Food and Agriculture Organization of the United Nations

LADA

LAND DEGRADATION ASSESSMENT IN DRYLANDS

LADA PROJECT

MANUAL FOR LOCAL LEVEL ASSESSMENT OF LAND DEGRADATION AND SUSTAINABLE LAND MANAGEMENT

PART 2

Field methodology and tools

GLOBAL ENVIRONMENT FACILITY 20 YEARS INVESTING IN OUR PLANET

UNEP

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PART 2

Field methodology and tools

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CONTENTS

Foreword

This document is the second part of a two part manual on local level assessment of land degradation and sustainable land management:

- **Part 1 – Planning and Methodological Approach, Analysis and Reporting**
- **Part 2 – Field Methodology and Tools**

The two parts should be used together as Part 1 provides the background information for the conduct of the methods and tools that are provided in Part 2.

The manual incorporates inputs and feedback from many individuals involved in piloting the local level land degradation assessment tools and methods in the six countries that participated in the **Land Degradation Assessment in Drylands project (LADA)** supported by the Global Environment Facility (GEF) and executed by FAO during the period 2006-2010. It draws on tools developed with the **World Overview of Conservation Approaches and Technologies (WOCAT)** for the assessment of sustainable land management (SLM). It also incorporates feedback from a series of national and inter-country workshops conducted during the period 2007-2010.

The development process was guided by the LADA team in the Land and Water Division of the Food and Agriculture Organisation of the United Nations, Rome, Italy, with substantial contributions from the School of International Development, University of East Anglia, Norwich, UK, under the overall technical supervision of Freddy Nachtergaele, LADA Coordinator and Riccardo Biancalani, LADA Technical Advisor.

Lead authors of the manual were:

- Sally Bunning (sally.bunning@fao.org), FAO Land and Water Division (NRL)
- John McDonagh (j.mcdonagh@uea.ac.uk), School of International Development, University of East Anglia, UK
- Janie Rioux (janierioux@gmail.com), Consultant FAO/NRL

The participatory testing and adaptation of the tools and methods was an iterative process, with the LADA country teams building on a series of inter-country training and review workshops, namely:

- Initial workshop hosted by the University of East Anglia (Norwich, June 2007);
- Pilot Training of Trainers session hosted by Tunisia (Béja, November 2007);
- Mid-term review workshop hosted by Argentina (Mendoza, January 2009);
- Final review workshops hosted by the Universities of Amsterdam and Wageningen respectively (the Netherlands, August 2010).

The final peer review and editing was conducted by Anne Woodfine, independent expert in natural resources management (FAO consultant).

The support of the host and partner institutions in the six LADA pilot countries, which provided policy, technical and co-financing support for the local assessment piloting and workshop venues, is gratefully acknowledged. Insights, experiences and suggestions were provided by LADA country teams in developing this local assessment methodology, notably by:

- **Argentina**: Elena Abraham (Mendoza Region), Stella Navone (Puna Region), Donaldo Bran and Hugo Bottaro (Bariloche) and Esquel (Patagonia), who coordinated the local assessment teams with the institutes of IADIZA, FAUBA and INTA in the regions; supported at national level by Vanina Pietragalla, Maria Laura Corso and Andres Ravelo, Secretaría de Ambiente y Desarrollo Sustentable;
- **China**: Wang Guosheng, Jiping Peng and Kebin Zhang, with inputs during training by Lishui Nie and Tien Huan *et al.*; and overall guidance by Yang Weixi of the National Bureau to Combat Desertification;
- **Cuba:** Candelario Aleman, N. María Nery Urquiza and Fermin J. Peña Valenti, supported by the Agencia de Medio Ambiente, Ministerio de Ciencia, Tecnología y Medio Ambiente;
- **Senegal:** Déthié Soumare Ndiaye, Gora Beye, Abdoulaye Wele, and other team members, Centre de Suivi Écologique, Ministère de l'Environnement, de la Protection de la Nature, des Bassins de rétention et des Lacs artificiels;
- **South Africa:** Liesl Stronkhorst, Agricultural Research Council and Lehman Lindeque, Department of Agriculture, Forestry and Fisheries, Ministry of Agriculture, Forestry and Fisheries, with support from their institutions;
- **Tunisia:** Hattab Ben Chaabane, Rafla Attia, Leila Bendaya, with technical support of IRA (Institut des Régions Arides), Médenine and CRDA (Commissariats Régionaux au Développement Agricole) de Médenine, Siliana and Kasserine,guided at national level by Hédi Hamrouni, LADA Coordinator, with support of the Direction Générale de l'Aménagement et de la Conservation des Terres Agricoles, Ministère de l'Agriculture et des Ressources Hydrauliques.

A number of technical specialists and other staff in their institutions made significant contributions to the development of this manual. In particular, the valuable contributions of three key individuals Malcolm Douglas, Yuelai Lu and Michael Stocking are acknowledged and also two key partner institutions, namely:

- **Centre for Development and Environment**, University of Berne, host of WOCAT (World Overview of Conservation Approaches and Technologies) Secretariat;
- **United Nations University** (UNU) which supported inputs by UEA and use of an early rapid version of the local assessment manual through its SLM project in the Pamir Alai Mountains in Tajikistan and Kyrgyzstan.

Finally, this work was accomplished thanks to the following institutional support:

- **Technical and policy support of the Food and Agriculture Organization of the United Nations (FAO)** which executed the LADA project, in particular by Parviz Koohafkan, Director, Land and Water Division, and the interdisciplinary Project Task Force; and
- **Funding and implementation support of the Global Environment Facility (GEF) and United Nations Environment Programme (UNEP)** respectively to the LADA project.

The manual draws, in particular, on the following references:

FAO-WOCAT (2011) A Questionnaire for Mapping Land Degradation and Sustainable Land Management (QM) v2. Food and Agriculture Organization of the United Nations, Rome, Italy.

Department of Agriculture, Government of South Africa (2009). The core indicators for pasture / range condition scoring in LADA-Local were adapted from the pasture (veld)/ rangeland quality and vegetation assessment used in South Africa. (A list of visual indicators for assessing veld condition trend on farms and extensive grazing areas used with farmers, extension staff and researchers and repeated yearly. Ref. Roberts,1970; Roberts, *et al.* 1975; Fourie & Roberts, 1977, as described by Jordaan, 1991).

Douglas, M., (2008; unpublished). Assignment Report from China LADA Local Assessment Training Workshop, 10 -15 October 2008 including Guidelines criteria for the prioritisation of watersheds for improved management;

FAO. (2009a) Towards defining forest degradation: comparative analysis of existing definitions, Forest Resources Assessment Working paper, 154, Food and Agriculture Organisation, Rome, Italy.

FAO (2009b) Measuring and Monitoring Forest Degradation through National Forest Monitoring Assessment (NFMA). Eds. Tavani, R.; Saket, M.; Piazza, M.; Branthomme, A.; Altrell, D., Forest Resources Assessment Programme Working Paper 172, Food and Agriculture Organisation, Rome, Italy.

FAO / TerrAfrica (2011) Sustainable land management in practice: Guidelines and best practices for sub-Saharan Africa (authors Liniger, H., Mekdaschi Schuder, R., Hauert, C. and Gurtner, M.), Food and Agriculture Organisation, Rome, Italy.

McGarry, D. (2006). A Methodology of a Visual Soil - Field Assessment Tool "VS-Fast" to support, enhance and contribute to the LADA program;

Stocking, M. and Murnaghan, N. (2001). Handbook for the field assessment of land degradation. Earthscan Publications Ltd, London, UK.

The participatory tools for Sustainable Rural Livelihoods' approaches/analysis draw from several publications, including:

Ellis, F. (1998). Survey article: Household strategies and rural livelihood diversification. The Journal of Development Studies. Vol.35, No.1, pp.1–38;

FAO Livelihoods Support Programme manuals and guidelines http://www.fao.org/es/esw/lsp/manuals.html; and

Scoones, I. (1998). Sustainable rural livelihoods: A framework for analysis. IDS Working Paper. No.72. Institute of Development Studies, Brighton, UK.

The soil and vegetation assessment methodology used in the local assessments in Argentina and South Africa also drew on the Landscape Functional Analysis (LFA) methodology, developed in Australia and adapted in Argentina as the MARAS system. While LFA has not been incorporated in the manual since it was used and validated for LADA Local in only 2 of the 6 LADA countries it presents, however, an acceptable alternative to the proposed LADA-Local VSA Fast soil and vegetation assessments and is posted on the LADA website.

Tongway, D. and Hindley, N. (2004) Landscape Function Analysis: Methods for monitoring and assessing landscapes, with special reference to mine sites and rangelands. CSIRO Sustainable Ecosystems, Canberra, Australia.

Oliva, G., *et al*, 2008 Manual para la instalación y lecturas de Monitores MARAS (Monitoreo Ambiental para Regiones Áridas y Semiáridas), INTA, Proyecto PNUD GEF07/G35.

Also posted on the LADA website is the following wetlands assessment tool that was developed in South Africa and used by LADA-South Africa to complement the LADA Local water resources tools. This would need to be validated in other countries for wider application.

Government of South Africa. (2007). Manual for the assessment of a Wetland Index of Habitat Integrity for South African floodplain and channelled valley bottom wetland types, Department of Water Affairs and Forestry, Pretoria, South Africa.

Acronyms and abbreviations

BOD	biological oxygen demand
DPSIR	Drivers-Pressure-State-Impact-Response (D-P-S-I-R)
EC	electrical conductivity
ES	ecosystem services
FAO	Food and Agriculture Organization of the United Nations
FGD	focus group discussion
GEF	Global Environment Facility
GIS	geographical information system
GPS	Global Positioning System
km	kilometre
l	litre
LADA	Land Degradation Assessment in Drylands
LADA-L	LADA Local
LD	land degradation
LSU	livestock units
LUS	land use system
LUT	land use type
m	metre
MDG	Millennium Development Goal
m	minute
ml	millilitre
mm	millimetre
NGO	non-government organisation
N-LUS	national-land use system
SDC	Swiss Agency for Development and Cooperation
sec	second
SLM	sustainable land management
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
WOCAT	World Overview of Conservation Approaches and Technologies

SECTION 1

Characterization of the study area

Introduction

The characterisation of the study area is organised and conducted using a participatory process with the selected local community/communities and resource people from local/ national technical sectors and local authorities. 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 larger local assessment area and / or one of the national level land use systems (LUS) within it (see Chapters 3 and 5 in Part 1 of the Manual (FAO, 2011a)).

2. Secondly, the characterisation will provide the team with a rational basis for selecting the location, the required number of representative communities, transects and detailed assessment sites. The definition of the community depends on the settlement pattern; it may be a village or a dispersed population that is organised for administrative and / or productive purposes. It should be representative of the local population and include the full range of land users.

Five tools are provided for the characterisation, which need to be backed-up by the following activities by the assessment team:

- Organise a general meeting with the local authorities to inform them of the assessment objectives and activities and request their support;
- Collect and review available secondary information sources where available. A list of recommended secondary information is provided in Section 5.2 in Part 1 (FAO, 2011a);
- Identify key stakeholders and relevant projects and NGOs located in the area;
- Conduct an initial field visit, ideally before the focus group discussion (FGD) with the selected community/ies (Tool 1.1). A tour by road with a few key informants will help the team to familiarise themselves with the study area, land uses, also the extent and severity of degradation and types and extent of conservation and improved land management measures. If this takes place before the FGD, it can reveal interesting land resources features and observations for discussion with the community.

The following four tools are described in this section:

- focus group discussion;
- wealth ranking;
- institutional analysis;
- study area mapping.

Although these tools (1.1 - 1.4) are presented separately, it is logical to combine them as much as possible during the assessment. Following the community focus group discussion, the participants could be immediately divided into two groups, one to conduct the wealth ranking exercise to identify distinct land user groups and the second to draw a community map of the community territory and study area. Both groups should involve representatives of different social groups (i.e. both men and women of all ethnic- and age-groups). In some cultural contexts this may require separate sub-groups, but ideally they should be combined and the facilitator can help ensure that their various and often diverse, issues and views are raised and taken into account.

The extent of the community territory requires careful discussion, as it may vary according to the use of resources. For example, land area belonging to the community (i.e. settled and farmed) may be much smaller than the land exploited for various resources (i.e. usufruct right, for example for fuel wood, grazing, water).

Tool 1.1 Community Focus Group Discussion

The objective of the community focus group discussion (FGD) is to obtain information about the range of land-users, their individual and communal management regimes and the history of the area. This will help the team to gain a better understanding of how the socio-economic and institutional factors influence land users' perceptions and management of land resources at the community and landscape levels, also within the different land use systems present in the study area. The community focus group discussion can be used to stimulate debate about the types of land degradation, their degree, extent and trends in the study area, as well as the effectiveness of, or the need for, interventions to prevent or mitigate degradation and restore or improve land resources (Chapters 4 and 6 in Part 1 (FAO, 2011a)). It will also help with interpreting the results from the detailed assessments of land degradation and effects of current land management practices under different land use types and systems.

The FGD can be conducted with a small number (6-10) of community 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. At least two members of the assessment team should facilitate and record the discussion.

After the discussion, the other team members need to be fully briefed on the findings before proceeding with the assessment. Local resource persosn may be consulted to provide clarification on specific issues raised.

The following outline questionnaire should be reviewed by the team prior to the focus group discussion, in order to adapt the questions to the local context and terminology. Questions can be modified, added and / or omitted. The length of the questionnaire can also be adjusted to suit the time available and the level of knowledge of community members and local informants.

Questionnaire - Checklist

1. What is the population of the whole community (number of people and of households)?

2. What is the history and pattern of settlement in the area?

3. What are the main/important a) land use types differentiated by the community and b) water resources available and used by the community in the study area?

4. What are the main livelihood / production activities during the i) rainy and ii) dry seasons (include the main things people do for subsistence and to generate income)?

5. What are the main natural resources that the community uses for production / livelihoods? (e.g. cropland, grazing land, fuelwood, timber, medicinal plants, dry season water sources etc.).

6. What are the important types of land degradation[1] in the territory? For each distinct type: What do you consider are the main causes? What are the main impacts? What are the changes in the last 10 years or so, in terms of type, extent and severity? (See Chapters 4 and 6 in Part 1 (FAO, 2011a))

To facilitate the discussion, the team may need to prompt for more details on the causes and impacts of soil, water and vegetation degradation and resource use, for example:

a. **Soil:** Is soil erosion occurring or are there other types of soil degradation? What are the main causes? What indicators do the locals use to describe soil erosion / degradation (e.g. loss of fertility, salinity, soil loss, gully formation (active / under control), build-up of sand or shifting sand dunes, sediment load or pollutants in water resources etc.)?

b. **Vegetation:** Is deforestation occurring in the study area? Is this exploitation for local use, for transport to cities or both? Has it increased? What is the main local source of fuel for cooking (and heating)? Have the cover and / or species composition and quality of vegetation been increasing or diminishing? Have the abundance (number of plants) and richness (number of species) in a given area of i) palatable species for livestock or ii) invasive species increased

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

or decreased in the area? Since when have the changes taken place? What are the causes? What conservation / management practices are used in crop, pasture and forest land? Depending on the responses further questions can be asked for example: Are fires a serious problem? Has the frequency and severity increased – or decreased? Is burning used for pasture management and / or pest control? What are its effects? Are grazing rotations or rangeland enclosures practiced? Since when and why? Are there other related problems relating to livestock numbers, land tenure etc?

c. **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; drying up of water points, changes in levels of water in wells and boreholes; changes in river / stream flow, changes in water quality (salinity, pollution)). Is water used for irrigation and where is it sourced (e.g. rainwater harvesting, streams / rivers or wells / boreholes)? What crops are irrigated, when (all the growing season or only during specific critical period) and by whom (few/most farmers; large/smallholders, public/private sector? Do community members pay for water and under what circumstances?

7. Has the study area experienced i) drought, ii) flooding or any other extreme weather event (e.g. intense storms) in the last 10 years? Is the frequency and severity normal or exceptional?

8. What are the strategies and coping mechanisms adopted i) during drought or unusual dry years or ii) to reduce risk of flooding or iii) to reduce damage from wind/storms?

9. What are the livestock management strategies and related problems in terms of degradation or related benefits in terms of sustainable land management? Strategies could include, for example, range enclosures, rotational grazing, ranching, stall fed animals, seasonal livestock movements (agropastoralism), permanent livestock movements (nomadic pastoralism), cattle grazing corridors, as well as relevant bye-laws (e.g. relating to the control of livestock numbers or burning etc.)

10. Are there any conflicts in relation to land and water uses in the area?

11. What are the main livelihood problems / difficulties (i.e. serious / long term);(less serious / short term) faced by rural households (food insecurity, poverty, access to resources, access to markets)?

12. Are there successful areas where land degradation control (i.e. conservation, restoration and or improvement of land resources) has been achieved? What were the main sustainable land management (SLM) practices or measures (policies, legislation, bye-laws etc.) to prevent land degradation that were implemented in specific land use systems / types? Were they aimed: i) to improve or restore the productive capacity of the land (e.g. soil fertility, use of water); or ii) 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. (Refer to Section 4.2, Chapter 6 and Annexes 2-5 in Part 1 (FAO, 2011a)). What approaches were used (e.g. participatory, watershed management, farmer field schools etc.).

13. If possible, identify any interventions that have gone beyond a focus on soil and water conservation and productivity in situ to address wider ecosystem services (e.g. water catchment / supply, carbon sequestration, reduced greenhouse gas emissions, pest and disease regulation, protection of biodiversity and aesthetic landscape values etc.). What practices were used and what was achieved?

Venn Diagram: (to complete with the Tool 1.3, institutional mapping)

14. What are the various organizations that determine the way land (including water and vegetation resources) is managed in the community (e.g. informal groups or cooperatives of land or water users, NGOs operating locally, private sector investors, local leaders or authorities, government departments or research agencies, etc.)? (Prompt to solicit positive and negative effects).

15. 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?

16. How do laws, rules and regulations concerning land resources affect the extent of land degradation and / or conservation? (Prompt for positive and negative effects).

Wealth ranking: (to complete with Tool 1.2, wealth ranking)

17. What other major social divisions (apart from poverty / wealth) exist in the community (e.g. religious or caste groupings, pastoralists or settled farmers, farmers practicing irrigation or rainfed cropping) that affect the differential access people have to resources and / or the ways in which they manage their land?

A field form for the community focus group discussion is provided at the end of this section to help in recording the results, but it will need to be amended in line with any amendments in the questionnaire. This should be a semi-structured process i.e. efforts should be made to record information in the order that issues are raised by the community, as this reflects the issues that are most important to them. Some prompting may be required to fill gaps and solicit adequate responses, but to avoid following the form from start to finish or posing rigid questions.

Tool 1.2 Wealth ranking

The wealth-ranking exercise can be completed immediately after the community focus group discussion or later with 3-4 community members.

The relative "wealth[2] status" or "level of well being" of individuals in the community is often an important factor in determining their views and behaviour in relation to the land resources they use directly and the natural resources in the study area. Both the extent to which people are responsible for LD / SLM and how they are affected by the impacts of LD / SLM are strongly linked to their wealth or assets status and wellbeing.

The first step to categorize the household / livelihoods in the community using a simple wealth ranking exercise is to identify with the community members a set of key indicators for the three main (relative) wealth groups: better-

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

off, medium, poor. These should be reliable local indicators that distinguish households in the community (e.g. farm size, number of livestock, size of household, type of house, off farm employment, financial assets/ indebtedness, education level, social assets, etc.). The indicators representing the three wealth groups should be agreed upon and recorded. For example, in a rangeland area, number of livestock could be 0 to 9 cattle for poor households, 10 to 100 for medium and more than 100 for the better-off and so forth. The second step is to order these indicators in terms of importance relative to the study area.

These simple wealth ranking indicators should be used subsequently to rank those households selected for the livelihoods interviews and ensure that each group is adequately sampled (in terms of land use in the field and household interviews). These indicators of wealth will be used as a reference to weight the capital assets in the household livelihoods assessment and identify different household profiles.

Tool 1.3 Rapid land tenure analysis and institutional mapping

Land tenure affects the way people have access to and manage the farmland, rangeland and forested land, also the associated natural resources and ecosystem services. In some contexts, land tenure is a major driver of land degradation.

In relation to land use and management, it is consequently important to consider, by group of land users, the implications of:

- tenure and access rights on land resources;
- formal and informal land rules;
- governance and land policies.

Issues that should be discussed include whether land is owned, with or without titles, under tenancy or leasehold agreements, whether share cropping or other arrangements are in place (harvest; labour), issues of rights of access to resources including by female headed and landless households or other marginalised groups, conflicts arising over land and water and energy resources and so forth.

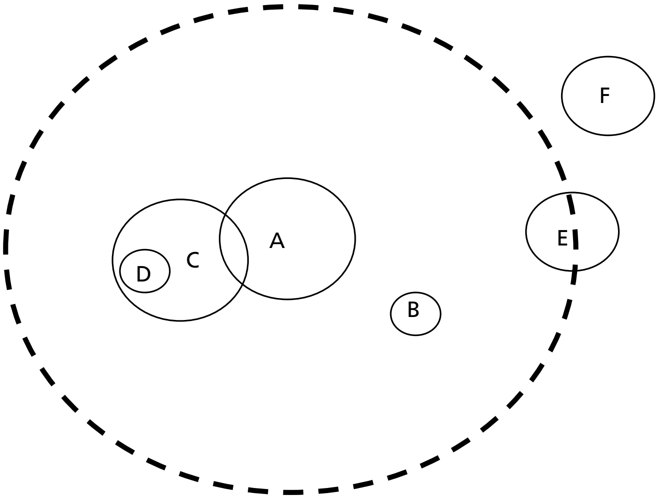
There are a number of tools that use ranking or institutional mapping (Venn diagrams) for probing the effectiveness of organizations and institutions that are relevant in regard to land degradation and sustainable land management. Figure 1 illustrates a Venn diagram from a hypothetical institutional mapping exercise.

This type of diagram is useful to enable communities to represent visually the importance, in terms of profile / activity, and the effectiveness of organizations / institutions that influence to a lesser or greater extent land and ecosystems management.

A relatively simple diagram like this can be generated during a focus group discussion. It can be very informative and a good way to represent

BOX 1 Drawing a Venn diagram

Circles represent organisations and their degree of influence – in this case in regard to LD and SLM
Size of the sphere: the larger, the higher the profile and level of activity of that organisation
Position: the closer to the centre, the more positive the influence of that institution on land management (outside the main circle representing the community) = a negative influence).



- Organization (or institution) A is the most useful as it is active (large circle) and also has a very positive influence on land management (close to the centre of the dotted circle).
- Organization B is less active and less relevant (smaller, more distant from the centre).
- C is just as active as A but not as relevant or effective in its influence on land management, C also overlaps a little with A (i.e. the two organizations have some activities in common).
- D is rather low profile and entirely duplicates C.
- E has quite a high profile in terms of activity but no discernable influence on land management.
- Organization F has a significant negative influence on land management.

FIGURE 1 **Example of a Venn diagram**

the information in the final report (see Chapter 7, Part 1 (FAO, 2011a).

Tool 1.4 Study area mapping

Sketch mapping is used to provide a graphical representation of the study area, or the part of it relating to the community territory, from the perspective of community members (at least 4-5 members, male and female) who have participated in the community focus group discussion. This sketch map should be prepared by the land users (farmers, herders, forestry workers, state farm managers etc.) but other persons knowledgeable of the study area, such as extension workers or local authorities, could provide suggestions of other things that the land users should add to the map (taking care that they do not take over!).

Various visual aids can be used to facilitate discussion and representation of the situation, such as the LADA national land use and degradation maps, aerial photographs, satellite images, more detailed topographic or thematic maps, etc. It is important to include the community members' perceptions and assessments of the land resources conditions, also the causes and impacts of land uses and management practices on those resources. The community members may wish to divide into groups to map different issues.

The map should show and give relative locations of:

- boundaries of the study area;
- main areas for settlement, the roads and locations of markets and other services;
- important land units differentiated by the community in terms of slope, quality of soils, vegetation, water resources etc. as well as by land use (cropping, orchards, grazing, forest, wetland, etc.) and management practices, etc.;
- water sources (natural and manmade) in the territory such as rivers, streams, lakes, ponds, wells, boreholes etc.;
- types and locations (distances – either in km or estimated time to walk) of key resources located beyond the community boundaries but used by the community such as communal pastures and water sources;
- areas suffering from land degradation (significant erosion features – sheet wash, rills, gullies, landslides, etc. and other significant areas/types of soil, vegetation and water degradation and any land use/ management features they seem to be associated with (e.g. newly planted forest, recent logging, poorly developed (thin) forest stand, roads, water points, etc.).
- areas of successful soil and water conservation/ land degradation control / specific sustainable land management measures.

Remember that the map should clearly show the legend / key for the different symbols used.

All the information described below will be important subsequently for locating the transects and selecting sites for the detailed assessments (see Chapter 3, Part 1 (FAO, 2011a)).

Step 1: The assessment team members should ask the community members to draw the above issues on the mapping sheets without too much prompting or intervention so that it reflects their own perspectives. The male and female members can be asked individually if they agree with the representation or if they have additional features to add; as they may not all have the same vision. This initial base map should be photographed and eventually the original copy left with the community.

Step 2: This base map of the community territory and its relationship to the wider study area can then be used to stimulate discussion on land units (terrain) and land resources that are differentiated by the community in terms of quality of soils, vegetation, water resources and in relation to land use (cropland, grazing lands, forest, wetland) and management. For example, in Figure 2, land-users distinguish several land units in terms of soil types. The map makes it possible to estimate the relative importance of the land units (different slopes, plateau, floodplain etc) and soil types (fertile, poor, waterlogged etc.) in terms of area and the location / share of cropland compared to other uses (grazing, forest, settlement). To distinguish soil types, farmers should be encouraged to pay special attention to visible aspects of the soil, such as colour, plant indicators and soil characteristics that have direct management implications, such as ease of ploughing (which is influenced by the texture of the topsoil and rainfall).

The map legend includes infrastructure, water resources, land units, areas of degradation etc.

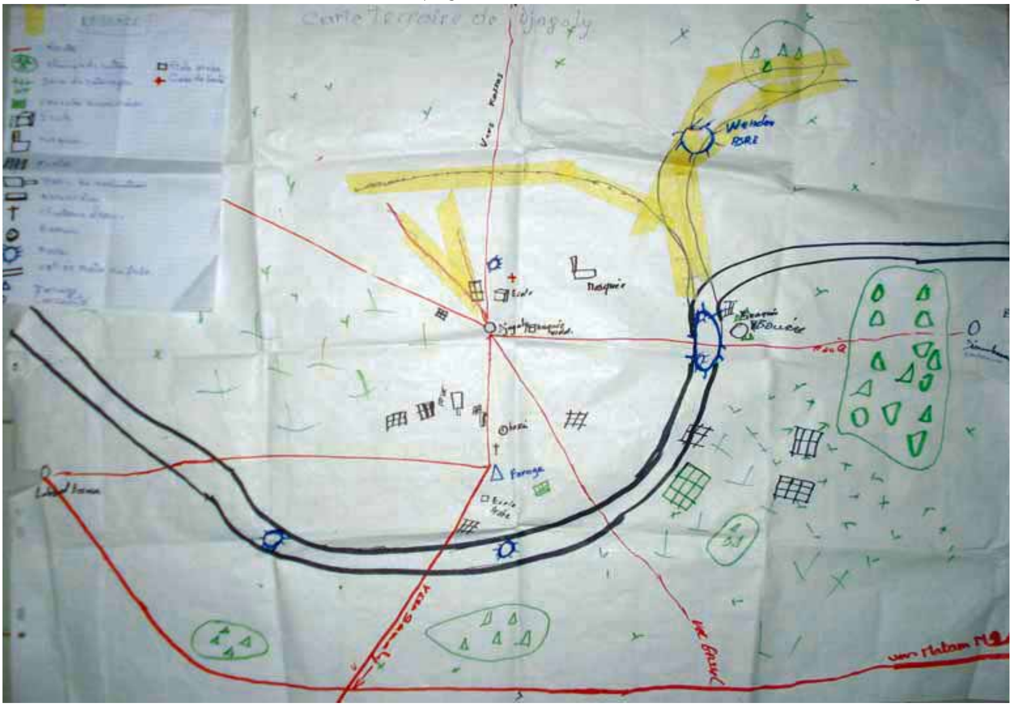


FIGURE 2 **Community territory map drawn by Diagaly community, Barkedji, Senegal**

Step 3: The community territorial map should also encourage discussion with land users and show the location, extent and severity of different types of land degradation (soil erosion, soil properties, natural and planted vegetation, water resources) and their causes. This could also provide information on the history of land use, e.g. how long cropped or forested, previous land uses, crops and tree types grown, agroforestry and agropastoral systems, etc. Discussion could also identify the location and effect of significant weather conditions, such as intense rain events, flash floods, greater than or lower than average rainfall in recent years, etc. It could also provide information on how land productivity has changed in the recent past, e.g. "the land used to produce larger and better crops", "now with every rain event we lose more soil", "the streams are full of soil after every rain", etc.

Step 4: It should also show interventions by the community and other actors (projects, technical sectors, investments etc.) to address the various types of degradation, and their effects on land resources and productivity such as:

- communal soil and water conservation measures to protect uplands and enhance production;
- control of bush or grassland burning to safeguard vegetation cover and biodiversity;
- grazing management / control to allow restoration of pasture / range and improve livestock productivity;

- improved crop and / or livestock rotations and agronomic practices to restore soil fertility and crop and livestock productivity;
- control of settlement expansion to prevent loss of productive lands;
- crop expansion into fragile lands or loss of wetlands and their functions;
- control of irrigation and drainage to prevent over exploitation of limited water supply and reduce risk of salinity and increase productivity.

Step 5: This information should then be used to initiate discussion on the effectiveness of existing interventions, or the need for interventions to address degradation, conserve, restore or improve land resources. This may also raise issues in regard to land use planning, legislation, local bye-laws / regulations or other interventions in land use / management that have been developed or applied, or that may be considered. Constraints and opportunities for their implementation can also be discussed.

Step 6: If available, the community mapping can be later complemented by use of high resolution satellite images (such as "Quickbird") or lower resolution Google Earth images (note usually several years old) of the local assessment area. With only very limited manipulation, such images may be more recent than opographic maps and can be used to cross-check (with community members) and supplement the completed hand-drawn study area map, or serve as a basic picture on which to draw the community map.

Field form for the community focus group discussion

[This form refers to the questionnaire check list (Tool 1.1). The questions have to be reviewed by the team prior to the focus group discussion, in order to adapt the questionnaire to the local context and terminology.]

Study area or community name:______________ Name of record keeper:___________________
Date of discussion:__________

1. Population size and number of households:____

2. History, migration and pattern of settlement:
____
____
____

3. Land units, land use types and water sources in the study area as differentiated by community members

Land Units (biophysical)	**Land use types** (includes management practices)	**Water Sources** (natural and manmade)

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

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	**Products** **F**- Food **W**- Wood **E**- Energy **G**- other products **I**– Income
1.			
2.			
3.			
4.			
5.			
6.			

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

Land degradation			
Types	**Causes**	**Impacts**	**Changes (trend)**
Erosion by water (splash, rill, gully - specify which)			
Erosion by wind (dust storms, sand blow, sediment deposits, dunes, etc)			
Soil physical degradation (compaction, surface sealing, crusting, pulverisation, etc.)			
Soil biological degradation (loss or soil organic matter or soil life, declining fertility			
Soil chemical degradation (nutrient mining, salinity, acidity pollution, etc)			

Bullet points 7 to 10 below are used to record, as appropriate, relevant details on soil, vegetation, water and / or socio-economic aspects of land degradation:

7. Indicators and causes of soil degradation – including erosion and deterioration of soil properties, as perceived by the community

Locally perceived Soil Indicators	Causes of Soil degradation

8. Indicators and causes of degradation of natural vegetation and biodiversity, as perceived by the community in crop land, in grazing land and in wood/forest land (specify).

Vegetation Indicators	Changes/Trends (Yes/No; L, M, H)	Causes
Deforestation		
Composition of vegetation (structure and species diversity)		
Health and quality of grazing lands		
Health and quality of forests		
Abundance of useful species (edible, palatable, medicinal, used for energy, building or crafts, etc.)		
Presence of invasive, harmful or less useful species (toxic, pests, less palatable species)		
Bush encroachment		
Evidence of frequent or severe burning		
Extent and vegetation of wetlands		
Diversity of habitats in the area		
Other (specify)...		

9. Livestock management measures and their problems in terms of land degradation or benefits in terms of sustainable land management

Livestock management measure	**Presence** High, Moderate, Few, None	**When and Why? (reasons)**	**What problems do they cause?**	**What are the benefits?**
Range enclosures				
Rotational grazing				
Ranching				
Stall fed (zero grazed) animals				
Seasonal livestock movements (agro-pastoralism)				
Permanent livestock movements (nomadic pastoralism)				
Cattle grazing corridors				
Use of bye laws, other measures, to control livestock numbers, burning, etc.				
Other				

10. Forest management measures

Forest management measure	**Presence** High, Moderate, Few, None	**When and Why? (reasons)**	**What problems do they cause?**	**What are the benefits?**
Clear logging				
Selective felling				
Coppicing or pollarding				
Livestock grazing in forest				
Fire control (fire breaks etc)				
Use of bye laws, other measures, to control forest use and exploitation of products and wildlife				
Other				

11. Changes and causes of water quantity and quality

Water	**Changes** (trends)	**Causes**
Quantity • Rainfall • Drought • Flood • Demand -surface water • Demand - groundwater (wells, boreholes) • Irrigation area/use • Other uses		
Quality • Drinking water • Irrigation • Other uses		

Who practices irrigation in the community? Have the area / crops / seasons changed?

____

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

What are the implications?

Bullet points 12 to 13 below are used to record livelihoods problems and coping mechanisms

12. Main livelihoods problems relating to land use / management and degradation:
1.
2.
3.

Specific issues relating to:
- Occurrence of conflict(s) ______________________
- Food Insecurity ______________________
- Poverty ______________________
- Drought/Flood ______________________
- Access.rights/tenure ______________________

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

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

SLM practices	Reasons for implementation	When, and by whom	Results

15. Importance of organizations influencing sustainability of land management at local level:

Organizations (specify)	**Influence on sustainability of land management (LD / SLM)**		
	Importance H- High, M-Medium, L-Low	**Influence** + or -	**Remarks**
Informal group			
Cooperative of land users			
NGO local/international			
Private sector			
Local leader			
Government authorities			
Research agencies			
Other			

16. 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 rights system	**Details**	**Influence on SLM**
• Cropping lands • Grazing lands • Forest Lands • Trees • Water		

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

Laws, rules and regulations	Effects on land degradation / SLM

18. 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

19. Record any other relevant information arising during the discussion:

SECTION 2

Reconnaissance visit and transect walk

Introduction

Using the community study map, it is a good idea to conduct an initial reconnaissance visit in the study area with a few community members and the assessment team to verify features raised in the community discussion. This will help obtain a general understanding of the state of natural resources (vegetation, soil, water), what degradation types and processes are associated with which land use types (LUT) and management practices, also what are the main response measures and interventions being used. This completes the area characterization and mapping exercises (Tools 1.1 – 1.4 in Part 2 (FAO, 2011b)) and helps in selecting locations of Transect Walks (Tool 2.1) and detailed sampling sites for assessing vegetation (Tools 3.1 – 3.4), soils (Tools 4.1 – 4.4), and water resources (Tool 6.1 - 6.6). The reconnaissance visit / initial transect walk includes a rapid assessment of vegetation and soil erosion with local informants and land users (Tool 2.1). The assessment of water resources will require a specific visit to water sources in the study area and this should indicate sites where detailed assessments should be conducted (see Section 6).

The reconnaissance visit will help the team to appreciate the variation in land use, farm types, land degradation and land management measures and identify the location and number of transects. It will also identify along each transect where are possible "key" sites for detailed assessments that will provide useful comparisons of different land management practices and to learn in more detail the causes for land resources degradation, conservation (stable) or restoration (improving) and the behaviour and reasoning of the land users.

PHOTO 1 **Locating transects with land users, Tunisia**

The decision on the location and number of transects should be made with some community members, building on information collected during the community discussion and mapping exercises (Tools 1.1-1.4). One to three transects per study area are recommended to capture most of the land resources and LD / SLM features of interest in the area. They should if possible cut across the major LUTs and different land units (reflecting changes in soil and terrain) (for definitions see Table 3 in Part 1) or in the case of a very uniform landscape, cut across an area with as much variation as possible in land-user type (smallholder, large commercial farmer, herder, etc) and management practice. Some socio-economic criteria can also be used in identifying representative transect sites, such as population density.

The transect walk is not intended as a quantitative sampling tool, therefore the number, length and width are flexible. The length of each transect walk will depend on the variation in terrain and land type but in general some 2-5 km is adequate to capture the variation in land resources and in human management / land use. In heterogeneous areas, two or three short transects may be better than a single long one to capture the variation and issues of interest in LD / SLM within the study area. The transect width is effectively the land easily visible to the naked eye as one walks. It will be narrower in areas under complex and different land-uses, or in forest, than in extensive pasture or open savannah, because of visibility and the time required to record information.

Tool 2.1 Transect walk and diagram

The objectives of the transect walk are:

1. to identify the main land use systems (1-3) and the land use types within each study area;

2. to obtain a general understanding on the ground of the landforms and resources status (vegetation, soil, water), what degradation types / processes are associated with which land use types (LUT) and which management practices, also what are the main response measures / interventions being used in the study area;

3. to identify any wider off-site and landscape effects of land use pressures (e.g. deforestation, overgrazing, burning, encroachment of wetlands, overexploitation of fragile drylands) and resulting degradation processes (e.g., water erosion, downstream impact of runoff and sediment deposition, landslides, wind erosion, sust storms, and shifting sand dunes, water or soil pollution, etc.);

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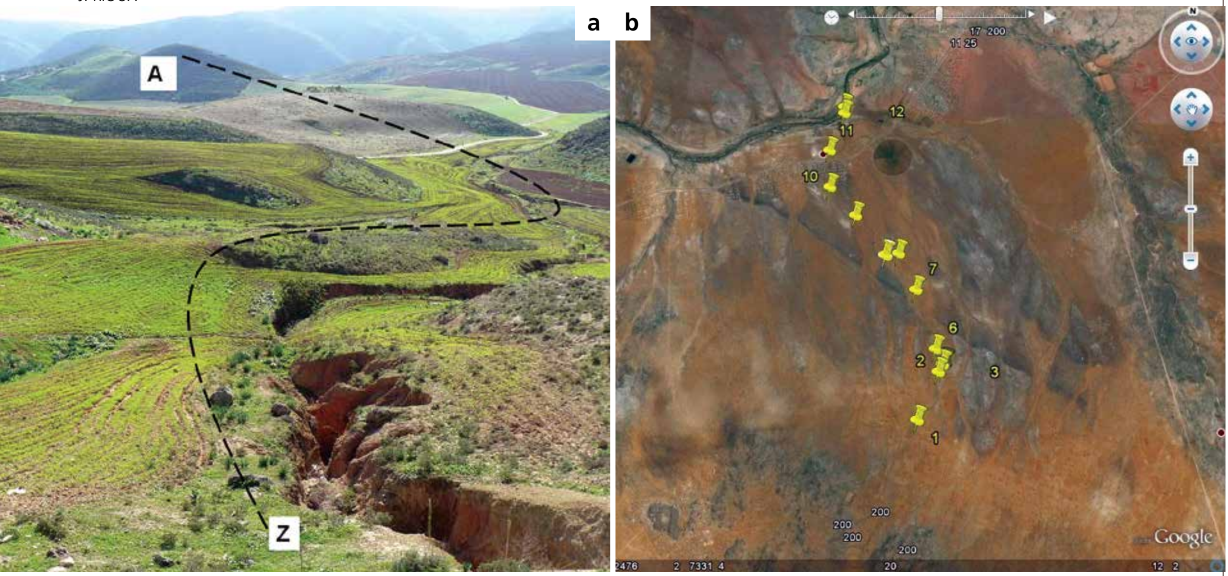


PHOTO 2 **Use of a) Photographs (Béja, Tunisia) and b) Google earth images (Mankotsana, South Africa) to show the location of transects**

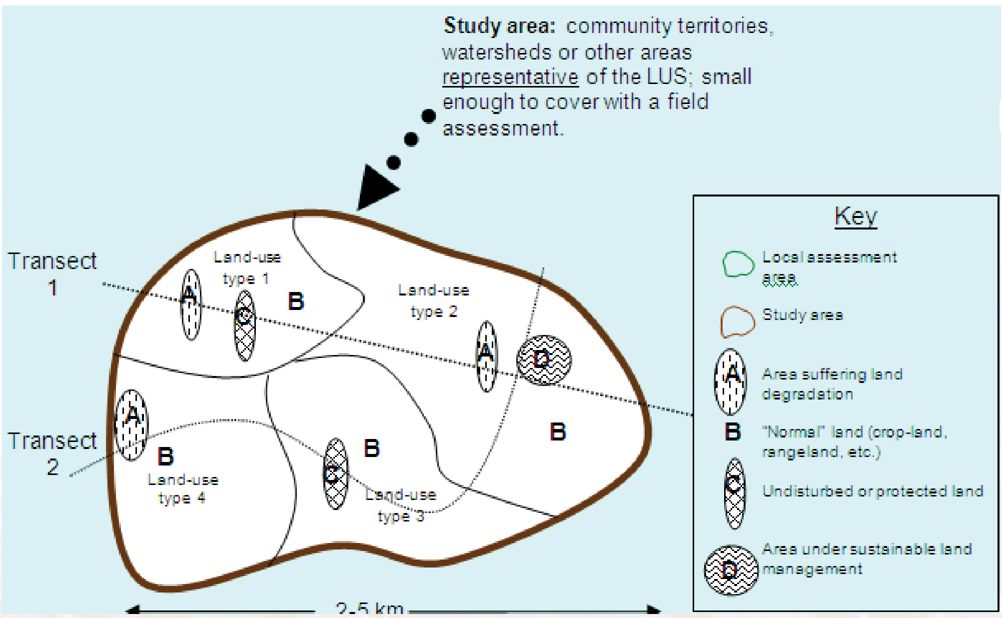


FIGURE 3 **Hypothetical study area marked with two transects cutting across the main LUTs and land units and representative areas showing land degradation and SLM**

4. to help locate sampling sites for the detailed vegetation and soil assessment.

Transects do not need to follow a straight line. They are used to verify features discussed in the community discussion and to identify sites for detailed assessments, they are not used as detailed quantitative sampling tools (see Figure 3).

Comparison is at the heart of the sampling strategy. Detailed assessments are conducted in areas of LD, SLM and undisturbed or protected land, then the results are compared (e.g. A, B and C are compared in land-use 1; A, B and D are compared in land-use 2 etc.). The number of comparisons possible will depend on the heterogeneity of the study area.

Expected outputs

The transect diagram, in conjunction with the study area map and photos, provides a record of the land uses and state of resources in the study area (at the given date) and contributes to the selection of the detailed assessment sites. Reasoned / systematic decision-making on where to locate detailed comparative assessments (sampling sites) is enabled by the information and understanding of the area obtained during the reconnaissance visit and transect walk. The transect information and diagram also facilitates subsequent analysis with the community of the reasons for certain land uses and management practices (i.e. direct causes as well as indirect causes or driving forces and the consequences and responses in terms of degradation and conservation / SLM – see section 7.2, Part 1 (FAO, 2011a)).

Participants

The local team should be accompanied by 2-3 local people / "informants" (selected from those involved in the community focus group discussion and study area mapping (Tools 1.1 and 1.4) and the land users encountered, both men and women, with knowledge of land use changes, of vegetation species and uses (local names), their crop, livestock and forest management practices. It is important that the local community are supportive of the choice of informants.

Materials / preparations required:

- note-taking materials (paper and clipboard);
- maps, aerial photos and/or satellite image to locate transects, features and boundaries;
- GPS to record locations and altitude (of major changes in land use, land form, vegetation, soil) and detailed assessment sites;
- digital camera;
- compass to indicate slope aspect and location of features (or GPS can be used);
- Abney level or clinometer to take slope and tree height measurements;
- tape measure to measure distances;
- machete to cut through thickets (optional);
- a spade to check topsoil type (colour, texture) and soil impediments (hardpans, exposed rock, depth to bedrock, perched water table, etc);
- plastic bags to take any samples (vegetation, insect pests).

Time required

Three to four hours per transect (depending on distance, complexity, ease of access etc.).

Steps of the Transect Walk

1. Identify key informants and land users (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 these key informants (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 (including common property resources (forest or pasture lands) and protected areas (parks, reserves));
    - to capture variation in socio-economic variables (population, farm size etc.);
    - to cut across areas that are degraded / eroded and areas with productive land or where there have been major conservation / land resources management activities.

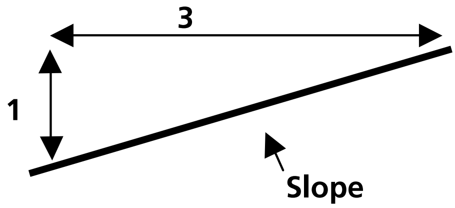
3. Discuss with the key informants and list the different factors to be drawn on the transect: land use, natural vegetation, soil, water, crop, livestock and forest management; degradation types; problems and opportunities as perceived by the community.

4. Walk along the transect route with local informants: identify on the recording form by observation and GPS coordinates, the start and end points and the actual length and width.

5. Along the transect, record altitude (m) and GPS coordinates at each main change in LUT or land unit and where the transect crosses a road, river or other infrastructure or administrative border (e.g. protected area); this helps to compare ground observations with satellite imagery (Google earth etc) and facilitates subsequent monitoring.

6. Take notes and photos as the team walks along the transect to record each distinct change in LUT, landform, land resources status, degradation features, management practices. In each LUT, discuss with land users and key informants the relationship between land degradation and the management practices. Record the range of observations / information on a sketch map and as notes as detailed in Table 1 and in the transect diagram below:
    - landform (position in the landscape), land unit (soil and terrain), land constraints;
    - land use (use LUS and LUT classes - see Table 2 in Part 1);
    - vegetation type, cover, biodiversity and signs of degradation / management;
    - main soil types and degradation features (erosion, compaction, etc.);
    - water sources (rivers, streams, springs, wetland areas, wells / bore-holes), main uses, and signs of degradation / management (as and when they occur along the transect line);
    - watershed / soil and water management / evidence of burning and use of fire management.

7. **Landforms**: For each main land unit across the transect, it is useful to characterise the landform, slope form, gradient and orientation, also the drainage density using the classes in Table 1. Record the landform and position in the landscape (see Figure 4) as this affects the hydrological conditions of the site: indicate whether there are signs of surface and subsurface runoff, drainage and if the unit is predominantly water receiving or water shedding. (FAO, 2006).



where for example:
Slope Ratio: 3:1 or 3 to 1
Percent Slope: 33%
Degree Slope: 18.4°
33 cm in 1 m

FIGURE 4 **Calculating slope degree or percentage**

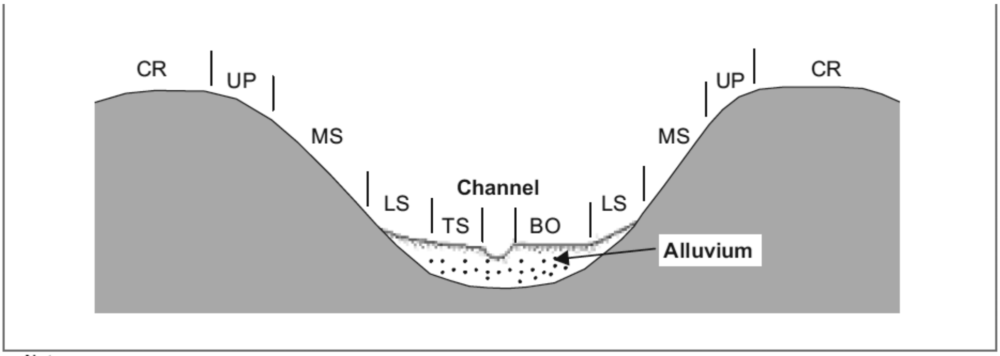
Indicate whether the slope is level, gently sloping or steep and record the slope gradient using the Abney level or clinometer in degrees or % (be consistent). Also indicate the form of the slope (S straight; C concave; V convex; T terraced; X irregular) and whether the area is subject to erosion or whether it is a zone of deposition. Indicate if any management practices have altered the slope (e.g. contour bunding, terracing, levelling, raised beds).

Indicate the orientation of the slope as this influences the exposure to sun and hence temperature, aridity and hence productivity. South (S) facing slopes are sunnier and warmer than north facing slopes in the northern hemisphere (conversely in the S hemisphere), while east and west facing slopes will show less variation or extremes.

8. **Hydrology and water resources:** It is also useful to describe the hydrological pattern in the study area (see Table 2) and how that affects water availability and management. During the transect walk, specific questions can be asked about changes in water availability, quality and access however the transect might not cross several water points. Since the water resources are distributed across the whole study area, it will require

TABLE 1 **Hierarchy of main landforms and slopes** *(source: FAO, 2006)*

Landform	Slope	%	Degree
Level land (L)		**<1**	
• Plain (LP) • Plateau (LL) • Depression LD) • Valley floor (LV)	1. Level 2. Nearly level	0 – 1	<0.6
Sloping land (S)		**1 – 15**	
• Escarpment zone (SE) • Hill (SH) • Mountain (SM) • Dissected plain (SP) • Valley (SV)	3. Very gently sloping 4. Gently sloping 5. Sloping 6. Strongly sloping	1 - 2 2 – 5 5 – 10 10 – 15	0.6 – 1.1 1.1 – 2.9 2.9 – 5.7 5.7 – 8.5
Steep land (T)		**10>**	
• Escarpment zone (TE) • Hill (TH) • Mountain (TM) • Valley (TV)	6. Strongly sloping 7. Moderately steep 8. Steep 9. Very steep	10 – 15 15 – 30 30 – 45 > 45	5.7 – 8.5 8.5 – 16.5 16.5 - 24 24 >



Note:

Position in undulating to mountainous terrain
CR = Crest (summit)
UP = Upper slope (shoulder)
MS = Middle slope (back slope)
LS = Lower slope (foot slope)
TS = Toe slope
BO = Bottom (flat)

Position in flat or almost flat terrain
HI = Higher part (rise)
IN = Intermediate part (talf)
LO = Lower part (and dip)
BO = Bottom (drainage line)

Source: Redrawn from Schoeneberger *et al.*, 2002.

FIGURE 5 **Slope positions in undulating and mountainous terrain**

a specific visit by team members with some community members / key informants to selected natural and manmade water points and key hydrological features (e.g. wetlands, rivers) backed-up by the FGD with community members (Tool 1.1) and

TABLE 2 **Hydrological patterns**

Hydrology		Water availability	Water management
No evident water courses	Very dry, flat areas; sandy well drained soils; little or no surface flow	Wells and boreholes to access groundwater	Harvesting of runoff from compacted area Aquifer recharge
Sparsely spaced watercourses	Few widely spaced, slow flowing water courses in flat or undulating topography	Few, natural water points may be supplemented by wells and boreholes	Flood control Wetland management Water pumped for irrigation
Moderate, incised	Many closely spaced water courses in hilly lands with fast flow in rainy seasons	Many rivers and streams and springs	Soil and water conservation to reduce runoff Dams for water regulation and storage
Densely spaced watercourses	Many closely spaced (branching) water courses in steep or dissected landscapes	Many rivers and streams fed by upstream catchments (rain or snowmelt)	Soil and water conservation to reduce runoff Dams for water regulation and storage

key informant interview (Tool 6.1) to assess the status and trends of water resources (see chapter 6 in this document).

9. **Vegetation:** This reconnaissance / initial transect walk should enable the team to obtain an overview of relationships between land use / vegetation and degradation (type and severity), conservation or sustainable management practice across the different land units. Where possible, for each land use, comparisons should be made with a benchmark site that is protected or under good management and with little evidence of degradation. The main vegetation indicators that reflect degradation or improvement are:
   - **Vegetation cover** which protects soil from degradation by sun, wind and water erosion (good, medium, poor);
   - **Vegetation structure and species composition** which determines cover, shade, use, productivity, key vegetation types. Change in dominant species is a key indicator of degradation and is readily seen by comparing the situation with a well managed/protected site (benchmark). The share or ratio of beneficial/economically valuable species to harmful / unpalatable / invasive species is also important as this influences livelihoods;
   - **Habitat, species and genetic diversity:** (high, medium, low) may be assessed in terms of occurrence and connectedness of varied habitats which is important for beneficial species such as pollinators, predators and other wildlife species that provide food, fuel, other products for human use. Homogeneous farming or mono-cultures often face increased pest and disease incidence compared to farms with diverse crops (rotations, intercropping) and field borders (hedges, windbreaks etc.);
   - **Specific indicator species:** Land users will be able to indicate reduction or loss of useful species and products and to identify **Indicator plants** that reflect constraints to use such as salinity, waterlogging, poor soil fertility, fire incidence, or good land condition (fertile soil; etc.);
   - **Vegetation health and productivity** includes quality/extent of damage (by fire, pests, overexploitation, etc.) and regeneration capacity (poor. moderate, good) i.e. numbers of dead plants compared to seedlings/extent of re-growth;
   - **Management:** the intensity of use, the management practices and uses of products.

10. **Soil Erosion:** During the reconnaissance visit / transect walk, the team can conduct a rapid qualitative estimate of the relationship between the land management practices and the type of soil erosion, its state (i.e. whether it is active, party stabilised or stable), also its extent and severity for each LUT designated on the community map of the study area (or land units identified through other maps, aerial photos or satellite images). The types or processes and visual indicators of wind and water erosion include:
    - **Soil erosion by wind:** the removal and the deposition of soil particles by wind action and the abrasive effects of moving particles as they are transported. The visible features are described in Table 3 below and Annex 1 and include:
      - **Signs of the movement /transport of soil particles** by wind.
      - **Wind scouring** signs (depressions, soil horizons exposed; plant roots exposed).
      - **Deposits of wind-blown soil** where the wind is obstructed.

- Mobile sand dunes that may encroach on farm land, pastures, settlements, roads.

- **Soil erosion by water:** the transport and deposition down slope of soil particles through a number of processes, the visible signs are summarised in Table 5 below and Annex 1:
  - **Splash erosion** – where raindrop impacts displace soil particles vertically and down slope and may create a compacted surface crust that inhibits plant establishment.
  - **Sheet erosion** – by surface runoff that picks up and transports soil particles dislodged by raindrop impact. It is a gradual, uniform process and difficult to detect until it develops into rill erosion.
  - **Rill erosion** – by the scouring action of water as it runs down slope during rainfall creating shallow linear channels in the soil surface less than 30 cm deep. Rills can be completely smoothed out by cultivation with animal or machine drawn implements (though traces may remain with hand cultivation).
  - **Gully erosion** – develops where drainage is concentrated, creating a channel or ravine over 30 cm deep that may reach several metres deep and wide. Gullies are prevalent on deep loamy to clayey soils, unstable clays (e.g. sodic soils) and on steep slopes subject to seepage of water and landslides. Gullies form a physical impediment to cultivation and cross-

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PHOTO 3 **Gully erosion towards Niakha wetland (Senegal)**

slope movement of people and farm implements. They require specific interventions for stabilisation or rehabilitation

– **Mass Movement** is the relatively large down-slope movement of soil and / or rock (landslides, slumps, earth flows and debris avalanches) that may be caused by water or by earthquakes.

During the walk, indicate the erosion feature and use the visual indicators in Tables 3, 4 and 5 to assess its state (active, partly stabilised, stable) and severity (low, moderate, severe). Relate these observations to the vegetation assessment that has just been made and take into account the time of year / seasonality. The risk of wind erosion is highest prior to the onset of the rains (e.g. due to strong winds, dry topsoil, poor vegetative cover, lack of windbreaks). The risk of water erosion is highest at the onset of the rains when the soil is bare or poorly covered.

11. **Land Management:** During the transect walk the team should identify specific issues that need to be further investigated during the detailed site assessments (i.e. possible land use management and degradation relationships) and should locate suitable assessment sites that facilitate comparisons (i.e. between well and poorly managed crop, pasture, or forest land). To facilitate selection of sites for the detailed assessment the digging of many, rapid, "one spadeful" holes is encouraged to provide a rapid overview of soil types, human management impacts, soil-vegetation relationships. Discuss, reach agreement and record the altitude (m) and GPS coordinates of selected sampling sites so that they can be recorded on the transect diagram. During the detailed site investigations over the following day(s), more in depth and time consuming vegetation sampling (using quadrats and collecting specimens for identification) and soil sampling (soil properties and soil erosion measurements) are undertaken as described in the vegetation and soil sections of this manual.

TABLE 3 **Indicators of the state of erosion by wind, water and mass movement**

	State of Wind, Splash, Sheet, Rill and Gully Erosion	State of Mass Movement
Active Erosion	One or more of the following conditions apply: • evidence of recent sediment movement; • sides and / or floors of rills & gullies are relatively bare of vegetation; • sand dunes have little vegetative cover, with signs of scouring on the windward side and deposition on the leeward side	Landslide scars clearly visible with sharp boundaries and less than 10% vegetation cover within the landslide area.
Partly Stabilised	Localised evidence of active water and / or wind erosion; but part of the eroded area shows evidence of stabilisation and partial re-vegetation.	Landslide scars clearly visible; vegetation cover 10-50% of the landslide area
Stable	One or more of the following conditions apply: • no evidence of recent sediment movement; • sides and / or floors of rills and gullies are re-vegetated • sand dunes well vegetated with few bare areas from which soil could be removed by wind.	Landslide scars still detectable but no longer with sharp boundaries and with greater than 50% vegetation cover within the land slide area.

TABLE 4 **Indicators of the severity of wind erosion**

Severity	Wind erosion
None	No obvious visual signs of wind erosion (but minor evidence may have been masked by e.g. recent tillage
Slight	• Some signs of soil particle transport by wind • A few superficial roots exposed by wind scour. • Deposits of wind blown soil < 2 cm thick where wind has been obstructed. • A little wind blown soil accumulated in ditches. • A light cover of wind blown material on roads
Moderate	• Clear signs of transport and deposition of soil particles by wind • Some scouring but < 5 cm in depth. • Some tree, shrub, grass and/or crop roots exposed within the topsoil • Deposits of wind blown soil 2 to 5 cm thick where wind has been obstructed. • Moderate accumulation of wind blown soil in ditches. • Moderate cover of wind blown soil on roads/ settlement
Severe	• Clear signs of whole sale transport and deposition of soil particles by wind. • Extensive scouring > 5 cm in depth • Extensive exposure of tree, shrub, grass or crop roots. • Exposed subsoil horizons at or close to the soil surface. • Drainage ditches filled with wind blown soil. • Original soil surface buried under at least 5 cm of wind blown soil • Wind blown material accumulating deeply on roads/ settlements with negative impact on transport and living conditions.

12. **Land users behaviour:** Local informants and land users can be prompted during the transect walk to provide information to cross check information from the community FGD. Questions should be flexible and relevant to the field observations, helping the team to understand the reasons why land users do or do not invest to maintain land productivity and ecosystem services. To the extent possible, land user interviews will be conducted in the field during the vegetation, soil and water resources detailed assessments.

13. During the transect walk the team should identify and request some of the specific land users to be available for the detailed site assessments and for more detailed semi-structured interviews. In case of absence of key land users, the team should ascertain if they could be contacted another day. Issues raised may need to be followed up with officials from land and forestry offices and through specific questions with land users during the detailed site assessments.

14. **Transect diagram:** A rough transect diagram should be drawn and, if possible, cross-checked with key informants immediately after the walk to verify it is a good representation. Then return to the field team's "office" and complete the transect diagram, or matrix, with details including the detailed assessment sites, as shown in Figure 6. Table 6 summarises the information that can be shown on the transect diagram

TABLE 5 **Indicators of the severity of soil erosion by water and mass movement**

State and severity	Splash erosion	Sheet erosion	Rill erosion	Gully and ravine erosion	Mass movement	Stream / river bank erosion
None (or not apparent)	No obvious visual signs of splash erosion (indicate if this may be masked by recent tillage).	No visual indicators of sheet erosion (indicate if this may be masked e.g. by recent tillage).	No rills present.	No gullies present	No sign of slumps / slides	• Stream bank has close to 100% vegetative cover, no active erosion • Little if any signs of undercutting on outer bends of meanders and little active deposition of sediment on the inside.
Low	• Some visible splash of soil particles onto plant stems / under-sides of leaves. • Signs of surface sealing due to rain drop impact • Any surface crust is thin and weak.	• Some visual evidence of the movement of topsoil particles down slope through surface wash • No evidence of pedestal development. • Only a few exposed superficial roots.	A few shallow (< 0.1m depth) rills affecting no more than 5% of the surface area.	A few shallow (<0.5m depth) gullies affecting no more than 5% of the surface	Isolated land slump/ slide events, small in size or affecting less than 0.1% of the total area.	• Limited loss of vegetative cover (>80% cover) and only slight erosion on 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 on the inside.

TABLE 5 **Indicators of the severity of soil erosion by water and mass movement** *(continued)*

State and severity	Splash erosion	Sheet erosion	Rill erosion	Gully and ravine erosion	Mass movement	Stream / river bank erosion
Moderate	• Clear signs of splash of soil particles into the air - moderate soil coating on stems / undersides of leaves • Clear sign of surface sealing by raindrop impact • Surface crust < 1 cm thick; readily broken	• Clear signs of down slope transport and deposition of topsoil by surface wash. • Some pedestals but < 5 cm. in height. • Some tree, grass, crop roots exposed in topsoil. • Evidence of topsoil loss but no exposed subsoil	Presence of shallow to moderately deep rills (<0.2m depth) and/or rills affecting up to 25% of the surface area.	Presence of shallow to moderately deep gullies (0.5-1.0 m depth) and/ or gullies affecting 5 - 25% of the surface area.	A moderate number of individual slump/slide, events- small to- moderate in size and/ or affecting up to 1% total area.	• 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	• Clear generalised splash of soil particles - presence of soil on stems and leaves. • Clear surface sealing by raindrop impact • Hard surface crust > 1 cm thick.	• Clear evidence of whole sale downslope transport and deposition of topsoil particles by surface wash. • Pedestals > 5 cm high • Extensive exposure of tree, grass, crop roots • Subsoil horizons exposed at /near soil surface.	Presence of deep rills (up to 0.3m depth) and / or rills affecting more than 25% of the surface area.	Presence of deep gullies (>1m depth) and/ or affecting > 25% of the surface	Significant number of slump / slide events, may be large and/ or affecting > 1% of total area.	• Severe loss of vegetative cover (<50% cover) and moderate to severe erosion on mid to upper portion of the stream bank. • >15% of outer bends of meanders over a 1km stretch with active under-cutting at upper part of the bank and heavy deposition on inside.

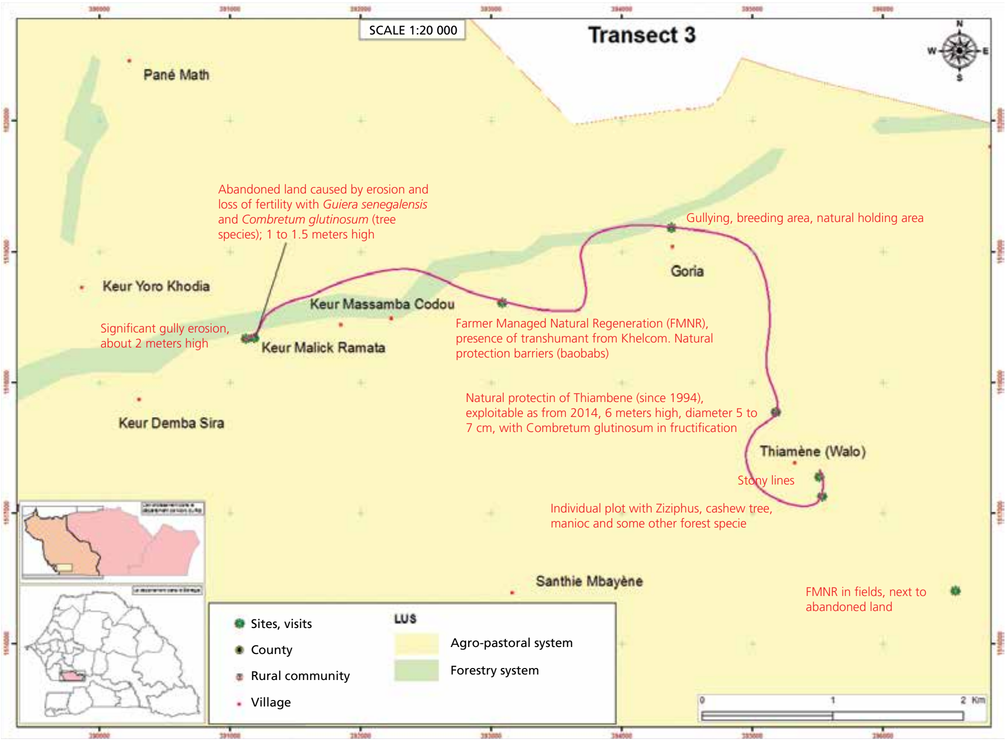


FIGURE 6 **Image showing a transect walk cutting across two land use types and indicating detailed assessment sites in Senegal**

TABLE 6 **Summary of the information to record on land use, resources, degradation types and management practices along transects**

Theme / Issue	Indicators of land uses, resources, degradation and management
Natural resources status and trends	
Land use	• Land use system (LUS) – if available - and land use type (LUT) • Land use intensity: density of homesteads / farms, farm size, fragmentation, individual to communal lands etc.)
Land unit / soil and terrain • ask what terms / criteria locals use to distinguish land units • take care not to mix degrees ° and % slope	• Land form (plateau, summit, mountain/hill slope, foothill / filtration zone, valley, river terrace etc.) • Average slope (% or degree; steep, moderate, gentle, flat) • Aspect / direction of the slope (compass bearing e.g. N facing) • Soil fertility (good, medium, poor) • Soil texture (sandy – loamy- clayey) and colour (dark or light; red-yellow-brown-black reflects minerals and organic matter);
Land constraints indicate main constraints for human use	• Steep / unstable slopes • Extent of rock outcrops, shallow soils • Surface hardness (crusts; laterite), stoniness /l arge clods • Salinity- whitish salt deposits • Surface waterlogging / ponding • Exposed to strong / dry winds / dust storms
Main land degradation features	• Presence of sheet erosion, rills and gullies (slight, moderate, severe), and state (active, partly stabilised, stable) • Sediment deposits from wind or water erosion • Land slumping or landslides • River / stream bank erosion • Degraded vegetation (bush encroachment / deforestation / overgrazing burning- extent (h, m, l) and severity (h, m, l)
Vegetation cover, type, diversity and degradation signs	• Cover quality: living plants and residues /litter (low, medium, high) ; % ground and % canopy cover • Type and structure (% grasses / other herbaceous spp. (perennial / annual), shrubs, trees)- planted or natural • Species: dominant species; share of i) beneficial / economically valuable species and ii) harmful / unpalatable / invasive species; • Plant health: extent / area of disease / pest / fire damage (h, m, l, n) and age structure (number of dead plants / seedlings / re-growth • Indicator plants (salinity, waterlogging, infertile soils, fire resistant) • Habitat diversity: fragmentation / connectedness; occurrence of trees, woods, field borders, live fences, fallow land etc.) • Evidence of wildlife (pigs, rabbits, rodents, snakes, birds etc.)

TABLE 6 **Summary of the information to record on land use, resources, degradation types and management practices along transects** *(continued)*

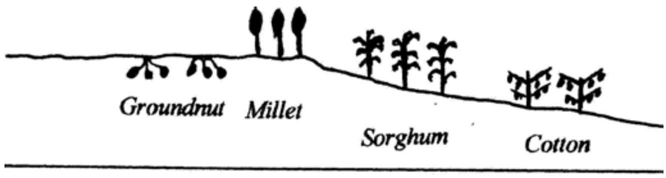
Theme / Issue	Indicators of land uses, resources, degradation and management
Water sources, availability, quality, use and degradation signs	• Drainage pattern (dense, medium, light) • Water source: river, stream spring (perennial / ephemeral) • Wetland condition (protected, stable, degraded); % converted (e.g. drained and cropped) • Water point: well, borehole, piped water, dam / pond, (perennial, seasonal, abandoned) • Water quality: turbidity / sediment load (dark, light, clear) ; evidence of pollutants (smell, visible signs, aquatic weeds) • Water availability (g, m, p), trend (increase, stable, decrease) and uses (household. livestock, irrigation, other) • Access (distance / time in dry and wet season) ; public / private
Ecosystem integrity in selected catchment / landscape	• Wider landscape value (aesthetic, tourism, etc.) • Threats / risks to sustained resources, ecosystems and productivity (urban /settlement expansion, encroachment of agriculture, charcoal production, commodity specialisation, etc.) • Resilience / opportunities for sustaining resources, ecosystems, productivity, diversity)
Management practices/systems and their effects	
Watershed / soil and water management/ water storage / harvesting / irrigation	• Type and % area under protection measures (e.g. protected, afforestation, protection of water sources, gully reclamation, dune stabilisation, etc.) • Improved farming / soil and water conservation practices (e.g. contour farming, tied ridges, vegetation strips, stone lines, bunds, terraces, zai) • Management and use of water storage structure (catchment of dam, pond, tank; controlled access livestock and grazing; troughs / pumping for irrigation) • Type and source of contamination (domestic / livestock waste, agricultural or industrial pollutants) • Water harvesting (type, extent, purpose) • Irrigation type (sprinkler; furrow; drip; flood; border), water source, surface area, crop; use of waste water
Forestry system management	• Primary / secondary forest - main species; loss of useful species • Planted / managed forest - main species, loss of useful species • Forest health (g, m, p); quality (clearings, damage) and age structure (mortality/regrowth) • Management practice (coppicing, firebreaks etc) • Biomass (density, height and diameter of trees / shrubs- carbon content) and productivity (timber, firewood, other products) • Degradation causes / trends: deforestation, overexploitation, burning, conversion to other uses (slight, moderate, severe)

TABLE 6 **Summary of the information to record on land use, resources, degradation types and management practices along transects** *(continued)*

Theme / Issue	Indicators of land uses, resources, degradation and management
Grazing system (range / pasture) management	• Livestock types, herd size and composition (age, sex) • Extensive / intensive grazing (% area) • Livestock management / feeding (free grazing, fenced, tethered, stall-fed, cut and carry, improved pastures; seasonal movements; grazing corridors, pest /disease management) • Pasture health (g, m, p) and composition (% shrub / herbaceous species); indicator species, palatable/undesirable species- thorny, poisonous, salt tolerant etc); • Plant biomass (height and density) and productivity / livestock carrying capacity (from secondary information – see section 5.2 in Part 1 (FAO, 2011a)) • Degradation causes / trends: overgrazing, burning, conversion to other uses (slight, moderate, severe)
Cropping and mixed systems management (agroforestry, agropastoral; agrosilvopastoral)	• Crop types and diversity (annual / perennial species / varieties, mixes) • Previous land use / crop rotation (1-4 years) • Crop management practices: use of residues / mulch, organic matter, weeding, • Agropastoral practices (use of manure for crops, of crop residues for feed / fuel) and livestock type(s) and management • Agroforestry practices- tree species (indigenous / introduced), % area (e.g. alley cropping, contour planting, scattered) • Tillage mode (% hand, oxen, tractor) ; % cultivated area under conservation agriculture (zero tillage, permanent cover) • Fallow natural / improved % of land (fallow / cultivated), • Recent losses of important crop species, varieties and uses, also of useful associated species (pollinators, predators of pests) • Productivity (forage crops, grain, straw, tubers, fruits, other) • Degradation causes / trends: nutrient mining, monocultures, inappropriate use of chemicals, poor cover / organic matter management.

FIGURE 7 **Example of a transect diagram including information on land use, degradation type, extent and control measures**

Description of land resources, degradation and management for each land use type along the transect walk

LUS: .... Example: Annual cropping	**Annual crops, grazing mix**	**Annual crop land, grazing mix, trees**
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
Altitude range (from start to end)	XXX – YYY	XXX - YYY
Average slope (in degree or %)	XX	XX
Land / soil resources • **soil texture** • **soil colour** • **soil fertility (G, M, P)**	• Gravel, sand • Red • medium/shallow	• Sand, loamy-sand • Red to brown • poor
Water sources / hydrology	• none	• none
Major constraints to use	• Low moisture • shallow soil, exposed rocks	• Erosion risk
Natural vegetation • **type and cover** • **main species** • **indicator species**	Poor cover, few trees • *Combretum* sp., *Burkea africana* •	Negligible ground cover • *Vitellaria paradoxa*, small *Parkia biglobosa* • ....
Major crops, livestock and/or planted tree species	Millet, groundnut Small ruminants tethered at homestead	Sorghum, millet, cotton, groundnut
Land degradation features – soil, water and vegetation (specify also extent and severity)	Drought prone Deforestation	Soil erosion – rills/gullies Active- severe
Land management / soil and water conservation / restoration measures (specify extent and effects)	Mulching on some fields	Contour tillage demo. Planted grass strips / trees in some fields –less erosion
Land use intensity (farm/field sizes; fragmentation, borders etc.)	• larger farms • trees and shrubs in borders	• small field and farms

Description of land resources, degradation and management for each land use type along the transect walk

LUS: .... **Example: Annual cropping**	**Annual crops, grazing mix**	**Annual crops**

GPS location (from start to end)	XXX - YYY	XXX - YYY
Altitude range (from start to end)	XXX - YYY	XXX - YYY
Average slope (in degree or %)	XX	XX
Land / soil resources • **soil texture** • **soil colour** • **soil fertility (G, M, P)**	• Sandy loam to loam • Brown to black • good	• Clay • Black • good
Water sources / hydrology	• 1 well and 1 borehole in the village	• Small river (dries up in some dry seasons)
Major constraints to use	• Soil sticky; land difficult to prepare • Drying	• Water logging • Land difficult to prepare
Natural vegetation • **type and cover** • **main species** • **indicator species**	Healthier vegetation • Large *Parkia biglobosa*, and *Vitellaria paradoxa*, *Daniellia oliveri*	Hydrophilous plants: • *Terminalia macroptera* • *Mitragyna inermis*
Major crops, livestock and/or planted tree species	Maize, sorghum, some cotton	• Rice, vegetables • Small herd of cattle
Land degradation features – soil, water and vegetation (specify also extent and severity)	Soil erosion – rill/sheet Active-slight	• Waterlogging, • water pollution, • sedimentation
Land management / soil and water conservation / restoration measures (specify extent and effects)	None	None
Land use intensity (farm/field sizes; fragmentation, borders etc.)	• small fields and farms	• very small fields

SECTION 3

Vegetation assessment

Introduction

Sites: The sampling sites for the detailed investigations and scoring will have been identified during the transect walk and reconnaissance visit of the study area (section 2). They need to be representative of a specific land use type. It is important that selected sampling sites can be compared with a benchmark of similar vegetation / land use type in good conditions. Digital photographs should be taken of each sampling site and to the extent possible comparative pairs of sampling sites should be assessed (healthy forest versus a degraded forest etc.).

Equipment: In addition to the standard recording materials, GPS, camera and abney level / clinometer for measuring slope and maps used in the transect walk (see Annex 1 in Part 1 (FAO, 2011a)), further 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 (1 metre metal/bamboo square with 10 cm grids of wire or string);
- calibrated Aluminium Disk Pasture Meter (optional);
- the Abney level will be used for measuring tree height (as appropriate).

Quadrat size: A quadrat is a predetermined sample surface area (usually square) used repeatedly to sample vegetation and measure species presence, frequency, abundance and cover. The quadrat size that should be used depends on the vegetation type and density and should be decided for each particular site:

- for herbaceous cover / grasslands a $1m^2$ quadrat divided into grids (e.g. 10 cm^2);
- for dense forest or crops a 5x5m or 10x10m quadrat can be marked out using a tape measure (e.g. with one person or a stake at each corner)
- for shrub land and open grass / wooded savannah a 20x20m to 50x50m quadrat can be used, as above, or a line transect used (see below).

Line Transect: In rangelands and very dry areas with extremely sparse vegetation, a line transect tends to be used rather than a quadrat, this may be 50 or a 100 m long depending on the heterogeneity of the vegetation. For estimating tree density, a 50 to 100m quadrat can be paced out. To ensure a representative sample up to 3 line transects may need to be taken in a 500 m^2 area.

There are three steps in assessing vegetation degradation:

Step 1: Before going to the field, information on changes in vegetation areas and intensity of use can be obtained from time-series aerial photos and satellite images, also from reports of natural resources / vegetation inventories and land cover surveys.

Step 2: Information on vegetation condition and health can be obtained in the field through visual observations of vegetation cover and condition (dominant species, size / growth; mortality and regeneration) backed-up by vegetation sampling using quadrats and measurements to compare vegetation on sites / areas that have been subject to different levels of protection, management and utilisation. Specimens of indicator plants should be collected in plastic bags, (or in a plant press, if available) with labels to record the site and local plant names for later identification with specialists (botanists, foresters, pasture specialists, ecologists, etc.).

Step 3: As with the assessment of other land resources, it is important to supplement and triangulate the data from the vegetation observations with information provided by key informant interviews (see Tool 5.2). This should help provide explanations of changes in vegetation area, intensity of use and products harvested. Household interviews (Tool 7.1) should provide more detail on the quantity and quality of the products harvested from particular areas. Different household members need to be involved, as they may have different information depending on which specific and products they harvest (in particular women may use vegetation resources in very different ways to men).

The following tools are provided:

– Tool 3.1 Vegetation assessment in forests / woodlands

– Tool 3.2 Vegetation assessment in pasture / rangeland

– Tool 3.3 Vegetation assessment in croplands

– Tool 3.4 Degradation effects on cropland productivity

(See also Tool 5.2 Interviews on Vegetation Resources.)

More detail on vegetation assessment and biodiversity indices are given in Table 5 in Part 1.


PHOTO 4 **Natural veld grazed by cattle, sheep, goats and donkeys (South, Africa)**

Vegetation types and indicators

Objectives:

- To compare the 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);
- To identify / verify indicator plants of land degradation, conservation or improvement;
- To assess vegetation (forest, pasture, rangeland, cropland) in terms of productivity and ecological function and capacity to maintain the range of ecosystem services.
- 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.

Participants: As with the soil assessment, if possible, the local team should be accompanied in the field by the land owners / land users.

Type of vegetation: The first task is to classify the vegetation:

Forest / woodland type (F): whether the trees are coniferous, evergreen broad-leaved, semi-deciduous, deciduous, or xeromorphic (arid and semi-arid areas) and the density:

- **Forest (FF):** Trees usually over 5m tall with crowns interlocking (generally 60-100% canopy cover). Shrubs, herbs and non-vascular plants may be present with any cover value;

- **Woodland (FW):** Open stands of trees usually over 5m tall with crown not usually touching (generally 25-60% canopy cover). Shrubs, herbs and non-vascular plants may be present with any cover value;
- **Sparse woodland (FS):** Trees usually over 5m tall with widely spaced crowns (generally 10-25% canopy cover). Shrubs, herbs and non-vascular plants may be present.

As described in Table 2 in Part 1, it is also useful to specify the land use type i.e. if the forests/woodlands are virgin / natural, planted forests/plantations and or protected such as a forest reserve or wooded savannah in a game park. If the forests are grazed this should also be indicated i.e as in agrosilvopastoral systems

Grazing land type (G): Land that is grazed or browsed by livestock and wildlife may consist of tall /medium / short grassland or forbs, and sparse or dense bush or dwarf bush and a range of trees (evergreen, semi-deciduous, deciduous, or xeromorphic species):

- **Herbaceous (H):** Grasses and/or herbaceous plants (including ferns) generally forming >10% cover. Trees, shrubs, and dwarf shrubs may be present, but with cover 10% or less. Non-vascular plants may be present with any cover value.
- **Bush (S):** Shrubs and or small trees usually 0.5-5m tall with individuals and clumps not touching or interlocking (generally >25% canopy cover). Trees may be present but with cover 10% or less. Herbs and non-vascular plants may be present with any cover value.
- **Sparse Bush (SS):** Shrubs and or small trees usually 0.5-5m tall with individuals and clumps widely spaced (generally 10 - 25% canopy cover). Trees may be may be present with 10% cover or less. Herbs and non-vascular plants may be present with any cover value.
- Dwarf Bush (SD): Low growing shrubs and/or dwarf trees usually under 0.5m tall (though dwarf forms 0.5-1.0m can be included), with individuals and clumps not touching or interlocking (generally >25% canopy cover). Trees and shrubs greater than 0.5m may be present, but with canopy cover 10% or less. Herbs and non-vascular plants may be present with any cover value.
- Sparse Dwarf Bush: As above though low growing shrubs and/or dwarf trees (generally 10-25% canopy cover).

As described in Table 2 in Part 1, it is also useful to specify the land use type i.e. if the grassland or shrubland is essentially unmanaged, extensively managed or intensively managed for grazing by livestock and wildlife and/or if they are protected areas. If available the livestock types and stocking density should also be specified

Cropland type: Cropland may contain natural (maintained) or planted trees, shrubs and grasses in field borders and hedges and as biological soil and water conservation measures such as grassed contour bunds or strips, or alley cropping of useful leguminous or fruit tree species. The cropping system (crop types, rotations, inter or relay-cropping, fallow period, etc.) should be described as well as the natural vegetation.

As described in Table 2 in Part 1, it is also useful to specify if the cropping is perennial trees or shrubs (e.g. vineyards, orchards, coffee, tea, sisal), perennial crops (sugar cane, banana, perennial fodder crops, etc.) or annual crops (food and fodder crops, horticulture) and whether they are irrigated or rainfed. It is also useful to specify if they are mixed agropastoral systems if grazing is also taking place or stall fed animals are kept on the farms

The forest, grassland or crop species may have specific characteristics related to the soil and terrain conditions for example saline resilient species in saline soils, drought resilient species on very shallow and stony soils and water tolerant species in wetland areas.

Vegetation indicators

Vegetation condition is a key aspect of degradation in grasslands, wood/forest lands and croplands. For this range of land uses six key vegetative indicators of degradation are used in the assessment (stability or positive changes would indicate conservation or SLM):

- **Decline in vegetation cover (plant and litter):** reduced cover means increased exposure of the land to sun, wind, rain and wind and water erosion;. Vegetation cover can be divided into basal cover (herbaceous), shrub cover and canopy cover (trees) for a more in depth analysis
- **Changes in vegetation structure and species composition** which determines cover, shade, use and productivity. Change in dominant species is a key indicator of degradation and the share of beneficial / economically valuable species to harmful / unpalatable / invasive species influences productivity and livelihoods;
- **Decline in species and habitat diversity:** reduction or loss of biodiversity is associated with loss of useful products and functions (habitat for wildlife, pollinators) and reduced resilience (e.g. to climate change and to pests and diseases);
- **Changes in abundance of specific indicator species:** the specific species may indicate, for example, low pasture or soil quality (or the converse), invasive species (e.g. leading to bush encroachment or out competition of more palatable species), or specific land degradation concerns such as salinity (halophytes), waterlogging due to soil compaction, fire incidence;
- **Reduced vegetation health and productivity** which includes the vegetation quality or extent of damage of natural and planted species (e.g. to leaves, buds, roots, cambium, branches, trunk) by fire, pests, over-exploitation, etc., and reduced growth/ regeneration capacity of forest, shrubs, trees and herbaceous species (few young plants, many old/ senescent plants);
- **Vegetation management and use:** whether it is intensively or extensively used; the management practices that are used and the use of products harvested from the land.

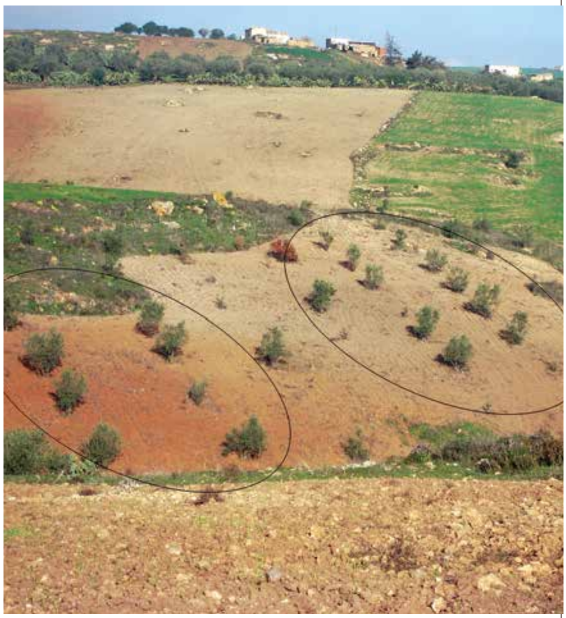


PHOTO 5 **Photos can be useful to back up observations and measurements**

Tool 3.1 Vegetation Assessment in Forest / Woodland

It is important to understand the history and the stage of the vegetation in natural forests and woodlands (primary, secondary) and to relate the forest condition to pressures on the forest from local and other users of wood and non-wood forest products. This tool is used also for assessing the condition and productivity of trees outside of forests / woodlands (i.e. trees in grazing lands and croplands).

Sampling

An appropriate quadrat size should be selected with the advice of the vegetation specialist ecologist in the team (see Table 7) and used to determine the cover, condition and productivity of trees in woods / forests compared with a benchmark site which is assessed to be in good condition using the following indicators. This draws from FAO National Forest Monitoring and Assessment (FAO, 2009). As a rough guide the quadrat size is normally equal to the height of the tallest vegetation

A field form is provided in Table 9 below to assist with systematic recording and documentation of the various vegetation indicators. This could be adapted as required by the assessment team during an initial pilot assessment

1. Vegetation cover: Each of these indicators should be assessed, as appropriate (none / negligible <5%, little 5-10%, moderate 10-40%, high 40-70%; dense >70% cover)

1.1. Tree canopy cover: estimate the ground surface covered by the vertical projection of the tree canopies, as a percentage of the total ground area;

1.2. Shrub canopy cover: estimate the ground surface covered by the vertical projection of the shrub canopies % of the total ground area; and,

1.3 Ground cover: estimate the ground surface covered by herbaceous vegetation or litter.

2. Species composition

2.1 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 if the vegetation is diverse. Compare to the benchmark site and ask the local informants / land users to indicate if there has been a change in the dominant species as this is a key indicator of degradation, also ask the reasons (overexploitation – by whom?, specific management practices, climate change etc.);

TABLE 7 **Optimal size of quadrats in vegetation surveys**

Type of vegetation	Vegetation height (m)	Size (m)
Moss / Lichens	< 0.05	0.1 × 0.1
Short grassland (annual grassland))	< 1	1 × 1
Tall grassland (perennial grassland)	< 2	2 × 2
Shrub	< 4	5 × 5
Young forest (sub-forest))	< 8	10 × 10
Mature forest	> 8	20 × 20

Source: http://hosho.ees.hokudai.ac.jp/~tsuyu/lecture/glossary/on_quadrat.html

2.2. Indicator species: identify any species which is an indicator of problems or constraints (e.g. invasive species, weeds, plants that indicate salinity, waterlogging, low fertility etc.) and record the abundance (i.e. whether the number of each indicator species in the quadrat is - abundant (many); medium (common); or rare (few)).

2.3 Useful species and products: compare to the benchmark site and ask the local informants / land users to indicate:

1. If there has been a change in the dominant species, as this is a key indicator of degradation and ask the reasons (overexploitation, management practices, climate change etc.);
2. Which are useful tree / shrub species? What products they provide (timber, charcoal, food and medicinal products, other)? and for whom? (land use group; men or women) and whether there has been a change (i.e. loss of valuable species and products or decline in productivity)?;
3. Whether there has been a change in the share of beneficial / valuable species to harmful / unpalatable / invasive species or in the wildlife (e.g. loss of habitat, feed).

3. Condition and wood productivity
3.1 Growth: measure the average height (h in m) and diameter at breast height (Dbh in cm) for trees and for 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 the diameter is measured at stump height (Dsh). For stumps, ask the land users if they can indicate the time since the tree was cut (<1, 1-5, 6-10, >10 years) as this will indicate recent pressures. Ask local informants / land users the age of planted trees - this is a useful measure of productivity and of carbon stocks.

3.2 Overall tree condition: record the 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 or the tree has fallen.

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

3.4 Tree stem quality: for species used for timber / building materials, assess if the stem 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).

3.5 Causes of damage: ask local informant / land users if they know the causes of damage (e.g. due to insect infestation (defoliation, leaf feeding, etc.); presence of fungus (leaf spots, leaf or needle discolouration, etc.); burning; 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).

3.6 Management practices ask local informant / land users what types of management practices are used in the forest / wood land, what is the intensity trend and whether there are any bye laws affecting management practices and use of products (see Photo 6 and Table 8).

A. WELE

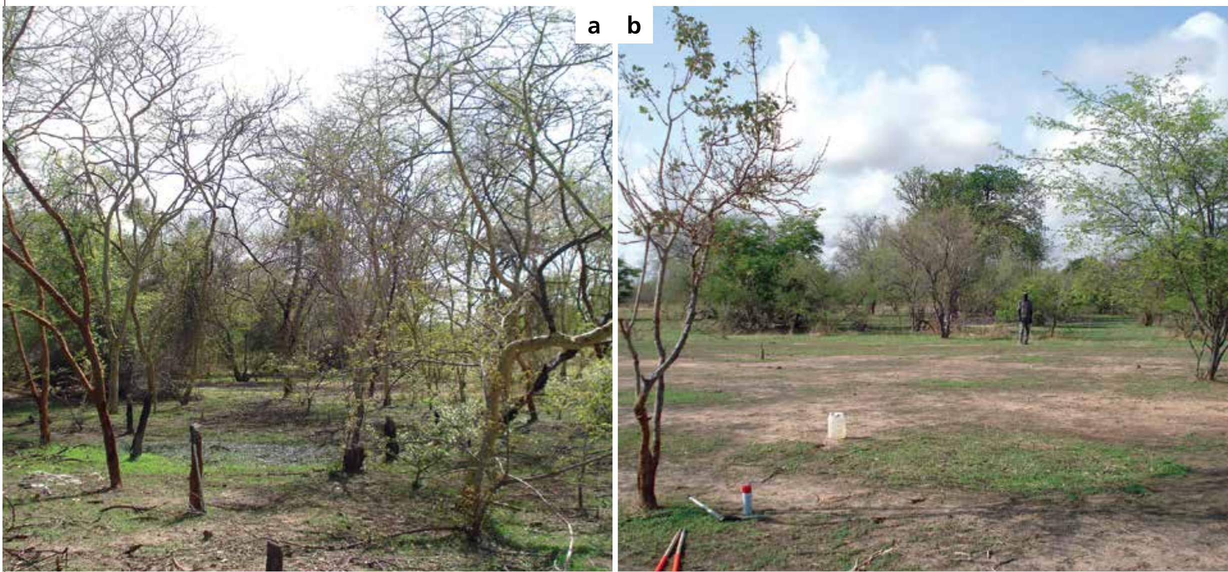


PHOTO 6 **(a) and (b) Assessing grazing land with trees (Touba Ndar Fall, Senegal)**

TABLE 8 **Review of management practices in forest / woodland**

Management practice and measures in forest/ woodland	**Extent of application** (V- Very high; H- high; M- medium; L- low)	**Use of products**	**Effect/Intensity trend** (O - Overuse C - conservation (stable) L- low use)
e.g. thinning / coppicing of trees/ clear felling…, etc.		e.g. use of wood/ wild fruits/nuts/ medicinal plants,	
e.g. byelaws, regulations on access, rights of use			

TABLE 9 **Field form for vegetation assessment (degradation/ SLM) in forest/woodland**

				Species		Growth				Canopy			Health			Products			Users	
Site No	Tree	Shrub	Stump	Common name	Scientific name	Av. Diameter Dbh.	Av. height	Year(s) since cut	Tree Stem quality	Tree canopy cover	Shrub cover	Ground cover	Crown condition	Tree/shrub condition	Cause of damage	Wood and building materials	non wood food and medicinal products	Charcoal	Local use	Commercial use
						cm	m		C	%	%		C	C	C					

Ntes:

Tool 3.2 Vegetation assessment in pasture / rangeland

Visual indicators and methods

An understanding is needed by at least some members of the assessment team of the processes of rangelands degradation and issues of seasonality. 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 consequently on livestock carrying capacity.

Changes in grass species composition, notably the decline in the percentage and absolute number of desirable (palatable) species, combined with any 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 in Table 10 for a visual assessment of pasture / rangeland condition - comparison is the key between well and poorly managed land (see Photos 8a and b.[3] The proposed scoring needs to be tested and adapted / calibrated for each situation. The findings should be integrated with the soil investigations (Section 4).

These methods are subjective, the accuracy depending on the judgement of the operator, but they need no in-depth knowledge of the pasture and can be applied easily. 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 future monitoring.

Sampling

Select an appropriate quadrat size or use a line transect to determine the cover, condition and productivity of the pasture or rangeland for the selected assessment site using the indicators in Table 10. Where possible, repeat the measures to compare the site in the given land use with another site in relatively good condition.

The score sheet (Table 10) 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 locally appropriate indicators can be included in the score sheet, or they can be used to make a more informed assessment of the existing indicators.

This scoring system has been calibrated in South Africa and was tested in the five other LADA project countries, but it may need to be re-scaled in other locations.

3 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. (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.

TABLE 10 **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) *[N.B. Cover is critical for soil protection from raindrop impact, high temperature and to reduce runoff volume and rates.]* *Cover can be divided into basal cover (herbacecous), shrub cover and tree canopy cover for a more in depth analysis.*
1.2	**Bare spots**	Spots without vegetation. In savanna - 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 (i.e. rainfall and drought).
	Moderate	Vegetation height, diameter and plant vigour slightly lower than the representative site.
	Poor	Vegetation height, diameter and plant vigour significantly lower than representative site and sub-optimal.
	Very poor	Serious reduction in biomass (vegetative production), resulting in stunted and defoliated growth 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 are perennial
	A lot	Single annuals are present
	Little	Perennials are present but not important
	None	Perennials not seen

TABLE 10 **Indicators and classes for assessing pasture / rangeland quality** *(continued)*

Issues and core indicators		Category
2.3	**Proportion (dominance) of useful species**	*This could include: - Ecological functions (e.g. 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
3. Ecological integrity, biodiversity and change dynamics		
3.1	**Proportion of each vegetation strata**	% / proportion of trees, bushes / shrubs, forbs[4], 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 plants poisonous 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 termites (defoliated vegetation and termite nests visible), rodents, locusts or others.
	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

4 Forbs are herbaceous flowering plants that are not grasses, sedges or rushes.

TABLE 10 **Indicators and classes for assessing pasture / rangeland quality** *(continued)*

Issues and core indicators		**Category**
3.8	Bush / shrub encroachment	A key factor of pasture / range degradation is 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, woodland and savanna areas to other land uses due to over-cutting of trees. One consequence is soil erosion, which results in the loss of protective soil cover and 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. With minor efforts it can be easily stopped and damage repaired.
	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 a simple hand balance in the field. However, dry weights of biomass samples weighed in a lab. are more accurate and comparable than wet weights in the field.

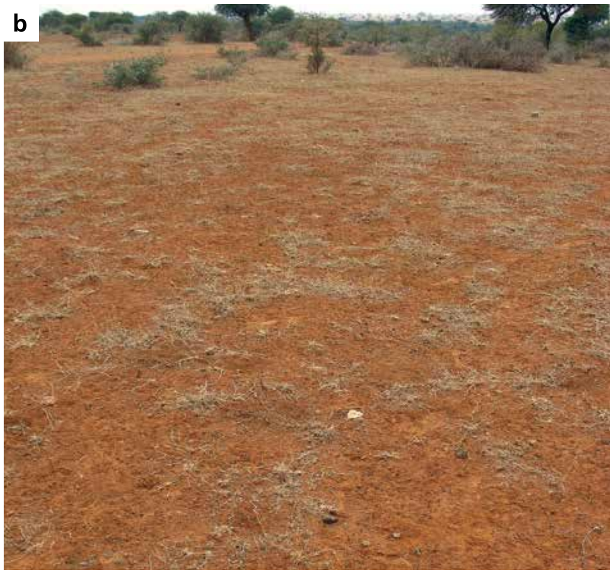


PHOTO 7 **a) Average basal cover (left) and b) low basal cover (right) due to grazing pressure (South Africa) (see Table 10)**

Scoring

Once the class has been assigned for each indicator, the range / pasture condition can now be scored. Using Table 11, for each indicator mark one of the columns. 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 / pasture.

TABLE 11 **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

TABLE 11 **Scoring using visual indicators for assessing range quality** *(continued)*

Range condition indicator	Best class	Moderate	Poor	Worst class
3.2 Species that decrease with grazing pressure	Dominating	Lot	Little	None
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				

Convert the score to a percentage (score / number of points X 100) and interpret the condition using the following classes:

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	

[NB This scoring system was developed for grassland and grazing animals and should be adapted for browsing animals.]

Management practices in range and pasture lands

Discuss with the local informants / land users and describe the reasons for the current vegetation status (cover, composition, ecological integrity, biodiversity etc.) and where available, also the reasons for change dynamics.

Complement this information with information gathered from the FGD (Tool 1.1) on vegetation and from household interviews (Tool 7.1) on the:

- Management and conservation practices in place (or missing) to ensure sustainable utilization of vegetation resources;
- Use of products: what products are used from the grazing land (e.g. wood from trees for timber or firewood, straw for thatching, wild animals for food etc.);

TABLE 12 **Review of management practices in grazing land**

Management practices / measures in grazing land (indicative examples)	**Extent of use/ Intensity** (H- high; M- medium; L- low)	**Use of products**	**Intensity trend** (O - Overuse; C - conservation (stable); L- low use)
• pasture species management • removal of invasive species • thinning of bush		• use of grass / straw for thatch, medicinal plants, etc.	
• density of livestock (in relation to expected stocking capacity)		• use of manure for fuel, etc.	
• use of trees/shrubs in grazing lands (shade, fodder, felling)		• use of tree wood / wild fruits / nuts etc.	
• specific regulations, bye laws (e.g. stocking rate)		• specific laws (e.g. harvesting rate)	

- Direct pressures, also the socio-economic and bio-physical driving forces that explain the current pasture / rangeland status (e.g. 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, backed up where possible by photos (see the example of Photo 8).

Table 12 indicates how such information could be recorded and documented

Grazing quality and carrying capacity

Grazed and browsed 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 the 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, also the potential **carrying capacity**.

Carrying capacity[5] 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. Carrying capacity is dynamic and influenced by several factors, including climate, soil, topography and veld / grassland type

5 As defined by Trollope, *et. al.*, 1990; Jordaan, 1991; and Fourie, *et. al.*,1985

(botanical composition, quantity and quality of grazing material).

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, 1982; Trollope *et al.*, 1990).

Different livestock species generate different grazing or browsing pressures; for example, goats are hardy and can live on poorer quality grazing than sheep or cattle but cause more degradation because of their feeding habit. A change in livestock species should be noted, as it may be responsible for a decline in vegetation quality.

A pasture / rangeland area under assessment, or a specific farm, usually contains several grassland (veld) 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 area being assessed, the team may want to include these more detailed measurements.

Trees in the grazing landscape

Besides the assessment of vegetation for livestock grazing it is also important to assess the trees on grazing lands as they provide valuable shade for livestock and windbreaks, they help to maintain a cooler microclimate, provide firewood and other products.

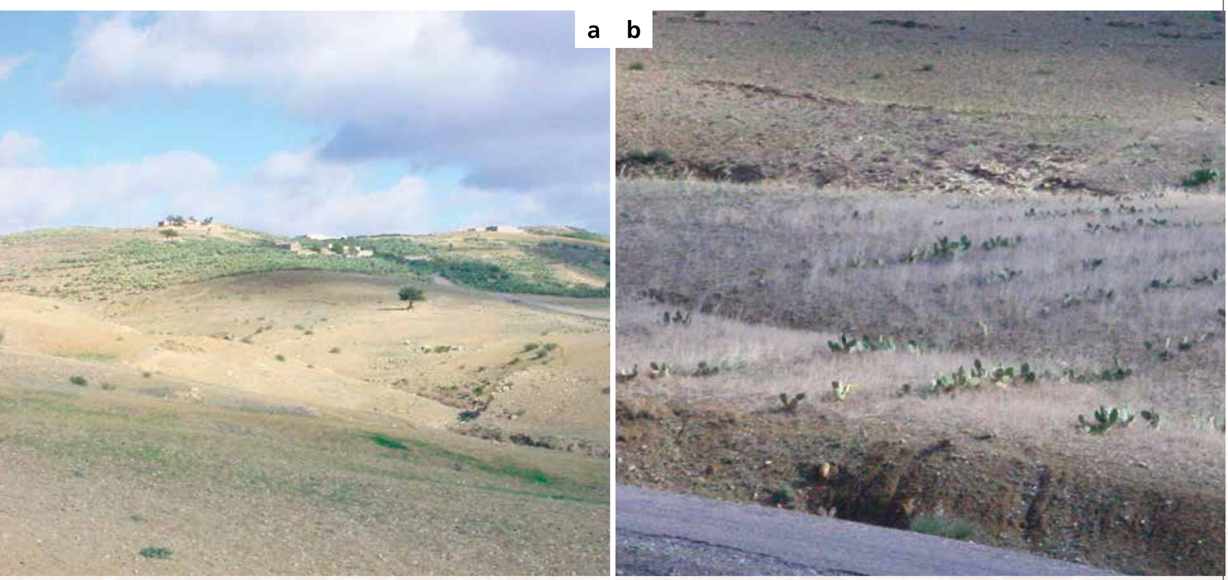


PHOTO 8 **Comparison of a) bare exposed cereal land with b) managed pasture & cactus, Tunisia**

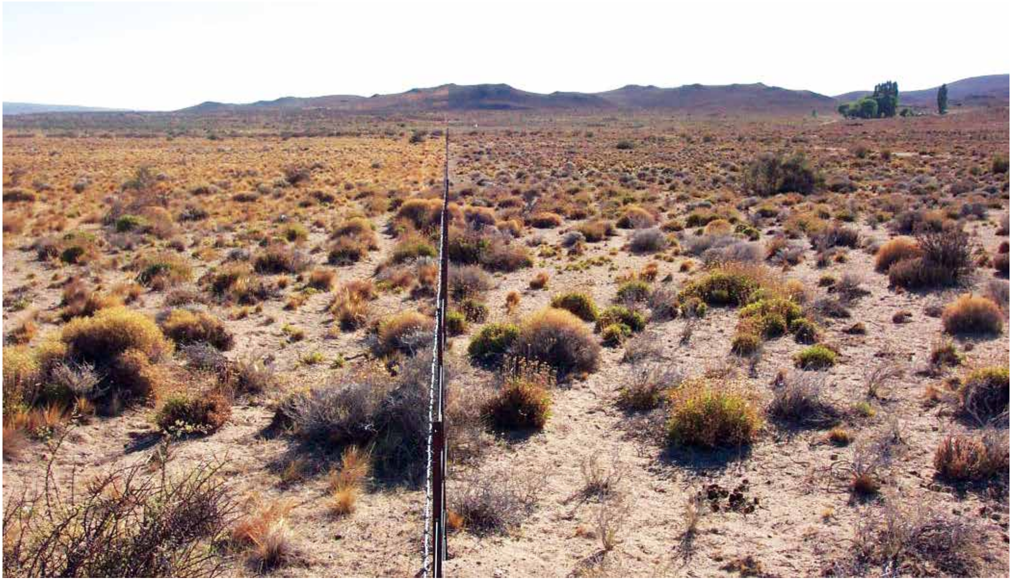


PHOTO 9 **Comparing vegetation and management on different sides of a fence (Bariloche, Argentina)**

PHOTO 10 **Comparing an area before and with project (Fengnin, China)**

– **Density and spatial distribution of trees in the grazing land;** provides a useful indicator of the extent to which trees have been maintained in the environment. (none; scattered / sparse; grouped in blocks; trees in lines (e.g. along fences, roads) in, plantations; other.

– **Tree health, condition and use of products:** where the trees are used for timber, or other non wood forests products the protocol on forest / woodland assessment can be used to assess the trees in the grazing landscape.

Tool 3.3 Vegetation assessment in croplands

Natural vegetation is also important in croplands. In addition to the indicators specified under crop productivity below (Table 13), five other vegetation indicators are included here that should be observed in the field and assessed through the land user and household interviews:

- **Ground cover:** as with pasture and forest land soil, ground cover by live vegetation, mulch (see Photo 11) or crop residues is a key factor in protecting the soil from raindrop impact, soil erosion, high temperatures and excess evaporation;
- **Permanence of the crops or period of cover:** determines exposure of bare soil and erosion risk;
- **Cropping system diversity:** diverse crop systems provide resilience to pests / diseases, capacity to restore and make better use of nutrients / organic matter 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; a crop rotation will make better use of nutrients and water in the soil profile);
- **Diversity of natural vegetation within the cropland:** natural vegetation provides habitat for associated species and their beneficial ecological interactions (e.g. pollination). In drier farming systems, there is a need to minimise competition for water between species through the use of appropriate species and management practices;
- **Land fragmentation / proximity to natural vegetation:** increased fragmentation and reduced proximity to natural vegetation will indicate intensification pressure;
- **Use of natural vegetation** for restoring soil protection and organic matter content, also other uses (e.g. wood and non wood forest products etc.

PHOTO 11 **Maize stubble left on soil surface to provide mulch (South Africa)**

TABLE 13 **Indicators of vegetation condition in croplands**

Indicators	Value
Ground cover (inverse of bare soil)	
• cover by crops	%
• cover by mulch	%
• cover by plant residues	%
Permanence of the various crops and cover	
• period of cover	low, moderate, high
• cover in the dry season(s)	low, moderate, high
• cover at start of rainy season (s) when wind and water erosion are greatest risk	low, moderate, high
Crop diversity	
• crop species diversity (number and share of. local /indigenous to introduced species))	no.; low/medium/high
• crop varieties (number for 3 main crops)	no.; low/medium/high
• harvested products diversity (grain, straw, beans, fruit, fibre, etc.)	no.; low/medium/high
Fragmentation/proximity to natural vegetation	
• average farm/field size	ha
• average number of parcels	no.
• extent/share of fallow land	%
Diversity of natural vegetation in / around cropland	
• distance of cropland from natural vegetation (grazing, forest / wood, managed fallow, unmanaged)	none / close / far
• landscape features- presence of hedgerows, trees, grassed bunds/ waterways, windbreaks, etc. -specify	none / few / many
• contribution to household of gathered products (e.g. share of fuelwood, wild foods, charcoal, materials, medicinal plants,...)	low / moderate / high
• reduction/loss of useful species and products	low / moderate /, high
Use of natural vegetation	
• for protective mulch	low / medium / high
• for restoring organic matter management	low / medium / high
• for other products (wood, firewood, etc)- specify	low / medium / high

Assessing crop biodiversity

Simple diversity measurements of richness, evenness and divergence can be used to compare the status and trends in on-farm crop species and varietal diversity. In many countries, biodiversity is of increasing interest and especially its relationship to land degradation / SLM and climate change. The following indicators can be used:

a) Identify and list the **range of species and varieties grown** in a sample of farm households (small, medium, large farms) (e.g. there may be 30 species in total and for one crop species e.g. maize there may be 5 varieties grown etc.);

b) Assess the average **species and varietal richness** for each farm size - the number of different kinds of individuals (regardless of their frequencies), for example:
   – average number of i) plant species and ii) average number of plant varieties per household iii) number and share (%) of traditional plant varieties per household;

c) Assess the **evenness among farms and among the whole community** -

how similar are the frequencies of the different variants (low evenness indicates dominance by one or a few crop types);

d) Assess **divergence** (as a %) (i.e. the partition of diversity between and within farms) this can be measured by the difference between community and farm index values divided by the community value (high divergence may indicate high potential of households in the community to grow different varieties).

Through discussions with land users, explain the findings, for example:

- Crop genetic diversity may continue to be maintained on farm, in the form of many species and / or several traditional crop varieties. Alternatively, crop diversity may be very low, in which case there are few species and few varieties maintained;
- A large part of crop diversity may be held in the larger community, rather than in any one farmer's fields.(i.e. the diversity is spread throughout the community);
- There may be a close relationship between traditional varieties' richness and evenness (i.e. farmers who grow traditional species will also grow several varieties of each crop);
- In some cases, crops may be maintained at farm and community level with one or two dominant varieties and a large number of other varieties that occur at lower frequencies. This suggests that farmers maintain the low frequency varieties as an insurance to meet future environmental changes or for social and / or economic reasons. For other crops that show a more even frequency of distribution of traditional varieties, this implies that farmers are selecting varieties to serve current needs;
- Divergence estimates across crops and varieties may show that small-scale farmers who manage different varieties in different ways are a major force for maintaining crop genetic diversity;
- Climate change and variability may be influencing which crops / varieties farmers grow, as they adapt to reduce risk of crop failure.

Tool 3.4 Degradation effects on cropland productivity

Land users are usually most interested in the impacts of LD / SLM on productivity, as this is directly linked 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.

Information can be obtained on the effects of degradation 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:

- low or declining yields (actual yields and trends);
- poor growth characteristics;
- plant nutrient deficiencies and toxicities.

Assessing yield and productivity

There are 4 possible sources of information.

- **Historic comparison of yields from records** (review of secondary data)
  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.

- **Discussions with land users to assess change in yields and land productivity**
  See Tool 5.3 Interview with land users on crop productivity and yield.
- **Assessing change in production costs that may be related to soil degradation**
  Assessing whether production costs have increased because of increased tillage / fertiliser requirements and herbicide / fungicide application over the years can be estimated by farmers' perception or can be calculated using annual farm balance sheets (see Figure 8). (FAO, 2008).

Ground preparation, fertiliser, herbicide and pesticide inputs can account for some of the main costs in a cropping system and can increase significantly with soil degradation. As degradation increases, the density and strength of the soil increases and, as a result, the soil becomes more resistant to tillage forces. In mechanised systems, plough resistance increases so that larger tractors are required to avoid excessive wheel slip and the need to operate at lower ground speeds in a lower gear. The size, density and strength of soil clods also increase with increasing loss

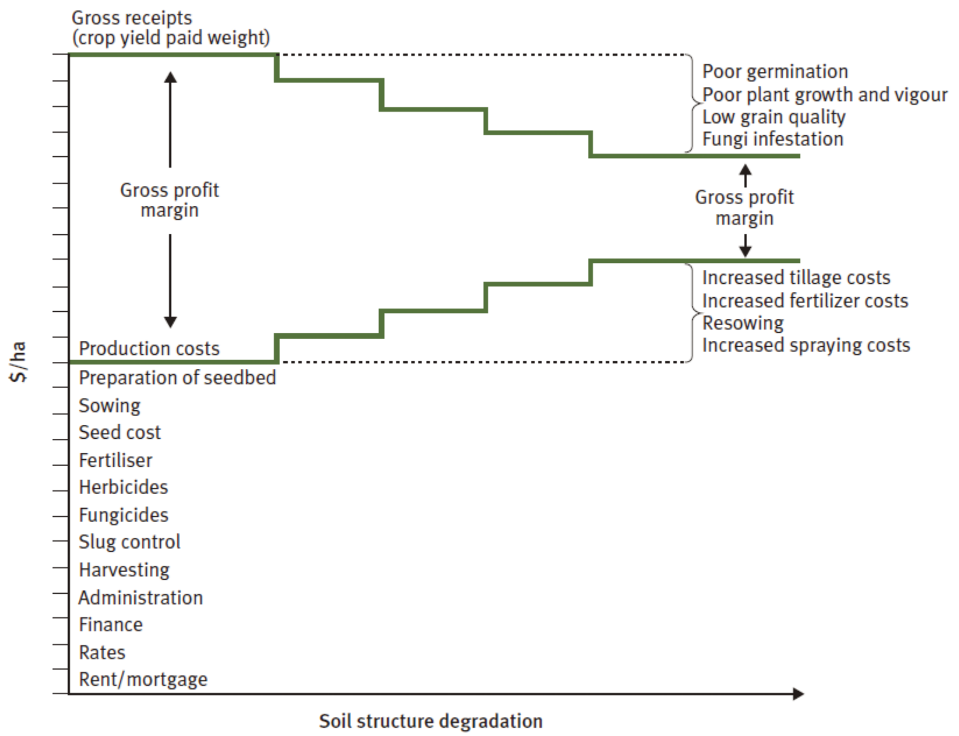


FIGURE 8 **Assessment of production costs**

Visual score (VS)	Production costs
2 [Good]	Production costs including ground preparation, fertiliser, herbicide & pesticide requirements have not increased
1 [Moderate]	Production costs including ground preparation, fertiliser, herbicide & pesticide requirements have increased moderately

of soil structure, therefore careful timing and additional energy is needed to break them down to a seedbed. This energy is generally applied by using more intensive methods of cultivation and by making a greater number of passes. As a result, conventional tillage costs can increase by over 300 percent.

Continuous cropping using conventional cultivation techniques increases the rate of soil organic matter decomposition and damages soil structure. This depletion of soil organic matter reduces soil fertility and the ability of the soil to supply nutrients to crops. Higher amounts of fertilizer are needed to compensate for the loss of these nutrients. Furthermore, the loss of soil organic carbon under continuous conventional cultivation could incur a possible carbon tax in the future.

Reductions in crop yield are often not recognised as the result of the degradation of soil structure. Growers often assume that soil fertility is at fault and increase their production costs by applying extra amounts of fertilisers.

- **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. This would depend on the assessment being undertaken at harvest time (which is unlikely) but information could be subsequently collected by the local team members.

Plant growth characteristics

These may include:

- **crop establishment** (germination, plant emergence and root growth are restricted by a crusted soil surface, also compacted soil in the root zone which impedes air and water movement);
- **numbers of tillers in cereals** (this is partly determined by plant genetics and planting density but is also an expression of plant vigour and growth which is regulated by nutrient and water availability and soil condition);
- **plant leaf colour** prior to completion of grain filling provides a good indication of water and nutrient status, also soil condition (crop yellowing due to inadequate formation of chlorophyll occurs as a result of low N, K, S, Fe, Mg, Cu, incorrect pH and / or poor soil aeration; blemishes can result from lack or excess of P, K, S, Mg, Mn, Zn, Cu and B);
- **root growth** determines uptake of nutrients and water (root length and density can be restricted by soil

TABLE 14 **Possible field indicators for assessment of crop production**

Plant growth measurements or observations	Good condition (2)	moderate condition (1)	poor condition (0)
Crop establishment (Plant population/m²)	Good emergence and crop establishment, with few gaps (due to poor germination) and crop showing a good even height.	Moderate emergence & crop establishment with significant gaps in the crop and variation in seedling height. Emergence may be moderately slow but may recover.	Poor emergence and crop establishment, with many gaps in the crop (e.g. due to crusting) and a large variation in seedling height (e.g. moisture stress, areas of erosion and deposition, variation in organic matter management). Plants may appear sickly thus more vulnerable to pest and disease.
Number of tillers (e.g. wheat, barley and oats) crucial in determining number of ears and hence a proxy for yield	Depending on the cultivar, the plant has 3 well developed tillers with little variability compared to the main stem.	Depending on the cultivar, the plant has 2–3 tillers with moderate variability compared to the main stem.	The plant has 1 or no tillers at all, with significant differences in terms of development to the main stem.
Leaf colour (nutrient uptake is closely linked with soil aeration)	Leaf colour is uniformly deep green. The odd colour blemish on leaves may be apparent within a broad area.	Leaf colour is yellowish green (i.e. has a distinct yellowish tinge). Few colour blemishes on leaves may occur within a wide area.	Leaf colour is quite yellow over a wide area. Colour blemishes on leaves may commonly occur.
Root development and disease	Good root length and root density in the upper 0.25–0.30m of soil. Rare root diseases.	Moderate root length and density in the upper 0.25–0.30m of soil. Common root diseases.	Poor root length and density in the upper 0.25–0.30m of soil with the root system being restricted to limited areas. Very common root diseases.
Plant height and diameter (as proxies of yield) • relative values in relation to resource quality / degradation signs but care as depends on variety	Tall strong cereal and fodder crops Large vegetables e.g. carrot length and diameter, cabbage and lettuce diameter.	Moderate in size.	Small and stunted - may be due to low soil fertility, waterlogging in the root zone, or subsoil compaction limiting the depth of soil from which the roots can obtain water and nutrients.

TABLE 14 **Possible field indicators for assessment of crop production** *(continued)*

Plant growth measurements or observations	Good condition (2)	moderate condition (1)	poor condition (0)
Wilting	No signs of wilting • medium textured deep soils with no compacted layers restricting root growth and with near neutral pH (neither too acid or alkali).	Some signs of wilting.	Evident signs of leaf wilt and moisture stress: • in sandy soil or areas with a stony or shallow profile; • during drought periods in heavier textured soils; • if subsoil is compacted; • if water uptake restricted by very acid or alkaline subsoil.

compaction, hardpans, reduced soil pores and aeration, salinity, sodicity and nutrient deficiencies; root disease and pest damage increase with poor soil structure and poor aeration; good root growth is enhanced by soil organic matter);

- **crop height and diameter** at maturity is a useful indicator of soil condition if agronomic factors have not limited crop development, but is also affected by climate, fertiliser use and size of grain kernels in cereals / numbers and size of tubers.

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 plant growth are given in Table 14. These can be assessed qualitatively or quantitatively using quadrats etc.. However, some of the indicators will be relevant only at certain times of the year.

Plant nutrient deficiencies and toxicities

Nutrient deficiencies are one of the commonest ways in which land degradation affects production (see Annex 2). Expertise is required for 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.

Possible causes of nutrient deficiencies should be investigated with the land users, such as:

- long and / or intensive cropping with insufficient applications of manures or fertilizers to replace the nutrients removed in the harvested products (i.e. nutrient mining);
- 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 (especially in sandy soils); and
- excessive liming with increased soil alkalinity causing 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 2** 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.

The information gathered on maintenance and use of natural vegetation, the cropping system or crop-livestock system and management practices (tillage, nutrients management, organic matter management etc.) of relevance to land degradation and sustainable management can be summarised, in a format as, for example, Table 15 (below).

A field form is provided in Table 16 for recording and documenting the information gathered on cropland in terms of natural vegetation and crop condition and productivity through observations and discussions with farmers or other land users.

TABLE 15 **Field form – Review of management practices in cropland**

Management practice in cropland (indicative examples)	**Practices causing degradation**	**Good management practices**	**Products and their use**	**Productivity trend** (+, 0, -)**	**Intensity trend** (O, C, L)***
Management of natural vegetation, its use and biodiversity	e.g. - overexploitation of trees, loss of wildlife and reduced Carbon stocks	e.g.- biodiversity conservation through management of hedges / maintenance of trees - growth of specific shrubs / trees for organic matter / mulch etc.	e.g. - use of wood / organic materials / other wild products		
Management of the farming system* and species/varietal diversity	e.g nutrient mining due to intensification and fragmentation increased runoff due to bare soils and removal of resides for livestock				

* Farming system is used to denote cropping, agroforestry and crop-livestock integration
** Productivity trend (+) Increasing, (0) stable , (-)decreasing
*** Intensity trend: O - Overuse C - conservation (stable) L- low intensity

TABLE 16 **Field form – Assessment of (natural vegetation and crop condition and productivity in croplands**

				Species (natural vegetation and crop)		**Natural vegetation**					**Crop condition**							**Products and Yield**			
Site No	Av. Farm size (ha)	Av field size (ha)	Av. number of parcels	**Common name**	**Scientific name**	Distance from cropland	Landscape features	Contribution to household	Use for mulch, soil OM	Ground cover	Crop establishment/ vigour	Crop size	Crop species diversity	Crop varietal diversity	Crop cover	Pest / disease incidence above ground and roots	Leaf colour / signs of nutrient deficiencies	Production costs	Y Yield (1ary and 2ary products)	Users of products (share local users to external)	Harvested product diversity
	ha	ha				km	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C

crop size e.g (e.g. ht; or diameter at maturity)

SECTION 4

Soil assessment

Introduction

There are two parts to the soil assessment, firstly assessing soil properties which results in a scoring of soil health, and secondly, assessing and scoring soil erosion activity, type and severity. The procedures for selecting and describing the sites for detailed assessment have been outlined in the above sections.

Soil Properties and Health: The tools for assessing soil properties and health are taken from the VS-Fast methodology (McGarry, 2006) and selected VSA methods of Shepherd (2000). Emphasis with VS-Fast is on the assessment, both qualitative and quantitative, of soil physical condition conducted during field visits. The core set of indicators used provides a robust, yet rapid and inexpensive approach to assessing the following soil characteristics:

- description of 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.

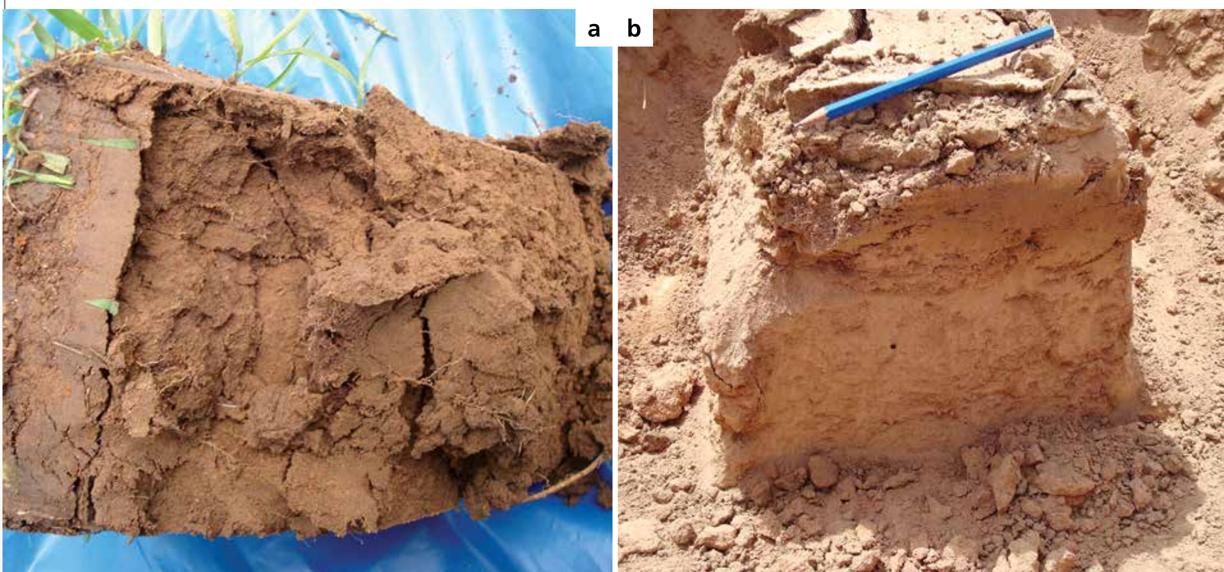
The measures are designed to be reproducible and quickly learned. Additionally, as they are field methods, they provide immediate indications of soil quality, quickly interpretable for the farmers and land owners present during testing. The methodology generates quantitative data on soil quality and condition, also providing guidelines for scoring and ranking the results to enable comparisons to be made between soils at the detailed assessment sites.

The soil zone of greatest interest in terms of VS-Fast occurs from the soil surface to approximately 0.4m depth. This represents the most important zone in cropland and improved pastures for seedbed development, early germination and plant growth. In crop, forest and pasture land, it is the zone with the greatest potential for negative impacts on water infiltration, soil carbon losses etc., due to soil compaction also erosion by wind and water.

Spade technique, hole size and depth: The following procedures (Tool 4.1) are based on the examination of an excavated spadeful of soil at a site selected for detailed assessment.

A spade with a flat (though usually slightly curved) blade is used to remove an intact "block" of soil, commonly up to 0.3 or 0.4m deep and 0.25m 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.

Scoring of soil health: 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 4.1) and the other based on the soil



G. BÉYE

PHOTO 12 **a) Taking a spadeful of humid soil and b) excavating a block in sandy soil, (Diagaly, Senegal)** measurements (section Tool 4.2). For recording the VS-fast information and data from Tools 4. 1 and 4.2, **score-cards** are included at the end of this section after soil visual indicators (section A) and measurements (section B).

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 can not 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.

Soil erosion assessment

A set of simple, field usable indicators and measurements are provided to observe, quantify and report on soil erosion at detailed assessment sites in various land use types (bare field, crop, pasture / rangelands and forest). The basis is simple field observation and measurement of recognized erosion features with the aim of both recording erosion status (type, state, extent and severity) at any one site as well as comparing between sites that differ in soil, climate, land use and management practices, etc. The: measurements of erosion features (dimensions) are optional and can be used where erosion is a significant degradation process to provide quantification of rates and quantity of soil loss in a study area. (Tool 4.3.3). The specific tools to be used can be selected on the basis of the soil erosion features observed in the field during the study area characterisation (Section 1): i.e. sheet erosion, rills, gullies/ravines, exposed rock, sediment deposits, sand dunes, etc..

Direct measurements can be made of the amount of soil eroded by runoff through rill and gully erosion. Indirect measurements can be made of soil erosion by water or wind through:

- plant / tree root exposure;
- fence post/other structure base exposure
- tree mounds;
- pedestals
- solution notch/rock colouration, and
- enrichment ratio;

Further tools are provided and can be used, if appropriate, but involvement of a soil erosion expert is advised as they are more problematic as explained below:

- the armour layer (erosion by water);
- soil/sand build up against a barrier (erosion by wind);

Tool 4.1. Visual assessment of soil quality

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, these are:

1. Soil depth;
2. Soil texture;
3. Soil structure (tillage pan, aggregate size distribution);
4. Surface crust;
5. Soil colour;
6. Soil life (i.e. earthworms and other biota);
7. Roots.

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

1. Soil depth

Soil depth is important as it determines rooting depth. If the soil is shallow, this will be a limiting factor to plant growth (reducing access to water and nutrients) and hence land productivity. Soil erosion and compaction may reduce the soil depth available to the plant.

Firstly, using a measuring tape, ruler or stick graduated in centimetres, assess and measure the location (depth and thickness) of any visible soil layers; in terms of colour, soil structure (see below), root density etc. The depth to any hard compacted layer or "hardpan" should be recorded, this may be caused by mineralization of certain compounds or by repeated hoeing / ploughing at a certain depth.

Record these depths and prepare a sketch of the soil profile, annotated with depth and principal soil features.

2. Soil texture

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

- Clay particles are the smallest particles, less than 0.002 mm in size.
- Silt is a medium size particle between 0.002 and 0.05 mm in size.
- Sand is the largest particle, diameters from 0.05 to 2.00 mm; commonly divided into fine sand (0.05–0.5 mm) and 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 (Figure 9).

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. Compare the shape achieved to Table 17 and refer to Figures 8 and 9. Record the texture class determined, on the field sheet.

Figure 10 shows the % of sand, silt and clay in the textural classes. Note: specify diagram for sandy soils (source: FAO, 2006. Guidelines for soil description).

The point at which the soil becomes malleable and can be hand-shaped, indicates its texture (use Figure 10 in conjunction with Table 17).

3. Soil 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.

3a. 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).

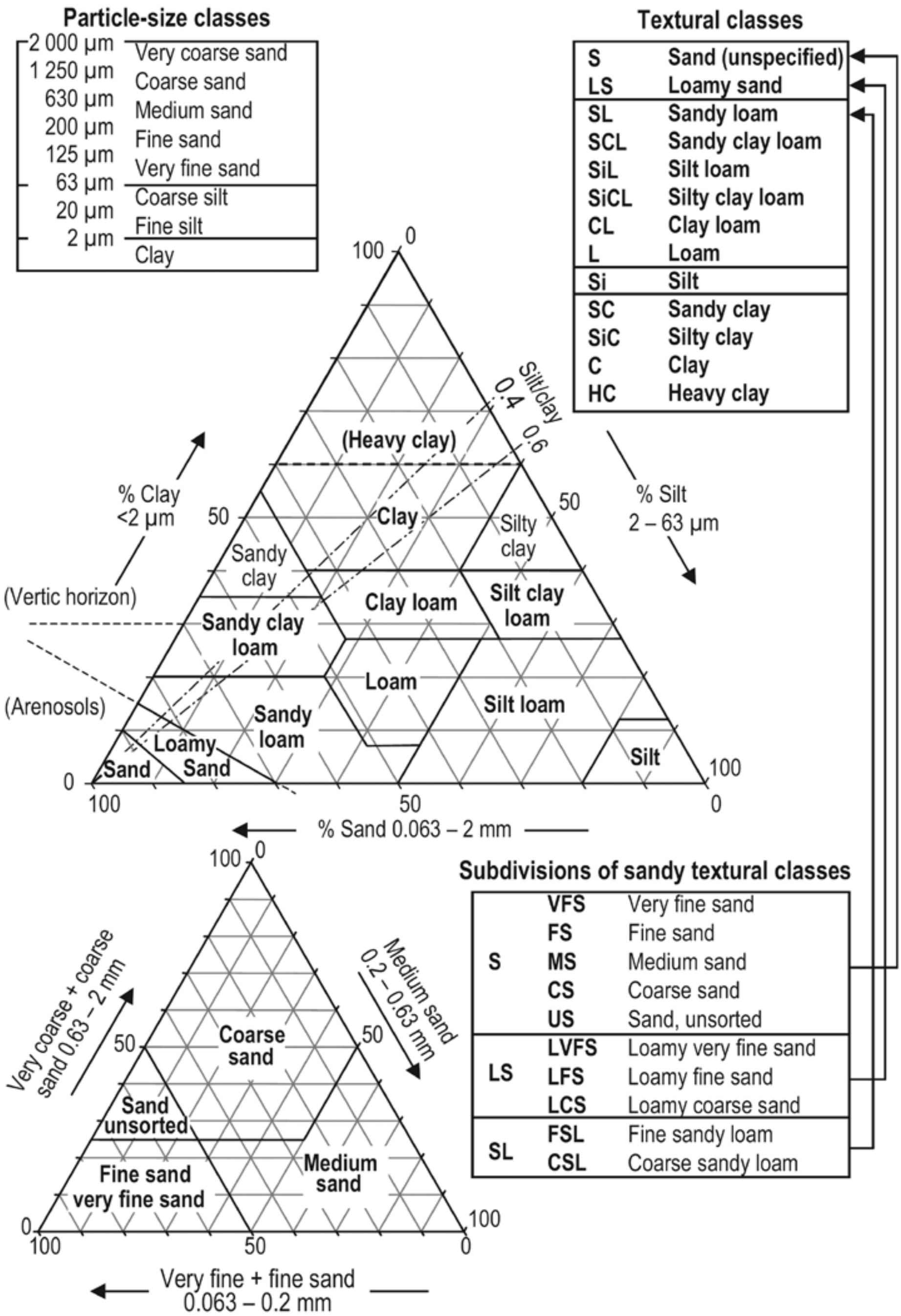


FIGURE 9 **Soil texture classes**

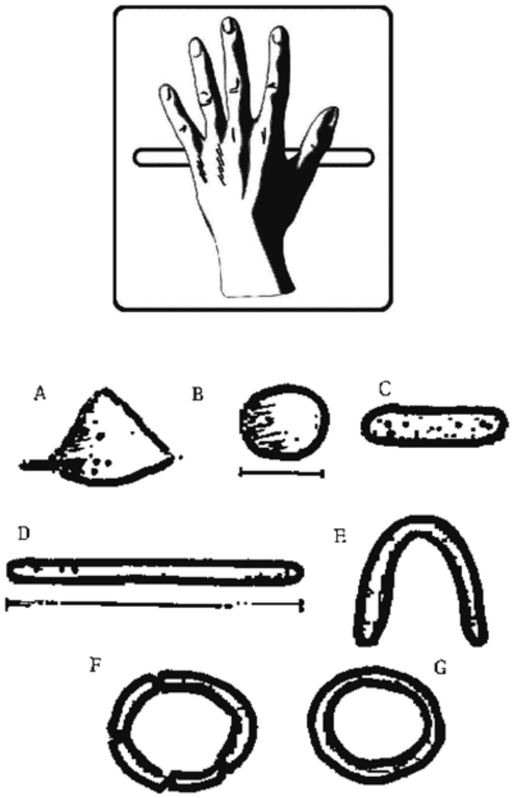


FIGURE 10 **Hand assessment of soil texture**

TABLE 17 **Soil texture descriptions**

A **Sandy**	The soils stays loose and separated and can be accumulated only in the form of a pyramid
B **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
C **Silty loam**	Similar to a sandy loam, but the soil can be shaped by rolling it into a small short cylinder
D **Loam**	Contains almost equal amounts of sand, silt and clay. Can be rolled into approx. 14 cm long cylinder that breaks when bent.
E **Clayey loam**	Similar to the loam, but the rolled cylinder can be bent and given a Ü" shape (without forcing it) without breaking
F **Fine clay**	The soil cylinder can be bent into a circle, but shows some cracks
G **Heavy clay**	The soil can be shaped as a circle without any cracks

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[6] (after Shepherd 2000):

- Good condition (score = 2): no tillage pan (or any other type of pan), with

6 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.

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.

3b. 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 (Figure 11).

Effectively, this is a field method of aggregate size distribution. Degraded soil tends to have a greater proportion of coarse structure units than a well structured soil (Figure 11).

GOOD CONDITION VS = 2
Good distribution of friable finer aggregates with no significant clodding.

MODERATE CONDITION VS = 1
Soil contains significant proportions of both coarse firm clods and friable, fine aggregates.

POOR CONDITION VS = 0
Soil dominated by extremely coarse, very firm clods with very few finer aggregates.

FIGURE 11 **Soil aggregate size distribution test**

Examples of (left) finely structured soil and (right) coarsely aggregated soils are 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

4. Soil crusts

Soil crusts are a soil surface phenomenon, most commonly regarded as a **negative** soil feature, however, in certain circumstances they can have **positive** effects on soil moisture and landscape health. There are two main types:

4a Chemical and physical crusts are inorganic features such as a salt crust or platy surface crust, often formed by trampling. They comprise a consolidated layer commonly <10 mm thick that can be separated from and lifted off the soil beneath, on drying. Inorganic crusting is most common in fine textured soils (loams and sands), though clays with low aggregate stability (see stability test Tool 4.2.1 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).

4b Biological soil crusts are formed by living organisms and their by-products, creating a crust of soil particles bound together by organic materials at the surface of desert soils. They are predominantly composed of cyanobacteria (formerly called blue-green algae), green and brown algae, mosses, and lichens. Liverworts, fungi, and bacteria can also be important components. (These soil crusts are also known as microbiotic, cryptogamic, cryptobiotic, and microphytic crusts depending on the organisms concerned). See Photos 13 and 14. These are "positive" crusts specific to arid, desert areas (e.g. north west China), where their widespread occurrence has a strong positive impact on the soil and landscape condition through binding the soil surface, hence greatly reducing wind erosion (specifically windblown sand). As they are concentrated in the top 1 to 4 mm of soil, they primarily affect processes that occur at the land surface or soil-air interface. These include soil stability and erosion (both by wind and by water), atmospheric nitrogen-fixation, nutrient contributions to plants, soil-plant-water relations, infiltration, seedling germination, and plant growth.

Aboveground biological crust thickness can reach up to 0.10m. Their appearance in terms of colour, surface topography and surface coverage varies. Mature biological soil crusts are usually darker than the surrounding soil due to the density of the organisms and the often dark colour of cyanobacteria, lichens, and mosses. Biological soil crusts generally cover all soil spaces not occupied by vascular plants, and may be 70% or more of the living cover.

Crust-forming cyanobacteria have filamentous growth forms that bind soil particles. Fungi, both free-living and as a part of lichens, contribute to soil stability by binding soil particles with hyphae. Lichens and mosses assist in soil stability by binding particles with rhizines/rhizoids, increasing resistance to wind and water erosion. The increased surface topography of some crusts, along with increased aggregate stability, further improves resistance to wind and water erosion.

Studies show that biological crusts can alter water infiltration: where crusts greatly increase surface roughness water infiltration may be increased, but where effects on surface roughness are not significant, infiltration is generally reduced due to the presence of cyanobacterial filaments. These effects are site-specific and also related to soil texture and chemical properties. In dryland and grassland regions, such crusts may prevent infiltration into the soil so most rainwater is evaporated, therefore, they potentially affect the hydrological circulation in the upper layer in sandy land.

For measurement and assessment of biological soil crust, 3 indicators can be used:

- coverage (%) of the biological soil crust in the assessment area;
- thickness (mm) of the biological soil crust;
- impacts of the biological soil crust on rainwater infiltration into soil (using a double ring infiltrometer, see Photo 15 below) .

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. Chemical and physical crusting (negative):

- 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. Biological soil crusting (positive) (only relevant in arid / desert lands):

- 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.

Biological soil crusts can be monitored using visually defined categories in areas dominated by cyanobacteria. Photo 14 shows six categories selected in the Colorado Plateau, USA. that are easily distinguished by both trained and untrained observers and are closely related to cyanobacterial biomass and the resistance of the soil surface.

5. 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 / oranges in particular, show good soil aeration and drainage (the iron in the soil is in the ferric (oxidised) state).

PHOTO 13 **Development of biological soil crust in sandland of dryland region, China**
(photo: Kebin Zhang)

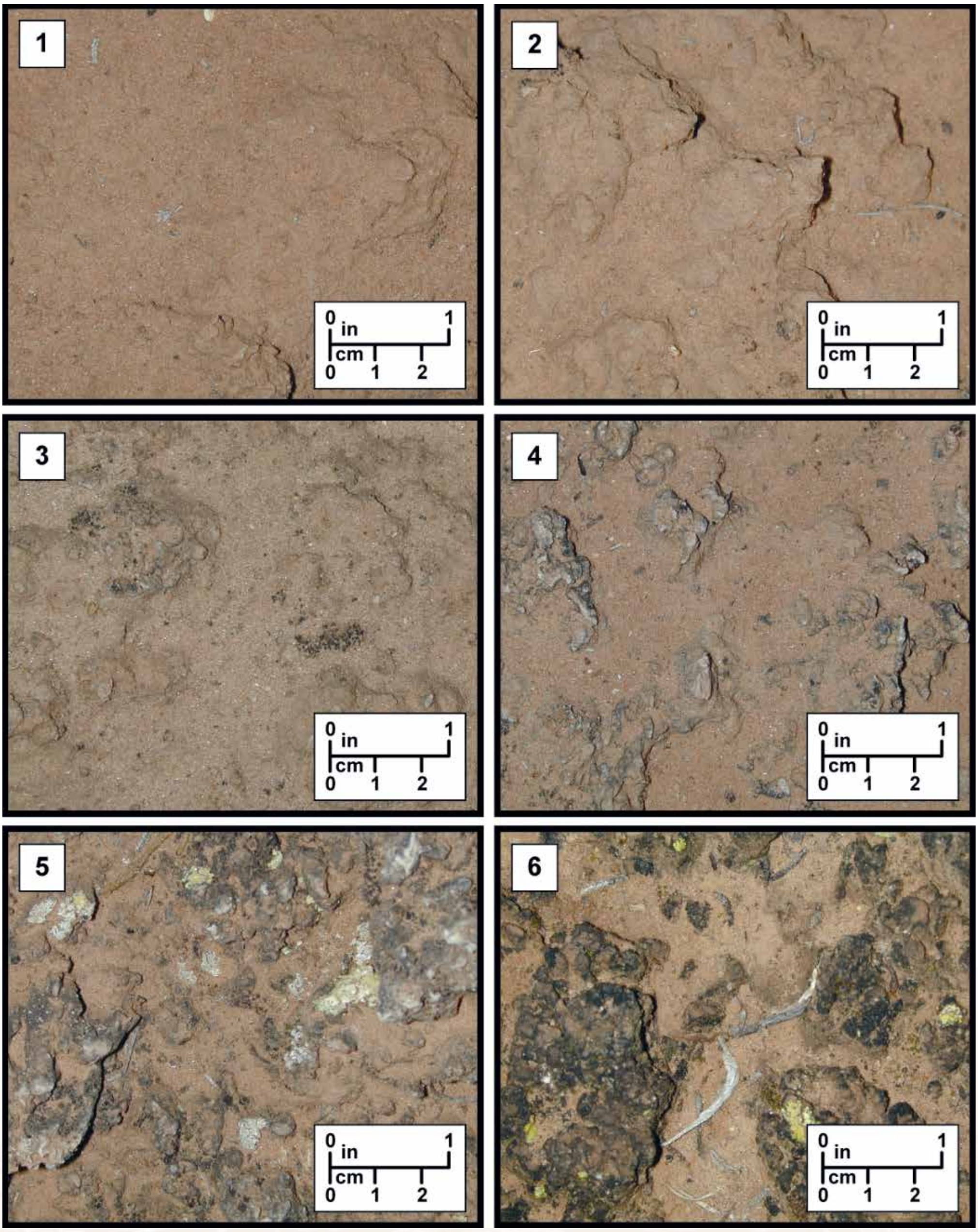


PHOTO 14 **Visual categories of soil crusting (Colorado Plateau, USA)**

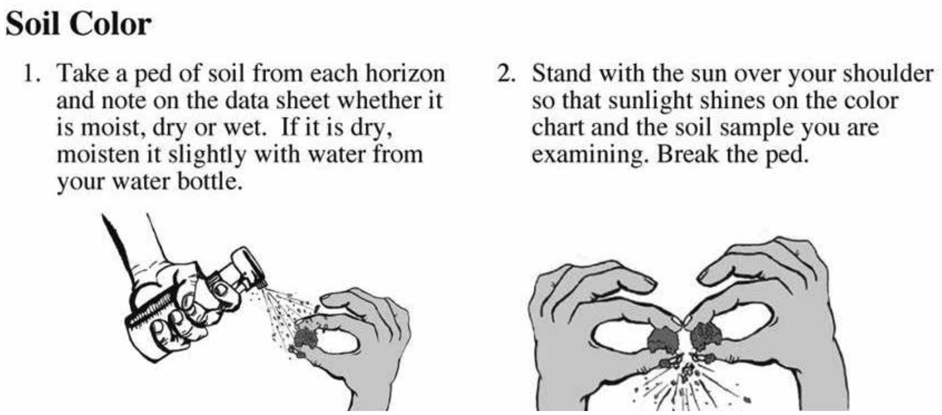


FIGURE 12 **Procedure of determining soil colour in the field (from NASA 2004)**

D. MCGARRY

PHOTO 15a **Assessing effect of soil compaction or crusting on water infiltration**

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 to assess the soil colour?

1. Take a lump of soil from the layer / horizon to be described. Break the lump to expose a fresh face (Figure 11).
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 the Hue / Value / Chroma and the name of the colour.

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

6. Earthworms (and other soil biota)

Soil biota are usually an indicator of good quality. Earthworms are particularly good indicators as they 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, while termites affect both nutrient pools and the flow of water into the soil through their interconnected galleries. Currently, research is limited[7] 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 strong evidence of their earlier presence may be visible (i.e.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, 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 and use a more appropriate group.

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.

Record earthworm numbers on a 1 m^2 (a square meter) spade depth basis. So if the spadeful of soil is a 0.2m 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.

7 See: http://www.environorth.org.au/windows/all/all_termites.html

Estimating % bare soil (% plant cover/crop residues)

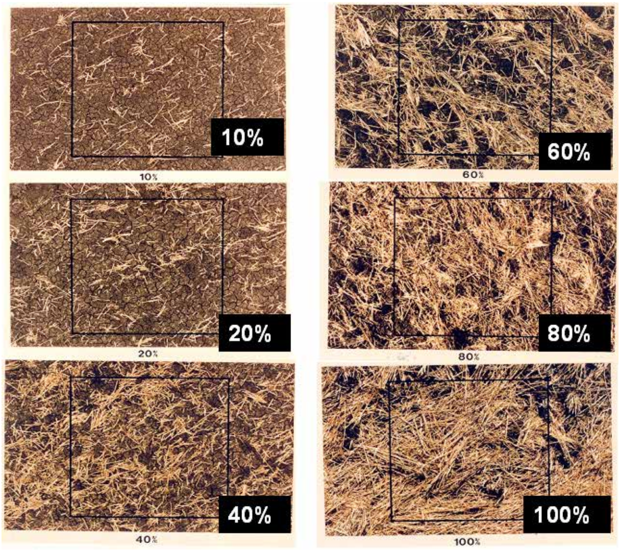


PHOTO 15b **Crop cover is vital to enhancing moisture capture and storage, and reducing water runoff and soil erosion**

PHOTO 15c **Soil profile to observe depth and distinct layers**
(Photo D. McGarry)

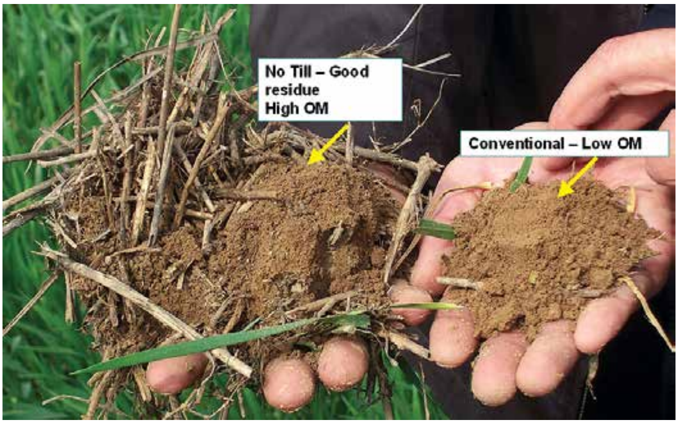


PHOTO 15d **Comparing soil colour under no-till and conventional tillage (Linfen, Shanxi, China)**
Soil visibly darker due to organic matter increase on No-till site (left hand) compared to conventional tillage (right hand)
Photo: D. McGarry

PHOTO 15e **Earthworms in soil after 12 years zero till, Pampas of Argentina**
Earthworm numbers can be counted and compared from a soil block (spade test) from different sites/management practices
Photo: D. McGarry

PHOTO 15f **Restricted root growth**
Soil compaction such as a tillage pan (bottom left) or other obstructions can be observed by bent / deformed plant roots -L shape growth- where roots fail to penetrate.
Photo: D.W. Reeves and D McGarry

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.

7. 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 (e.g. 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 (hardpans) – 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 / or
- ⊗ 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 4.2 Soil measurements

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

1. Slaking and dispersion (Tool 4.2.1)
2. Soil pH (Tool 4.2.2)
3. Water infiltration (Tool 4.2.3)
4. Organic carbon (labile fraction) (Tool 4.2.4)
5. Soil and water salinity (electrical conductivity) (Tool 4.2.5)

The soil measurements 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:

Firstly, 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 of the 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 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 organic carbon (labile fraction) 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, then 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.

1. Slaking and dispersion (Tool 4.2.1)

The inherent ability of a soil, 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 an 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 4.2.4) and sealing are major impediments to both water penetration (causing rain water to pond on the soil surface with strong potential for erosion) and 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 this 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) following immersion, a visual judgement should be made of the degree of dispersion on a scale of 0 – 4 (see Photos 16 and 17).

NOTE 1: The scoring should be the reverse of the scoring in Field et al. (1997), as the VS-Fast methodology gives a higher (not lower) score for better conditions.

NOTE 2: 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, i.e. 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 half 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**).

Record the score value on the field sheet

PHOTO 16 **Area severely affected by salinity as seen by strong soil dispersion in water (Granma, Cuba)**

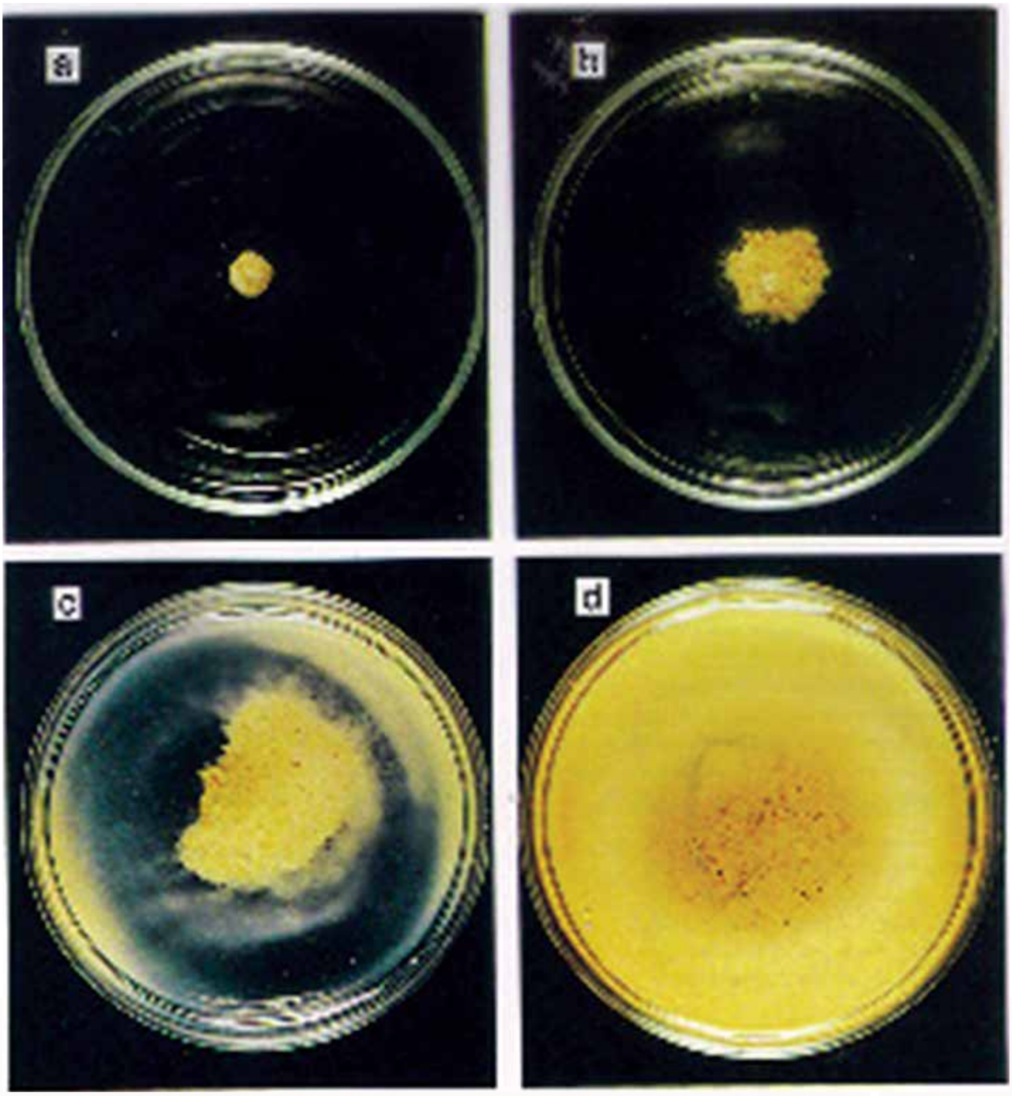


PHOTO 17 **Examples of the nature and the range of dispersion classes in the soil dispersion test for a clay rich soil. (Source: McKenzie *et al.*,1992)**

- the aggregate remained intact with no slaking or dispersion [score = **4**];
- a slaked aggregate with no dispersion i.e. no visible individual mineral grains [score = **4**];
- the aggregate slaked and moderately dispersed i.e. evident individual mineral grains [score = **2**];
- the aggregate completely slaked and dispersed with clearly evident and abundant mineral grains [score = **0**].

2. Soil pH (Tool 4.2.2)

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 lends itself to the "alignment" procedure (mentioned above) where the samples from the exposed soil profile are placed in the porcelain dish in the correct (depth) order and positioned beside the exposed soil profile for photography. In this way, a lasting record is provided of pH with the corresponding, visible soil layers / features.

The procedure is as follows:

- 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.
- Add some of the black / purple liquid from the Test Kit (this is Universal "Raupach" indicator).
- Add just enough of the liquid to thoroughly moisten the soil. [It is important not to flood the soil.]
- Mix the soil and the indicator well together with a plastic or wooden rod (e.g. a clean stick or old "biro" pen).
- Let the mixture sit for two minutes (to allow the two to react).
- 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.
- Match this colour with the closest match on the Test Kit colour chart.

Record the pH value on the field sheet (to an accuracy of 0.5 of a unit.)

3. Water infiltration (Tool 4.2.3)

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

Interpretation of the measured rates of hydraulic conductivity, similar to the interpretation of crust observations (section 4.2.4) changes with soil type. 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, hence loss of water for subsequent plant use. Comparably, on paddy (rice) soils, zero hydraulic conductivity is an attractive soil situation. Hence, two scoring systems will be presented – one solely for use on sandy soils and paddy soils, the other for all other situations.

The following simple but robust method for the rapid estimation of soil hydraulic conductivity. [8] is based on fundamental, globally tested and accepted soil physical principles.

The method (see Photo 18) considers two scenarios:

- 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 0.1m (length) x 0.1m (diameter) ring (metal or PVC with a sharpened tip), a container holding exactly 0.4l of water and a watch with a "seconds" hand or digital stopwatch.

The procedure[9] is as follows:

- 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.
- Place the metal ring on the soil surface and push it a few mm into the soil to get a seal between the ring and the soil surface but ensuring minimal soil disturbance inside the ring.
- Pre-wet the soil surface in the ring by applying 50 to 100 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.
- After 15 to 30 minutes, add 0.4l 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)
- Note the time for the water to disappear (infiltrate) into the soil.
- Tables 18 a) and b) allow conversion of the infiltration time to a permeability class for each of the 3-D and 1-D scenarios respectively.

8 The soil hydraulic conductivity measurement has been devised by Dr Freeman Cook, CSIRO, Australia.

9 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).

PHOTO 18 **Assessing soil hydraulic conductivity rate**

Record whether 1-D or 3-D infiltration was measured and "fast", medium" or "slow" rate using the times in Tables 18.

NOTE: the same "result" in terms of hydraulic conductivity rate needs to be interpreted as "negative" for sands and "positive" for all other soils, as follows:

Scoring (from Tables 17 a and b):

- Fast rate (score = **0** for sands and **2** for
- all other soils);
- Medium rate (score = **1** for all soils);
- Very slow rate (score = **2** for sands and **0** for all other soils).

4. Soil organic carbon – labile fraction (Tool 4.2.4)

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

TABLE 18 **Estimation of hydraulic conductivity**

a) Simple estimation of K on the basis of 3-D flow from a pond

Time for 400 ml of water to be gone from ring with radius 50 mm.	**Hydraulic conductivity - K** (mm/hr)	**VS-Fast Score**	
		"negative"= sands	**"positive" = other soils**
< 10 min	> 36 (fast)	0	2
>10 min, < 2 hr	> 3.6 (medium)	1	1
> 2 hr	< 1 (very slow)	2	0

b) Simple estimation of K on the basis of 1-D flow from a pond

Time for 400 ml of water (vol.) to be gone from ring with radius 50 mm.	**Hydraulic conductivity – K** (mm/hr)	**VS-Fast Score**	
		"negative"= sands	**"positive" = other soils**
< 30 min	> 36 (fast)	0	2
>30 min, < 10 hr	> 3.6 (medium)	1	1
> 10 hr	< 1 (very slow)	2	0

BOX 2 Laboratory testing of total soil C versus field testing of labile soil carbon

As the soil labile carbon procedure is time consuming in the field and the calibration of the reagents is rather complicated, LADA countries tended to prefer to analyse the soil carbon in the laboratory. However, the standard lab tests give a value of total soil carbon, which is felt to give a less accurate measure of recent changes in soil organic matter as the labile carbon fraction.

It is suggested that the proposed labile carbon measurement method is used, but either the same day of or the next day after the field survey, in a suitable room with a person experienced in laboratory tests, to test all the soil samples collected from the field. The results will then be available while the team is still in the field, so that the findings can be consolidated and discussed with the land users and community members.

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[10] 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.

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

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° Celsius) 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.

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.

BOX 3 **The calibration procedure**

The calibration procedure is as follows using varying concentrations of the stock solution:

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 $KMn0_4$ solution; representing zero labile organic carbon in subsequent soil samples] (Figure 12).
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 $KMn0_4$ (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 (Figure 12).
7. Plot the above data (a straight line fit); as *mM* of $KMn0_4$ (x-axis) versus the absorbance reading (y-axis), as in Figure 13. A regression line can be fitted to the relationship.

NOTE: *The period of time the soil is in contact with the permanganate solution is critical, 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)
8. Measure the absorbance of the sample (soil) as in the calibration procedure
9. From the standard curve (Figure 12), calculate the concentration of $KMnO_4$ (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.

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

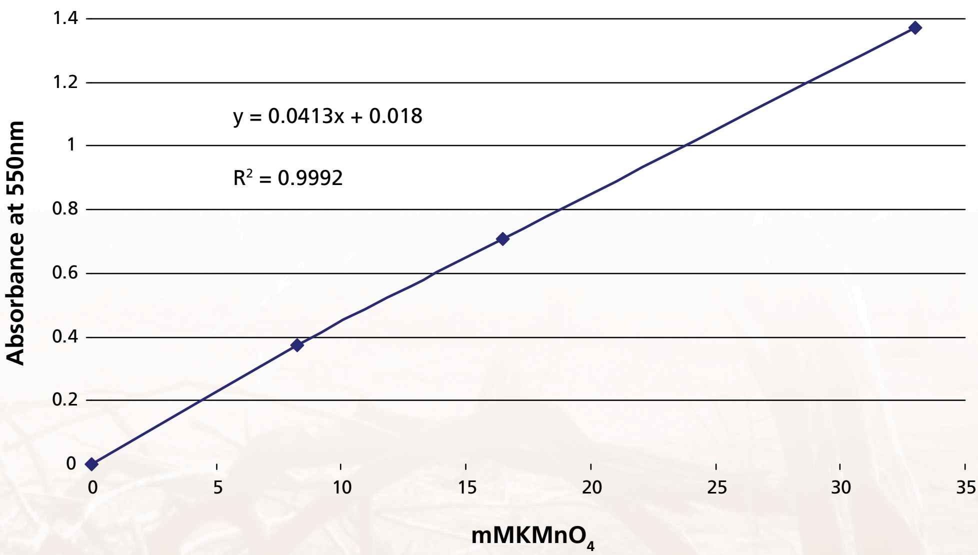


FIGURE 13 **Standard calibration curve of four strengths of 33 mM KMnO4 (x – axis) with colorimeter read-out (y – axis)**

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

where:
Mo = initial concentration of $KMnO_4$ (33 mM)
$M1$ = concentration of $KMnO_4$ (mM) after oxidation (calculated from standard calibration curve: Fig. 11A)
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 Figure 13.

Scoring (from Table 19 and dependent on soil texture):

- good organic matter status (score = **2**);
- moderate organic matter status (score = **1**);
- poor organic matter status (score = **0**).

This uses the four strengths of 33 *mM* $KMnO_4$ of Figure 12 and equation 1.

This shows the relationship between "total" organic carbon (%) by the Leco method and active (labile) carbon from the permanganate field method for several soils. (Data and analysis of Dr P. Moody (NR&W, Queensland, Australia) with fitted line & regression equation with R^2.)

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). Dr Phil Moody (pers. comm.), from analysis of several tropical and semi-arid agricultural soils,

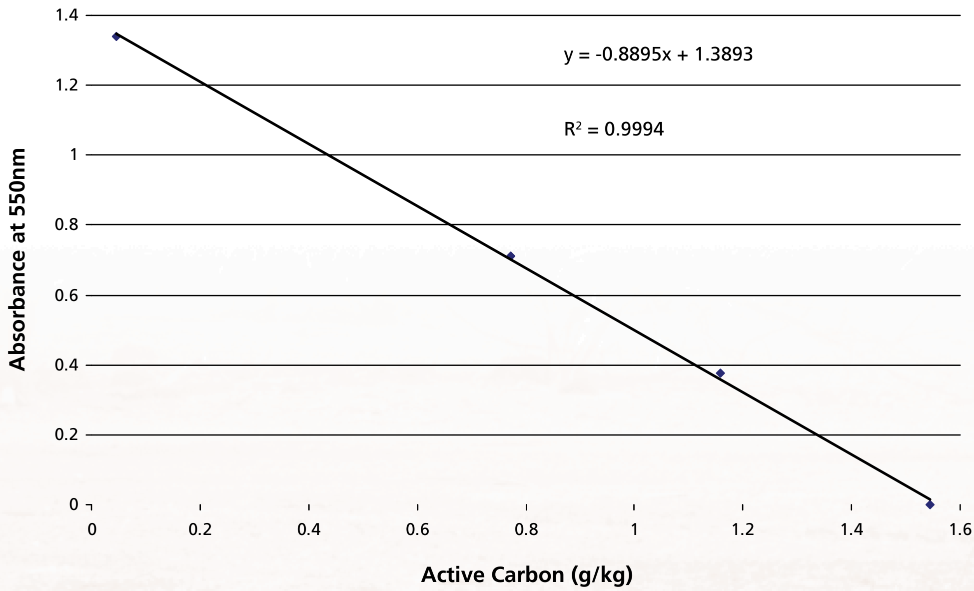


FIGURE 14 **Relationship between the colorimeter readout (absorbance) and the amount of labile ("active") carbon (g/kg)**

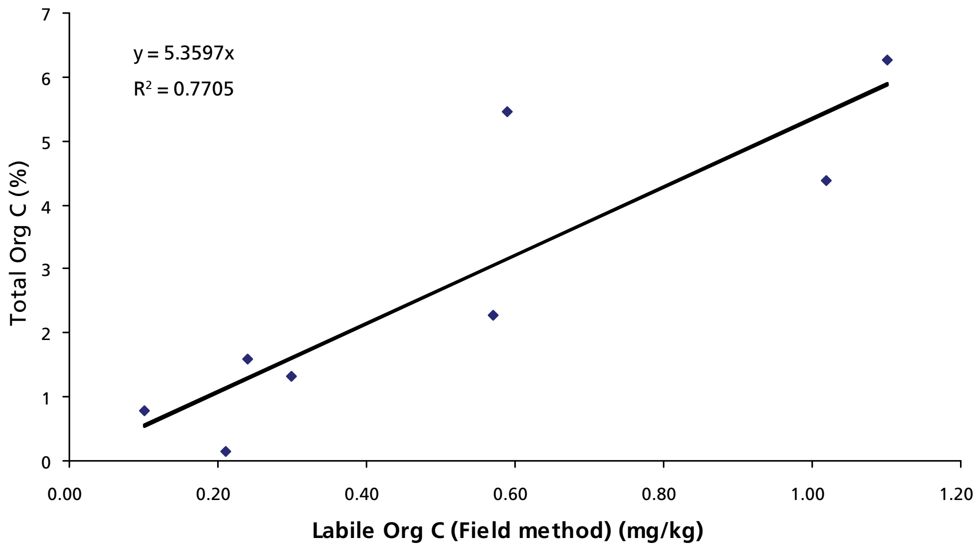


FIGURE 15 **Relationship between "total" organic carbon and active carbon**

TABLE 19 **Permanganate (33 mM) oxidisable carbon contents (g/kg) 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.

states that the total organic carbon fraction by the Leco method (%) = 5.36 active C by the 33 *mM* $KMnO_4$ (mg/kg) method as described here). Future studies relating these two fractions of organic carbon will improve the fit and the understanding of this relationship.

5. Soil and water salinity measurements (Electrical conductivity) (Tool 4.2.5)

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). Tables 20 and 24 give some visual indicators of salinity for the field.

TABLE 20 **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.
Water indicators	• Depth to water table and salinity of water (measurements)	
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.	

Particularly in sandy and / or arid areas, 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, thus long term sustainability and productivity.

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. Thus 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.

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)[11], 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.

11 To aid in conversions: 1 decisiemen 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).

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; i.e. 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;
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. a toothbrush), ready for the next soil solution.

Salinity (ECw) in water, whether irrigation, surface or groundwater 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 in dS/m.

The quality of groundwater 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. It is important to determine the 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).

TABLE 21 **Relative values of ECse, VS-Fast and plant salinity tolerance classes**

Level of soil Salinity	Plant salt tolerance grouping	ECse range (dS/m)	VS-Fast score
"not" saline	sensitive crops	< 1	good = 2
mildly saline	moderately sensitive crops	1 - 2	good = 1.5
moderately saline	moderately tolerant corps	2 - 4.5	moderate = 1
	tolerant crops	4.5 – 8	moderate = 0.5
strongly saline	very tolerant crops	8 –12	poor = 0
very strongly saline	generally too saline for crops	> 12	poor = 0

ECse values, with corresponding VS-Fast class and score, corresponding to the plant salinity tolerance classes of Maas and Hoffman (1977).

Values of soil and water EC can be related to available tables on: (i) plant salinity tolerance classes and the ability of specific crops to tolerate salt respectively (Tables 21 and 25) that is part of the VS-Fast scoring sheet at the end of this section, (ii) plant hazard of salinity in irrigation waters (Table 22), (iii) water quality for domestic use and stock supplies (Table 23). If measured, these values should be noted on the VS Fast score sheet.

TABLE 22 **Plant hazard of salinity in irrigation water (ECw)**

Hazard	dS/m
none	< 0.75
slight	0.75 – 1.5
moderate	1.5 - 3
severe	> 3

Source: Morris and Devitt (1991)

TABLE 23 **Water quality guidelines (ECw) for domestic and stock (animals) supply**

ECw range (dS/m)	**Usefulness 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; adult dry sheep tolerate 23 dS/m

From Anderson and Cummings, 1999

TABLE 24 **Salinity class range**

Level of salinity	Visual indicators	ECe range
S0 (Not Saline)	• No vegetation appears affected by salinity and a wide range of plants present.	< 2 dS/m
S1 (Slightly Saline)	• Salt tolerant species e.g. sea barley grass often abundant. • Salt sensitive plants in general show a reduction in number and vigour especially salt sensitive legumes (eg. white and sub–clover, soybeans, chick pea, etc.). • 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.	2 - 4 dS/m
S2 (Moderately Saline)	• Salt tolerant species begin to dominate the vegetation community and all salt sensitive plants are markedly affected by soil salinity levels. • At the upper end of the range, some slightly tolerant species disappear and are replaced by others with higher salt tolerance. The plant community is dominated by grasses, shrubs and flat weeds. Legumes are almost non-existent. • 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.	4 – 8 dS/m
S3 (Highly Saline)	• Salt tolerant species like sea barley grass and buck's horn plantain may dominate large areas and only salt tolerant plants remain unaffected. • In low rainfall areas, unlikely that any improved species will be present; trees may show some effects (i.e. dieback). • 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 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, some plant species display both salt tolerance and waterlogging tolerance. In drier areas, salt tolerant plants generally do not have high waterlogging tolerance. • At the upper end of the range, halophytic plants may dominate the plant community and some species may show a reddening of the leaves.	8 – 16 dS/m
S4 (Extremely Saline)	• Only highly salt tolerant plants survive and the community will be dominated by 2 or 3 species. Moderately and highly salt tolerant species may show a reddening of the leaves and 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.	> 16 dS/m

Source: Victorian Resources Online: Salinity Class Ranges
http://www.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/water_spotting_soil_salting_class_ranges#s0

TABLE 25 **USDA ratings of relative crop tolerance to salinity**

Plant grouping	High salt tolerance	Medium salt tolerance	Low salt tolerance
Vegetable crops	**EC_{se} = 12–10** Garden beets; Kale; Asparagus;	**EC_{se} = 10–4** Tomato; Broccoli; Cabbage; Bell pepper; Cauliflower; Lettuce; Sweet corn; Potatoes (White rose); Carrot; Onion; Peas; Squash; Cucumber;	**EC_{se} = 4–3** Radish; Celery; Green beans;
Forage crops	**EC_{se} = 18–12** Alkali sacaton; Salt grass; Nuttall alkali grass; Bermuda grass; Rhodes grass; Fescue grass; Canada wild rye; Western wheat grass; Barley (hay); Bird's-foot trefoil;	**EC_{se} = 12–4** White sweet clover; Yellow sweet clover; Perennial rye grass; Mountain brome; Strawberry clover; Dallis grass; Sudan grass; Huban clover; Alfalfa (California common); Tall fescue; Rye (hay); Wheat (hay); Oats (hay); Orchard grass; Blue grama; Meadow fescue; Reed canary; Big trefoil; Smooth brome; Tall meadow oat grass; Cicer milk-vetch; Sour clover; Sickle milk-vetch;	
Field crops	**EC_{se} = 16–10** Barley (grain); Sugarbeet; Rape;	**EC_{se} = 10–4** Rye (grain); Wheat (grain); Oats (grain); Rice; Sorghum (grain); Sugarcane; Corn (field); Sunflower; Castor beans;	**EC_{se} = 4–3** Field beans Flax
Plants are listed within groups in order of decreasing tolerance to salinity. ECse values (dS/m) correspond to 50% decrease in yield.			

(EC_{se} = the EC (dS/m) of a saturated soil extract as given in section 4.2.12 Source: Van Lynden *et al*, 2004

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

FIELD SCORE CARD

Soil Condition Assessed using VS-Fast Methodolgy

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...

Tool 4.3 Soil erosion assessment

Introduction

The presence of soil erosion in arable, forest and pasturelands is a prime indicator of soil degradation by water or by wind; often caused by a reduction in protective vegetation cover. It may reflect imbalance in the co-achievement of productive capacity and ecologically sustainable land management, i.e. intensification for increased production without adequate means to restore land resources and ecological functions. Soil erosion through topsoil loss is an indicator and cause of reduced land fertility, and hence potential productivity. It may also hinder access to land for crop/forest production. Moreover, the transported sediments and nutrients may cause problems downstream in terms of sediment deposits and reduced water quality. Despite the recognised importance of controlling and reversing soil erosion through soil and water conservation practices, there are few attempts to systematically observe and measure soil erosion as part of an integrated assessment of degradation and management (soil, vegetation, water and ecosystems) as this manual tries to do.

For the most part, the methods presented here are designed to be used in the field, during the assessment by the multidisciplinary technical team, and in the presence of land users - crop, pasture, forest - and, if possible, representatives of local government. This will aid interpretation of the observed erosion features and their impacts, for example, in regard to recent management, weather patterns and policy and technical interventions, if any.

Soil erosion is a commonly used indicator of negative land quality or condition as it is more visible than some other types of degradation such as nutrient mining or salinization. The immediate causes of soil erosion are wind and water as energy sources that translocate soil particles but unsuitable land use and management practices greatly exacerbate the problem (indirect causes), particularly on land prone to runoff and exposed to strong winds and soil movement (e.g. steeper slopes, loose or bare soil, inappropriate cultivation, etc.).

– **Erosion by water** is the detachment and transport of soil particles downslope through a number of processes, driven principally by the energy and the concentration of the water as it passes over the land.

– **Erosion by wind** is the detachment and transport of soil particles by wind action and commonly considers also the effect of the abrasive action of the particles as they are transported and of the soil deposits or sediments.

Measurement of wind and water erosion may include descriptions and measures of the erosion and deposition **features** but above all should focus on the **impacts** of the soil movement, *e.g.* the effects on the land potential through the loss of soil and nutrients and the effects of the transported and deposited particles, for example: silting of wetlands or floodplains, sandstorms, moving sand dunes, sediment load in rivers and streams). While erosion and hence loss of soil particles and nutrients will negatively impact on land productivity in the upper part of a catchment, it may provide fertile silts and nutrients downstream in the floodplains, i.e. having a positive impact on productivity.

This section is a composite of two sources: the erosion concepts and indicators from Stocking and Murnaghan (2001) as well as a more recent GITEC/ADB/GEF project on Sustainable Pasturelands in Tajikistan by Mulder and McGarry (2010).

What to measure

This section provides a set of simple, field usable indicators and measurements to observe, quantify and report on soil erosion at detailed assessment sites in the various land use systems and land use types (bare field, rainfed or irrigated cropland, pasture / rangelands, natural or planted forests, etc.). The specific tools need to be selected on the basis of the soil erosion features observed in the field: sheet erosion, rills, gullies/ravines, exposed rock, sediment deposits, sand dunes, etc..The field measurements are robust, relatively rapid (once the team members are familiar with the tools), cheap and replicable. The aim is to compare erosion status and trends under different sites (varied topography, exposure, etc.) and different land uses and management practices.

The methods aim to achieve clarity and uniformity in recording visible soil erosion features, in terms of three distinct but inter-related qualifiers and quantifiers:

- field observations that describe soil erosion by wind or water using four descriptors of the erosion feature: type, state, extent and severity; (Tool 4.3.1);
- a field scoring method, based on the descriptors in the field observations, to provide a more quantified basis for inter-site comparisons (Tool 4.3.2). This was developed and tested by the LADA team in Tunisia (DG/ACTA, 2010) and further reviewed (McGarry, 2011); and,
- field measurements of specified dimensions of erosion features to provide quantification of rates and quantity of soil loss in a study area. (Tool 4.3.3). These draw from the Field Guide for Soil Degradation Assessment (Stocking & Murnaghan, 2001).

The information gathered on soil erosion can also be related to the community map (Tool 1.4) and other land use and topographic maps of the study area to understand wider implications of soil erosion in the landscape. Through discussions with land users and informants the assessment team should try to estimate the main effects of the erosion and sedimentation processes on productivity and other ecosystem services, on-site and off-site, including damage to infrastructure and effects on human welfare (e.g. sandstorms).

The outputs of the soil erosion assessment could include:

a. an overview of the major erosion features (type, state, extent and severity) affecting different land use types and land use systems in a selected study area and, to the extent possible, an indication of their potential impacts on- and off- site (productive land area lost, reduced productivity etc.);

b. identification and understanding of the main direct and indirect causes of erosion in the study area through observations of local causative factors and their interactions and cumulative effects:
   - rainfall amount and intensity,
   - slope of land,
   - soil type (sands and silts being more erosion prone than clays and loams;

   degree of soil cover (litter, crop, tree, residues) as related to land use, time of the year (bare fields post harvest or after land preparation), crop/ pasture/forest age and management practices (young, emerging crops, and young or well-thinned forest have less cover to protect the soil), extent of land clearing, etc.

c. the planning and design of soil and water conservation measures and land management practices for:
   - the affected sites to prevent or mitigate the main causes of erosion identified in the study area (direct and indirect) and, where feasible, to repair the erosion features and restore productivity or
   - new areas being opened up to production or undergoing land use changes, to ensure minimal erosion problems from the intervention (e.g. biofuel production, conversion of marginal lands to forest land, pasture or cropping, conversion of agro-pastoral areas to intensive cropping or ranching).

d. a baseline for subsequent monitoring of the status of erosion features by repeating the given observations and measurements on a specified time period, for a given area i.e. to monitor continued degradation in a "non-intervention" scenario (control) compared to an area with interventions that lead to reduced erosion, prevention of erosion, or restoration of eroded lands.

Part 1 section 6 Shows how analysis of the qualitative and quantitative information on vegetation, soil properties, soil erosion, water resources and the land use and management practices of different types of land users/ farmers and land degradation processes and conservation measures can be brought together as an integrated landscape and ecosystem assessment

Tool 4.3.1 Field observations of erosion – type, state, extent and severity

How to select observation sites

The following process is foreseen to identify areas for the required erosion observations and measurements in order to understand cause, type, extent, severity, etc. and, in turn, enable to propose and plan improved land management or rehabilitation actions:

1) conduct if possible a "desktop" study of the intended study areas using any available maps and remote sensing images ((topographic and cadastral maps, Google Earth®, air photos, satellite imagery, digital elevation models -DEM, soil/ geology maps, etc.) and previous studies and reports to elucidate any major erosion features, their place in the landscape (land unit, slope) and their association with recognizable land uses in the area, etc.

2) seek out representative sites in the various land use types (LUT) in the area under consideration (e.g. cropping land, forest, pasture or fodder producing land, orchard, vegetable production, etc); and

3) be led by locals who live or work in the area (i.e. land users, farmers, herders, forestry workers, state farm managers, etc. as a follow up to the Community Focus Group Discussion, see Tool 1.1) to those areas that they believe are most degraded, or on which they are most dependent (e.g. for food production, forest replanting, winter pasture regrowth, etc.) or previously eroded areas that have been effectively restored through effective management measures.

It is important to collect information on timescales of relevance to soil formation and erosion processes in order to understand the impact of the different erosion types/ processes and particularly the capacity to repair or diminish their impact.

- sheetwash may be an annual event or more frequent occurrence;
- rills may form after a series of heavy rainfall events on ploughed land;

- gullies and ravines are most commonly the effect of several seasons or years of water concentration that result in deep incisions;
- landslides and mudflows are often rare events but these more serious erosion types are more likely to occur on certain soil types and sedimentary materials.

Repair strategies, therefore must be prepared and designed for relevant timescales. For example, rills may be readily ploughed out and can be prevented by appropriate vegetation cover and soil and water management practices but gullies will require years to reclaim by installing physical barriers (e.g. gabions and check dams) and through vegetation enrichment with suitable trees, shrubs and grasses.

The "secondary data" from maps, images and reports can be validated and updated in the study area using the observations and measurements outlined below (Tools 4.3.1 to 4.3.3). This on-site ground truthing should be backed up by interviews/ discussions with land users/other knowledgeable persons to cross-reference the observed types, extent and severity of erosion features with recent and historic land practices and weather observations; rainfall periodicity and intensities for water erosion and wind intensity for wind erosion features. This should provide good understanding of the processes, timescales and causes that have resulted in the currently observed erosion features.

Describing soil erosion on the community sketch map - initial observations STEP 1

As described in Tool 1.4, the community sketch map that is prepared with land users as part of the community focus group discussion should highlight major visible features in the area to be evaluated, in terms of terrain, land use, soils / geology, water resources, their relative proportion of the total land area; degradation features, including soil erosion (sheet erosion, rills, gullies) and causes (overgrazing, intensive cropping, wetland encroachment, etc.) and existing conservation / sustainable land management measures and their effects (negative and positive) on land productivity. If the sketch map has not clearly indicated erosion features or if more specific information is required for a selected study area, a few community members can be asked to reassess these issues and highlight if and where erosion by water or wind is a significant factor and the main causes.

Once the main erosion features are drawn on the "community sketch map", each soil erosion area can be qualified in terms of four descriptors: type, state, extent and severity. Each of these is defined below to the extent possible (though wider application of the tools and feedback is envisaged to lead to better definition of the classes and terms).

On the community sketch map (Figure 15), which reflects the landscape view showed on Photo 19, discussion with locals led to

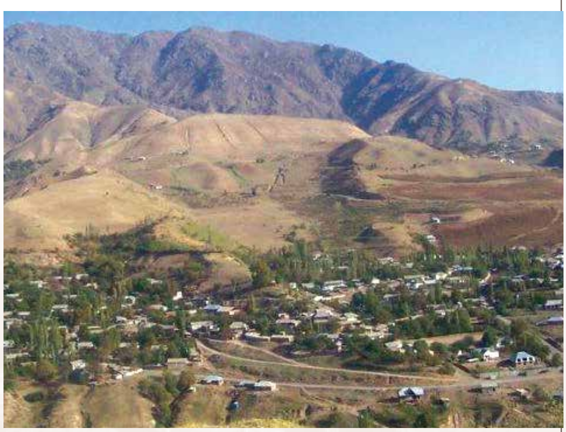


PHOTO 19 **Example of a "distant view" of an area of land to be investigated for erosion features (just north of Dushanbe, Tajikistan)**

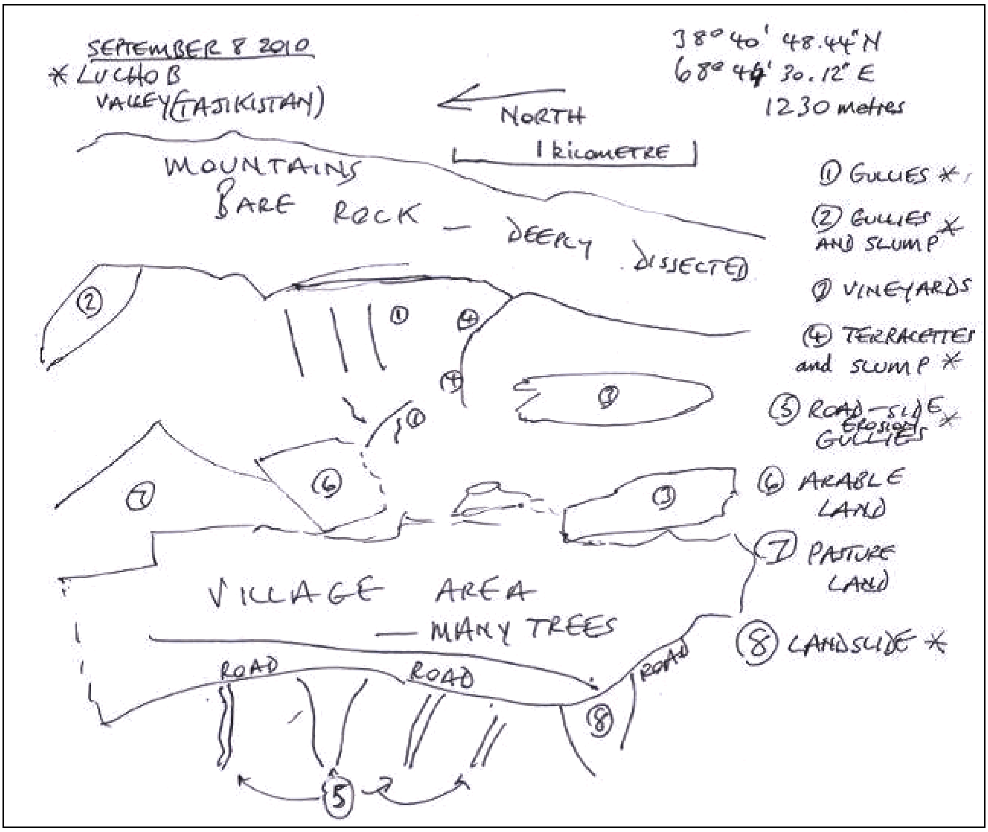


FIGURE 16 **"Community map" sketched on-site, overlooking the area in Photo 19**

delineation and description of the main erosion features, other relevant information (vegetation, main land uses, slopes, villages, roads, streams, etc) and location (latitude, longitude, elevation and north point) of the observation point using a GPS unit.

Erosion Type, <u>STEP 2:</u> Erosion types are specified progressing from those that are the least evident to those that are most evident i.e. from (rain) splash and sheet wash, to rills, to gullies, to ravines and landslides and other mass movements (see Annex 1). It is important to specify that "type", as used in this guide, describes the physical nature of an erosion feature and indicates the boundaries that determine when one erosion type becomes another (e.g. When does a rill become a gully?). This will ensure more commonality of erosion type definition, hence replicability between users and geographic areas.

TABLE 26 **Types of Soil Erosion – definitions, indicators and boundaries**[12]

Type of soil erosion & Score	Code	Definition	Indicators (How to recognize
Splash (1)	SP	Raindrop impact displaces soil particles vertically and downslope	Soil particles on lower parts of plants and/or a compacted (or dispersed) soil surface crust
Sheet wash/ Sheet (2)	S	Erosion of the top layer /sheet of the soil as differentiated from linear erosion (rill, gully, ravine)	Gravel/stones protruding from soil surface; root exposure; loss of darker topsoil horizon; subsoil exposure
Rill (2)	R	Irregular, downslope, linear channels, shallow (up to 0.3 m deep and wide)	Shallow, commonly long channels running downslope
Gully (4)	G	Irregular, V-shaped, steep-sided, linear channel formed in loose material, deep (0.3 – 2.0 m deep) formed by water erosion	Deep, pronounced channels
Ravine (4)	A	As in the definition for “gully” but very deep and wide (> 2m deep and wide)	Very deep and wide, pronounced channels
Landslide (4)	L	Sudden downslope movement of a concentrated mass of soil and rock, mainly under influence of gravity, triggered by water saturation or earthquakes (sometimes termed mass movement)	Almost vertical sides; rounded head (gully has narrow or sharp head)
Slumping (2)	SL	Slow, irregular, downward progression or of a thin (< 1m) layer of soil, due to water saturation, but possibly in combination with freezing-thawing	Rounded scar; irregular, uneven, downslope surface
Rotational slumping (3)	RS	A form of mass movement where rock and soil move downwards along a concave face. The rock or soil rotates backwards as it moves in a rotational slip. They always have a concave sliding plane and multiple scars (while slides have relatively straight shear planes).	Series of irregular scars and wide cracks
Terracettes (2)	T	Irregular small step-like formations, from a combination of slumping and preferential animal movements (tracks) on the surface of moderate to steep slopes	Irregular on-contour steps of about 0.1 to 0.2 m height on moderate to steep slopes in grasslands

12 Note: Annexe 3 provides more detailed descriptors of the nature and causalities of many of these erosion types, that may be used to aid identification.

TABLE 26 **Types of Soil Erosion – definitions, indicators and boundaries** *(continued)*

Type of soil erosion & Score	Code	Definition	Indicators (How to recognize
Tunnel (3)	TU	Sometimes hidden, sub-surface holes and tunnels that can break-through to form surface gullies	Often hidden but may break through the soil surface as potholes and gullies
Roadside erosion (2 or 3)	RE	Erosion (mostly gullies) caused by concentrated water flow over the impervious road surface; cutting back into the road and causing damage to roads or erosion downslope. Score depends on gully or tunnel intensity	Erosion features below the point where water runs off the road
Stream bank erosion (2 or 3)	SE	Undercutting of streambank by running water. Score depends on gully or tunnel intensity	Fresh cuts in banks; exposed tree roots; collapsed structures
Wind erosion (Variable)	WE	Detachment and transport of soil particles by wind. Score difficult as the features observed are almost always "effects" of wind erosion: dunes, scouring of vegetation, posts, etc	Scouring on windward side or deposits at leeward side of obstacles. Sand dunes (stable or moving)

Erosion State: STEP 3, For each erosion type, one of four classes below is used to describe the level of activity:

(i) **active** – erosion feature is increasing in size or extent;

(ii) **partly stabilized** – between active and stable;

(iii) **stable** – it is either an historic (relic) feature from past climate and land use, or a more recent erosion feature for which recent anthropogenic interventions (e.g. contour bunds or change in land management) have slowed or stopped the erosion process;

(iv) **decreasing** – where recent anthropogenic interventions have begun to reverse the erosion process i.e. rock, sediment and vegetation filling of gullies, leading to stabilization and increased soil organic matter and plant growth.

Erosion Extent, STEP 4: An estimation is made of the spatial extent of each erosion type. The intent is less to measure actual areas, in hectares or square metres (though some may choose to do this) and more to provide a good estimate of the area under consideration that is affected by the erosion types recorded. As such, it is considered that **extent** (used in this way) implies the proportion of a stated area that is affected by the recorded erosion type. The five terms used to define extent are:

- **negligible** (0-2% of the area under study)
- **localised** (3-15% of the area)
- **moderate** (16-30% of the area)
- **widespread** (typically 31-50% of the area)

Note that the class "widespread" is intentionally maximised at 50% of the area under consideration. This reflects that each erosion type is classed individually, so it is possible (in one area) that there is, for example, sheet wash, terracettes and gullies, with localised (10%), widespread (50%) and moderate extent (20%) respectively – showing that 80% of the area is eroded but by these three different erosion types.

There are various ways to record extent.

1. The areas affected by the specified erosion types can be drawn on a "community map" as in Figure 2.
2. Where available, the erosion features can be either located or drawn onto available maps (topographic, soil, etc), aerial photos, ortho-photos, satellite images, Google Earth® images, etc.
3. If required for detailed study, a theodolite or dumpy level can be used for accurate mapping and geo-placement of recorded erosion features; though this requires a high level skill set with related expense and time considerations.

Erosion Severity, STEP 5: Severity in terms of soil erosion is often defined as the "degree of the effect of the (specified) erosion type". A more pragmatic definition is the rate or "average amount of soil that is moved by water or wind", expressed as units of mass/ area/time (Leys, 2010). Based on this definition, a field usable estimate of erosion severity is made using five classes, recognising that the mass of soil loss will rarely be known (particularly with historic erosion features) (Leys, 2010). Over time with wider usage, these classes may be better defined and perhaps oriented to specific geographic areas.

- **low** – minimal erosion types evident; most commonly splash or rill erosion
- **moderate** – evidence of erosion but eroded sediment remains within the area under study
- **high** – evidence that sediment is being exported off site
- **severe** – sediment is exported off site and surface lowering < 0.1 m
- **extreme** – sediment exported off site and surface lowering > 0.1 m.

An important consideration is that certain erosion types, by their nature, will never be described as of "low" or "moderate" severity. The most obvious examples (from Table 26) are gully, ravine, landslide, tunnelling – all of which immediately fall into the severe and extreme classes as the erosion feature is >0.1 m deep. Nonetheless, it is important to bear in mind that insidious sheet or rill erosion, that is continuous throughout rainy seasons and year by year over large areas, may be equally or more serious to widely spaced gully erosion in terms of total soil loss and impacts, especially in shallow soils.

Tool 4.3.2 Field scoring method for soil erosion features

A simple scoring system is presented for the erosion types present and recorded in a study area. This scoring system has been substantially adapted from a first version developed and tested by the LADA team in Tunisia as part of an earlier version of the LADA-Local manual (FAO 2010). As such the scoring aims to provide a quantitative judgment of erosion and to allocate an erosion class. The aim is to provide a basis for inter-comparisons of erosion status and trends that may vary between land uses, management practices, topography, etc. and over time.

The scoring system is based on the classifications of type, state, extent and severity as defined above. Each of the classes in these four sets of descriptors will be allocated a score and the **sum** of the scores (for any one area, however defined) will allow the allocation of an erosion class (Table 28).

Important is that this scoring system is taken and used for what it is: a simple methodology of better quantifying erosion degradation for a given area. There are several, recognised problems with the scoring system, some of which will be covered here, so users should be aware of these in interpreting the cumulative scores obtained and the resultant allocation of an erosion class :

– The allocation of the score classes to the erosion types (Table 27) is somewhat arbitrary. The concept is that either end of the scale (1 and 4) is readily ascribed. In most circumstances splash erosion is a minor feature (score = 1), whereas gully, ravine, landslide, tunnel erosion are considered very serious landscape features as they cannot be readily repaired (score = 4). Between the two extremes, the current score allocations are based on the author's experience and may change with time and wider use of this system
– As discussed above, certain erosion types, by their very nature, will never be describable as of "low" or "moderate" severity. The most obvious examples (from Table 26) are gully, ravine, landslide and tunnel – all of which fall into the severe and extreme classes, as the erosion features are >0.1 m deep. So, not only do these erosion types score "4" for type, they also immediately score "3" or "4" for severity (rate).
– If several types of erosion are found in the area under investigation, the current system scores each type separately, then sums the individual scores to give a composite score. The basis for this summation approach is both that each of the types of land degradation is inter-related, and their presence in one area has an additive, negative effect on land productivity. This composite scoring system may change in the future with time and wider use of this system.

Table 28 gives the final erosion class for any one erosion type in a study area, arrived at by summing the score value of each of the **four** categories of type, state, extent and severity. Where more than one erosion type exists in

TABLE 27 **Scores for the individual descriptors of a) state, b) extent and c) severity of the soil erosion types**

State	score	Extent	score	Severity	score
				extreme	**4**
active	**3**	widespread	**3**	severe	**3**
partly stabilised	**2**	moderate	**2**	high	**3**
stable	**1**	localised	**1**	moderate	**2**
decreasing	**0**	negligible	**0**	low	**1**

TABLE 28 **Erosion classes**

Erosion class :	negligible or decreasing	low /weak	moderate	severe	very severe
Score :	0-1	2-5	7-10	10-12	13 +

one area, the class values of Table 28 are added together for each erosion type – to give a composite score. It is evident that in situations where two or more erosion types are present in an area, the erosion class will almost always be «severe» (i.e. a score of >13).

The erosion classes are derived by **adding - up** the individual scores for each of type, state, extent and severity of Tables 26 and 27).

Worked examples of scoring erosion features
Five examples will be given, based on the descriptors in section 4.4.1, the individual scores in Table 27 and the classes of the summed scores in Table 28.

- **Example 1** presents the scores for the incidence of gully erosion (score 4) that is active (score 3), widespread in extent (score 3) with extreme severity as the soil loss in eroding areas is over 1 m deep (score 4). The total (summed) score = **14.** So, the overall erosion class is **very severe.**

- **Example 2** is one of rill erosion (score 2) that is partly stabilized (score 2), localized in extent (score 1) with moderate severity (score 2). The total (summed) score = 7.
So, the overall erosion class is **moderate.**

- **Example 3** is one of ravine erosion (score 4) that is decreasing in state (score 0), moderate in extent (score 2) with severe severity (score 3). The total (summed) score = **9.**
So, the overall erosion class is **moderate.**

- **Example 4** scores an area that has two erosion types: (i) splash (score 1) that is active (score 3) localized in extent (score 1) with low severity (score 1); Total score = **6**; and (ii) *landslide* (score 4) that is stable (score 1), localised in extent (score 1) with extreme severity (score 4); total = **10**; The total (summed) score = **16.**
So, the overall erosion class is **very severe.**

- **Example 5** scores an area that has three erosion types: (i) *sheet wash* (score 2) that is active (score 3) localized in extent (score 1) with moderate severity (score 2); Total score = **8;** (ii) *terracettes* (score 2) that are active (score 3), localised in extent (score 1) with moderate severity (score 2); total = **8;** and *gullies* (4) that are partly stabilized (2), localized (1) and extreme (4); total = **11.** The total (summed) score = **27.**
So, the overall erosion class is **very severe.**

Note that, though the between-examples scoring gives some basis for comparisons of the impact of the erosion features, it is complex to definitively compare scores between such physically different types of erosion, as rills and gullies. A whole landscape may be covered in rills, and the resulting soil loss may be very large with important implications on soil depth and fertility, but a few large ravines in the same unit area would give quite different management problems (e.g. access for timber removal, thinning of stands and the cutting of roads that impair general access) and will require major, expensive interventions to repair and conserve.

Additionally, although generally scored low the cumulative effects of sheet and rill erosion should not be underestimated, particularly as they strip away the all important surface soil layers that are generally richer in organic matter and nutrients from plant residues, litter accumulation and vegetative growth.

Field measurements of erosion features to quantify rates and amount of soil loss (Tools 4.3.3 and 4.3.4).

This section provides field techniques to measure soil erosion features with the aim of gaining more quantified data on rates of soil erosion.[13] Such quantification would be valuable if soil erosion is identified as being a major degradation process in the study area and to understand the implications in terms of rate and quantity of soil loss, effects on productivity and off site implications in terms of nutrient and sediment load of water resources, siltation of valley bottoms/floodplains and wetlands, etc. However, it is an optional tool for the local level assessment according to the importance of erosion and the time and budget of the assessment team.

Of the 13 erosion types in Table 26, only 3 erosion types - rill, gully and ravine - lend themselves to a direct, rapid and simple method of field determination of **amount of soil loss** (**Tool 4.3.3**). Rates and quantities of soil loss from the other erosion types listed in Table 26 can be estimated indirectly by measuring the **effects** of erosion (**Tool 4.3.4**).

Tool 4.3.3 Direct measurement of erosion

1. Measurement of rill erosion

The estimate of the soil loss through rill erosion is based on measuring the space volume from which the soil has been eroded, to arrive at the mass of soil now missing from the rill. The measurement of soil loss from rills assumes that the depression forms a regular geometric shape that is estimated to be triangular, semi-circular or rectangular in cross-sections, as determined by field observation.

13 This sections is based almost entirely on the original concepts of quantification of field observed erosion features as detailed in Stocking and Murnaghan (2001).

To calculate the quantity of soil lost, measurement is made of the depth, width and length of the rill. It is important to collect a number of measurements of both the width and depth of any one rill and of many rills in the study area to get an average cross-sectional area. The average catchment area for the rills in any one area must also be estimated, i.e. the area of land that contributes material to the rill. If it is known how long it has taken for the rill to form (if, for example the land was last cultivated two months or two years ago, or has only recently been cleared of forest) then an annual rate of soil loss can be estimated. Note, that the combination of the averaging of many field measurements, and the estimation of the cross-sectional shape of the rills (in any one area) to be predominantly triangular, semicircular or rectangular causes the soil loss calculation to be only an estimate of the actual soil loss.

Method: Using the average measurements of width and depth, calculate the average cross-sectional area of the rill, using the formula for the appropriate cross-section:

- triangle = ½ horizontal width x depth
- semi-circle (1.57 x width x depth)
- rectangle (width x depth).

Worked example:

a. For an area where the average dimensions of many measured rills is:
   width = 0.12 m, depth = 0.042 m,

b. The average cross-sectional area of the rills in a study area, assuming a triangular cross-section is:
   ½ * 0.12 * 0.042 = 0.00252 m^2

c. Assuming the average rill length in the study area was 2.5 m, the volume of soil lost from an average rill is:
   0.00252 * 2.5 m = 0.0063 m^3

d. The volume of soil lost, from the estimated catchment area (here 12 m^2) is converted to a volume per square metre :

$$0.0063 / 12 = 0.000525 \, m^3/m^2$$

e. The volume per square metre is converted to tonnes per hectare, using an estimated soil bulk density value of 1.3 t/ m^3:

$$0.000525 * 1.3 * 10{,}000 = 6.9 \, t/ha$$

Hence in this worked example, 6.9 tonnes / ha have been lost in rill erosion, alone.

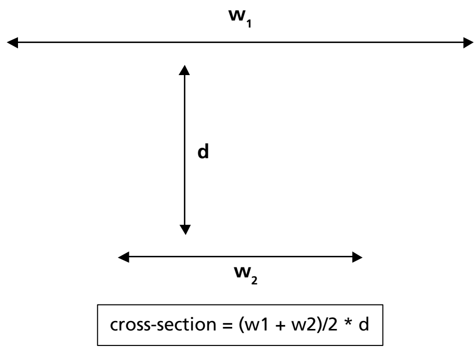


FIGURE 17 **Calculation of the cross-section of the trapezoid shape of gullies/ ravines**

2. Measurement of gully and ravine erosion

Gullies and ravines have the same, general shape of a flat floor and sloping sides, hence the bottom of these features (the floor) is less wide than the top (parallel to the soil surface). Such a shape is best estimated as that of a trapezium[14] (Fig. 3). Calculation of soil loss, therefore, is generally similar to rills, except with a different cross-sectional shape. As with rills, the measurement of the dimensions of the gullies and ravines gives an estimate of the amount of soil displaced from the area

To calculate the quantity of soil lost from a gully or ravine, measurement is made of the depth, width at lip (the top of the feature) and base, as well as the length of the feature. Equipment used to collect these measurements will vary between operators, but could be a laser-based rangefinder (expensive) for large gullies and ravines, or a 30 to 100 m tape for smaller features. It is important to collect a number of measurements of both the width and depth along any one feature and also of many gullies in the study area to achieve a representative sample. An annual rate of soil loss from gullies and ravines is more feasible than from rills, as the former are more or less permanent features of the landscape.

Information on soil loss over time can be achieved in various ways, including repeated visits (particularly if permanent monitoring stakes can be installed as reference points), and time series of aerial photographs and/or satellite imagery. Even with such methods over a known time period, the annual rate of soil loss is "at best' an estimate due to such factors as:

(i) different rates of soil loss will occur as the gully/ravine deepens and different layers of soil are exposed;
(ii) rainfall totals and periodicity will vary annually, particularly the incidence of rain with vegetative state around the gully or ravine;
(iii) change in forest density with time (both growth and thinning/clearing phases) will influence erosion rates;
(iv) tunneling may also occur on the sides of the gullies and ravines, greatly exacerbating soil loss in some years.

14 A trapezium is a quadrilateral that has only one pair of parallel sides.

Method: Using the average measurements of width at lip and width at base, and depth, calculate the average cross-sectional area of the gully or ravine (considering the cross-sectional shape is trapezoid; Fig. 3), using the formula:

(width at lip (m) + width at base (m) / 2) * depth (m)

Worked example:

a. For an area where the average dimensions of many measured gullies or ravines is :
   width at lip = 10.2 m, width at base = 4.8 m, depth = 2.0

b. The average cross-sectional area of the rills in a study area, assuming a trapezoidal cross-section (Figure 16) is :
   $((10.2 + 4.8)/2) * 2.0 = 15\ m^2$

c. Assuming the average gully or ravine length in the study area is 200 m, the volume of soil lost from an average gully or ravine is:
   $15 * 200\ m = 3000\ m^3$

d. The volume of soil lost, from the estimated catchment area (here 1 km^2) is converted to a volume per square meter :
   $3000 / 1{,}000{,}000 = 0.003\ m^3/m^2$

e. The volume per square meter is converted to tonnes per hectare, using an estimated soil bulk density value of 1.3 t/ m^3:
   $0.003 * 1.3 * 10{,}000 = 39$ t/ha

Hence, in this worked example, 39 tonnes / ha have been lost in gully or ravine erosion.

Tool 4.3.4 Indirect measurements of erosion

Indirect measurements of soil erosion rely on features observed and measured in the field that demonstrate the « effects » of soil erosion. In total, seven erosion proxies will be presented here: plant/tree root exposure; fence post and similar structures' base exposure; tree mounds; pedestals; solution notches and rock colouration; armour layer; and soil build up against a barrier. The erosion types that most commonly lead to these erosion effects are splash, sheet wash and wind erosion (Table 26).

With all but the last of these indicators (soil build up against a barrier), the general mode of measuring soil loss from erosion is to measure the current (eroded) soil level against the evident location of the original (or at least a recently previous) topsoil level. Particularly in terms of measuring soil loss against living objects such as trees or plants, if the planting date is known then an estimate of annual soil loss is possible. The same is also true if the date of installing fences, poles, walls, houses, etc. are known.

In measuring soil build up against a barrier the reverse is measured, i.e. the accumulation of eroded sediments behind a physical barrier such as a hedge or fence. The depth of this deposited soil is measured relative to the current topsoil level. The amount of soil loss can only be estimated if the area contributing eroded material and the area of deposition can be determined.

3. Plant / tree root exposure

The removal of soil particles by water or wind can lead to the exposure of the roots of trees, and other plants as erosion lowers the overall soil level. 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 (with a ruler) between this mark and the present soil surface, an estimate can be made as to how much soil has been lost[15]. (see Photos 20 and 21) In the case of lateral roots away from the tree trunk, the upper surface of the most exposed roots is usually taken as the former soil surface. For forests and perennial crops, the soil loss estimate would cover the period from when the crop/ tree was planted. In areas of degraded natural vegetation (scrubby forest and bush land), it may not be so easy to relate the measured soil loss to a particular number of years. In the case of an annual crop an estimate of soil loss in one growing season can be estimated.

Care is needed as some roots give a deceptive impression of soil loss such as the aerial roots of maize plants (see Photo 22)

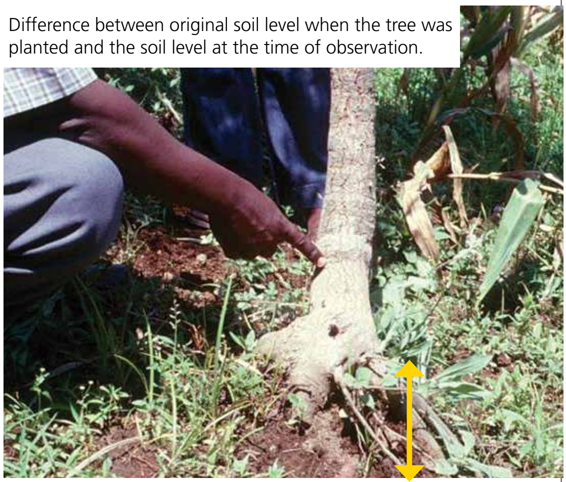


PHOTO 20 **Tree root exposure, Vietnam (source Stocking)**

PHOTO 21 **Tree root exposure by erosion (Library on soil erosion processes UNEP/FAO)**

15 1 mm of soil loss is equivalent to 13 t/ha where the bulk density is 1.3 g/cm^3

PHOTO 22 **Exposed aerial roots of maize, Brazil**

As with measurements of erosion features (above) several examples of exposed tree / plant roots need to be measured and averaged, to improve the site-representativeness of the measurements. Additionally, the data should also be cross-checked with other erosion indicators (as below) to determine, whether the estimated soil loss is realistic.

There are several cautionary notes that with common sense will ensure greater validity of the data collected.

- Differences in root exposure may reflect different erosion processes (e.g. rain-splash and sheet wash) occurring in the same field.
- Roots and stems may act as an obstacle to runoff and may cause channeling 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 roots and stems 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 over- or under-stated.
- Some plants have a tendency to lift 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.
- 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 of more erosion than actual.

Method: Using the average of the measurements of the height difference between the top of the exposed tree/ plant roots or stem and the current soil surface.

Worked example :

a. For an area where the average depth of soil loss is :

   5.88 mm

b. This drop in soil level is converted to tonnes per hectare, using an estimated soil bulk density value of 13 t/ha[16]:

   5.88 * 13 = 99.23 t/ha

c. If the average age of the plants or tree where the soil level change was measured was 4 years, then the estimated annual soil loss is:

   99.23 / 4 = 24.8 t/ha/yr

Hence in this worked example, ~25 tonnes / ha year have been lost to soil erosion.

16 A bulk density of 13 t/ha is equivalent to 1.3 g/cm^3 for 1 mm depth of soil

4. Fence post (and similar structures') base exposure

Similar to plant / tree exposure, the exposure of the bases of anthropogenic structures such as fence posts, house and bridge foundations, telegraph poles, etc. can provide indicators of soil loss, principally, again, from splash, sheet and wind erosion.

The measurement strategy depends on the object used for establishing the original ground level. For fence posts and poles this can be established by determining the height of the exposed part of the post/pole and/or the length buried into the ground. Often standard post/pole lengths are used in any one area. If not, it is necessary to determine a typical value by measuring the above ground length of posts in those sites that appear to have been least affected by soil erosion. The distance between the new ground surface and the point on the post that would originally have been at ground level can be measured using a ruler. In some instances erosion may remove soil equivalent to the depth of the below ground portion of the post in which case, providing it is certain that the post was not broken and that no part remains below ground, a minimum rate of erosion can be estimated. In other cases, the post may be entirely free of the soil but held in position by taut wire and hence the full extent of erosion can be determined.

Cautionary notes with interpretation of these measurements include the following.

- The age of the structure (fence installation, house and bridge construction, etc.) is required to present data on an annual soil loss basis.
- Any of these anthropogenic structures can actively promote erosion or sedimentation and may act differently, depending on rainfall amounts, intensity and periodicity, as well as wind direction and strength in the case of wind erosion.
- It will be important to have close discussions with locals to better ascertain the weather modalities since the structure was put in place.

Method and calculations: as per the plant / tree root exposure example above.

5. Tree mound

In contrast to the above two indices, the use of tree mounds to provide measures of soil loss depends on the umbrella- and raindrop energy-absorbing properties of tree canopies. This often causes the soil under a tree canopy to be at a higher level than the soil in the surrounding area, as it has been protected from raindrop impact and subsequent splash and sheet erosion.

The difference in height between the soil surface under the tree and in the surrounding area provides an indicator of the amount of soil loss that has occurred during the life of the tree (tree age gained from forest records or by talking to locals). It is recommended that such measurements are recorded for a range of trees of different size and age in the study area as there is large variation in the capacity of the canopies of different species to protect the underlying soil, and some varieties may be leafless during the peak rainy season, for example. (see Photo 23).

Cautionary notes with interpreting soil loss data, based on tree mounds include the following.

- Mounds around the base of trees, shrubs and other plants may have been caused by factors other than erosion, e.g. termite mounds or sediment (water and wind) and tree litter build up against the tree trunks.

PHOTO 23 **Tree mounds (Stocking and Murnaghan, 2001)**

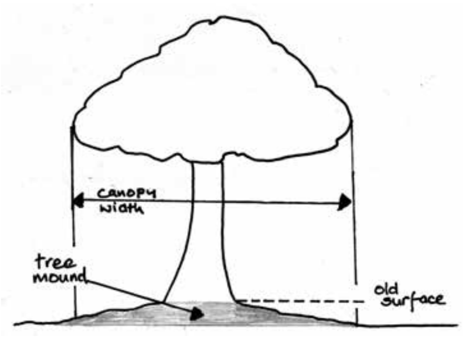


FIGURE 18 **Sketch of tree mound (Stocking and Murnaghan, 2001)**

– 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 actual.
– Tree canopy size and density changes as the tree grows, hence 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.

Method and calculations: as per the plant / tree root exposure example above.

6. Pedestals

A pedestal is a column of soil standing out from the general eroded surface, protected by a cap of resistant material (such as a stone or root). Bunch grasses can also protect the soil immediately under them (comparable to tree canopies and tree mounds, above) and give a pedestal-like feature. Care is required, however, in interpreting these latter observations.

Pedestals are caused by differential rainsplash erosion, which dislodges soil particles surrounding the pedestal but not under the

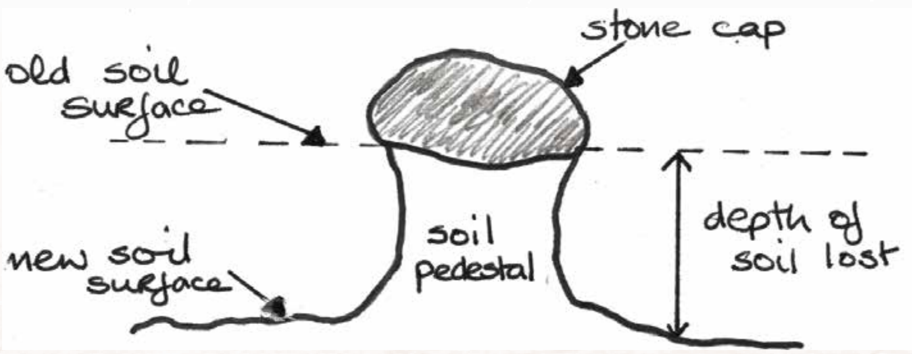


FIGURE 19 **Sketch of a soil pedestal capped by a stone (Stocking and Murnaghan, 2001)**

resistant capping material that absorbs the energy of the raindrops (Figure 18). (Note: Pedestals can be artificially simulated by using bottle tops pressed into the soil. Pedestals are created, as the bottle top protects the soil beneath from erosion, whereas the surrounding soil is exposed. They give a ready indicator to monitor surfaces where erosion rates are very large due to high intensity rainfall).

Measurement of pedestals is done using a ruler and it is important that a number of measurements are taken in the study area, even to the extent of dividing up the area and averaging pedestal height in each of the subdivisions, seeking across-site variability. Assuming that the cap was at the surface when erosion started, the measurement should be from the base of the stone or other capping material to the base of the pedestal, where it meets the general soil surface around. This measurement represents the soil loss since the soil was last disturbed (through forest clearing or cultivation). Therefore, by knowing the timing of the disturbance, it is possible to estimate an annual rate of soil loss.

Cautionary notes with pedestal height measurement and interpretation of data include the following.

- Pedestals often form under trees or crops where intercepted rainfall falls to the ground as a larger drop. If this is the only location in which pedestals are found they would provide an unreliable estimate of the level of soil loss for a larger area.
- Measurement of pedestals in association with clumps of vegetation should be avoided as the vegetation can accumulate soil.
- Capping stones may have originally been buried in the soil and are now exposed with an underlying pedestal; hence the pedestal height will underestimate erosion.
- Localised redistribution of material eroded from under the stone requires accounting for local accumulation, hence needs to be subtracted from the calculated soil loss.

Method and calculations: as per the plant / tree root exposure example above.

7. Solution notches and rock colouration

Solution notches are indentations found on rocks that indicate historic soil levels (Fig. 5). They arise because of chemical reactions between the soil, air and the rock and particularly mark the level of past topsoils that due to their greater organic matter content (hence humic acids) etched a notch at the air/soil interface The definition is extended here to include stone or rock discoloration, that again may indicate historic soil levels, where the soil (now eroded) discolored the rock, so leaving evidence of earlier soil levels. Solution notches are most likely to occur on limestone and calcareous rocks as they are more susceptible to acid organic chemicals, see Photo 24.

PHOTO 24 **A solution notch on a limestone rock (Stocking and Murnaghan, 2001)**

The solution notch also coincides with an obvious change from the stained (iron oxide and humus materials) to the original grey rock colour, above.

Measurement is made of the distance from the notch or colour change to the current soil level, using a ruler, to give an indication of how much soil has been eroded. It is important that a number of measurements are taken in the study area. One difficulty with soil notches is determining the time over which soil loss has occurred, though calibration with other soil loss indicators (e.g. tree trunks of known age) to estimate a rate of soil loss.

Method and calculations: as per the plant / tree root exposure example above.

PHOTO 25 **Removal of a portion of an armour layer. (Stocking and Murnaghan, 2001)**

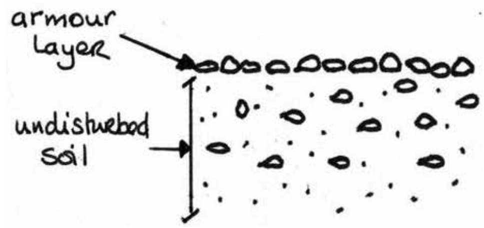


FIGURE 20 **Diagram of an armour layer**

8. Armour layer

An armour layer is the concentration, on the soil surface, of coarser soil particles that would ordinarily be randomly distributed throughout the topsoil (Figure 20).

The concentration of coarse material in the armour layer is interpreted as indicating that finer soil particles have been selectively removed by the energy of wind or water, leaving behind the coarser particles. 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. See Photo 25.

Cautionary notes with interpretation of the measurement of armour layers are many.

- Stones on the surface may arise for other reasons, such as the exhumation of a concentration of stones in the subsurface soil by animals or frost action.
- Accurate measurement (to mm tolerance) of the thickness of the armour layer is critical, as for every 1 mm, the equivalent soil loss is 13 t/ha (assuming an average bulk density of 1.3g/cm^3).
- As well as erosion processes, repeated shallow tilling of the soil may concentrate more stones near the surface. Where this happens, the erosion rate will be exaggerated, unless the percentage concentration of stones in the original soil is based on an estimate well below the (tilled) topsoil.

Method: Using the average of the measurements (mm) of the thickness of the armour layer.

Worked example:

a. Convert the average soil loss (1mm) to equivalent in metres:
   1.0 * 0.001 = 0.001 m

b. Calculate the depth of soil required to generate the 0.001 m of armour layer, where the proportion of coarse material in the topsoil was determined as 20% on average (i.e. a 1:5 ratio)
   0.001 * 20% (= 1/5th) = 0.005 m

c. Calculate the depth (m) soil lost :
   0.005 – 0.001 = 0.004 m

d. This drop in soil level is converted to tonnes per hectare, using an estimated soil bulk density value of 1.3g/cm^3 (or 1.3 t/m^3), where 1 mm of soil loss is equivalent to 13 t/ha, so 1m soil loss would be equivalent to 13,000 t/ha
   0.004 * 13,000 = 52 t/ha

Hence in this worked example, 52 tonnes / ha have been lost to soil erosion.

9. Soil / sand build-up against a barrier

The build-up of eroded material against a barrier is a measure of the movement of soil across an area of interest rather than loss from that area. In this case, the eroded materials are halted by an obstruction, and the materials deposited against the obstruction as the water slows (see Photo 26). The result is 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. A visual examination of the area close to the barrier will indicate how far the deposition extends into the field. This distance

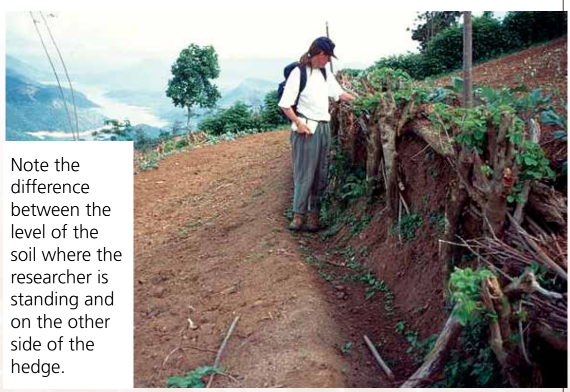


PHOTO 26 **Build up of soil behind a Gliricidia hedge (Sri Lanka)**

(length) should be measured at a number of points. The depth of the soil accumulated against the barrier can be determined by examining the soil level against the barrier on the other side from the accumulation. In order to calculate the amount of soil accumulated a linear slope is assumed and the « wedge » of soil behind the barrier is regarded as a triangle.

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.

Cautionary notes with interpretation of the measurement of accumulations behind barriers are many:

- There is a danger that because of soil erosion on the lower side the soil level next to the barrier will have been lowered.
- The depth of the accumulation of soil behind the barrier is not constant. Rather the depth of accumulated soil becomes thinner (less deep) with distance away (up slope) from the barriers.
- 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.
- Forest clearing may increase the soil depth behind barriers, particularly where conservation techniques such as terracing have been introduced to lessen the effect of slope. If the slope was convex before the barrier was constructed, the estimate of soil loss will be understated as it assumes a linear slope.
- The soil level below the barrier may not be the original soil level. As evident in Figure 26, excavation and leveling of the area immediately below the fence has occurred for road building.

Method: Using the average measurements of depth of the deposit at a barrier of 7 metres length, and the length of the accumulation up slope of the barrier of 0.945 m, the average cross-sectional area of deposit (considering it is triangular) is calculated using the formula:

depth at barrier (m) * (horizontal length (m) / 2)

Worked example:

a. For an accumulation against a barrier that has:
   depth at barrier = 0.16 m, length of accumulation = 0.945 m

b. The average cross-sectional area of the deposit behind the fence, assuming a triangular cross-section is :
   $(½ * 0.16) * 0.945 = 0.07560\ m^2$

c. For a barrier that is 7 m in length, the volume of soil accumulated behind the barrier is:
   $0.07560 * 7\ m = 0.5292\ m^3$

d. The volume of soil lost, from the estimated catchment area (here 70 m^2) is converted to a volume per square meter :
   $0.5292 / 70 = 0.00756\ m^3 / m^2$

e. The volume per square meter is converted to tonnes per hectare, using a estimated soil bulk density value of 1.3 t/ m^3:
   0.00756 * 1.3 * 10,000 = 98.3 t/ha

f. If the barrier is known to have been constructed three years before the measurements were collected, the annual soil loss as represented by the soil accumulated behind the barrier is:
   98.3 / 3 = 33 t/ha/yr

Hence in this worked example, 33 tonnes / ha /year have been lost from this site and accumulated behind the barrier.

10. Enrichment ratio

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. A field form is provided in Table 29 for recording measurements.

Potential for Error

1) The technique for assessing the enrichment ratio requires considerable field experience because estimation of proportions of soil particle sizes is difficult. The novice field assessor is best advised to accompany an experienced person.

2) As the selective removal of fines is a natural process care must be exercised to ensure that the observed trends relate to the land management practices and not to features inherited from prior conditions. For example, ant hills, termite mounds and earthworm casts often contain higher proportions of finer material than the topsoil. Because erosion of these structures may result in the redistribution of this finer material

downslope, any observed increase in fines may have little to do with existing land management practices.

3) Estimates undertaken solely by visual inspection of fine particles are very approximate. If possible, laboratory determination of macronutrient (Total N, P or K) content or of organic matter should be done to corroborate findings. This is particularly the case for clayey materials.

4) The enrichment ratio can be understated where not all the eroded material is deposited in the site where the enriched soil is identified. The finest particles may have been carried away completely from the site.

5) Understatement of the seriousness of erosion may also occur where deposition from upslope occurs on the eroded soil, thus masking the full extent of finer materials lost.

Similarly, the enrichment ratio may be overstated where run-on to the site from further upslope increases the level of fine particles in runoff thus contributing to the enriched soil.

Erosion measurement intensity, frequency and reporting

In terms of advising on the intensity, frequency and reporting protocols for observations and measurements of erosion features in drylands, it is difficult to be prescriptive due to the variety of circumstances where these data will be collected. In particular, timescales of erosion vary greatly depending on climate, soil type, slope and current vegetative cover. Accordingly, observations and measures to record the various degrees of effect and the intensity and frequency required to capture erosion correctly will vary widely.

There is, however, the over-riding consideration in terms of recording dryland erosion of establishing protocols of "benchmarking and monitoring". With this, the first observations and data collected act as the baseline for all subsequent observations and measurements, to record continuing degradation or improvements with time. Critical is to apply the same set of observations and measures (detailed above) to provide a true "change with time" evaluation. As stated earlier, monitoring considers both non-intervention scenarios (where the erosion is allowed to continue) as well as interventionist scenarios, where some physical or vegetative barrier is created to begin to mitigate the negative impact of the observed erosion. Frequency of monitoring observations is commonly different between the two scenarios. Non-intervention scenarios are commonly monitored on a fixed interval basis that is governed by the intensity of the erosion process; annually in active erosion situations or sensitive watershed/crop land scenarios and perhaps every 5 or 10 years where erosion is less active and widespread. Intervention scenarios are monitored as required to capture the effect of the intervention; commonly more observations soon after implementing the intervention, then less often with time once the improvement trend is captured.

Intensity of observations considers the number of observations to be conducted at one time in an area of interest. Again, a prescriptive approach is impossible due to the many situations that may be experienced. However, the observation and measurement protocols given above provide many "entry levels" to the type and intensity of observations that could be conducted on any one occasion.

Worked example

TABLE 29 **Field form - Enrichment ratio**

Site:
Date:

Measurement	**% of fine particles in eroded soil:** i.e. soil remaining in-field	**% of fine particles in enriched soil:** i.e. soil caught downslope and deposited
1	20	28
2	25	25
3	15	30
4	22	30
5	20	35
6	20	35
7	22	35
8	19	25
9	20	30
10	20	28
11	18	28
12	20	32
13	18	30
14	22	32
15	22	28
16	20	28
17	18	26
18	20	30
19	20	35
20	19	30
Sum	400.00	600.00
Average*	ERODED = 20.00%	ENRICHED = 30.00%

NB: To obtain an average divide the sum of all the measurements by the number of measurements made.

Calculations:
(1) Calculate the ratio of fine materials in the eroded soil to fine materials in the enriched soil

ENRICHED	30%	÷	ERODED	20%	=	ENRICHMENT RATIO	1.50

At the simplest level, a "community map" could be sketched rapidly for short time time intervals, then the time sequence of sketches compared to investigate the more active or widespread areas and types of erosion features, for closer investigation.
The next level is to solely describe and class the erosion features present in an area of interest, using Tables 1, 2 and 3.

Lastly, the measurements of soil loss (section 3, above) take the longest time, so tend to be used less often and less intensively.

Intensity of observations is also governed by the types of erosion features that occur in a study area. For example, if there are only 5 to 10 gullies in a given LUT, then the tendency would be to describe and measure all of these in some detail, even installing fixed measuring posts to exactly measure soil loss and gully encroachment. At the other end of the scale, in a heavily degraded, recently cleared, steeply sloping land in the monsoon season there may be all of sheet wash, rills, gullies and landslides. Most often human resources are inadequate to comprehensively describe and record so many types that are changing so rapidly. Photography and community sketches would be the best approach as these can be subsequently analysed to capture the rapidly changing situation.

It is important to identify relationships between the various erosion types recorded and current or recent management activities that contributed to the type, state, extent and severity of the erosion. Such linkages will provide a more proactive consideration of soil erosion with consideration of the potential to repair or diminish the recorded erosion, lessen the chance of its re-occurrence and, particularly in areas being newly opened up for production, to initiate from the outset improved management strategies to avoid or minimise erosion.

This section aims to provide a field usable and scientifically robust set of methods for describing the various types of erosion, scoring the degree of negative impact of each type and estimating the quantities of soil lost. The results should then be considered together with other type of degradation (of soil properties, vegetation and water quality and water resources) to assess impacts on productivity, other ecosystem services and resilience.

The analysis of the qualitative and quantitative information on soil erosion can be subsequently related to the community map and other land use and topographic maps of the study area to understand wider implications of soil erosion in the landscape.

5

SECTION

Key informant and land user interview

Introduction

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 land users and key informants. These land user and key informant interviews 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 and crop / pasture productivity with land users and with officials from land, water, agriculture and forestry offices. These individuals may offer plausible explanations for particular observations or behaviour.

The team should decide on the local land users and key informants who should be interviewed along the transect walk and during the detailed assessments of soil and vegetation, in order to understand the reasons why land users do or do not invest to maintain land productivity and ecosystem services.

This section includes guidelines to interview on aspects of land degradation and sustainable land management (Tool 5.1), on vegetation resources (pasture and livestock productivity) (Tool 5.2), and on cropping productivity and yield (Tool 5.3).

Tool 5.1 Land User and Key Informant Interview on LD / SLM

This interview focuses on sustainable land management and practices adopted to mitigate the impacts of land degradation in the study area, and can be conducted during the reconnaissance visit, transect walk or during meetings with natural resources officers. The team should question the interviewees on the following:

1. What are the main changes experienced in the study area (e.g. lower yields, increase in gullies, change in grazing species composition, invasive species, less palatable species, lower groundwater table, increase salinity, etc.)?

2. What is done to remedy this / these change(s)? What are the methods used to improve soil fertility, to reduce erosion, and to manage water resources? Has there been adoption of new practices and / or changed your management patterns?

If adoption:

3. Is the measure used to prevent, reduce degradation or rehabilitate degraded lands?

4. Who introduced the practice (Land user, extension officer, and project)?

5. What is the effectiveness of the new/ traditional practices (+, neutral or –)?

6. 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? The possible replies include:
   - soil services (protective cover, organic matter and nutrient cycling and vulnerability to wind erosion (windbreaks, shelterbelts etc.);
   - water regulation (evaporation, infiltration, runoff and erosion) and water supply (surface, ground);
   - climate regulation (carbon sequestration; greenhouse gas emissions e.g. wetland, paddy rice);
   - productivity (status and trends) and livelihoods.

If no adoption:

9. 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)?

10. Identify the sustainable land management practices implemented by land users to maintain land productivity and ecosystem services using Table 30.

Tool 5.2 Land User and Key Informant Interview on Vegetation Resources

Some initial information on vegetation resources will have been obtained from the initial community focus group discussion (Tool 1.1) and the reconnaissance / transect walk (Tool 2.1).

Additional FGDs on vegetation resources should be organized with 6-10 established community members separately for i) forest / woodland ii) grazing land and iii) cropland.

TABLE 30 **Field form – Sustainable land management practices**

Land degradation problem	**Sustainable land management practice**	**Conservation effectiveness** (+, neutral, -)	**Benefits of SLM practice**	**Utilization by land users in the area %**	**Constraints to adoption***

* Examples of Constraints:

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

1. Has the quality of the [forest] [grazing] [crop] land changed over the last 20 years? How and why?
2. What plants show that [forest] [grazing] [crop] land/soil quality is i) good? or ii) bad? Do they have any particular characteristics?
3. Which plants have appeared in [forest] [grazing] [crop] areas that indicate that land quality and productivity has:
   i) improved? What do they indicate?
   ii) declined? What do they indicate?
   (e.g. grazing land: palatability / toxicity, overgrazing, annual vs. perennial grasses etc.)

(e.g. forest / wood land: loss of valuable species and products; invasive shrub species)
(e.g. cropland – weed intensity, infertile soils (e.g. parasitic weeds such as Striga) species resilient to salinity)

Record up to 3 plant species for each land use 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 (see Table 31 below).

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 the FGD and through household interviews with land users and compared with the information obtained on the ground:

4. 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)?;
5. What are the main livestock products (milk, meat, hides), yields/annum and trends?;
6. What are the forage production trends (increasing, stable, decreasing)?
7. 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.

8. How common are fires (rare, occasional, frequent)? Are they wild or controlled?
9. How severe is fire damage to the rangeland and forest vegetation (none, low, moderate, severe)?
10. 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.)?
11. Are there any control measures (e.g. bye laws, fire breaks or fire committees)?
12. How frequent and severe are drought periods? (It may help to draw a timeline)

TABLE 31 **Field form – Plant indicator species**

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

13. Has drought caused any changes in land-use over the last (approx.) 10 years?
14. 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:

15. 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?
16. 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 5.3 Interview with Land-User on Crop Productivity and Yield

It is important to understand the characteristics, management and environmental history of the sampling sites. Discussions with farmers are most important. The best location for this interview is in the field, next to the plots 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 in terms of crop production;
- 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 management such as bunding, levelling, terracing, (and if in specific areas of the site);
- rainfall (recent and historical) (e.g. "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?
- what attempts have been made to introduce "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.

Note: 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 7.1) builds on this interview and does not duplicate it when the land user is interviewed for both. 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.

Time line - yield trend

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 factors 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 are not yet felt (e.g. on land cultivated for the first time) or masked by land user's management (e.g. increasing amounts of fertilizer 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.

Change in crop yield may be caused by a decline in soil fertility among many factors such as extreme weather, pests / diseases etc. However, unlike the effects of extreme weather and pest / diseases, the effect of soil fertility on crop yield is usually more gradual. Reconstructing a crop yield time line can help to identify the causes of yield change and the extent of the impact of the change.

A time-line of crop yield can be constructed using the following steps:

- Find key informants and farmers who know about past and present conditions of the community and who are willing to share their knowledge. It is important to include elders in the community, because information relating to the past needs to be found and shared.
- Discuss how far back in time participants would like to talk about these issues. Draw a time line of particular events (e.g. drought, significant pest/disease attack, conservation/management practices, change of variety etc.). The time line of particular events helps participants remember and also helps to explain the change of crop yield over time.
- Participants can then write down the crop yield for 1980, 1990, 2000, 2005, 2010 comparing the yields from different years. It is better to use farmers' own units (e.g. the number of bags per acre), but it is useful to convert these units into standard units (e.g. kg/ha) when the exercise is completed. Record the information in Table 32.
- Discuss the yield-time lines with participants; attempt to assess the contributions of soil fertility decline, drought, diseases to the change and fluctuation of crop yield. Discussion topics which should be covered include:
  - If we have good rainfall now, can we get a yield as high as 20 years ago without using fertilizer?
  - (if no)
  - What inputs are required to get a yield as good as the yields 20 years ago?

TABLE 32 **Field form – Yield trend analysis**

Time (year)	**Yield**	**Events**

- If the yield has increased in the last 20 years, what are the main reasons for the increase?
- What is the highest yield in this area for a particular crop?

Economics of soil erosion and conservation

(This section has been adapted from Stocking and Murnaghan, 2001)

Impact of soil erosion on productivity

Soil erosion has both on-site and off-site impacts. The main on-site impact is the reduction in soil productivity which results from the loss of the nutrient-rich upper layers of the soil, and the reduced water-holding capacity of many eroded soils. Movement of sediment and associated agricultural pollutants into watercourses is the major off-site impact resulting from soil erosion.

The effects of erosion on productivity is site specific. The same amount of soil erosion can have different impacts in different soils, while for the same soil, the impact on productivity of same amount of soil loss varies with time (or the stage of erosion). Crop yield is often used as an indicator of soil productivity. Figure 21 shows the way in which yields (productivity) declines with cumulative soil loss – the sort of soil loss that could accumulate over a number of years, depending upon the rate of land degradation.

The impact of soil erosion can be partially masked by various soil management measures, such as use of fertilizers and / or organic matter (compost / manure). Part of these inputs is in fact used to compensate for the productivity loss caused by soil erosion and nutrient loss. The productivity impact of soil erosion can also be assessed using the extra compensating inputs.

The productivity impact of soil erosion is often mixed with other factors, which also contribute to crop yield changes, such as drought and pest attacks. A reliable way to isolate the erosion impact from other factors is to examine soil erosion and soil productivity changes over a longer period.

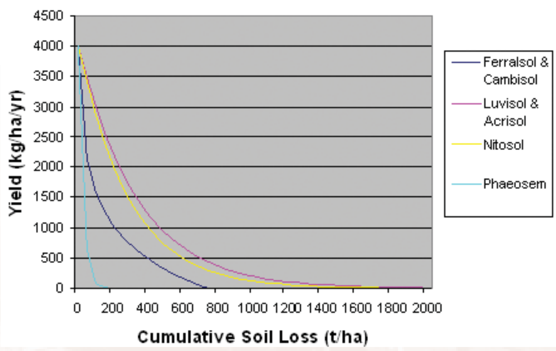


FIGURE 21 **Erosion-productivity relationships for different soil types**

Cost and benefit of soil erosion and conservation

Soil erosion involves a *cost* to land users, in terms of declined crop yield or increased input demand in order to maintain the same yield. By preventing soil erosion through conservation measures a *benefit* is derived for the land user in terms of yields and easier farming practices. Figure 22 a) and b) shows the costs of soil erosion and the benefits of soil conservation. The shaded part shows the cost and benefit measured as yield lost (compared with baseline of non-degradation) and yield saved (compared with base line of continuing degradation).

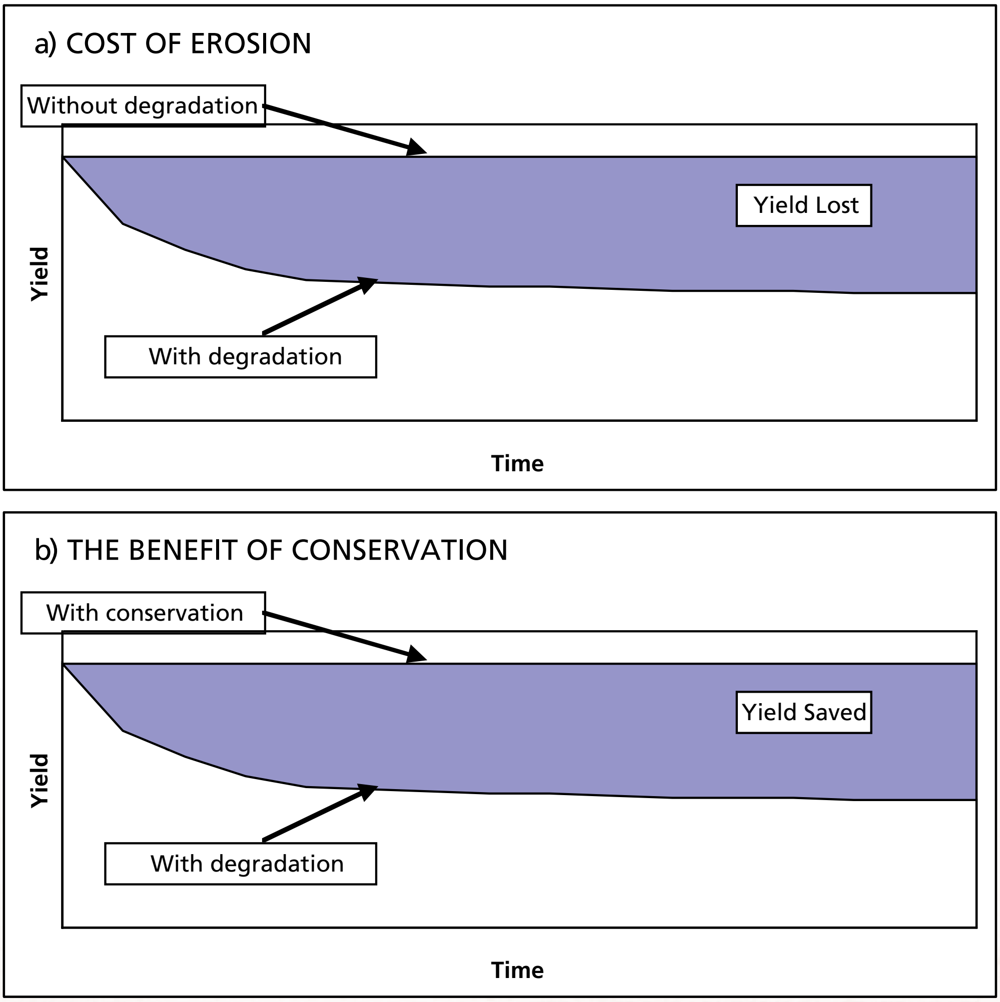


FIGURE 22 **a) Costs of erosion and b) benefits of conservation**

Comparing the costs and benefits of soil erosion and conservation is essential for land users to make decision on when and where conservation measures to be taken. Most of conservation measures involve extra costs, either labour, material or the land forgone. To determine which conservation measure is more appropriate, a cost-benefit analysis for conservation measures is needed.

The following 10 steps are a suggested approach for assessing the net benefit gained from implementing a conservation measure. They are given only in outline form, to illustrate the sequence – for more information the reader is referred to any standard text on cost-benefit analysis.

Step 1: Define the 'with' and 'without' technology situations.
A systematic description is needed of the technology to be appraised. How does it function? What does it do? What materials are needed to implement it? And so on.

> *In this example, the 'with technology' situation is single-row Gliricidia hedgerows planted across the contour. The 'without technology' situation is steep-slope arable cropping without any direct measure of keeping soil on the slope.*

Step 2: Convert the data into common units.
Usually it is sensible to convert field areas into hectares, and yields into kilogrammes per hectare, although locally relevant measures may also be used. Money should be in local currency terms, with values reflecting real values and real costs to the land user. So, crop revenues should be calculated based on the price paid to farmers for their crops – the producer price – not the price at which they can be bought in the market – the market price. Inflation is a major problem in many countries, so a fixed date for valuation will usually need to be specified.

Step 3: List the costs and benefits.
This is the first vital step in bringing the information into some common format – two columns representing costs to the land user and benefits. Field observations and data collected from farmers are vital in undertaking this listing. The list should include only costs and benefits that occur as a result of adopting the technology. Any cost or benefit that would also occur if the farmer did not adopt the technology should not be included. Double-counting of benefits must be avoided.

Step 4: List the monetary values for each costs and benefit
The monetary values must be based on the costs and benefits to the land user, expressed usually in local currency (such as Rupees) per hectare. Costs and benefits for which there are no monetary values are usually excluded.

Step 5: Identify the ranges in data to be used in the appraisal
One of the commonest mistakes is to assume that rural society is homogeneous and that all farmers have the same perspectives. Different farmers have different values and they give responses accordingly. This variation needs to be reflected in terms of minima and maxima (i.e. ranges in value that encompass the spread). These ranges are then used for further calculation; they will identify especially where some farmers may gain a net benefit and others a net cost because of their different circumstances.

Step 6: Identify the time period for the appraisal
The time period may be the life of the technology itself, as recognised by farmers, or it may be the number of years over which farmers assess it

as an investment in improving their land. The time period has important implications, because improvement in land quality happens slowly, so some benefits may only be realised after the life of the technology.

Step 7: Construct a summary table

The summary table (Table 33) should have years listed in the first column, with a row assigned to each year of the appraisal. The body of the table is then devoted to two main sections for costs and benefits, with two columns for each type of cost or benefit to accommodate the range of values from the minimum to the maximum. If actual and relatively unchangeable costs are known for some items, then these are used.

Table 33 shows an example of summary of costs and benefits for *Gliricidia* hedgerows. Costs and benefits are specified in local currency at prevailing prices to the farmer. So fertilizer 'benefit' is priced at the price delivered at the farm gate. The values a to k will be used in the next step.

Step 8: Calculate total costs and benefits, and net cash flow for each year

The minimum and maximum data are kept separately. So for both total cost and total benefit, a minimum and maximum value is calculated for each year. The net cash flow is then calculated for each year by subtracting total costs from total benefits (see Table 34).

From the summary table for *Gliricidia* hedgerows, total costs, benefits and net cash flow are entered. The items a to k at Step 7 show how the data are ordered. Note especially that minimum net cash flow equals minimum total benefits minus maximum total costs. Similarly, maximum net cash flow equals maximum total benefits minus minimum total costs.

TABLE 33 **Summary table of costs and benefits of management practices**

Year	Costs (and resources required)					Benefits					
	Labour		Tools	Loss in crop area		Increase in crop yield		Savings on fertiliser		Pole production	
	Min	Max	Actual	Min	Max	Min	Max	Min	Max	Min	Max
1											
2	a	b	c	d	e	f	g	h	i	j	k
3											
etc.											

TABLE 34 **Calculating net cash flow**

Year	Total Costs		Total Benefits		Net Cash Flow	
	Min	Max	Min	Max	Min	Max
1						
2	a + c + d = r	b + c + e = s	f + h + j = t	g + i + k = u	t – s	u - r
3						
etc.						

Step 9: Adjust the net cash flow for the time value of money

The time-value of money is involved in investment on conservation measures because sums of money are received (benefits) and spent (costs) at different points in time. The sums of money are multiplied by a factor that is related to 'discount rate', which expresses how the value of money diminishes over time. The appraisal reflects only the value now – or 'net present value' (NPV), so a benefit in the future is worth less than a benefit now. A cost in the future is worth less at the present time than a cost now. Because discount rates are often difficult to fix and depend upon external factors such as the cost of borrowing money, it is good practice to set a lower and upper discount rate and to use both of these in the calculations (see final step 10).

Gliricidia hedgerows and their associated terraces demand a lot of labour to plant and to construct initially. Then there are some maintenance costs in pruning the hedges and replanting any trees that have died, but this is relatively small in cost. Benefits, however, come only slowly. The soil improves in quality only after a long time, having to recover from the initial earth movement in making the terraces. So, with the costs coming early and the benefits coming late, the adjustment for net cash flow for the time value of money means that very few farmers will find investing in these hedgerows financially worthwhile. Maybe only farmers who are retired employees with other sources of income can afford them.

Step 10: Calculate the net present value of the technology

The net present value (NPV) is calculated by adding the present values of the net cash flow for each year of the appraisal. The upper and lower discount rates and the minimum and maximum discounted cash flows should be kept separate. The discount factor is derived from standard tables – the further into the future, the smaller is the factor to account for the lower net present value of money as time progresses. NPV then is the sum of discounted net cash flows over the period of the appraisal. If NPV is positive it indicates that at that discount rate, the benefits of the investment exceed the costs. So the investment is economically worthwhile at that discount rate. Alternatively, if NPV is negative, the investment is not economically viable. Conservation technologies with negative NPV are very unlikely to be acceptable to land

Table 35 **Comparing cash flow scenarios**

Year	Lower discount rate			Upper discount rate		
	Discount factor	Minimum discounted net cash flow	Maximum discounted net cash flow	Discount factor	Minimum discounted net cash flow	Maximum discounted net cash flow
1						
2						
3						
etc.						
NPV Total	-			-		

users because, to implement them, the land user would be poorer.

Because the whole appraisal has been carried out with ranges of data (minimum/maximum; upper/lower discount rate) there will be several answers, ranging from a best to a worst case scenario.

The final table brings all the calculations together (see Table 35). This will show the varying values for NPV ranging from best case scenario (maximum discounted net cash flow at the lower discount rate) to worst case scenario (minimum discounted net cash flow at upper discount rate).

SECTION 6

Water resources assessment

Introduction

Water resources, their management and any degradation are important to land resource components in most dryland assessment sites. Water resources degradation and effects of land degradation on water quantity and quality should be assessed in more depth in areas where this is reported to be a critical issue. Of particular concern are:

- the effective use of rainwater for direct consumption, for productive purposes and for recharging surface and ground-water supplies;
- the reduced water quality through pollution, salinization and over-exploitation (by domestic, agricultural, forest and industrial uses);
- the reduced water quantity / availability for consumption (human and animals) and other uses because of drought or over-exploitation of water sources;
- the maintenance of the hydrological regime (i.e. recharge of groundwater, flood control – in catchments and watersheds)an important ecosystem service;
- the extent and performance of water resources management alongside soil, land use and vegetation management for mitigating effects of desertification, drought, and climate change.

Water indicators and assessment methods

There are three main components to assess the water resources in the local assessment area:

1. A review of the secondary information (see Section 5.2 in Part 1 of Manual (FAO, 2011a));
2. A key informant interview on water resources Tool 6.1 below); and
3. Field measurements of biophysical indicators for specific water sources including the effects and effectiveness of various water conservation, harvesting and irrigation measures (Tool 6.2, below).

It is important to *triangulate and thereby validate the information* derived from these three tools and sources of information. Water is a cross-cutting issue, so it is also important to relate the information on water resources with other sections of the assessment (vegetation, soil and livelihoods).

Tool 6.1 Key informant interview on water resources in the study area

The key informants for this exercise should be members of the community who are knowledgeable of the water resources in the local area. A small group (male and female) should be selected following the community focus group discussion (Tool 1.1). The interview focus is on changes in water resources quality, quantity, and availability. It should cover 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); the 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:

- the status and trends (S) of the water resources in terms of water quality, quantity and the hydrological regime (S);
- change in demand or pressures on water resources (P) and related drivers (D);
- the impacts (I) of changes in water quality and availability on productivity, livelihoods and the environment;
- some actual and possible policy or management responses (R) to conserve and / or manage water resources.

The focus group discussion with the community members and the reconnaissance visit / transect walks (Chapters 1 and 2) should answer questions on the general state and trends of the water resources in the study area. However, with accompanying land users and key informants, the team should complete their assessment by visiting most water sources in the study area(s) and answer some of the following questions.

[**Note:** as with all questionnaires, the questions have to be reviewed by the team prior to the field assessment, in order for them to be adapted and specific to the local context.]

In the study area, discuss the following issues with land users and key informants:

1. Changes in hydrological regime and water supply

1.1 Changes in the hydrological regime and sediment-related processes such as:

- surface runoff;
- peak flow / floods;
- base flow / dry season flow;
- ground water recharge;
- soil moisture recharge;
- erosion and sediment load.

(For example, high runoff could influence the size and severity of gullying and the quantity of sand deposited in reservoirs);

1.2 Drought / flood risk and incidence:

- Do serious droughts / floods occur in the area? How frequent are the drought / flood events? Have they become more or less common in the last 10 years? Why do local people think this is happening (i.e. such as bare, compacted or crusted soils increasing runoff and hindering infiltration, the use of less drought resilient crop species, the deviation of streams / oueds)/
- What is the period of drying up / flooding (months and interval)?
- What are the main impacts they have on the different livelihoods activities?

1.3 Changes in water quality of the different water sources and their causes:

- Pathogens;
- Nutrients and organic matter;
- Pesticides and other persistent organic pollutants;
- Salinity.

(For example, lower, stable or increasing pollution or salinity.)

1.4 Changes in water availability:

Types of surface and ground water sources, their number, their uses (e.g. human consumption, livestock, agriculture, industry), their size / capacity and any trends (e.g. decreasing, stable, increasing surface and / or ground water levels).

[**Note:** here it is important to understand causes of any changes in depth and quality of the ground water table. For example, in a pilot area in China, the water table had fallen some 2 metres over a number of years but local experts did not know the impact / relative importance of pumping for irrigation and household use or tree planting. The extent of land use changes need to be monitored and linked to water information (available form water authorities etc.)].

1.5 Distance and access to water:

- What is the approximate distance (km) and time (min) taken to reach water for: i) domestic consumption in the dry and wet seasons and for ii) livestock watering in the dry and wet seasons? Any changes in the last 10 years?
- How far (km) 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?

2. Water resources management and changes in demand

2.1 Demand on water:

Water use, water withdrawal, and water infrastructure:

- What changes have there been in demand on water and water withdrawals in the last decade for the different water uses (e.g. number of dried-up wells / boreholes)?
- How is the water supply managed and by whom? Is the management sustainable and equitable?
- Do all people in the community / area have equal rights to use water resource? If not what are the differences?

2.2 Water resources management

Have there been changes in the last 10 years in water conservation, water harvesting activities and irrigation:

a- Soil and water conservation: What techniques are used to optimise moisture and water capture, retention, infiltration and groundwater recharge? Have they

been effective in enhancing productivity / reducing degradation by wind and water erosion / maintaining surface and ground water supply? The answers could include one of more of the following:
- 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);
- Soil cover and mulching.

b- Water harvesting:
What are the water harvesting techniques present? Is the water collected used for agriculture, domestic use and / or livestock watering? How common is this harvesting (i.e. common, present, negligible)? The answers could include one of more of the following:
- Dams, tanks, reservoirs and pans to store excessive water;
- Roof catchment and cisterns;
- Negarim, half moon, zai etc..

c- Irrigation:
What are the types of irrigation systems are operational? What is the proportion of each type? The answers could include one of more of the following:
- Flood (%);
- Sprinkler (%);
- Drip (%);
- Pressure hose (%).

[It would also be useful to note any systems which are no longer operational and why.]

d- Are these measures effective in ensuring water use efficiency (high, moderate, low)? In terms of:
- Water capture and retention;
- Meeting plant water requirement;
- Drainage and leaching;
- Losses such as pipe / canal leakages;
- Losses through runoff;
- Standing water and evaporation from bare soil.

e- Constraints: What are the constraints to more productive / effective use of water? in regard to:
- salinity;
- shortage / access;
- conflicts;
- cost.

f- What are the impacts of the measures? in terms of:
- productivity;
- income;
- health;
- reduced risk (crop failure, livestock mortality).

g- What is the % of people applying these different water management techniques in the study area / community territory?

2.3 Water policy, legislation and institutional aspects

(i.e. what are the arrangements for water allocation / water rights and water conflict resolution / byelaws on water resources use and their application? Have there been significant changes in the last 10 years and why?

3. Off-site / on-site impacts on water resources:

Land use management in the study area may affect the water resources outside of the study area; as well as land use management outside of the study area may affect the water resources in the study area.

It is important to consider wider on-site - off-site causes of water resources degradation during the assessment, such as:

- increasing pressure / demand on the water sources, removal of natural vegetation, overgrazing, or inappropriate cultivation in the vital "sponge" areas of wetlands;
- drainage or permanent alteration of the water levels and flows to accommodate other use(s) of the water body (e.g. for building or irrigation purposes). This change can be caused by direct human interventions (e.g. drainage) or by a natural change such as change of a river course due to floods leading to sedimentation or deepening of the river channel or erosion of the banks.
- inflow of nutrients in run-off from fertilized farmland (causing rapid growth of algae in the water which depletes the oxygen supply in the water and may kill plant, fish and animal life);
- inflow of non-selective pesticides or herbicides in run-off from adjacent or upstream farm land - that effect water quality and impacts on animal and plant populations, also aquatic functions;
- changes in the water regime leading to increased floods, or reduced low flows (e.g. change of perennial to seasonal flow, perhaps attributable to draining of wetlands)
- human activity such as damming for water storage, irrigation or recreation and pollution in or close to the water body.

1. Does local land use and management (vegetation, soil and water) in the study area affect water resources in off-site/ neighbouring areas? (Select impacts from Table 36 below or note additional impacts).

2. Does land use and management outside the study area affect the water resources in

TABLE 36 **Off-site /on-site impacts on water resources caused by land use and management**

On / off-site impacts on water resources of land use and management
• Changes in water flow (peak, base) • Floods during extreme events or the rainy season • Sediment deposition/accumulation and dust storm • Contamination by airborne pollutants (e.g. from industry, mining, urbanization) affecting vegetation, soil and water resources) • Change in surface water availability during dry seasons/spells, droughts (e.g. river flows, lake levels, dams, ponds, etc.) • Changes in the water course of a stream or "oued"* • Change in ground water/subsurface water availability • Change in water constraints (water-logging, water salinity) • Change in water quality (for drinking, for agricultural or industrial use) • Change in water retention capacity of dams and upstream lakes (water storage and regulation) • Road damage due to intense rainfall, runoff and uncontrolled flow in Oueds • Active erosion gullies (unstabilised) • Increase in water extraction from increased numbers of private or illegal wells/ boreholes • Other (specify)

* **Oueds** are dried out river beds, containing channels, ledges and deep ditches.

TABLE 37 **Causes of on / off-site impacts on water resources**

Human induced causes	Natural causes
• Soil management (inappropriate / good) • Crop and rangeland management (inappropriate / good) • Deforestation and removal of natural vegetation (including 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 sources, or excessive runoff) • Release of airborne pollutants (urban / industrial activities) • Disturbance of the water cycle / change in water level of ground water aquifers, lakes and rivers • Over-abstraction/excessive withdrawal of water • Other (specify)	• 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 (specify)

the study area? (Select impacts from list Table 35 or note additional impacts).

3. What are the human and natural causes of off-site impacts? (Identify the relevant causes from Table 37 and rank them in order of importance starting with the most important)

Tool 6.2 Detailed biophysical assessment (state / trend) of specific water resources

Visit each important water source and conduct the following assessment with local key informants:

Water Source (type):____________________

GPS coordinates: ____________________

LUS / LUT:____________________

Season: ____________________

Water quantity: *for each indicator, select the most appropriate answer from those provided below and give a short explanation.*

1. Water level:
   - Only a small fraction of the capacity of the water body e.g. a very small flow of water in a large riverbed;
   - Below to half of the capacity (average to limiting water conditions);
   - Above half of the capacity up to the upper limit of the capacity of the water body.

2. Water depth:
   - height of water in wells and boreholes (water table depth).

3. Potential loss of rainwater by soil evaporation:
   - High- Soil uncovered and bare during long periods of time;
   - Moderate- Soil partly and seasonally not covered;

- Low- Soil permanently covered (litter/live plants).

4. Loss of rainwater by runoff:
    - 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;
    - Signs of surface water runoff and some soil movement (sheet erosion)- moderate cover and/or some soil and water conservation;
    - No signs of surface water runoff due to good soil cover and soil and water conservation measures.

Ask key informants:

5. Does it hold water just during the wet season or throughout the year? How reliable is it (does it dries out)?

6. What is the demand on the water source for different uses (human consumption, livestock watering, agricultural irrigation or industry) (heavy, moderate, light, none)? Has the pattern of use changed over the last 10 years?

7. What % of the total amount of water used (withdrawn) is permitted (legal, regulated) and what % is illegal? Indicate any changes in the last 10 years.

Water quality: *for each indicator, select the most appropriate answer with a short explanation*

8. Colour and Turbidity:
    - Green and opaque from eutrophication or sewage;
    - Brown and opaque from sediment;
    - Transparent / normal colour.

9. Pollution by:
    - Water smelling or of unnatural colour;
    - Signs of animal faeces;
    - Presence of discharge pipes / canals, drainage inlets with substantial inflow of sewage and other effluents;
    - No visual sign of water pollution;
    - Coliforms / BOD / bacteria using field microbiological water kit;
    - Other chemicals and heavy metals (lab test).

10. Salinity:
    - Whitish salt deposits around the water point (Y / N);
    - Water conductivity value (EC) – salinity of both surface and groundwater.

Ask informants on status and trends:

11. What is the water quality? If polluted, what are the causes (e.g. increase use of fertiliser, sewage discharge, increase pesticide use, industrial pollution)?

PHOTO 27 **Use of a water kit to assess quality in a pond, Cuba**

12. Has there been a noticeable change in the quality of this water source over the last 10 years (describe the changes in amount, seasonality or quality of the water)?

The visual observations of local informants can be backed up by a water testing kit that can usually be obtained from local water authorities, see Photo 25

Ecosystem and living aquatic resources: *(for each indicator, select the most appropriate answer with a short explanation)*

13. Aquatic life (fish, insect) and diversity:
    - Absence or very limited visible life;
    - Presence of only aquatic species known to be tolerant to some pollution;
    - Presence of diverse aquatic species indicating good water quality (sensitive to pollution).

14. Algae and/or invasive aquatic plants:
    - Abundance of algae and / or invasive aquatic species;
    - Presence of algae and / or invasive aquatic species;
    - No algae or invasive aquatic species.

15. Fish stocks / productivity:
    - Abundant
    - Moderate
    - Few
    - None

Additional measurements of water quantity and quality

These additional measurements can be made where there is a particular need to generate quantitative data on water resources perhaps to complement existing data sets / activities in the country or region concerned. Only limited detail on these methods is given here.

Water quantity measurements:

Water point width
To estimated water point width, in meters. This can be measured with a rangefinder or a measuring tape. In case of a lakes, ponds, dams and reservoirs then it is the average between the wider and narrower parts.

Water point depth
To estimate water point depth, in meters. This can be measured using a measuring stick or pole or a chain with a weight attached to the end. Manual measurement of depth is limited to 5-6 meters, so if the water point is deeper than 5-6m then indicate >6m.

Water flow
To estimate flow of rivers, streams and springs only (not ponds, dams or lakes), in litres/ minute (l/min). This is estimated by recording the time taken (T) for a twig /stick to move a certain distance (L) (e.g.20 m) along the water surface. For a U shape channel water flow = (average Width x average Depth x L)/T. For a V shaped channel water flow = (average width/2 x Depth x L)/2.

Water quality measurements:

Chemical and nutrient characteristics
There are a variety of water quality variables, including temperature, electrical conductivity (a measure of the total dissolved salts), pH (an indicator of the water's acidity or alkalinity), chlorophyll A, total phosphorous, total nitrogen, dissolved oxygen, and water transparency (Secchi depth). These parameters can be measured with individual instruments or

with one combination instrument that includes several types of probes.

Changes to water quality often occur over long periods of time, making it difficult to determine the role of human activity as distinct from natural processes, for example, the impact of climate change. The use of long term data sets on water resources may assist to determine cause and effects.

Turbidity
Estimation of the degree of transparency or opaqueness of the water due to suspended particles and sediments. Usually measured using test/turbidity column/secchi disc, in meters.

pH
pH value of water (to be measured using pH meter or pH paper).

Biological Oxygen Demand (BOD)
Measure of the Biological Oxygen Demand (BOD an indication of oxygen availability and hence degree of contamination). To measure, use a BOD test kit.

Sources of contamination
The main sources of contamination of the water point.

Aquatic species
The presence or absence of certain chemical or biological indicators can reflect environmental conditions. Taxonomic groups, individual species, groups of species, or entire communities can be used as indicators. It is possible to use species presence/absence, and in some instances abundances and habitat characteristics to assess the condition of inland water ecosystems.

Tool 6.3 Assessing degradation of river / stream banks and lake shores

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

By walking along a river or lake with local land users and / or key informants, assess the following indicators within 10-50 m from the bank / shore (depending on the size of the water body):

- What is the extent and severity (severe, moderate, low, none) of the bank degradation?
- What is the status of the river bank / lake shore vegetation? (select)
  - tree and bush vegetation is missing, the riverbank shows signs of cultivation, and is unstable or undercut with signs of active river bank erosion;
  - vegetation partly disturbed, cultivated land within less than 10 m of the river or lake shore;
  - stabilized by vegetation (mainly trees and bushes) and not cultivated or intensively used within 50 to 100 m.
- Are there signs of animal trampling on river / streams banks / lake shores? (select)
  - many entry points where animals have access to the water;
  - a few entry points where animals have access to water;
  - no signs of animals entering into the water.
- What are the other causes of degradation (e.g. landslip, erosion, undercutting) observed?

- Is there any danger of serious changes in the water course, landslips, etc. threatening: i) productive land, ii) settlements or human life or iii) infrastructures?
- 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)?
- What legislation and bylaws exist on river / stream bank protection and to what extent are they being respected / applied and if not why?

Tool 6.4 Assessing livestock watering points

Land degradation by livestock through overgrazing and trampling around watering points in grazing lands / rangelands is a common phenomenon. See Photo 28.

PHOTO 28 **Degradation is often more severe close to water points due to livestock trampling and loss of vegetation, Tunisia**

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 rainfalls. 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 watering point).

Interviews with local herders can provide information on:

- the distance to nearest alternative watering point;
- the trend in livestock numbers and species using the watering point in the 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;
- changes in vegetation (cover, palatable/ invasive species) as a result of changes in management practices
- 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 land cultivation (where feasible);
- change in livestock species composition from drought tolerant (e.g. camels) to more water demanding species (e.g. cattle).

Visual observations to assess extent and severity of degradation around watering points:

1. Ground cover:
    - more than 50% bare soil;
    - 10 – 50% bare soil;
    - 0-10% bare soil;

2. Erosion around the water point:
    - severe and extended erosion (rills, gullies);
    - some but limited sheet erosion or small rills);
    - no signs of erosion.

3. Soil crusting and soil compaction around the water point:
    - severe and extended soil compaction and crusting;
    - limited soil compaction and crusting;
    - no soil crusting or compaction.

4. Soil and water conservation measures in place:
    - absence of SWC measures to protect the water point;
    - some SWC to protect the water point but slight to moderately effective;
    - SWC techniques in place and effective in protecting the water point;

    What is their effectiveness (good, moderate, poor)?

5. Livestock management, 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.

6. Other management measures?

Tool 6.5 Assessing degradation and management of wetlands

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 are very important in drylands as they provide a range of important 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 from erosion and / or sedimentation, often due to human management activities such as wetland development for irrigated farming or rainfed horticulture (see examples in Photo 29).

The assessment is looking at degradation (and conservation) in the wetlands and the related impacts on its multiple functions.

1. What are the types, severity and extent of degradation in the wetland?
    - Has the wetland area and hence the habitat it provides 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)?

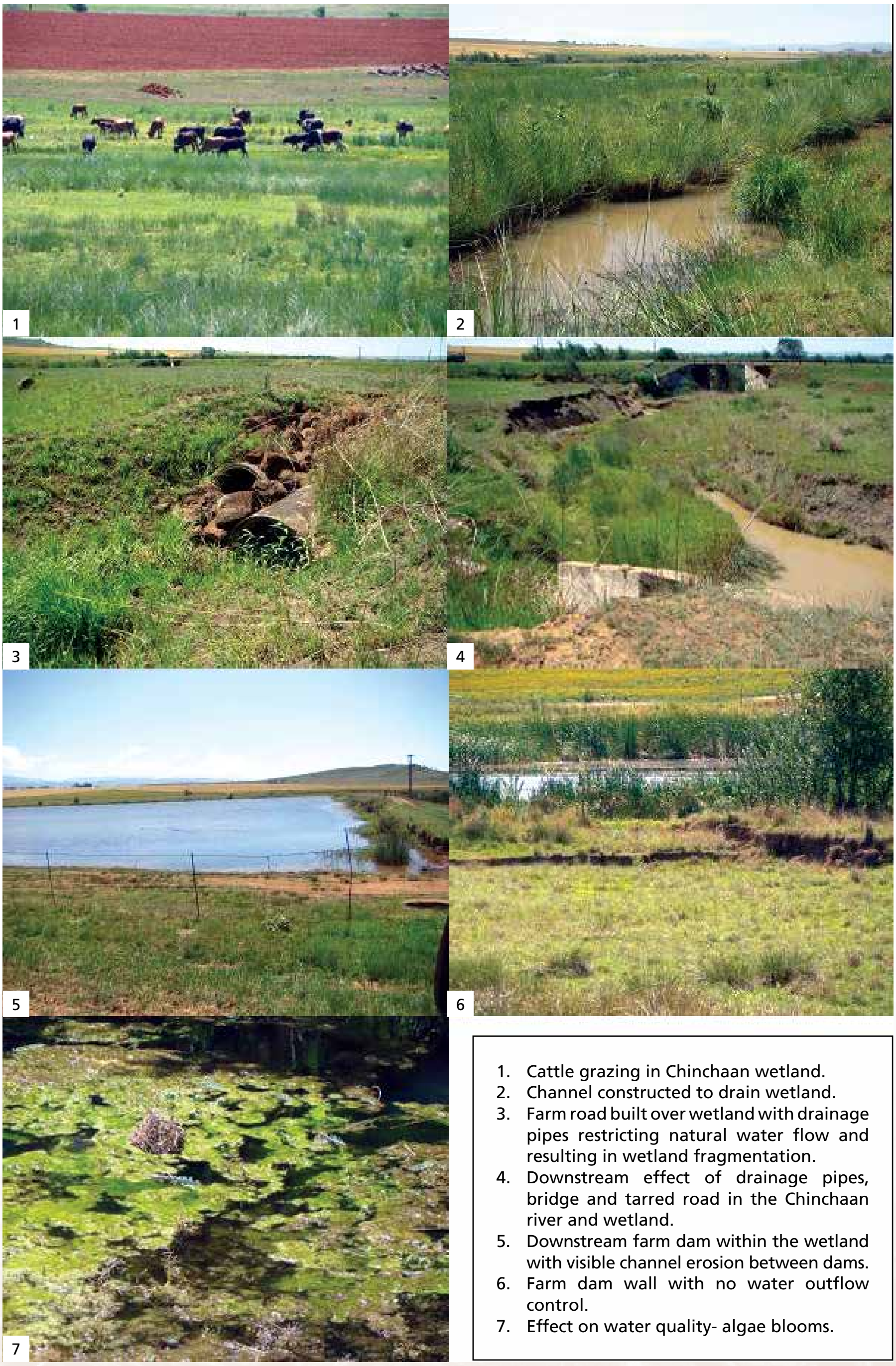
2. Have there been changes in and impacts on the functions provided by wetlands (hydrological; ecological / biological and livelihood support) as a result of degradation or improved management measures?
    2.1 Productive capacity (e.g. livestock grazing, wild foods harvesting, construction materials and cultivation):
    - poor productive capacity;
    - moderate production- limitations;
    - good productive capacity (e.g. for animal grazing, wild food collection, and rice cultivation).

    2.2 Downstream flooding:
    - frequent and damaging flooding;
    - moderate water flow;
    - water well retained by the wetland.

    2.3 Biodiversity / indicator species:
    - greatly reduced of flora and fauna biodiversity relative to "normal" communities;
    - significant reduction in biodiversity relative to "normal" communities; "normal" or close to "normal" biodiversity levels.

3. What are the main causes in terms of human management activities? For example:
    - 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);
    - run-off of non-selective pesticides or herbicides that degrade natural animal and plant populations and affect water quality;
    - drainage or permanent alteration to accommodate building / planting of rainfed or irrigated crops;
    - damming for water storage, irrigation or recreation;
    - human activity and pollution in or close to the wetland (e.g. brick making);
    - change in productive capacity of the wetland for livestock grazing, wild foods harvesting, construction materials and cultivation;
    - increased downstream flooding (flood incidence and severity);
    - diminution of plant and animal biodiversity or indicator species of threatened habitat.

[**Note:** South Africa has developed and has successfully used as part of its LADA Local assessments for the assessment of wetlands, a "Manual for the assessment of a Wetland Index of Habitat Integrity for South African floodplain and channelled valley bottom wetland types" (Governmnet of South Africa, 2007). This document is available on the LADA website www.fao.org/nr/lada. It is recommended that this is tested and, as required, adapted for use in the other countries where wetlands health and integrity is an important issue.]



1. Cattle grazing in Chinchaan wetland.
2. Channel constructed to drain wetland.
3. Farm road built over wetland with drainage pipes restricting natural water flow and resulting in wetland fragmentation.
4. Downstream effect of drainage pipes, bridge and tarred road in the Chinchaan river and wetland.
5. Downstream farm dam within the wetland with visible channel erosion between dams.
6. Farm dam wall with no water outflow control.
7. Effect on water quality- algae blooms.

PHOTO 29 **Types of damage to a wetland (South Africa)**

Tool 6.6 Assessing land degradation and management practices in irrigated lands

A separate manual has been prepared for assessing land degradation / management in irrigated lands "LADA for Irrigated Lands – an additional module for LADA-Local (McGarry, 2010). This is available on the LADA website www.fao.org/nr/lada. This aims to provide a quantified, improved understanding of the problem of salinity and sodicity (S&S) in irrigated lands, through the provision of specific tools to determine and interpret S&S levels in the soil and water and their causes (often the very surface or ground waters used for irrigation or underlying the irrigation areas). The aim is to help stakeholders identify and develop adapted integrated management systems (soil, water, crop, human management) for reducing degradation and improving productivity.

D. MCGARRY

PHOTO 29b **Surface salinity evident as a white crust following irrigation of wheat crops, near Yinchuan, Ningxia province, central north China**

SECTION 7

Livelihoods

Introduction

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. Particularly with poor land-users in marginal areas (common in the drylands), there are many factors relating to resource and market access, the 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, control land degradation or implement rehabilitation measures, often much more than their knowledge of land degradation processes or options for "improved" management. A good livelihoods analysis should help the team to understand 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 tool will capture livelihoods-related information that will improve countries' understanding the role socio-economic and institutional factors play in affecting the ways in which people view and manage their land resources.

The analysis should be conducted with 20-30 households responsible for managing the land assessed under the detailed bio-physical assessments and more generally within the local assessment area.

PHOTO 30 **Household interview (a) quality of human and (b) livestock housing, Tunisia**

Tool 7.1 Household livelihoods interview[17]

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.

As with any questionnaire, it is important to review the questions (modify, add, cancel as deemed necessary) to ensure they are relevant to the local context - this has to be done by the local assessment team before fieldwork.

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 and temperatures.)

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, price, safety quality and quantity)? What changes have occurred in uses, quality and access to over the last 10 years?

17 The approach draws on the work on sustainable livelihoods (Ellis, 2000) and also on the FAO guide for analyzing local institutions and livelihoods (FAO, 2003).

1.3 Land resources: How many hectares (or other measure – e.g. acre – then convert for recording) 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 by chief or other)? 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 What are the households' uses of each crop type?

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?

[Note: it is 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 have been the recent changes / trends?

2.2 Types land degradation: soil loss by run-off or wind, gully erosion, 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 conservation approaches not currently used? If yes, which ones?

3. Financial capital and production

(income/year should not be asked directly, 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 the household 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 problems, 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 What type of housing does the household have (building, roofing) and also what is the quality of livestock shelter/housing if any?

5.4 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, forest)? Have 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? See Photo 31.

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?

PHOTO 31 **Women's vegetable producer group, Tunisia**

8. Human capital and household composition

8.1 How many members are there in the household ? What are the numbers of children / migrants?

8.2 What is the educational level of the household head and children? Has he / she / they received any training – if so, in what (e.g. SLM etc)?

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, ideally the same day, to avoid misinterpretation.

Field form – household livelihoods interview

1. Natural capital

1.1 Calendar of farming / herding activities by seasons in relation to rainfall

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:					

1.8 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 / promote 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 Periods of each year 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

8.1 Educational level and training of family members

Family	Educational level	Training on conservation / SLM
Head		
Mother		
Children		

8.2 Composition of family members

Family	Number
Total members	
Active workers	
Children	
Migrants	

8.3 Age range of household head

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

ANNEX 1

Types and forms of erosion by water and by wind

1. EROSION BY WATER

1.1 Erosion by raindrop impact (« splash »)

EROSION DEGREE: VERY WEAK; VALUE = 1

This form of erosion is no longer visible after cultivation (ploughing, hoeing etc.)

Splash erosion is a two step process:
Break up of soil clods/aggregates and dispersion of soil particles by the kinetic energy of the raindrop impacting on the soil.

The dislodged particles may or may not be then moved down slope by surface runoff, and the detached soil particles resettle on the soil surface or are thrown onto plant stems and leaves (herbaceous vegetation or young seedlings).

1.2 Sheet erosion

This is the type of erosion that results from runoff that spreads across the soil surface during rainfall (i.e. when the infiltration rate has been exceeded). It may take various forms and degrees.

- Diffuse runoff:
  EROSION DEGREE: VERY WEAK, VALUE = 1
  This takes place during the rain as soon as the infiltration rate is exceeded and a film of water starts to move across the surface. Effects are limited to the transport of fine particles and development of a sandy film in small cultivation furrows (traces) or where the fine particles are trapped by small clumps of herbaceous vegetation. There may be occasional dislodging of small superficial roots.

- Removal of surface soil particles:
  EROSION DEGREE: WEAK, VALUE = 2
  A very slight reduction in soil depth due to down slope transport of soil particles. Removal of the surface layer does not reach the next soil layer (subsoil). Some roots of grasses, annual plants or trees may be exposed.

- Removal of surface soil with some excavation:
  EROSION DEGREE: MODERATE, VALUE = 3
  This is the most advanced form of soil loss, through removal of material and part of the soil profile with a tendency to develop into gullying. This state is accompanied by exposure of tree roots and exposure of the subsoil horizon.

1.3 Linear erosion

This is erosion due to concentrated runoff accompanied by scratching or scoring of the soil surface to various degrees.

- Surface scratches:
  EROSION DEGREE: WEAK, VALUE = 2

The first traces resulting from fast, concentrated surface runoff on sloping surface. The depth of the scratches does not exceed a few centimetres and are easily removed by cultivation.

- Rills:
  EROSION DEGREE: WEAK, VALUE = 2

Soil erosion due to the grooving action by many small rivulets and water channels caused by concentrated surface runoff. Rills do not exceed 30cm in depth and they can be readily removed by cultivation.

- Small gullies:
  EROSION DEGREE: WEAK, VALUE = 3

These are shallow gullies less than 1m deep that cannot be removed by ordinary cultivation.

Gullies: more than 1m deep that may be individual gullies separated from others or contiguous.

- Individual gullies:
  EROSION DEGREE: MODERATE, VALUE = 3

- **Individual gullies accompanied by collapse of the gully sides and /or tunnel erosion** (subsurface erosion creates a tunnel that then collapses):
  EROSION DEGREE: SEVERE, VALUE = 4

- Widespread gullies:
  EROSION DEGREE : SEVERE, VALUE = 4

- Badlands:
  EROSION DEGREE VERY SEVERE, VALUE = 4

Linear erosion also occurs in areas that are periodically flooded in the beds of waterways, in flooding areas around "oueds", in floodplains of rivers / alluvial deposition zones (know as "garaats", and "sebkhas" in northern Africa...).

The suggested degrees (rills - **2**, small gullies - **2**; gullies - **3**), may scored at one degree less if there are no envisaged negative impacts on the hydrological regime (flow quantity and quality), on infrastructure along waterways or risk to people. However, if the risk is high the degree should be **4**.

1.4 Mass movement

Type of erosion caused by soil saturation and gravity and set off by intense and/or prolonged rainfall.

- Landslides;
- torrential lava flows (suggest remove ?);
- mudflows.

- - Superficial mass movement:
  EROSION DEGREE: WEAK, VALUE: 2

This type of landslip affects non plastic materials (concave), clay soils with characteristic uneven terrain (**solifluction lens**) or other forms such as small **terracing, or creep**

- Deep mass movement:
  EROSION DEGREE: MODERATE TO SEVERE, VALUE : 3 TO 4

More significant land or mud slides that may be localised or widespread. This includes **landslides in the form of a slab, and mudflows**.

The figure below illustrates one type of mass movement known as rotational concave landslide and shows the tongue (langue in French) of the landslide and the detachment plane (niche d'arrachement in French) (source Roose, 1994).

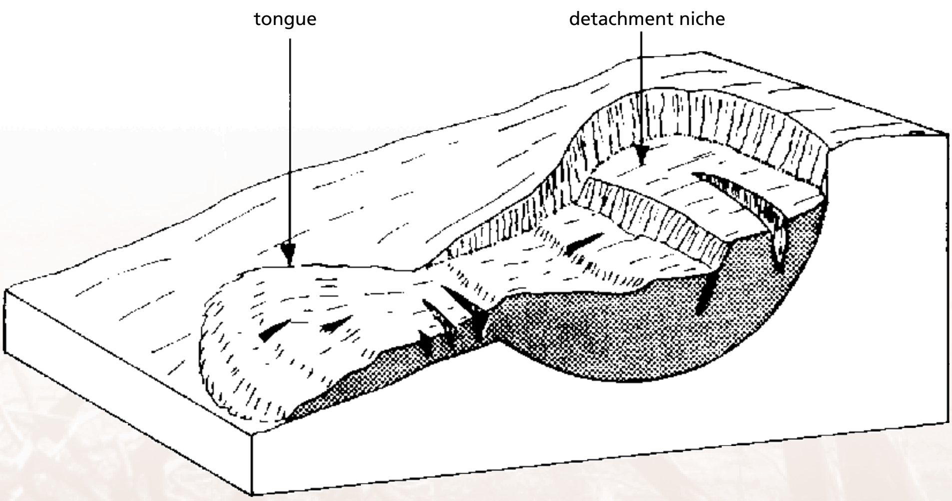


FIGURE 23 **Rotational concave landslide**

Mass movements (slow or fast) result from an imbalance between the soil mass, the stored water and vegetation cover, the friction forces of these materials on the weathered bedrock and the slope of the materials (limiting slope 30 to 40 degrees / 65 %). This imbalance can develop gradually on one or more slip planes following wetting or by exceeding the point of elasticity of the soil (slow landslides with deformation but without breaking up) or liquid materials (mudflows).

2. WIND EROSION

Wind erosion is the form of soil degradation by the action of the wind which abrades, transports and deposes soil / sand particles. These actions depend mainly on the type of soil, the climate, the vegetation cover, the speed and frequency of wind.

- Deflation
- Accumulation

2.1 Deflation:

DEGREE VERY WEAK TO SEVERE, VALUES FROM 1 TO 4

It is the action of removal of soil/sand particles which results in a loss of the surface soil layer, appearance of a stony surface and exposure of plant roots.

The degree of erosion depends on the abrasive power of the wind effect on the land, it varies from weak to severe, with values from **1 to 4** for the most severe.

Deflation is sometimes accompanied by **corrosion**.

2.2 Accumulation:

DEGREE FROM VERY WEAK TO SEVERE, WITH VALUES FROM 1 TO 4

It is the deposition of soil / sand particles that have been transported when the wind loses speed or becomes too laden. It can take several forms according to the power of aggression.

- Areas severely affected: well developed dune fields with or without vegetation
- Areas moderately affected: accumulation of material trapped at the edges of fields or along roads;.
- Diffuse accumulations: sandy layers around herbaceous vegetation and fine sand deposits less than 2 to 3 cm depth; characteristic of areas only weakly affected by wind erosion.

ANNEX 2

Some general and specific crop nutrient deficiencies

Table of nutrient deficiencies and toxicities–generalised symptoms and conditions

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.

Table of nutrient deficiencies and toxicities–generalised symptoms and conditions *(continued)*

Essential nutrient	Deficiency/Toxicity symptoms	Typical conditions
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.

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.

Examples of deficiencies in several tropical crops *(continued)*

	Maize	Beans	Cabbage
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.		

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