dominant shrub species.

- Tree Canopy cover: estimate the ground surface covered by the vertical projection of the tree canopies, as a percentage of the total ground area (no trees; <5, 5-10, 10-40, 40-70; >70%)

- Shrub cover: vertical projection of the shrub/bush canopies as percentage of the total ground area. (no shrubs <5%, 5-10, 10-40, 40-70; >70%)

- **Growth measurements** of average height (h in m) and diameter at breast height (Dbh in cm) for trees and stumps with i) a Dbh ≥ 20 cm in forest land; and ii) a Dbh ≥ 10 cm in non-forest land. For stumps lower than 1.3m (Bh) diameter is measured at stump height (Dsh). Estimated time since the tree was cut can also be recorded (<1, 1-5, 6-10, >10 years)

- **Overall tree condition:** where good = no symptoms of disease /other effects on growth and vitality; slightly affected = some symptoms; severely affected = symptoms that substantially affect the tree's growth and vitality; dead/dying = damage that is or will lead to death (leaves, buds, cambium) or the tree has fallen.

- **Crown condition/health:** good = dense, no dieback; moderate = dense, visible dieback, poor = less dense, significant dieback; dying = sparse, high dieback; dead = already killed

- **Tree stem quality:** to assess if it is straight and extent of damage due to fire, pests, diseases, animals, etc. (high: straight tree without visible damage; medium: some slight defects or damage; low: several defects or damage)

- Causes of damage: should be recorded, where the land users knows, for example, due to insect infestation (defoliation, leaf feeding, etc.); presence of fungus (leaf spots, leaf or needle discolouration, etc.); burned; wild or domestic animals; human induced (cuttings, bark damage, logging, etc.); extreme climatic events (e.g. broken branches by wind, snow, lightning, etc.); or other causes.

Site No	Tree	Shrub	Stump	*Species*		***Growth***				**Canopy**		***Health***		
				Common name	**Scientific name**	**Av. Diameter Dbh.**	**Av. height**	**Year(s) since cut**	**Tree Stem quality**	**Tree canopy cover**	**Shrub cover**	**Crown condition**	**Tree/shrub condition**	**Cause of damage**
						cm	**m**		**C**	**%**	**%**	**C**	**C**	**C**

Notes:..
....
....
....
....
....

Abundance of indicator species: as with rangeland is useful to show problems of invasive species, weeds, salinity etc which can be assessed in a selected quadrat (number of plants of that species- high = abundant; medium= common; low = rare) The FGD questions for rangeland can be adapted for forest land.

- **Spatial distribution of trees outside of forests:** is also a useful observation of the extent to which trees have been maintained in the environment (n.a,; scattered/sparse; grouped in blocks; trees in lines (e.g. fences, roads, plantations); other

Tool 13.4 Assessing vegetation condition in croplands

Natural vegetation is also important in croplands. In addition to the indicators specified under crop productivity (Tool 15) five natural vegetation indicators are included here:

- **Fragmentation/ proximity to natural vegetation**- may indicate intensification pressure
- **Diversity of natural vegetation within and around the cropland:**
  - Diverse crop systems make better use of soil and water and reduce erosion risk (e.g. a multi-storey agroforestry system will intercept and make better use of rainwater and the deep soil profile and protect the ground from erosion more than a cereal field).
  - Natural vegetation provides habitat for associated species and their beneficial ecological interactions. In drier farming systems there is a need to minimise competition for water between species through the use of appropriate species and management practices
- **Permanence of the crops or period of cover** determines exposure of bare soil and erosion risk
- **Crop diversity** determines resilience to pests/diseases, capacity to restore nutrients and organic matter

Table 19 Indicators of vegetation condition in croplands

Indicator
Degree of fragmentation – average farm/field size (ha) – % of fallow
Diversity of natural vegetation in/around cropland – hedgerows, trees grassed bunds/ waterways, windbreaks, etc. (none/few/ many) – distance /isolation of cropland from natural vegetation (none/close/far) – contribution to household of collected/gathered products (e.g. proportion of fuelwood, wild foods, charcoal, materials, medicinal plants) – presence/absence/loss of useful species (that used to provide products) – frequency/severity of pest damage
Permanence of the various crops – period of cover – % cover/bare soil.
Crop diversity – number of crop species (and source- local/supplier) – number of varieties of main crops (and source local/ supplier) – diversity of harvested products (variety and kg/ha of grain, straw, beans, fruit, fibre, etc.),

Site No	Av. Farm size (field dsize) ha.			*Species*		***Growth***						***Health***		
				Common name	**Scientific name**									

Assessing Biodiversity Degradation/Improvement

Unless biodiversity loss and related impacts are identified as a major issue that requires in depth investigation, it is not considered necessary for the land degradation assessment to undertake a detailed assessment in this area. As this is not part of the core assessment no specific indicators and methods are provided here for biodiversity assessment. Many methods exist, however, and it is likely that assessment teams will be able to select one or more that suited to specific local needs.

3.6 WATER DEGRADATION ASSESSMENT

The water assessment focuses on the following 7 issues:

1. Climatic conditions seasonality and trends - rainfall, evaporation, drought, flood;
2. Water management practices such as water harvesting techniques and water conservation practices,
3. Water allocations/access rules and arrangements, incidence and management of water conflicts, water policy, legislation and other institutional issues;
4. Water quality of the different water bodies;
5. Water quantity/availability from different water bodies, for different users, and uses;
6. Pressure/demand on water: water use/consumption, water withdrawal/abstraction, proportion of illegal water withdrawals, water infrastructure;
7. Water use efficiency: (e.g. excess losses through runoff and evaporation); type and efficiency of the water infrastructure in irrigated areas.

The complete assessment of water resources in the local area combines data from 3 sources:
(1) Secondary information,
(2) Focus group discussions (Tool 1), transect walks/reconnaissance visit (Tool 2), and household interviews (Tool 7),
(3) Field assessment (field based land user/key informant interviews, visual observations and field measurements) (Tools 14.1, 14.2 and 14.3 below)

This section is composed of 3 tools:

- **Tool 14.1 Key informant interview on water resources**
- **Tool 14.2 Semi-quantitative assessment of water resources**
- **Tool 14.3 Additional assessment of specific water body degradation**

Box: Seasonality and interrelations with other resources

There are some challenges with assessing water resources, in particular that there are large inter-annual and seasonal variations in availability which can make assessments carried out at a single point in time problematic. Moreover, water is intimately interrelated with vegetation and soil resources. This is therefore one of many parts of this assessment where it is important to triangulate visual observations and field measurements with secondary data and with more qualitative information from land-users, and key informants to build up a reliable picture of water resource state and dynamics, the seasonal fluctuations and the changes over time.

Tool 14.1 Key informant interview on water resources

Key informants are members of the community, knowledgeable of the water resources in the local area. A small group is selected following the community focus group discussion.

The focus is on changes in water resources quality, quantity, and availability. It includes on-site information (water sources, watering points, evidence of runoff, etc.) and wider off-site or ecosystem effects of land use/ management practices e.g. impacts of losses from surface runoff and evaporation from bare ground, and effects on the hydrological regime e.g. change in water flow and availability, depth of water table, drought periods and peak flood levels, etc.

The information needs to reflect change in demand on water resources or pressures (P), the status and trends (S) of the water resources and the hydrological regime (S), the impacts (I) of changes in water quality, quantity and availability on productivity, livelihoods and the environment and some possible policy or management responses (R) to conserve or manage water resources.

Survey questionnaire to conduct with key informants when assessing the key water resources/bodies in the local area:

1) Water resource status and dynamics (quality and quantity)

a) What is the quality of the water like for human consumption, animal watering, and/or irrigation (very poor, poor, adequate, good)? If not good then what is wrong with it (dirty, carries diseases, saline, toxic)? Does the quality vary? If so how and why?

b) Has there been a noticeable change in this water resource/body over the last 10 years (describe the changes in amount, seasonality or quality of the water)?

c) Does it hold water just during the wet season or throughout the year? How reliable is it (does it always hold water, even in dry years? Does it dry out (almost always, often, rarely, never)?

d) What is the demand on the water point? (heavy, moderate, light, none) for i) human consumption, ii) livestock, iii) agriculture iv) other uses) Has the pattern of use changed over the last 10 years?

2) Distance/Access

a) What is the approximate distance and time taken to reach water for i) domestic consumption in the dry and wet seasons, for ii) livestock watering in the dry and wet seasons, and for iii) irrigation? Any changes in the last 10 years?

b) How far are the main grazing areas from nearest potable water source in i) the dry season and i) the wet season. Has this changed over the last 10 years?

3) Drought Risk/Incidence

a) Do serious droughts occur in the area? How frequent are drought events? Have they become more or less common in the last 10 years?

b) What impacts do they have on i) humans, ii) livestock, iii) livelihoods activities, iv) income?

c) Do you consider that the main land uses are resilient? i.e can withstand shocks such as drought If not in do you consider they are slightly, moderately or very sensitive and to what specific situations

d) Is drought just a consequence of poor rains? Is this due to reduced rainfall amount or seasonal variability (i.e. more irregular rains and change in onset and end of rains)? Are there other factors that contribute (such as bare, compacted or crusted soils that increase runoff and hinder infiltration or use of less drought resilient crop species)?

4) Flood Risk/Incidence

a) Does flooding occur? How frequent are flooding events? Have they become more or less common in the last 10 years?

b) What impacts do they have on i) humans, ii) livestock, iii) livelihoods activities iv) income?

c) Do you consider that the main land uses are resilient? i.e can withstand shocks such as drought If not in do you consider they are slightly, moderately or very sensitive and to what specific situations

d) Is flooding just a consequence of intense rainfall events or are there other factors that contribute?

5) Demand on water: water use, water withdrawal, water infrastructure

a) What are the uses of the water resources/bodies?

b) What changes have there been in demand on water and water withdrawals in the last decade?

c) How is the water supply managed and by whom? Is the management sustainable and equitable (very poor, poor, moderate, high)

d) Do all people in the community/area have equal rights to use the resource? If not what are the differences?

e) What % of the total amount of water used (withdrawn from the water bodies) is permitted (legal, regulated) and what % is illegal? Indicate if there are differences for the various water bodies.

6) Efficiency of water uses:

a) Is there loss of water from surface runoff during rainfall (severe, high, moderate, low)? Have there been changes in run-offs in the last 10 years?

b) Is there a loss of water by direct evaporation from the bare soil or are there strong and (dry) winds that increase the evaporation loss?

c) What are the constraints to more productive/effective use of water? for example in regard to i) salinity, ii) shortage/access, iii) conflicts, Iv) cost, etc.

d) What are the local techniques for conserving water? (list types, see QM) How many people apply each technique (majority, some, few farmers/herders/households)

e) If used, what are the types of irrigation system(s)? Do they take/consume lots of water? How efficient are they (very low, low, moderate, high) in terms of losses of water by i) drainage, ii) pipe /canal leakages, iii) standing water and evaporation etc)? What are the impacts?

Tool 14.2 Semi-quantitative assessment of water resources

For all water resources, the main assessment indicators are:

1. **Water quality**
2. **Water quantity**
3. **Demand on water**
4. **Water use efficiency**

Scoring System (1-3) for assessing visual sub-indicators:

- Poor/Bad: score= 1
- Moderate: score= 2
- Good quality, good quantity and well-managed water resources/bodies: score= 3

Table 20 Water Quality (STATE)

Sub-Indicators	Methods	Visual observations + Scores
Colour and Turbidity: - Green and opaque from eutrophication or sewage, or - Brown and opaque from sediment load	Visual observations	1. Strong green or brown color, very cloudy 2. Light green or brown color, slightly cloudy 3. Natural transparent color
Algae and/or invasive aquatic plants	1. Key informant interview 2. Visual observations	1. Abundance of algae and/or invasive aquatic species 2. Presence of algae and/or invasive aquatic species 3. No algae or invasive aquatic species
Pollution by • Coliforms • Animal faeces • Discharge pipes (sewage, effluent)	• Key informant interview • Visual observations • Laboratory test (or from secondary information)	1. Presence of discharge pipes/canals, drainage inlets with substantial inflow and water either smelling or of unnatural colour 2. Presence of animal faeces or tracks and /or presence of small discharge pipes/ canals, drainage inlets and water of natural colour and not smelling 3. Absence of animal faeces and discharges pipes
Aquatic life (fish, insect)	• Key informant interview • Visual observations • Field measure of oxygen content in water	1. Absence or very limited visible life 2. Presence of only aquatic species known to be tolerant to some pollution 3. Presence of fish and insects indicating good water quality

		(sensitive to pollution)
Water salinity • Presence of salt tolerant plants • Salt on the soil surface • Water conductivity EC • High quantity of chloride, sodium, magnesium ions (water tastes bitter)	• Key informant interview • Visual observations • Field measure with EC meter • Laboratory test (or from secondary information)	1. Abundance of salt tolerant plants and/or patches or a thin layer of salt on the soil surface at the water edge 2. Presence of a few salt tolerant plants 3. No sign of salinization

Table 21 Water Quantity (STATE):

Sub-Indicators	Methods	Visual observations + Scores
Water level in river, stream, lake, wetland, dam, and reservoir	• Secondary information from water level recorders or previous monitoring • Key informant interview of change in capacity, period and frequency of water shortage/flash floods • Visual observation - Field measure of water level (m. altitude with GPS) with tape or rope	1. Only a small fraction of the capacity of the water body e.g. a very small flow of water in a large riverbed 2. Below to half of the capacity (average to limiting water conditions) 3. Above half of the capacity up to the upper limit of the capacity of the water body
Water depth height of water table in wells and boreholes	• Key informant interview • Secondary information (water authority) • Visual observation - measure of well/borehole depth and water depth - number of dried up wells/boreholes To capture clear evidence of falling ground water table over years i) record when well /borehole has been deepened or ii) since when it does no longer provide water in dry season- and causes.	1. Clear evidence of significant fall in ground water table over last 5 to 10 years, and severe impact on access 2. Slight fall in water table over last 5 or 10 years and slight impacts on access 3. No evidence of a falling water table over recent years
Period of drying up (months and interval)	Key informant interview	
Occurrence of floods	• Key informant • Visual observations of flood mark on the river bench or tree for information on changes in water availability, seasonality and flooding event	1. Clear evidence of significant increase in water volume; recent flood marks 2. Slight increase in water volume 3. No evidence of change in water volume

Table 22 Demand on Water (PRESSURE):

Sub-Indicators	Methods	Visual observations and scores
Water use e.g. for human consumption,	• Key informant interview • Visual observations	1. Water supply overexploited (demand more than supply)

Sub-Indicators	Methods	Visual observations and scores
livestock watering, agricultural irrigation or industry		2. Supply and demand in balance 3. No significant use
Water withdrawal/extraction- number, amount and period	• Key informant interview • Visual observations	Compared to available resource: 1. All the water withdrawn (frequently or at peak periods) 2. Substantial amounts of water withdrawn (many users or few large users) 3. Very little water withdrawal (few and small amounts) *Proportion of water withdrawn for different uses:* *a) only used for drinking/household* *b) water for people and animals* *c) mainly for industrial use* *e) mainly for irrigation* *f) or a combination*

Table 23 Aridification and Water Use Efficiency (PRESSURE):

Sub-Indicators	Methods	Visual observations + Scores
Increase or decrease of indicator species	Visual observations	1. Relative dominance of drought tolerant species compared with “normal” plant community. 2. Relative abundance of drought tolerant species 3. “Normal” plant community
Wilting and drying up of plants- dates and duration	• Visual observation • Key informant interview	Comparing land management practices: 1. Marked difference in drying up/ much less resilience to dry periods 2. Drying-up a little earlier than other land management practices 3. No difference between different land management practices
Loss of rainwater by runoff	Visual observations	1. Clear signs of water loss by runoff and soil erosion: Rills or gullies, due to inadequate soil cover and/or lack of or ineffective soil and water conservation 2. Signs of surface water runoff and some soil movement (sheet erosion)- moderate cover and/or some soil and water conservation 3. No signs of surface water runoff due to good soil cover and soil and water conservation measures

Sub-Indicators	Methods	Visual observations + Scores
Loss of rainwater by soil evaporation	Visual observations of soil cover *(combined with the vegetation and soil assessment)*	1. Soil uncovered and bare during long periods of time 2. Soil partly and seasonally not covered 3. Soil permanently covered (litter/live plants)
Irrigation technology (type is major determinant of water use efficiency)	• Key informant interview • Visual observation	1. Surface irrigation- furrow or flood (low efficiency) 2. Sprinkler irrigation – moderately efficient 3. Drip irrigation with good ground cover - very efficient Or a combination for different farmer types
Irrigation water distribution types and maintenance (affects degree of efficiency)	• Key informant interview • Visual observation	1. Pipes or canals (earth-lined or concrete) not well maintained and with major leakages and damage 2. Pipes and concrete canals with some damage or well maintained earth-lined canals and structures 3. Well maintained irrigation pipes or lined (concrete) water canals
Irrigation scheduling	• Key informant interview • Visual observation	1. Significant plant wilting or standing water 2. Slight signs of plant wilting or standing water on the soil between irrigations 3. Well scheduled irrigation (to meet plant demand and avoid over- drying or overwetting)
Water harvesting techniques (list types) • Bench terraces (level, forward or backward sloping) • Contour bunds / banks (level, graded, semi-circular, v-shaped, trapezoidal etc.) • Graded ditches, waterways and cut-off drains • Level ditches / pits (infiltration, retention, sediment and sand traps) • Dams, tanks, reservoirs and pans to store excessive water	• Key informant interview • Visual observation	Runoff water is captured and diverted to plants or stored for later use: 1. Limited/negligible water harvesting 2. Some water harvesting 3. Significant water harvesting *Clarify purpose:* *a) for drinking water by most households* *b) for diversion and direct use by trees or crops (increasing the soil moisture)* *c) for storage in tanks and above and below ground water reservoirs (dams, ponds for household, livestock and/or irrigation*

Sub-Indicators	Methods	Visual observations + Scores
• Soil cover and mulching		

Tool 14.3 Degradation assessment of specific water bodies

For specific water bodies, such as rivers, streams, lakes, water points, and wetlands, additional indicators (to the four ones in Tool 14.2) are proposed considering the important role of these water bodies in drylands.

1. **River/stream banks, lake shores, and coasts**
2. **Livestock watering points: wells, springs, dam/artificial reservoir**
3. **Wetlands**

It is important to consider the on/off site causes of water body degradation during the assessment.

On-site:

- increasing pressure to use the water body, removal of natural vegetation, overgrazing, or injudicious cultivation in the sponge areas of water body;
- drainage or permanent alteration of the water level and flow to accommodate other use of the water body (e.g. for building or irrigation purposes). This change can be caused by direct human interventions (e.g. drainage project) or by changing riverbed e.g. due to floods leading to sedimentation or deepening of the river channel or gully erosion.

In the upstream/catchment area (off-site), where a change in land use (vegetation, water and soil), leads to:

- inflow of fertilizer run-off from farmed land that may cause rapid growth of algae in the water which depletes oxygen supply in the water and may kill plant, fish and animal life;
- inflow runoff of non selective pesticides or herbicides (from adjacent or upstream farmed land) that degrade natural animal and plant populations and have impacts on water quality;
- change of the water inflow regime leading to increased floods, or reduced low flows (e.g. change of perennial to seasonal flow)
- damming for water storage, irrigation or recreation;
- human activity and pollution in or close to the water body.

1. River /Stream banks, lake shores and coasts – degradation or protection

Degradation of the river/stream banks may be caused by removing riverine forests, by change in land use, or planting of inappropriate species. It has implications on the sustainability of the watercourse, increased risk of erosion, landslides and sedimentation which may undercut road bridges or influence downstream infrastructure such as dams or settlements.

Most countries have legislation on the width of the protected area along the river, but the extent to which such legislation is applied and land users constraints/reasons for non adherence should be understood with a view to identify measures to improve riverbank protection and the sustainable use of river and other surface water bodies.

By walking along a river or lake the following indicators could be assessed within 10- 50 m from the shore depending on the size of the water body:

- What % of the bank is degraded for each land use type along the waterway (>60%, 30-60%, <30%) <30%, 30-60% >60%) to what extent (high, medium, low) and by which process (cutting of natural vegetation, landslip, erosion, compaction etc)
- Is there any danger of serious changes of the water course, landslips, etc. threatening i) productive land, ii) homesteads or human life or iii) infrastructure (high, medium, low)
- What land management /restoration practices are in place on the adjacent land next to the river/streambank/lakeshore, to what extent are they being applied/ respected (high, medium, low) and what is their effectiveness (poor, moderate, good)

Land users/key informants can be further asked

- What is the potential cost of riverbank degradation in terms of damage or loss of threatened infrastructure
- What legislation or bylaws are in vigour on river/stream bank protection and to what extent are they being respected/applied and if not why not.

Table 24 LD/SLM indicators for rivers and stream-banks

Indicators	Methods	Visual observations + Scores
Vegetation and state of river banks/ lake shores	Visual observations	River/streambed /lake shore are: 1. Tree and bush vegetation is missing, the riverbank shows signs of cultivation, and is unstable or undercut with signs of active river bank erosion 2. Vegetation partly disturbed, cultivated land within less than 10 m of the river or lake shore 3. Stabilized by vegetation (mainly trees and bushes) and not cultivated or intensively used within 50 to 100 m
Animal trampling on river/streams banks /lake shores	Visual observations	1. Many entry points where animals have access to the water 2. A few entry points where animals have access to water 3. No signs of animals entering into the water

2. Watering points (wells, springs and dam/artificial reservoirs) degradation/protection

Land degradation by livestock through overgrazing and trampling around watering points in grazing lands/rangelands is a common phenomenon. The assessment should include evidence and severity of degradation around watering points and management measures in place to mitigate degradation, for example:

- control of livestock numbers and distance between watering points in relation to environmental conditions and water demand;
- seasonal movements and management regimes and their effectiveness in protecting, ensuring sustainability of watering points and surrounding grazing lands;
- temporary limits/bans on use of watering points by large herds to allow adequate time for recovery and restoration of natural vegetation.

In general, grazing effects decrease with distance from the watering point and, in some areas, effects are temporary so their impacts largely disappear as vegetation responds to rainfall. Thus, the team should assess the extent and severity of the grazing gradients i.e. systematic change in vegetation cover and species with distance from water which remain after the rainy season. This will indicate probable long term soil and vegetation damage with as a consequence reduced availability and quality of forage and increased erosion risk (i.e bare soils and associated signs of degradation in a radius of 50-500m around the waterpoint.

This visual assessment of the vegetation gradient can be backed up by information from herders and key informants regarding problems associated with the use or opening up of a watering point, such as:

- Traditionally unused grass lands during the dry season become continually grazed or browsed by animals, which prevents or reduces natural vegetation recovery;
- Permanent human settlements develop around watering points which may increase deforestation for construction and fuel wood, permanent livestock numbers, and cultivated land (where feasible);
- Change in species composition from drought tolerant (e.g. camel) to water dependant (e.g. cattle).

<u>Indicators</u> for assessing land degradation around watering points using observations and a line transect:

Table 25 LD/SLM indicators for watering points

Indicators	Methods	Visual observations + Scores
Ground cover and types of vegetation	Visual observations comparing land close to the watering point with land further away	1. More than 50% bare soil 2. 10 – 50% bare soil 3. 0-10% bare soil 1. More than 50%change in vegetation structure or type, 2. 10 – 50% change 3. 0 – 10% change
Species composition of grassland	Visual observations comparing land close to the watering point with land further away • Key informant interview (local herders will be able to sort species into classes: poor, medium, good forage but identification may also require a local range expert)	Proportion of perennial /annual species: 1. Mostly annual species 2. Annual with few perennial species 3. Mainly perennial species Proportion of palatable species: 1. Very little palatable species present 2. Moderate presence of palatable species 3. All or most palatable species
Soil degradation types, extent and severity	Visual observations	Around the water point 1. Severe and extended erosion (rills, gullies) 2. Some but limited sheet erosion or small rills)

Indicators	Methods	Visual observations + Scores
		3. No signs of erosion
Soil crusting and soil compaction	Visual observations	Around the water point 1. Severe and extended soil compaction and crusting 2. Limited soil compaction and crusting 3. No soil crusting or compaction
Soil and water conservation measures in place	• Key informant interview • Visual observations	1. Absence of SWC measures to protect the water point 2. Some SWC to protect the water point but slight to moderately effective 3. SWC techniques in place and effective in protecting the water point

Key informant interviews can provide further information on:

- the distance to nearest alternative watering point
- the trend in livestock numbers and species using the watering point in wet and dry seasons and reasons for any changes (increase/decrease in pressure) - in the absence of precise data local herders may be able to give approximate numbers)
- the existence and respect/application of rules and regulations to control livestock numbers and protect the water point, including duration of use and resting / closing of watering points and surrounding areas, local customs and bye-laws and national legislation.

3. Wetlands

Wetlands are very important in drylands as they provide a range of important functions: hydrological and ecological/biological functions and livelihood support functions. Wetlands include swamps, marshes, bogs and similar areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support a prevalence of vegetation typically adapted for life in saturated soil conditions.

Wetlands provide a range of important functions in dryland regions notably: hydrological and ecological/biological functions (e.g. buffering of peak and low flows, purification of the water) and livelihood support functions (secure water supply during droughts, extreme events) . Changes in these functions as a result of degradation or improved management measures should be assessed. The changes in a wetland may be the result of erosion and sedimentation or human management activities such as wetland development for irrigated farming or rainfed horticulture .

The assessment includes three main aspects:

1. Does the wetland area and hence the habitat it provides has been reduced or affected through i) cultivation ii) afforestation or reforestation, iii) pollution, iv) hydrological cycle alterations, v) human management actions (e.g. intense grassland burning)?

2. What is the severity and extent of degradation in the wetland? i) vegetation (see Tool 13), ii) soil erosion (see Tool 11), and soil properties (Tool 12).

3. Have there been changes in the functions provided by wetlands (hydrological; ecological/biological and livelihood support) as a result of degradation or improved management measures and what are the main causes in terms of human management activities?:

- vegetation and soil erosion due to overgrazing or injudicious cultivation in the sponge areas of wetlands in the upper catchments of rivers;
- fertilizer run-off from farmed land that may cause rapid growth of algae in the water which depletes oxygen supply in the water and may kill plant, fish and animal life;
- runoff of non selective pesticides or herbicides that degrade natural animal and plant populations and impacts on water quality;
- drainage or permanent alteration to accommodate building or planting or rainfed or irrigated crops;
- damming for water storage, irrigation or recreation;
- human activity and pollution in or close to the wetland.

Supplementary indicators for assessing degradation in wetlands:

1- change in productive capacity of the wetland for livestock grazing, wild foods harvesting, construction materials and cultivation;

2- increased downstream flooding (flood incidence and severity);

3- diminution of plant and animal biodiversity or indicator species of threatened habitat

Table 26 LD/SLM indicators for wetlands

Indicators	Methods	Visual observations + Scores
Productive capacity - e.g. livestock grazing, wild foods harvesting, construction materials and cultivation	• Key informant interview • Visual observations	1. Poor productive capacity 2. Moderate production-limitations 3. Good productive capacity: e.g. for animal grazing, wild food collection, and rice cultivation
Downstream flooding	• Key informant interview • Visual observations	1. Frequent and damaging flooding 2. Moderate water flow 3. Water well retained by the wetland
Biodiversity/ indicator species	• Key informant interview • Visual observations	1. Greatly reduced of flora and fauna biodiversity relative to “normal” communities. 2. Significant reduction in biodiversity relative to “normal” communities 3. “Normal” or close to “normal” biodiversity levels.

3.7 ASSESSING THE EFFECTS OF LAND DEGRADATION ON CROP PRODUCTION

Land users are usually most interested in the impacts of LD/SLM on productivity as this is directly liked to food and livelihood security. There is a strong emphasis on productivity impacts with the rangeland assessment tools but some additional focus in this area will be required for cropland.

Tool 15 Degradation Effects on Cropland Productivity

Information can be obtained on degradation effects on cropland productivity through the household interviews and discussions with land users in the field and other informants (e.g. extension /project staff) backed up by data from agricultural research. There are three main groups of visual field indicators that are useful:

i) Low or declining yields (actual yields and trends)
ii) Poor growth characteristics
iii) Plant nutrient deficiencies and toxicities

i) Low or declining yields

Discussions with land users
Discussions with land users may reveal that yields have fallen over time and this may be an indicator that land degradation has taken place, particularly if the yield decline is found in areas suffering land degradation. Caution is required with interpretation as crop yields are affected by many considerations and there will not always be a "cause and effect" relationship between declining yield and land degradation when they are found together.

Even if yields are stable or increasing, land degradation may also be occurring but its effects not yet felt (e.g. on land cultivated for the first time) or masked by land user management (e.g. increasing amounts of fertiliser use). Where the assessment team believes this is occurring there is potential to use economic valuation tools to calculate the value of future lost production. These are not detailed here but can be powerful in demonstrating the impacts of LD/SLM on future production.

Historic comparison of yields from records
Farm records, local co-operatives, marketing boards or official government statistics can provide useful information on medium to long term trends in production. By then putting those records alongside statistics on fertiliser use, introduction of new varieties and other production-enhancing factors, a qualitative view may be gained of how far land LD/SLM may have impacted production.

Quantitative measures of changes in yield
Within-field differences in yield are often very significant. It may be possible to directly relate the yield differences to land degradation variables such as soil depth or erosion. Root crops (carrots, sweet potatoes, beet), are especially amenable to this technique. Farmers may also be willing to draw the size of their individual root crops onto paper. An equivalent size of tuber can then be purchased from the market, weighed, and the yield estimated by multiplying the number of plants in a fixed area by the estimated average weight.

ii) Plant growth characteristics

These may include plant height and diameter, numbers of tillers, plant population (can indicate germination rate). As with yield, differences in these characteristics may not be entirely due to observed LD/SLM but these simple measurements are very useful in obtaining a farmer-perspective on crop productivity.

Possible field indicators for the assessment of i) and ii) are given in Table 27. These can be assessed qualitatively or quantitatively using quadrats etc. (further detail on use of quadrats in Annex 2). However, some of the indicators will be relevant only at certain times of the year.

Table 27 Summary of indicators for assessing crop growth and yield

Field-based Yield Assessment	***Relevant situations and warnings***
Plant Growth measurements as proxies of yield	
Relative diameter of growing crops in relation to land degradation indicators, such as depth of topsoil, organic carbon content or slope.	Useful for vegetables, planted on same date but in different parts of the field. Lettuces or cabbages have significantly different diameters according to soil quality Good proxy for yield, especially if the farmer can show what size they are expected to reach at harvest.
Relative height of growing crops (as above).	A good proxy of yield for other crops, such as maize. But height is very specific to crop variety, so relative measures can only be used for the same variety.
Number of tillers on individual cereal plants, such as wheat, barley and oats.	For many cereals, the number of tillers is directly related to yield, because each tiller has a seed head. A useful proxy for yield, especially where the farmer can help by indicating size of expected seed head.
Plant population per square metre.	A useful proxy where germination is poor due to land degradation, plant population in degraded versus less degraded areas. This has been used with cereals, especially where soil crusting has affected germination.
Direct Farmer estimates	
Direct farmer assessments of bags of marketable yield.	From experience farmers will usually be able to estimate the number of bags of crop yield from a growing crop. Comparison of farmers' estimates between fields is especially useful.
Poor crop growth characteristics as indicators of land degradation	
Low germination or low seedling emergence	Could be caused by surface crusting. This would: i) reduce the effectiveness of the early rains – i.e. high loss of rainfall as surface runoff rather than infiltrating ii) even if sufficient water infiltrates for the seed to germinate, a strong crust could hinder seedling emergence
Stunted growth	May be due to low soil fertility, waterlogging within the rooting zone, or subsoil compaction limiting the depth of soil from which the roots can obtain water and nutrients.
Non-uniform crop growth within a farm plot	Could be an indicator of differential removal and deposition of the finer soil particles and lighter organic matter, as well as showing that land degradation has affected parts of the field more than others. May also be due to agronomic factors, e.g. variation in seed quality, use of different varieties of the same crop, localised outbreaks of pests and diseases, or uneven application of fertiliser and manure.
Wilting	In light textured subsoil or a stony or shallow profile: - Could signify that the soil can retain only limited water making it susceptible to drought.

Field-based Yield Assessment	*Relevant situations and warnings*
	In heavier textured soils: - Subsoil compaction would limit the depth of soil from which the roots can obtain water so that a short drought period during the growing season would more quickly lead to crop wilting than in a soil with a greater rooting depth. Care as rooting and thus water uptake can also be restricted by very acid or alkaline subsoil conditions.

iii) Plant nutrient deficiencies and toxicities:
Nutrient deficiencies are one of the commonest ways in which land degradation affects production. Expertise is required for the reliable identification of nutrient deficiency symptoms in the field as different plants respond in different ways to nutrient deficiencies. For example:

- Deficiencies of different nutrients (or toxicities or other degradation factors) may exhibit the same visual symptom. For example, yellowing of bean leaves can indicate lack of nitrogen, water-logging or even salinity. In maize, accumulation of purple, red and yellow pigments in the leaves may indicate N deficiency, an insufficient supply of P, low soil temperature or insect damage to the roots.
- Disease, insect and herbicide damage may induce visual symptoms similar to those caused by micronutrient deficiencies. For example, in alfalfa it is easy to confuse leaf-hopper damage with evidence of Boron deficiency.

Acute nutrient deficiencies can often be identified from the colour of a plant's leaves, whether the older or younger leaves are first affected, whether the terminal bud is affected, and by the plant's growth pattern. Slight or moderate deficiencies seldom show up as foliar symptoms. Similar symptoms can also be caused by damage from machinery or wind. Also one deficiency symptom can mask other deficiency symptoms.

Certain soil types, or soil uses, may be more likely to display nutrient deficiencies than others. The combination of particular soil conditions with visual indicators of nutrient deficiencies makes the conclusions drawn from the latter more robust.

The possible causes of nutrient deficiencies should be investigated with the land users, for example:

- long and/or intensive cropping with insufficient applications of manures or fertilizers to replace the nutrients removed in the harvested products;
- unbalanced applications of mineral fertilisers without applying manures;
- large applications of acidifying nitrogen fertilisers (e.g. sulphate of ammonia);
- excessive applications of trace element fertilisers causing other trace element deficiencies *(Note*: even small quantities of trace element fertilisers can cause deficiencies of other trace elements in sandy soils); and
- excessive liming which has raised soil alkalinity sufficiently to cause nutrient deficiencies.

Where such expertise exists in the assessment team and where crop nutrient stress appears to be a significant form of land degradation then reference should be made to **Annex 5** in which some general and crop specific nutrient deficiency symptoms are provided. In addition, the team may be able to obtain a copy of photographic keys to assist in the field identification of specific nutrient deficiency and nutrient toxicity symptoms from national agricultural research and/or extension services.

Nutrient deficiencies are caused by more than just removal in the processes of soil degradation. The principal cause (up to 100 kg N or more, in intensive cropping) comes from removal in harvested crops and insufficient replenishment through manures or fertiliser. Excess removal through harvesting, although unrelated to soil erosion, is a form of land degradation. Thus, in determining the cause of nutrient deficiencies, the team must judge carefully, tying field evidence with other aspects of farming practice and local knowledge.

Annexes to Part 2

The following annexes are provided in this section:

Annex 1 Classification systems for sustainable land management (SLM) for use in study area characterization

Annex 2 Further detail on vegetation assessment methods

Annex 3 Additional information to support soil degradation assessment

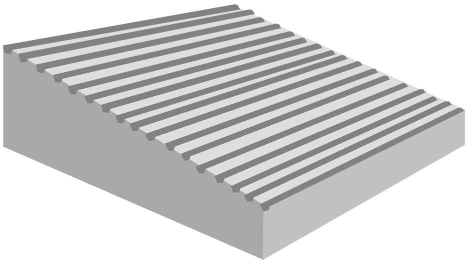
Annex 4 Supplementary tool for analysing nutrient flows and nutrient budgeting

Annex 5 Supplementary information on general and crop-specific nutrient deficiency symptoms

ANNEX 1 CLASSIFICATION SYSTEMS OF SUSTAINABLE LAND MANAGEMENT (SLM) FOR USE IN STUDY AREA CHARACTERISATION

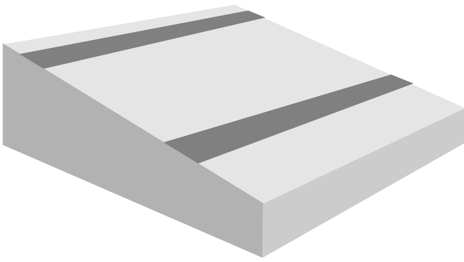
The main categories and types of conservation measures used in the different LUTs should also be recorded on the transect diagram. These are given in Table A1.2 below using the WOCAT SLM classification system.

Table A1.2 Categories and Type of Conservation/SLM measures



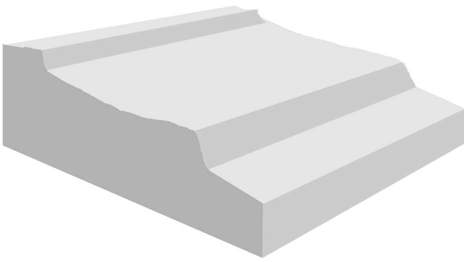
Agronomic measures *such as conservation agriculture, manuring / composting, mixed cropping, contour cultivation, mulching, etc.*
- *are usually associated with annual crops*
- *are repeated routinely each season or in a rotational sequence*
- *are of short duration and not permanent*
- *do not lead to changes in slope profile*
- *are normally independent of slope*

A1: Vegetation / soil cover
A2: Organic matter / soil fertility
A3: Soil surface treatment
A4: Subsurface treatment
A5: Others



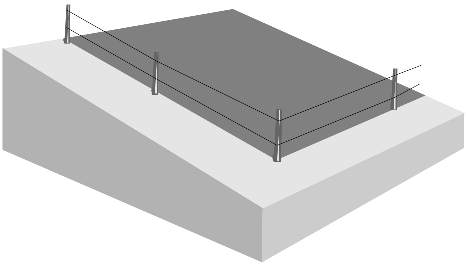
Vegetative measures *such as grass strips, hedge barriers, windbreaks, agroforestry etc.*
- *involve the use of perennial grasses, shrubs or trees*
- *are of long duration*
- *often lead to a change in slope profile*
- *are often aligned along the contour or against the prevailing wind direction*
- *are often spaced according to slope*

V1: Tree and shrub cover
V2: Grasses and perennial herbaceous plants
V3: Clearing of vegetation (e.g. for fire breaks, fuel)
V4: Others



Structural measures *such as terraces, banks, bunds, constructions, palisades, etc*
- *often lead to a change in slope profile*
- *are of long duration or permanent*
- *are carried out primarily to control runoff, wind velocity and erosion and to harvest rainwater*
- *often require substantial inputs of labour or money when first installed*
- *are often aligned along the contour / against prevailing wind direction*
- *are often spaced according to slope*
- *involve major earth movements and / or construction with wood, stone, concrete, etc.*

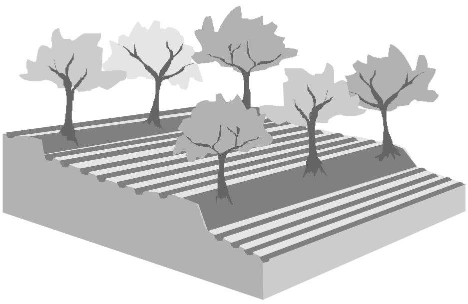
S1: Bench terraces (slope of terrace bed <6%)
S2: Forward sloping terraces (slope of terrace bed >6%)
S3: Bunds / banks
S4: Graded ditches / waterways (to drain/convey water)
S5: Level ditches / pits
S6: Dams / pans: store excessive water
S7: Reshaping surface (reducing slope)
S8: Walls / barriers / palisades
S9: Others



Management measures *such as land use change, area closure, rotational grazing, etc.*

- *involve a fundamental change in land use*
- *involve no agronomic and structural measures*
- *often result in improved vegetative cover*
- *often reduce the intensity of use*

M1: Change of land use type
M2: Change of management / intensity level
M3: Layout according to natural and human environment
M4: Major change in timing of activities
M5: Control / change of species composition (if annually or in a rotational sequence e.g. on cropland -> A1)
M6: Waste Management: includes recycling, re-use or reduce: includes both artificial and natural methods for waste management
M7: Others



Combinations *in conditions where different measures are complementary and thus enhance each other's effectiveness. Any combinations of the above measures are possible, eg:*

- ***structural:*** *terrace with*
- ***vegetative:*** *grass and trees with*
- ***agronomic:*** *ridges*

Example: **S1,V1, V2, A3:**

ANNEX 2 FURTHER INFORMATION ON VEGETATION ASSESSMENT METHODS

This annex contains further information on assessing vegetation cover and biomass

A2.1 Vegetation cover

A number of indicators can be used to estimate cover. Choice depends on vegetation type, litter and use of crop residues:

i. **Basal Cover** - the % of ground area covered by vegetation, and/or by particular species, with % estimates also made of other forms of ground cover such as litter, bare ground, and rocks. Basal cover is generally more stable (than folial cover) from year to year and changes less with climatic fluctuation or grazing pressure. It can be difficult to measure basal cover for herbaceous plants with single, small stems.
ii. **Folial Cover** - the percentage of ground covered by a downward vertical projection of the aerial portion of plant foliage, excluding small openings in the canopy. It is highly susceptible to yearly fluctuations due to climatic or biotic factors. It is easiest to measure for herbaceous plants, shrubs or succulents with large leaves. It can be difficult to measure for other growth forms
iii. **Canopy Cover** – an estimate of the area of influence of the plant – used for trees and forests. Gaps in the canopy are ignored. A vertical projection is made of the outermost perimeter of the natural spread of foliage of plants. For any area, the total canopy cover can exceed 100% because plants can overlap.
iv. **Plant residues and litter amount** (abundant, adequate, poor; or average %; and depth mm) should also be measured in cropping and agroforestry systems as the organic materials protect the soil and restore organic matter and nutrients. Crop residues, mulch or litter is often used by farmers and foresters to retain moisture and reduce runoff and erosion until a vegetation cover can be developed, for example in conservation agriculture systems where a key concept is building up of a litter layer and restoring soil health.

A2.2 Additional detail on vegetation assessment in pasture (veld)

i) Species composition, grazing quality and carrying capacity

A pasture/rangeland area under assessment, or a specific farm, usually comprises various grassland types, each with different plant communities and characterised by its own climate and soil characteristics. This restricts extrapolation of data from one grassland type to another; and carrying capacity must be determined annually for each vegetation type and for each grazing area.

Ecological units are useful for the geographical mapping of vegetation, e.g. pasture/ rangeland types, as the distribution of species with general habitat preferences is usually determined by environmental factors such as annual rainfall, altitude, temperature. For example in South Africa,

– Sour Bushveld, is characterised by *Eragrostis pallens* (steel grass*), Urelytrum squarrosa* (kina grass) and *Setaria sphacelata* (manna grass) which species are associated with higher rainfall, leached, sandy soils and trees such as *Terminalia sericea* (silver-leafed terminalia), *Burkea africana* (red syringa) and *Vitex rehmannii* (“pypsteel”).

- Thornveld areas are characterized by grass species such as *Panicum maximum* (white buffalo grass), *Urochloa mosambicensis* (signal grass) and other *Eragrostis* species, a lower rainfall, heavier, more fertile soils and *Acacia* trees.

Grazed species vary considerably in their response to management practices as well as in their nutritive value and acceptability to livestock. Such variation exists between- and within-species at different times of the year and in the same species growing in different areas.

Grazing management (utilisation and rest periods), fencing and stocking rate should maintain or increase the occurrence of palatable grasses, in order to enhance animal production without veld deterioration. Therefore, in assessing the vegetation resource and its grazing quality and level of degradation we should be able to:

- identify the plants concerned;
- know which species are more acceptable/ palatable to stock, so that they are not overgrazed
- recognize those plants which are unwelcome invaders so that steps can be taken to design gazing practices to control them before it is too late (when they out-compete and take over the grazing land).

ii) The grazing process-Why are certain areas and grasses utilized, others not?

In assessing effects of livestock grazing on vegetation quality it is helpful to understand the grazing process.

Livestock do not only select between species, but selection also differs between seasons, veld types, zones or ecotypes (Jordaan 1991).

While grazing, livestock have a choice between different grass species, each in a different stage of development (Daines 1976). Certain species (the palatable species occurring in the area) are selectively utilised as soon as the animals enter an area/ camp. As the grazing period increases, the animal is forced to use more tufts more selectively. Heavy use of palatable species then occurs. Thereafter, animals use less palatable, and later least palatable species. If the grazing period is long enough, unpalatable species are also grazed. In-between, palatable species are repeatedly defoliated. Certain species are used intensively, while others are left.

The following phases of veld utilisation can be observed

1. A creaming phase, where less than 50% leaf material is removed
2. A notable area or species utilisation pattern, where more that 50% leaf material is removed
3. An accentuated phase between grazed and ungrazed tufts, where all leaf material is removed
4. Total utilisation.

Individual grass tufts are defoliated through a first bite, which removes 50% leaf, a second bite, which removes more than 50% leaf, and a third bite, which removes all other material

iii) Carrying capacity

Carrying capacity is the potential of an area to support livestock through grazing/ browsing/ fodder production over an extended number of years without deterioration to the overall ecosystem (Trollope et. al. 1990). Carrying capacity is dynamic and influenced by several edaphic and botanical factors (Jordaan 1991). The main factors being climate, soil, topography and veld types (botanical composition, quantity and quality of grazable material produced) (Fourie *et. al.*,1985).

Carrying capacity can be expressed as **Livestock Units/ha** (LSU/ha = 1/(ha/LSU), where 1 LSU is defined as: an animal with a mass of 450 kg which gains 0.5 kg per day on forage with a digestible energy percentage of 55% (Meissner *et. al.* 1982; Trollope *et. al*. 1990).

Carrying capacity can also be determined **on the basis of the palatability and production of species** (Moore & Odendaal 1987). This method is the easiest to use, but must be repeated over time to obtain a proper norm. Dry material production is determined via harvesting (clipping 1m^2 quadrates, weighing the dried grass and converting the obtained production to kg/ha) or by using a disc pasture meter. The following formula is then used:

CC = 365 / (Production X Utilisation factor / Daily intake)

Where:

- 365 = days/year
- Production = production of palatable species (kg/ha)
- Utilisation factor = 35% = 0.35 (only 35% of all grass is considered to be utilized, the rest is wasted)
- Daily intake = 3% of body weight = ± 10 -12 kg/day

iv) Determining pasture/range condition

For the sustainable management of grasslands, it is of critical importance that farmers, extension staff and researchers can describe the condition of grazing on farms and in extensive grazing areas.

Method type A: Visual, semi-quantitative methods.

These are provided in the main tool-kit (Tool 3.2)

Further detailed vegetation assessments can be conducted, building on country experiences/research, notably:

- ecological monitoring of rangelands and wetlands in South Africa, and
- use of MARAS methods for environmental monitoring of arid and semiarid regions in Argentina,

Both of these use fixed transects with indices of landscape organisation, vegetation and soil (e.g. recording patches, size, distances, basal cover, litter, nutrient recycling) and indicator and alien species in order to assess heterogeneous morphological characteristics e.g. bare patches in landscape and grass cover and relate land use/pressure to effects on vegetation and landscape and functionality.

Method type B: Ecological classification methods [20]

More commonly the pasture/range condition of an area/ camp is compared with that of a benchmark - a similar veld type taken to be in a good condition that is chosen by the

[20] Developed and tested in South Africa by Foran et. al. 1978; Tainton et. al. 1980; Vorster 1982; Stuart-Hill et. al. 1986; Friedel & Blackmore 1988; Smit 1988 as described by Jordaan,1991

operator. Using botanical surveys, comparisons are made between different camps, relative to the condition of the benchmark and surveys are repeated over time to give an indication of pasture condition trend.

For the determination of a veld condition index, grass species are ecologically classified on the basis of their reaction to grazing (Table A2.1):

- Decreasers: species that decrease under over- or under-grazing
- Increasers Ia - species which increase under moderate undergrazing
- Increasers IIa - species which increase under moderate overgrazing
- Increasers IIb - species which increase under heavy overgrazing
- Increasers IIc - species which increase under severe overgrazing

Each of these groups is given a weighted value, based on the grazing/ecological value of the species (decreasers are given a value of 10; increasers are given values of 7, 4 and 1 for the a, b and c classes respectively). Botanical data (% species composition, % frequency or similar) of the relevant species is multiplied by the weighted value to give a species index. The total of all species indices gives the veld condition index, which is used to indicate veld condition.

THE KEY SPECIES METHOD

Veld type units (VTU) are identified and scored for veld condition. Here the concept of key species is used - those species effected by grazing. In this method, described by Trollope *et.al.* (1988), the site score is compared to that of a benmark site. The benchmark site represents veld in an excellent condition.

PROCEDURE

1. Choose 2 parallel transects through the veld type unit, 100 m long and at least 25 m apart. Make sure the area is homogenous and representative of the VTU. Mark the start and end of each transect so that they can be located in future.

2. Check 50 points along each transect 2 paces apart, use a stick or some other pointed object to determine each point. It helps to place the stick on the ground behind you when determining the point.

3. Record the grass plant nearest to the point if it one of the key species. If no plants are found within 25 cm of the point record it as bare ground. Take great care to record the exact number of points taken, it is a common mistake to end with more or less than 100 points.

4. The key species are classified into increasers and decreasers, with each species allocated a score out of 10 on the basis of it's grazing rating (see the attached table (Table 5) for scores and classification.)

5. Multiply the grazing value by the frequency of the species (number found in 100 points) to get the grazing score for each species. Add all the scores together to get the total score for the site (Table 4).

6. Each V.T.U. is given a benchmark value score (a score for tbe ideal or desired veld condition). The site score divided by the benchmark is the veld condition or production as a percentage of the ideal or benchmark.

Table A2.1 Key species and benchmark data: Sourish Mixed Bushveld

a. Benchmark score

	Freq. %	Index	Score
DECREASERS			
Red grass *(Themeda triandra)*	7	5	35
Copper wire *(Elionunus muticus)*	4	2	8
Thatch grass (*Hypamhenia filipendula)*	4	3	12
Bloubuffel *(Cenchrus ciliaris)*	4	7	28
INCREASER Ia			
Turpentine grass *(Cymbopogon plurinodis)*	4	1	4
INCREASER IIa			
Buffalo grass (*Panicum maximum)*	16	10	160
Yellow thatch grass *(Hyperthelia dissoluta)*	0	3	0
Assegai grass *(Heteropogon contortus)*	15	2	30
Kalahari salt grass (*Schmidtia pappophoroides*)	7	3	21
Enneapoyon scoparius	1	3	1
INCREASER IIb			
Curly leaf (Eragrostis rigidior)	7	0	0
Creeping curly leaf (Eragrostis barbinodis)	11	3	33
Aristida sp	4	1	4
Woolly finger grass *(Digitaria eriantha)*	2	3	6
Blackfoot *(Brachiaria nigropedata)*	2	3	6
INCREASER IIc			
Paper grass (*Urochloa mosambicencis*)	2	3	6
Stink grass (*Bothriochloa insculpta*)	0	0	0
Sokkiesklits (*Tragus berteronianus*)	0	0	0
Rolgras (*Trichoneura grandiglumis*)	2	0	0
Forbs	4	0	0
Bare ground	4	0	0
BENCHMARK SCORE	**100**		**356**

b. Site score

	Freq. %	Index	Score
DECREASERS			
Red grass *(Themeda triandra)*	1	5	5
Copper wire *(Elionunus muticus)*	1	2	2
Thatch grass (*Hypamhenia filipendula)*	1	3	3
Bloubuffel *(Cenchrus ciliaris)*	1	7	7
INCREASER Ia			
Turpentine grass *(Cymbopogon plurinodis)*	6	1	6
INCREASER IIa			
Buffalo grass (*Panicum maximum)*	9	10	90
Yellow thatch grass *(Hyperthelia dissoluta)*	0	3	0
Assegai grass *(Heteropogon contortus)*	8	2	16
Kalahari salt grass (*Schmidtia*	10	3	30

pappophoroides)			
Enneapoyon scoparius	0	3	0
INCREASER IIb			
Curly leaf (Eragrostis rigidior)	3	0	0
Creeping curly leaf (Eragrostis barbinodis)	19	3	57
Aristida sp	21	1	21
Woolly flnger grass *(Digitaria eriantha)*	12	3	36
Blackfoot *(Brachiaria nigropedata)*	3	3	9
INCREASER IIc			
Paper grass (*Urochloa mosambicencis*)	0	3	0
Stink grass (*Bothriochloa insculpta*)	0	0	0
Sokkiesklits (*Tragus berteronianus*)	0	0	0
Rolgras (*Trichoneura grandiglumis*)	0	0	0
Forbs	0	0	0
Bare ground	5	0	0
SITE SCORE	**100**		**282**

Expressed as a percentage of the benchmark score (282/356 X 100) this gives a veld condition score of 79.21% for the site.

Veld condition assessment – ecological classification method (Method B) (Survey form)

District............................... Farm............................... Camp no...........................

Sample site......................... Date................................. Operator.............................

Species	% Composition	Factor	Score

TOTAL			

ANNEX 3 ADDITIONAL INFORMATION TO SUPPORT SOIL DEGRADATION ASSESSMENT

This annex contains information on calibrating the soil organic carbon (labile fraction) tool (section 3.4)

Calibration for active carbon measurements

The calibration procedure[21] is as follows using varying concentrations of the stock solution[22]:

1. Zero the colorimeter by filling the colorimeter cuvette (to the mark) with deionised water, place cuvette in colorimeter, cover with cap (lightproof), press the “zero” or “tare” button. Readout should be 0.00.
2. Add 25 mL of the stock solution to a centrifuge tube, add 1 mL of the $CaCl_2$ solution.
3. Pipette-off 1 mL of liquid from the solution and dilute in a centrifuge tube to 50 mL with deionised water, ensuring (through repeatedly flushing the contents of the pipette) that all the stock solution is added to the tube.
4. Fill the colorimeter cuvette and place in colorimeter as before. Press “read” button. Note reading. [Note: this is the strongest (darkest) concentration of the $KMnO_4$ solution; representing zero labile organic carbon in subsequent soil samples] (Fig. 19A).
5. Pour out sufficient of the remaining solution in the centrifuge tube so only 25 mL remains. Make up this remainder to 50 mL with deionised water, pipette off 1 mL and repeat the colorimeter measurement procedure. The reading obtained is for ½ strength $KMnO_4$ (Fig. 19A).
6. Again, pour out sufficient of the remaining solution in the centrifuge tube so only 25 mL remains and make up the remainder to 50 mL with deionised water, pipette off 1 mL and repeat the colorimeter measurement procedure; so gaining a ¼ strength solution (Fig. A3.1).
7. Plot the above data (a straight line fit); as *mM* of $KMnO_4$ (x-axis) versus the absorbance reading (y-axis), as in Figure A3.1. A regression line can be fitted to the relationship.

[21] Note: this calibration procedure is a field-based (not analytical laboratory) technique, utilising the serial dilution of stock solution, with potential for compounding errors if care not taken to exactly measure the series of 1:1 solutions. Also, 1 mL of the $CaCl_2$ is added only once, whereas the soil testing procedure adds 1 mL to each fresh 25 mL of $KMnO_4$

[22] It is recommended that the calibration is conducted for each fresh batch of $KMnO_4$ and $CaCl_2$ solutions; to remove possible errors with slight mis-weighings and dissolving of the reagents.

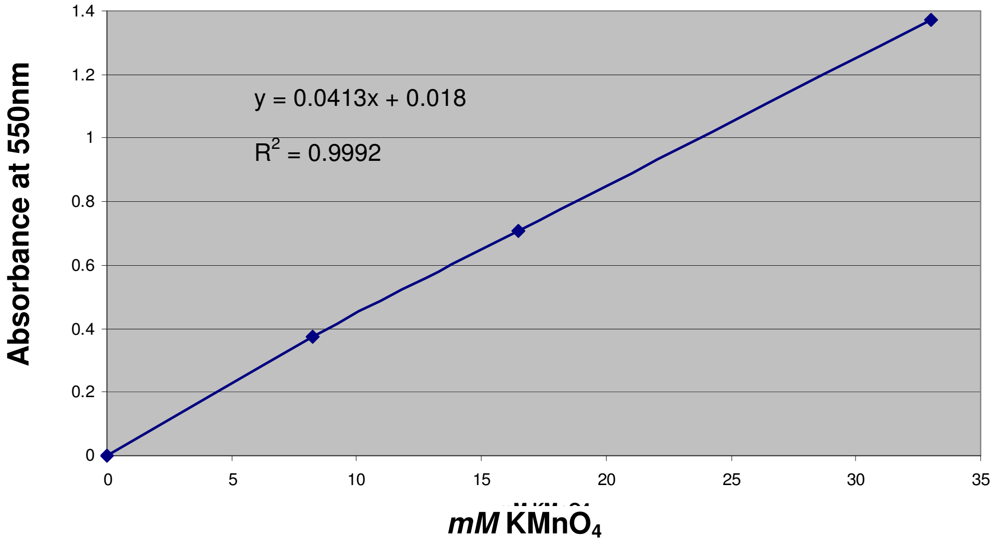


Figure A3.1 Standard calibration curve of four strengths of 33 *mM* $KMnO_4$ (x – axis) with colorimeter read-out (y – axis).

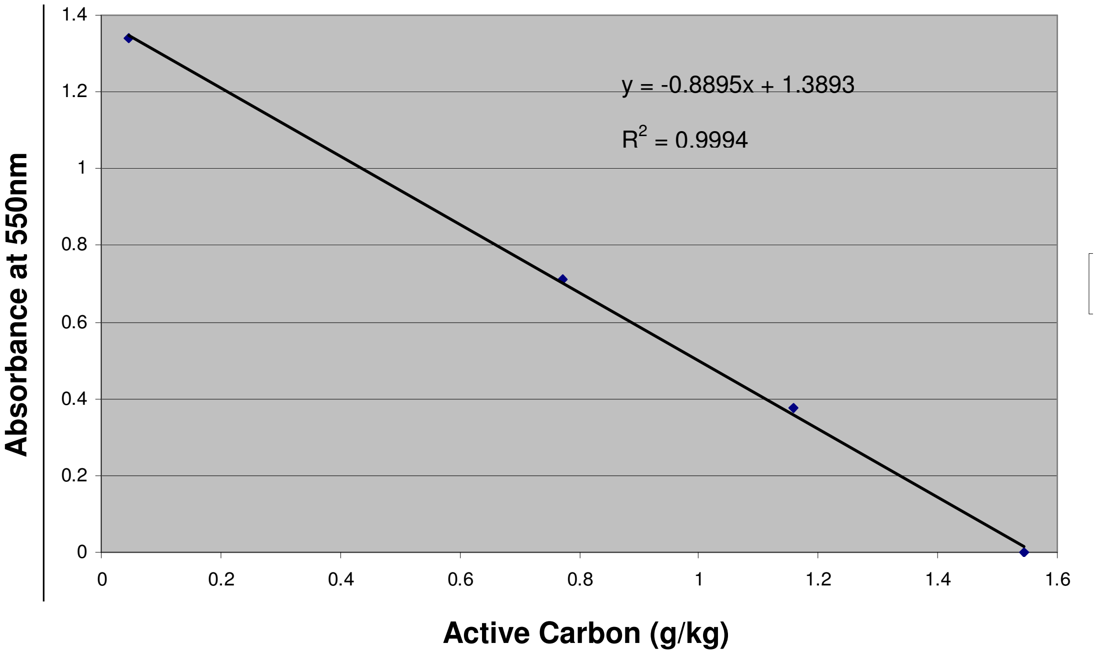


Figure A3.2 Relationship between the colorimeter readout (absorbance) and the amount of labile ("active") Carbon (g/kg), using the four strengths of 33 *mM* $KMnO_4$ of Fig. 19A and equation 1.

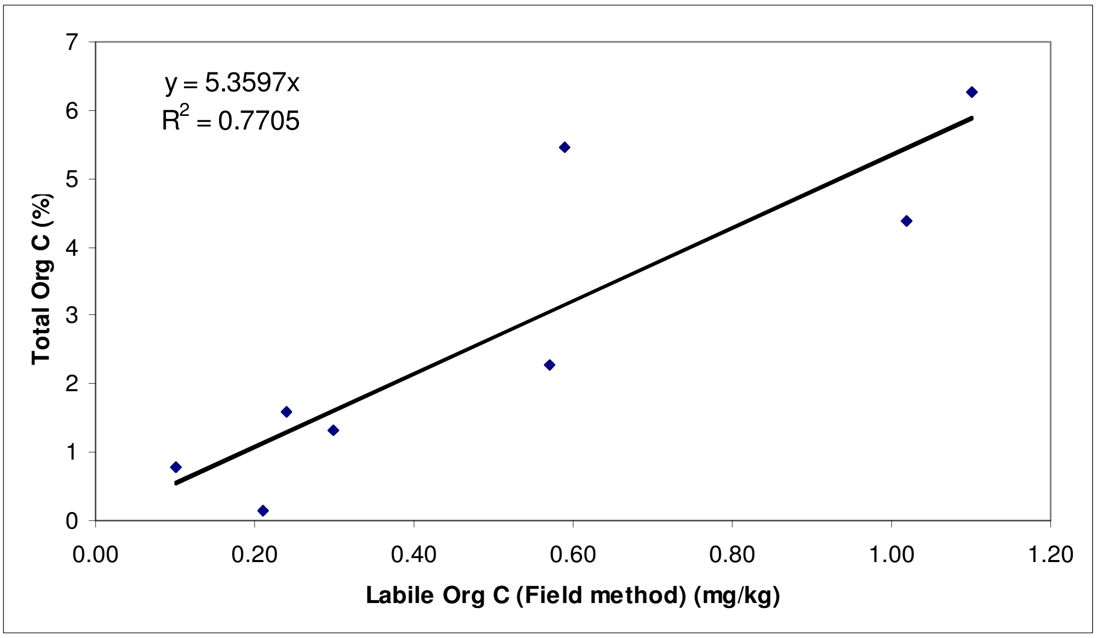
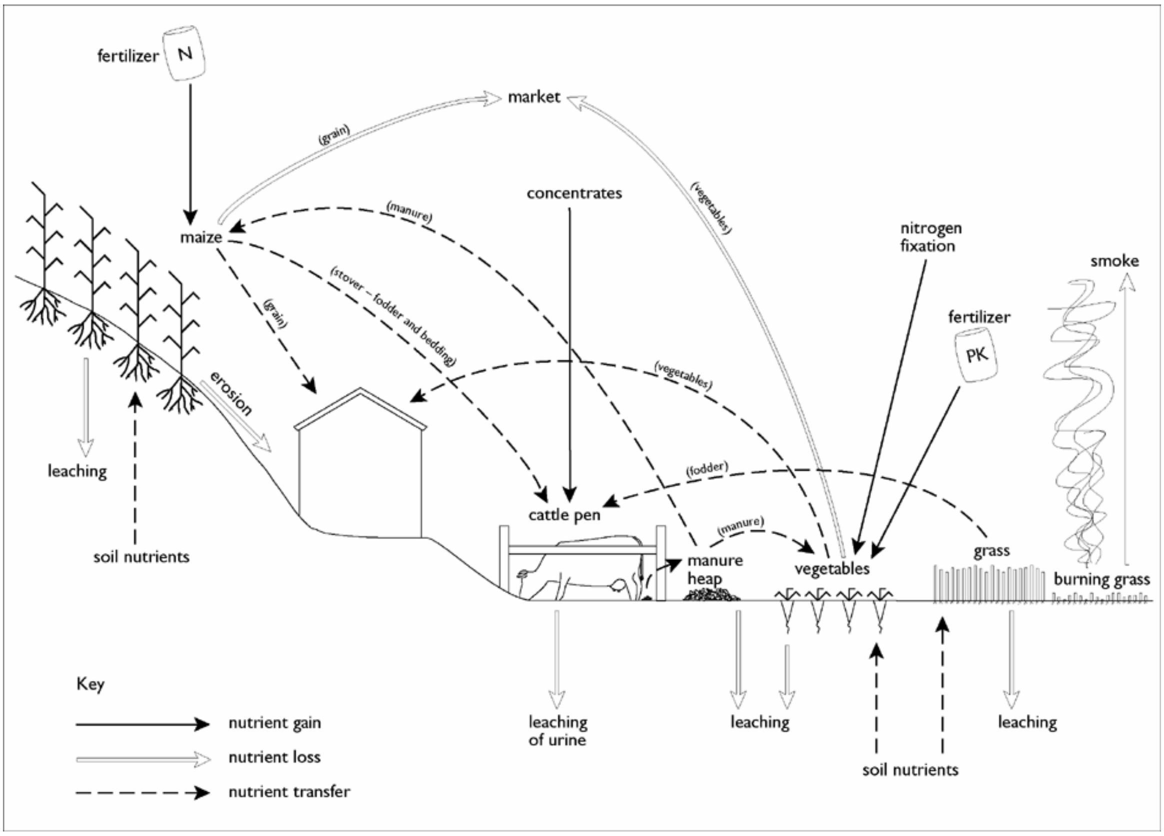


Figure A3.3 Relationship between “total” Organic Carbon (%) by the Leco method and Active (labile) Carbon from the permanganate field method for several soils (Moody et al. *In Press*) with fitted line and regression equation with R^2**.**

ANNEX 4 SUPPLEMENTARY TOOL ANALYSING NUTRIENT FLOWS AND NUTRIENT BUDGETING

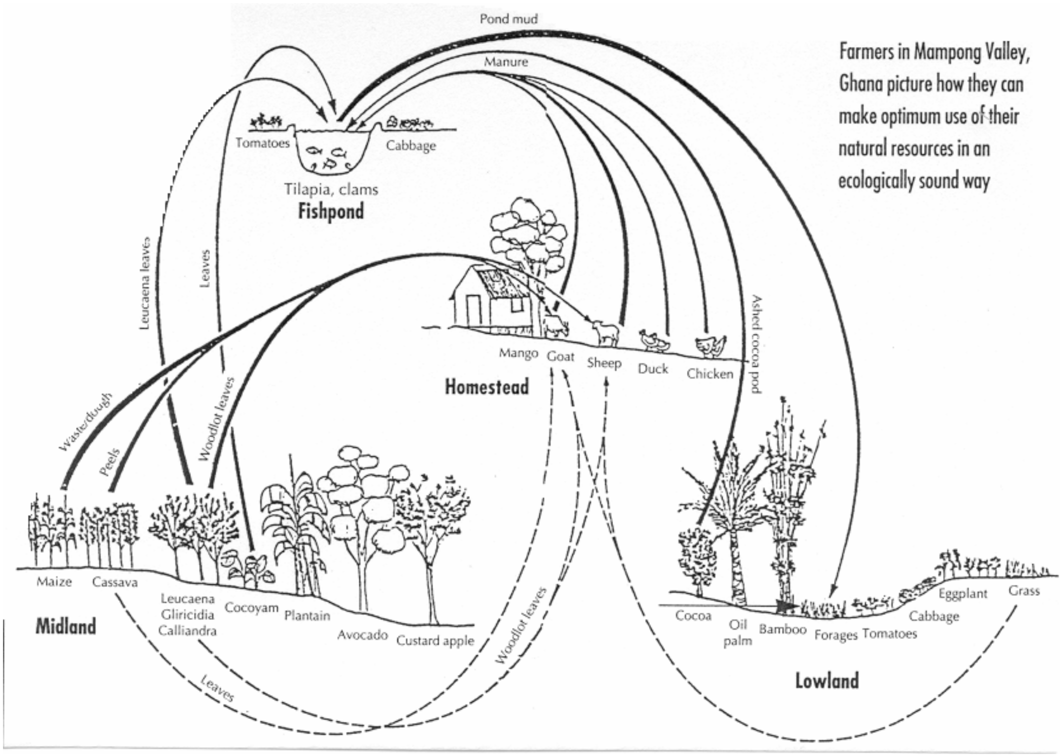
Nutrient flows and budgets can be estimated in discussion with farmers to determine whether there is a net negative or positive nutrient balance within particular farming systems and to show the relative flow of nutrients between different components within the household livelihood system and between different parts of the landscape within the study area. The procedure for identifying nutrient flows within mixed farming systems is as follows:

Pick a farming system (one that is representative of the major Land Use System) to be modelled in the flow diagram.
Start with the dominant cropping system and gradually build up the diagram by adding any other component cropping systems, the homestead plot, the livestock kraal/shelter, pasture/ grazing area(s), forests.
Identify the products which contain plant nutrients that move between the component elements of the household system (food crops consumed by the household, manure, crop residues, kitchen waste etc) and draw lines between them showing this movement.
Identify the products which contain plant nutrients that either leave the farm (eg. products sent for market) or are brought on to the farm (eg. purchased fertiliser, organic materials collected from off farm sources).
Determine the movement of nutrients into, out of, and within the farming system, as each component of the system is considered and insert arrows in the diagram to show the direction in which the nutrients flow.
Review and discuss the final flow diagram with the farmer(s) and key informants for



additional comments and suggestions.
Figure A4.1 Example 1 Nutrient Flows in a mixed farming system (Van Veldhuisen et al 1997)

Figure A4.2 Example 2 Nutrient Flows in a mixed farming system (Van Veldhuisen et al



1997)

Table A4.1 Input and Output Factors Governing Nutrient Flows in the Soil

Input		**Output**	
IN1	Mineral Fertiliser	OUT 1	Harvested product
IN2	Manure	OUT 2	Crop residues
IN3	Deposition	OUT 3	Leaching
IN4	Biological N fixation	OUT 4	Gaseous losses
IN5	Sedimentation	OUT 5	Erosion

Source FAO 2003

Table A4.2 Nutrient Removal in Crop Harvests

Crop	**Yield (t/ha)**	**Nutrient Removal (kg/ha)**				
		N	**P***	**K***	**Ca***	**Mg***
Maize grain	1	25	6	15	3	2
	4	63	12	30	8	6
	7	128	20	37	14	11
Rice grain	1.5	35	7	10	1.4	0.3
	8	106	32	20	4	1
Wheat grain	0.6	12	2.4	3	0.3	1.0
	5	80	22	20	2.5	8
Sorghum grain	1	20	0.9	4	4	2.4
	8	65	4	13	18	12.8
Finger millet grain	1.1	17	5	59	-	-
Cassava roots	8	30	10	50	20	10
	16	64	21	100	41	21
	30	120	40	187	77	40

Crop	Yield (t/ha)	Nutrient Removal (kg/ha)				
		N	P*	K*	Ca*	Mg*
Sweet potato roots	16.5	72	8	88	-	-
Beans	1	31	3.5	6.6		
Soybeans	1	49	7.2	21	-	-
Peanuts (unhulled)	1	49	5.2	27	-	-
Sugarcane (2 year crop)	100	75	20	125	28	10
	200	149	29	316	55	58
	300	254	35	499	96	80
Coffee dry beans	1	25	1.7	16	1	2
Tobacco cured leaf	1	116	14	202	-	-
Coconut dry copra	1.2	60	7.2	40	-	-
Oil palm fruits	15	90	8.8	112	28	-
Cotton seed	0.8	30	4.4	7	-	-
Banana bunches	10	19	2	54	23	30
	30	56	6	161	70	82
Pineapple fruits	12.5	9	2.3	29	3	-
Guinea grass (annual production from 6 cuts)	10	107	27	180	78	49
	23	288	44	363	149	99
	35	560	77	600	230	133

Source: Sanchez, 1976

* To convert from P to P_2O_5 multiply by 2.29; to convert from K to K_2O multiply by 1.2; to convert from Ca to CaO multiply by 1.4; to convert from Mg to MgO multiply by 1.66.

ANNEX 5 SUPPLEMENTARY INFORMATION ON GENERALIZED AND CROP-SPECIFIC NUTRIENT DEFICIENCY SYMPTOMS

Table A5.1 Nutrient Deficiencies and Toxicities – Generalised Symptoms and Circumstances

Essential Nutrient	*Deficiency/Toxicity Symptoms*	*Typical Conditions*
Nitrogen (N)	Leaves (first older ones) turn yellow/ brown, plants are spindly, lack vigour and may be dwarfed.	Sandy soils under high rainfall conditions and soils low in organic matter, where leaching occurs.
Phosphorus (P)	Not easily detected from appearance. Where deficiency is severe plant will be stunted, the leaves will take on a purplish tint and the stem will be reddish in colour.	Acid soils rich in iron and aluminium oxides (i.e. red tropical soils)
Potassium (K)	Yellow/brown spots appear on older leaves and/or necrosis of edges.	More frequent on light soils (as K is concentrated in the clay fraction of soils).
Sulphur (S)	Leaves are stunted, with uniform chlorosis.	
Calcium (Ca)	Roots are usually affected first – growth is impaired and rotting often occurs. In vegetative growth, deficiency may show in distorted leaves, brown scorching or spotting on foliage or bitter fruit (e.g. apple) or blossom-end rot (e.g. tomato).	Acid soils, or alkali or saline soils containing high proportions of sodium.
Magnesium (Mg)	Interveinal chlorosis, first on older leaves.	Acid, sandy soils in areas with moderate to high rainfall. Often occurs in conjunction with Ca deficiency.
Iron (Fe)	Chlorosis of younger leaves.	Calcareous soils, poorly drained and with high pH. (In neutral and alkaline soils P may prevent the absorption of Fe.)
Manganese (Mn)	Chlorosis of younger leaves.	Badly drained soils, over-liming or deep ploughing of calcareous soils can lead to Mn deficiency, as can the presence of high levels of Mg. The combination of high pH values (> 6.5) and high levels of organic matter can immobilise soil Mn.
Zinc (Zn)	Symptoms vary with plant type – in cereals young plants display purpling, whereas in broad-leaved plants symptoms include interveinal chlorosis, reduced leaf size and sparse foliage.	Soils with high pH. Available Zn is reduced by the application of lime or phosphates.
Copper (Cu)	Chlorosis of the tips of the youngest leaves and die-back of growing points.	Peat soils, or leached sandy or acid soils.
Boron (B)	In crops, other than cereals, the apical growing point on the main stem dies and lateral buds fail to develop shoots.	Sandy soils, dry conditions and liming can result in B deficiency.
Molybdenum (Mo)	Marginal scorching and cupping of leaves. Wilting is common in Brassicas.	Acid soils or soils with high pH. Mo deficiency can lead to N-deficiency as nitrate requires adequate supplies of

		Mo for metabolism. Mo availability can inhibit the uptake of Cu.
Chlorine (Cl)	Wilting of leaves.	Well-drained, sandy soils.
Sulphur Toxicity		Build up of sulphates as a result of irrigation
Manganese Toxicity	Brown spots and uneven chlorophyll in older leaves.	Soils with pH of < 5.0 (for susceptible species)
Copper Toxicity	Chlorosis of leaves and restricted root growth.	Soils with low pH
Boron Toxicity	Progressive necrosis of the leaves, starting from the tips and/or margins.	Soils with low pH
Aluminium Toxicity	Plants die after early growth.	Acid mineral soils, aggravated by low P status
Chlorine Toxicity	Burning of leaf tips, bronzing and premature yellowing of leaves.	Associated with irrigation using water containing chloride

Identification of Nutrient Deficiencies:

Observation of abnormalities in plants is a complicated and skilled task. Since nutrient deficiencies may be manifested in different ways depending on the crop in which they occur, particular criteria will be crop-specific. As an example, the visual indicators of nutrient deficiencies in several tropical crops are set out in the following table.

Table A5.2. Examples of Deficiencies in Several Tropical Crops

	Maize	*Beans*	*Cabbage*
General	High N requirement and sensitive to low phosphate supply. Relatively sensitive to water stress.	Tolerant to a wide range of conditions, but only high yielding with high N.	Demanding of N, P and K. Moderately sensitive to water stress.
Nitrogen	Reduced vigour; leaves a pale green or yellowish colour.	Plants are small, leaves are pale green and older leaves turn yellow. Few flowers are produced.	Young leaves pale green, older leaves are orange, red or purple. Severe deficiency renders the crop useless.
Phosphorus	Stunted growth, delayed ripening and purplish leaf colour, especially during early growth.	Stems are dwarfed and thin, leaves lack lustre. Early defoliation occurs, starting at base of shoot.	Leaves are dull green with purplish tinge, margins die.
Potassium	Small whitish-yellow spots on leaves. Poor root system, plants are weak and may be blown down.	Chlorosis of leaves, with necrotic brown patches at margins between veins.	Leaves are bluish-green. Leaf margins may show scorching and tips of older leaves may die.
Sulphur	Somewhat similar to N-deficiency. Plants short and spindly. Younger leaves pale beige to straw in colour.	Stunted growth, yellowing leaves. Delayed flowering and development of beans. Reduced nodulation on roots.	Smaller plants, with yellowing leaves.
Calcium	Poor germination and stunted growth.	Growth is stunted and growing point may die. In severe cases plants turn black and die.	Leaves rolled up at margins, necrosis of rims and death of growing point.
Magnesium	Whitish or yellow striping between the leaf veins, followed by necrosis.	Older leaves show interveinal reddish-brown mottling.	Interveinal chlorosis and puckering of older leaves.
Iron	Alternate rows of green and white on leaves	At early stage, patternless paling in leaf colour; later stage, yellowing of leaf similar to N- deficiency.	Whitish streaks on leaves. Veins unaffected at first, but larger veins eventually turn yellow.

Manganese	Yellow and green striping along the length of the leaf.	Chlorosis, initially of young leaves, followed by necrotic spots in interveinal areas. Leaves will fall off and plants eventually die.	Leaves are of smaller size and exhibit yellow mottling between veins.
Zinc	Chlorotic fading of the leaves, with broad whitish areas.	Leaves and flower buds are shed	
Copper	Leaves become chlorotic and the tips wither.		Leaves chlorotic, heads fail to form, growth stunted.
Boron	New leaves show transparent stripes. Growing points die and ears may not develop.	Leaves turn yellow and then brown. No flowers or pods are produced.	Leaves are distorted, brittle, mottled along margins and wilted.
Molybdenum	Not common by itself, but indicators include scorched patches on leaves.	Leaves are smaller, pale in colour with interveinal mottling developing into brown scorched areas.	Older leaves become mottled, scorched and cupped. Margins are irregular and heart formation is poor.
Chlorine	Plants short with poorly-developed stubby roots	Cl essential for the symbiotic fixation of N in legumes. No nodulation and stunted growth	Stunted roots with excessive branching and poor wilted top growth
Copper Toxicity	Reduced growth, chlorosis and stunted root development.		