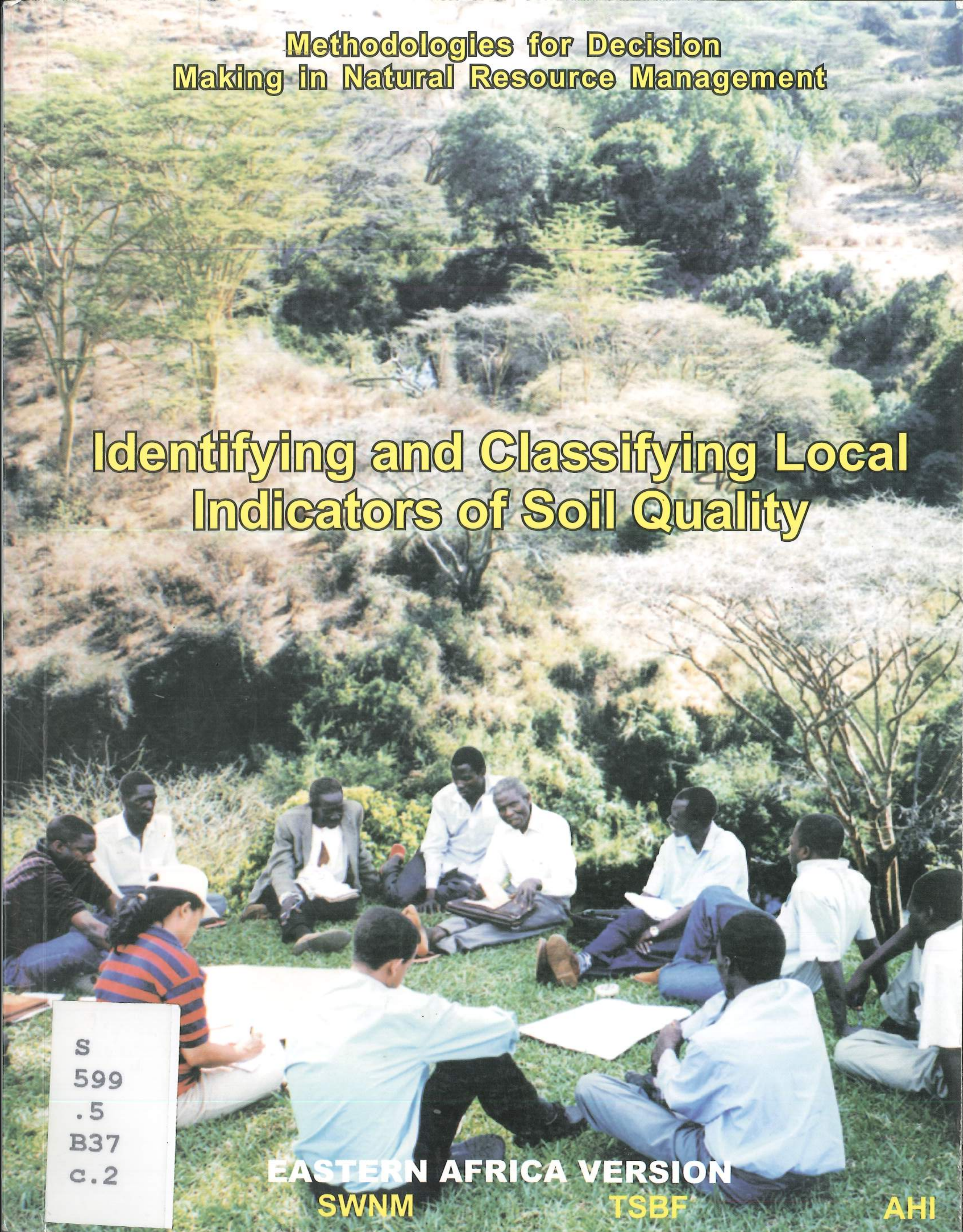
Methodologies for Decision Making in Natural Resource Management

Identifying and Classifying Local Indicators of Soil Quality



EASTERN AFRICA VERSION

SWNM TSBF AHI

Methodologies for Decision Making in Natural Resource Management.

Identifying and Classifying Local Indicators of Soil Quality

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EASTERN AFRICA VERSIÓN

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1. General Introduction, 2. Technical Indicators of Soil Quality, 3. Identifying and prioritizing Local Indicators of Soil Quality, 4.Integrating Technical and Local Indicators of Soil Quality, 5. Integrated Soil Management Strategies, 6. Soil Fair: Integration in Practice

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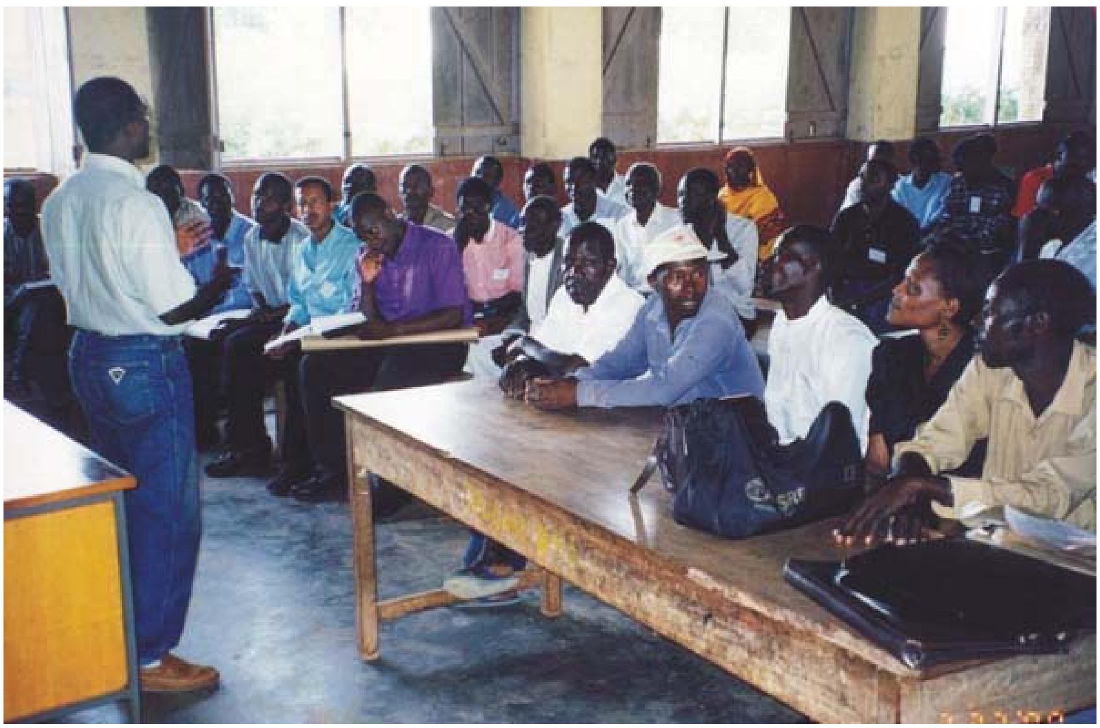
SECTION 1

General Introduction



Section 1. General Introduction

1. The Guide on Local Indicators of Soil Quality

1.1 Reason for this guide

This training guide aims at empowering local communities to better manage their soil resource through better decision making. The methodological approach presented here constitutes one tool to capture local demands and perceptions about soil constraints as an essential guide to relevant research and development activities. A considerable component of this approach involves the improvement of the communication between the technical officers and farmers and vice versa by jointly constructing a effective communication channel.

Sustainable land use in sub-Saharan Africa is a major concern because the natural condition of the continent creates a challenging environment within which to identify strategies to maintain and increase agricultural productivity (Defoer and Budelman, 2000). Many soils of sub-Saharan Africa suffer from inherently low fertility because the continent is dominated by geologically old, usually deeply weathered landscapes (Bationo et al., 1998). As agricultural production intensifies in better soils to satisfy the needs of an increasing population, the pressure on natural resources, such as soil, water and air also increases. Soil degradation is occurring at an alarming pace with 65% of African agricultural land, 31% of permanent pasture land, and 19% of forest and woodland already degraded and an estimated 332 million hectares of African drylands subjected to degradation (Bationo et al., 1998). In East and Southern Africa, for instance, nutrient depletion has been identified as the principal constraint on food supply (Nandwa and Bekunda, 1998). By using a nutrient balance approach Stoorvogel and Smaling (1990) showed that average annual nutrient losses were about 22 kg of N, 2.5 Kg of P and 15 Kg of K for each hectare of arable land for the last 30 years in 37 African countries (about 200 million hectares), excluding South Africa. Therefore, despite declining per capita food production for over three decades, there are clear indications that the basis of future yield increases in African agriculture will be dependent on improved nutrient supply to crops and forages as much of food production over the past three decades has been based on the mining of inherent soil fertility (Lynam et al., 1998).

The example of soil degradation through nutrient depletion illustrates the often late identification of a soil degradation process that has been operating for many years.

Therefore, soil users and those responsible for formulating policies, require indicators for early diagnosis of degradation processes. In this way, preventive rather than remedial approaches to soil degradation should become the norm rather than the exception. It is in this context that local indicators derived from an intuitive integration of changes in soil quality as a result of management and climate over time becomes of special importance (Barrios et al. 1994).

1.2 The Living Soil and Environmental Quality Standards

The soil is considered a living and dynamic resource whose condition is vital both for both agricultural production and ecosystem function. Due to the regulating role the soil plays as part of the nutrient biogeochemical cycles, as a modulator of water availability and quality, as well as its role in the filtering and decomposition of contaminating agents, it is a key natural resource for our future survival. It is imperative that we manage this basically non-renewable resource with better skills and foresight, to avoid additional degradation, and the loss of the agricultural production potential.

Society already has indicators and critical levels available for air and water quality; less attention, however, has been paid to the soil as an essential natural resource. Therefore, the need for indicators of soil quality (ISQ) has been recognized by the farming, extension, NGO and scientific communities, and by those responsible for formulating policies.

1.3 Soil Quality as a Diagnostic and Monitoring Tool

Soil quality has been defined in many ways. Here we use Doran and Parkin's definition (1994), according to which:

"soil quality is its capacity to be functional, within the limits imposed by the ecosystem and land use, to preserve the biological productivity and environmental quality, and promote the plant, animal and human health”

"Soil health", often used interchangeably with "soil quality", is defined here as: "the continuous capacity to operate as a vital biosystem, within the ecosystem and land use limits, to maintain the biological productivity, thus promoting quality in the atmospheric and hydric surroundings, and preserve plant, animal and human health" (Doran and Safley, 1997).
In order to establish a difference between these two concepts, it is suggested to use the expression "soil quality" when soil use is specified (Pankurst et al., 1997). The term "soil health" differs from "soil quality" because it includes a time dimension and the recognition of the soil as a vital biosystem.

Given that the soil keeps a unique balance among its physical, chemical and biological factors, ISQ should also be made up of combinations of these factors, specially in those situations where some parameters integrate the three factors and their functions. An example would be the water infiltration rate of a soil which is influenced by the soil physical structure (specially the texture), soil chemistry (relationships among soil surfaces, especially clays), and soil porosity (that can be affected by soil biological activity, e.g. earthworms). Biological indicators or bio-indicators are, by nature, integrative, as they reflect simultaneous changes in soil physical, chemical and biological characteristics. This characteristic allows them to capture slight changes in soil quality and, therefore, have a great potential for early diagnoses.

According to Doran and Safley (1997) and Beare et al. (1997), in order for ISQ's to be useful for a wide variety of users, including farmers, extension agents, researchers and policies makers, they should:

- Be relatively easy and practical, so that farmers, extension agents, specialists and researchers can use them under field conditions.

- Be relatively accurate and easy to interpret.

- Be relatively economic.

- Be sensitive enough to reflect the impact of soil management practices and climate on long term changes, but not so sensitive, that can be affected by short-term metereological patterns.

- Integrate soil physical, chemical and biological properties and processes, and serve as basic inputs for the estimation of soil properties or functions that are more difficult to be directly measured.

- Have a good correlation with ecosystem processes, with plant and animal productivity, and with soil health.

- Be, ideally, components of the existing soil data bases.

Selecting a suitable set of ISQ, and developing its use as a monitoring system (Soil Quality Monitoring System, SQMS), can be captured in the following figure (modified from Beare et al., 1997):

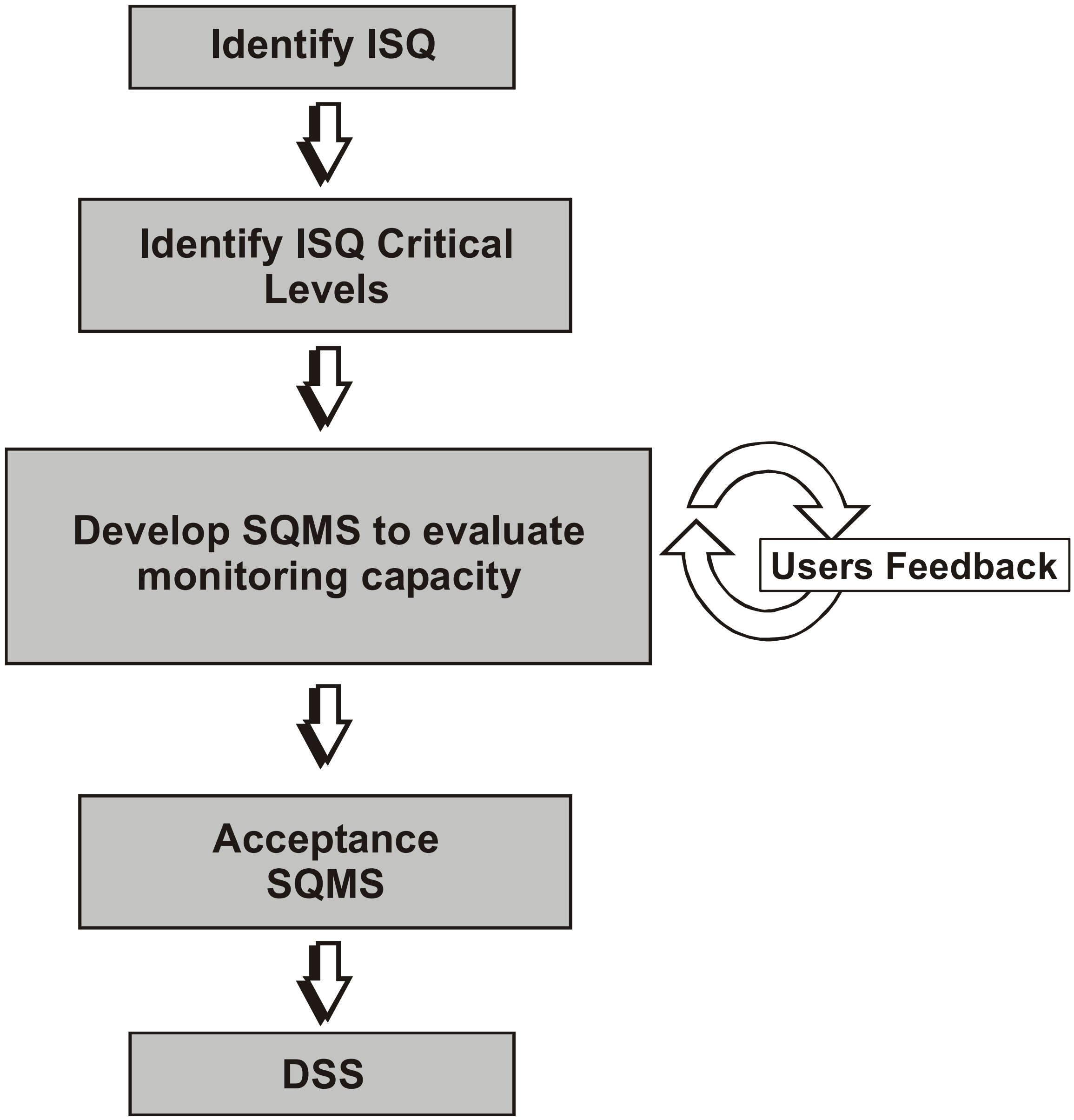


Fig.1 Process leading to the development of a Soil Quality Monitoring System

Suitable ISQ are identified from the local and technical knowledge base and critical levels defined. This phase is followed by the definition of guidelines to establish a Soil Quality Monitoring System (SQMS), along with interpretation information, as well as reaching an agreement about the suitable ISQ for the relevant conditions. User feedback is very important at this stage as it will provide the grounds for acceptance of the SQMS for soil quality diagnosis and monitoring. Once the SQMS is fully accepted by users it becomes part of the Decision Support System for Natural Resource Management

This "guide" is mainly focused on the first phase of this process; i.e.: identifying soil quality indicators that can be used by farmers, extension officers, NGO's, technicians, researchers and educators.

The ISQ will help in identifying the main soil biophysical limitations of the agricultural system under study. The most sensitive and robust ISQs selected for the soil constraints identified can then be incorporated into a Soil Quality Monitoring System (SQMS), and should include basic parameters such as bulk density, pH, effective rooting depth, water content, soil temperature, total C and electrical conductivity (Doran and Parkin, 1994).

Since our objective is to develop a SQMS for the land users, local indicators of soil quality must be included in the monitoring system. The combination of native and scientific parameters varies according to the monitoring objectives; e.g.: if they are farmers, extension agents or policies makers. It is likely that integrative ISQ might be more useful to land users, than a measurement of, for example, soil available P, since many indicators used by the farmers are also of the integrative type; for instance, soil color, soil structure, crop yield, presence of specific weed species. Attention should be paid to the inclusion of indicators that can be used while progressively increasing the scale at which results are applied (e.g. from plot to field and farm level, up to watershed, region and nation level). Some examples of such indicators might be crop yield and yield trends, land cover, land use intensity and nutrient balances (Pieri et al., 1995). More recently, Defoer and Budelman (2000) have proposed the use of resource and nutrient flows at farm scale to assess land use sustainability and local variation usually missed in studies at higher levels of aggregation (i.e. region, country).

1.4 Scaling up: from plot scale to landscape scale

The need to avoid site specificity and make local results and findings valid for wider regions requires interactive research activities carried out simultaneously at different spatial scales (Fig.2). Plot scale studies should detect soil quality changes generated by new cropping systems and the impact of the adoption of such cropping systems, in turn, should be detectable at the landscape scale (Barrios, 1998).

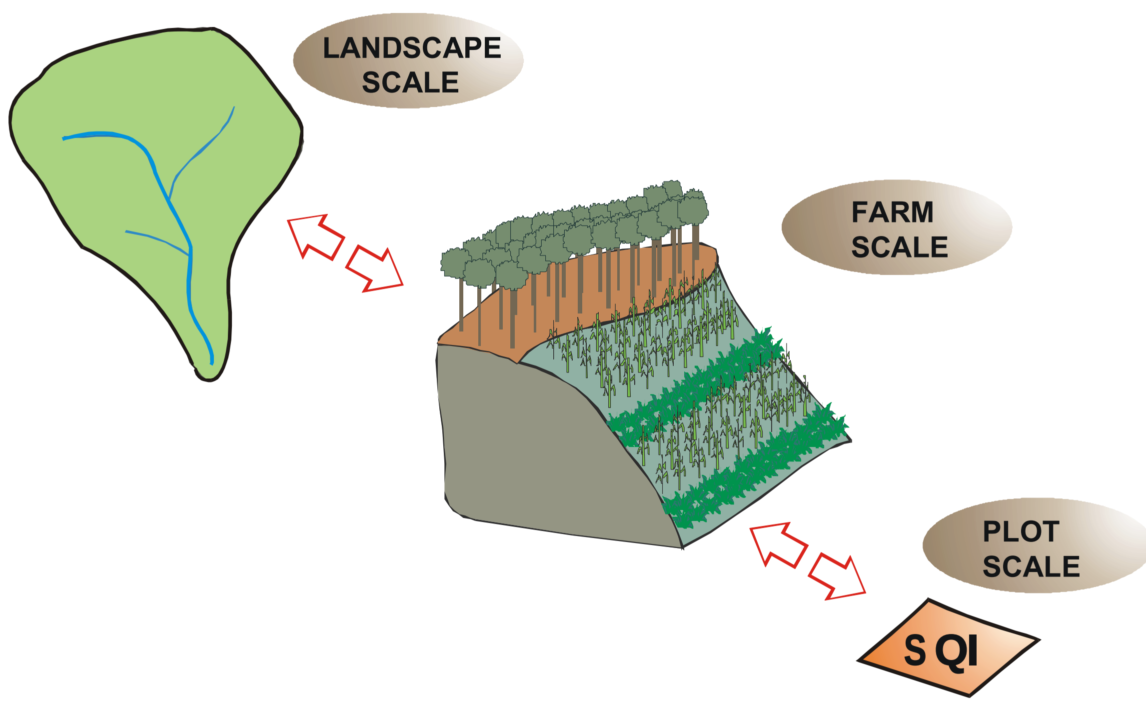


Fig.2 Relationships among processes simultaneously ocurring at different spatial scales (Barrios, 1998)

Watersheds are useful as landscape study units because they have clearly defined physical boundaries and the impact of land use changes can be measured in the water. Water quality (i.e. contents of pesticides, nitrates, etc.) becomes an integrative measure of soil use and management by cropping systems within the watershed. The integrative nature of this measure permits the establishment of a baseline associated with the current land use in the watershed. Therefore, it becomes possible to assess the impact of adoption of new cropping systems in the watershed by changes in selected water parameters in comparison with baseline levels (Fig.3).

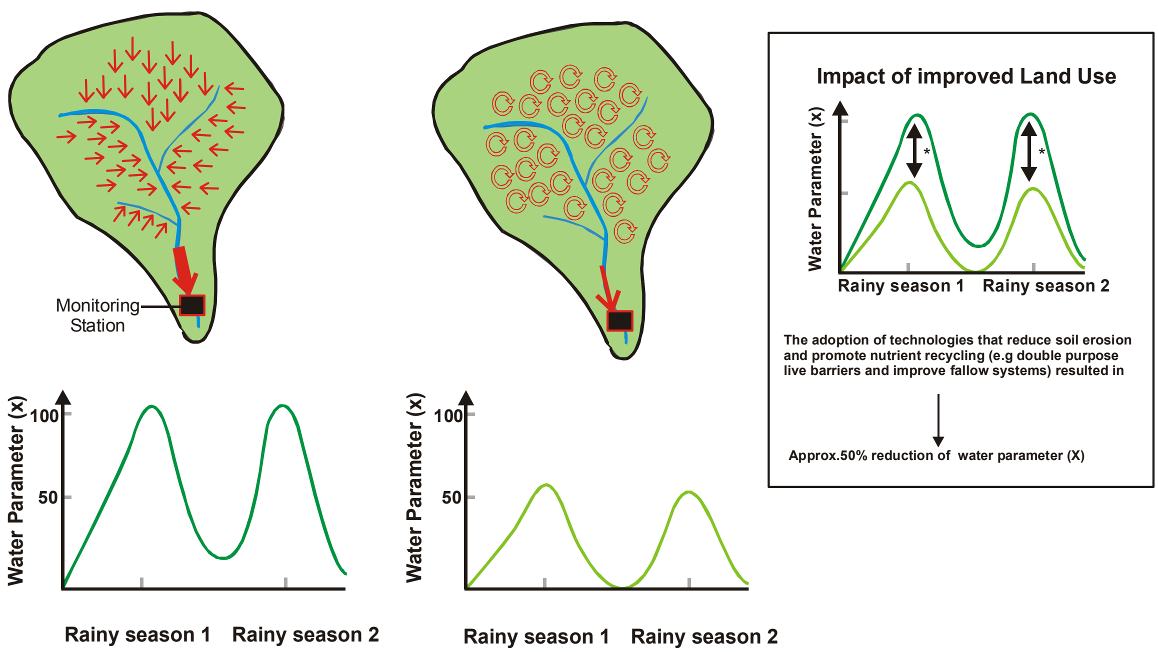


Fig.3 Detection of Nutrient losses in a Watershed under Conventional and Improved Management and a Measure of its Impact (Barrios, 1998)

This approach is based on the notion that soil changes generated by cropping systems within a watershed can be captured by ISQ but the impact of such land use in the watershed as a whole can be detected through water quality monitoring. The challenge consists in establishing robust correlations between

ISQ and indicators of water quality as a way to evaluate soil health at the watershed scale. These concepts will be discussed in further detail in a forthcoming training manual of this series dealing with Local Indicators of Water Quality.

1.5 Soil quality indicators for Eastern Africa

The Eastern African region houses a large proportion of rural poverty which contributes to food production through agricultural systems of low productivity and limited nutrient use efficiency. One of the main objectives of the methodological instruments for decision making in natural resource management is the application of participatory approaches for the ecologically sound intensification of agricultural systems through an efficient and conservative use of the natural resources.

The sustainable use of the soil is of fundamental importance to improve farmers' quality of life.This is particularly relevant for those located in the densely populated highlands where high soil erosion rates, as a consequence of land clearance and the lack of suitable soil conservation methods, is considered to be an important factor accounting for such degradation of arable land. Despite the vast amount of financial resources and efforts made to preserve natural resources, inappropriate soil management continues to be a concern, and has been emphasized by rural development projects.

During the field phase of many development projects, it is very common that several "sustainable" soil management practices are presented to farmers as a set of "solutions" to be implemented in their farms. It is only on few occasions, however, that recommendations emerge as a direct consequence of the community's needs and perceptions about the management of their natural resources. Within this context, the farmer's knowledge about natural resource management is not considered important and is rarely integrated into the development programs.

According to the experience of the researchers who developed this guide, one of the great limitations to farmer participation in the development of sustainable management practices, is the inefficient communication between technicians and farmers. In particular, the lack of a common language and methodological instruments allowing the systematic identification of farmer's knowledge about the soil, and its integration with the technical knowledge derived from soils sciences. This guide is an effort to provide ways to achieve a greater farmer participation in the solution of problems related to natural resource management.

2. OBJECTIVES

- After using this methodological guide:

- Participants will understand the importance of local knowledge in natural resource management.

- Participants will be able to use participatory methodologies to identify and prioritize local indicators of soil quality.

- Participants will be able to integrate local and technical indicators of soil quality.

Expected Results

Through the application of the methodology described in this guide participants should be able to use participatory approaches to include local knowledge, demand and relevance into their natural resource management research and development activities. In addition, participants should be able to use soil quality indicators to diagnose soil constraints, guide the choice of potential soil management strategies and also monitor the impact of such strategies to address identified constraints.

3.To the Users of this Guide

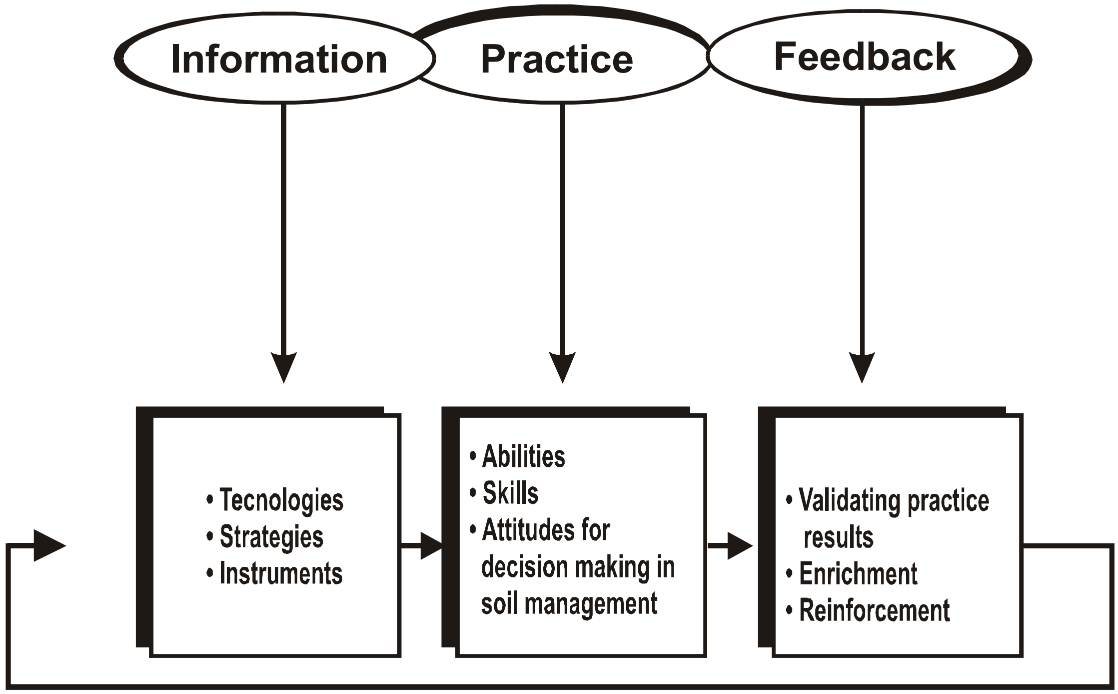
This Guide is the Eastern Africa Version of a previous one published in Spanish under the title "Participatory Method to Identify and Classify Local Indicators of Soil Quality" which has been widely used in Latin America as one of a series of nine guides called “Methodological Tools for Decision Making in Natural Resource Management”.

Two different types of audiences are addressed in this publication. The first is made up of professionals and technicians working with public and private sector agencies and institutions devoted to research, development and training activities in natural resources management. These users may take advantage of the guide to support planning, implementation, follow-up and evaluation of soil management initiatives. It is expected that, once trained in the application of this participatory methodology, they can later disseminate it among hundreds of professionals, technicians and producers, who will in turn adapt it to local soil management projects.

A second group of users is made up of the people from the African watersheds who are the users of natural resources. The local communities, with the support of extension agents from non-governmental organizations and State agencies, shall be able to use the methods and strategies offered here, in order to have an active participation in the management and conservation of soils.

This material has also proved to be very useful for teachers in faculties and schools of agrarian, environmental and natural resources sciences, who can incorporate it to the curricula or to their course programs as they find it suitable.

4. LEARNING MODEL



The guide on local indicators of soil quality contains three major components: (a) the introductory part. It comprises the introduction, the specification of objectives, the description of users, the general structure of the guide, and a series of opening questions followed by answers that the instructor may use to conduct an open discussion with participants about all major aspects of the guide; (b) the body of the guide that contains six sections or instructional sequences that will be later described, and (c) a series of instruments for the trainers to conduct the evaluation activities. Evaluation is made of the participants to assess their intellectual achievement. An evaluation of the trainers' performance is also conducted by the participants to provide them with feedback on their role as facilitators. An evaluation of the training event (workshop) is also carried out.

The learning model used to organize each section follows three sequential steps: information, practice and feedback. This model has proved to be useful in facilitating the learning process. It is geared to learn through practical experiences supported by scientific information and accompanied by peer and instructor feedback. Each learning sequence looks very much like a chapter, but it has a learning structure that contains the following components:

An introductory statement

The learning objectives that the instructor shares with participants at the beginning of each section

A structure of the section that explains all of its major components

A few introductory questions to be used as "ice-brakers" between the audience and the instructor

The scientific information to be shared by the instructor with the participants

One or more practical exercises to be performed by participants sometimes accompanied by a group of farmers. This guide offers a very reach experience in what is called "the soils fair", where participants accompanied by local farmers carry out different analyses of soil samples. These analyses altogether are the bases for a diagnosis of the quality of soils in a given area, and facilitate the formulation of recommendations by the technical personnel to the farmers.

The feedback sheets to help instructors conduct a feedback session on the results of practical exercises.

A summary of the section followed by the bibliography and

The originals for the overhead transparencies the instructor may copy to use as teacher aids.

In summary, this model proposes a training scheme in which information inputs resulting from field research serve as the raw material for developing capacities, skills and attitudes required by the final users of this particular instrument on local indicators of soil quality, to make appropriate decisions related to the management of soils. Feedback information constitutes the final part of each section. It provides an opportunity for instructor and participants to carry out a conceptual and practical synthesis of each aspect under study.

Practical exercises are the main learning axle. They intend to simulate real field experiences. Through these exercises, participants learn to use the instruments, the difficulties emerging from their application, as well as their advantages and opportunities within various decision making environments.

The exercises included in the guide were validated in Africa, after a large range of previous experiences in Honduran, Nicaraguan and Colombian micro-watersheds. Nevertheless, the instructors in other countries and regions are to extract from their own research projects and field experiences, examples and cases to adjust the content and exercises for use in their own contexts.

Uses and adaptations

This guide is by no means a straight jacket to fit the needs of all those who work on soil management. It provides a participatory scheme to approach the problems farmers face in their production activities. Therefore, the users may introduce changes in part or in the whole guide so that the final instrument they use to promote sound soil management practices or to support training activities, is a result of interaction with farmers, experimentation and validation on the field.

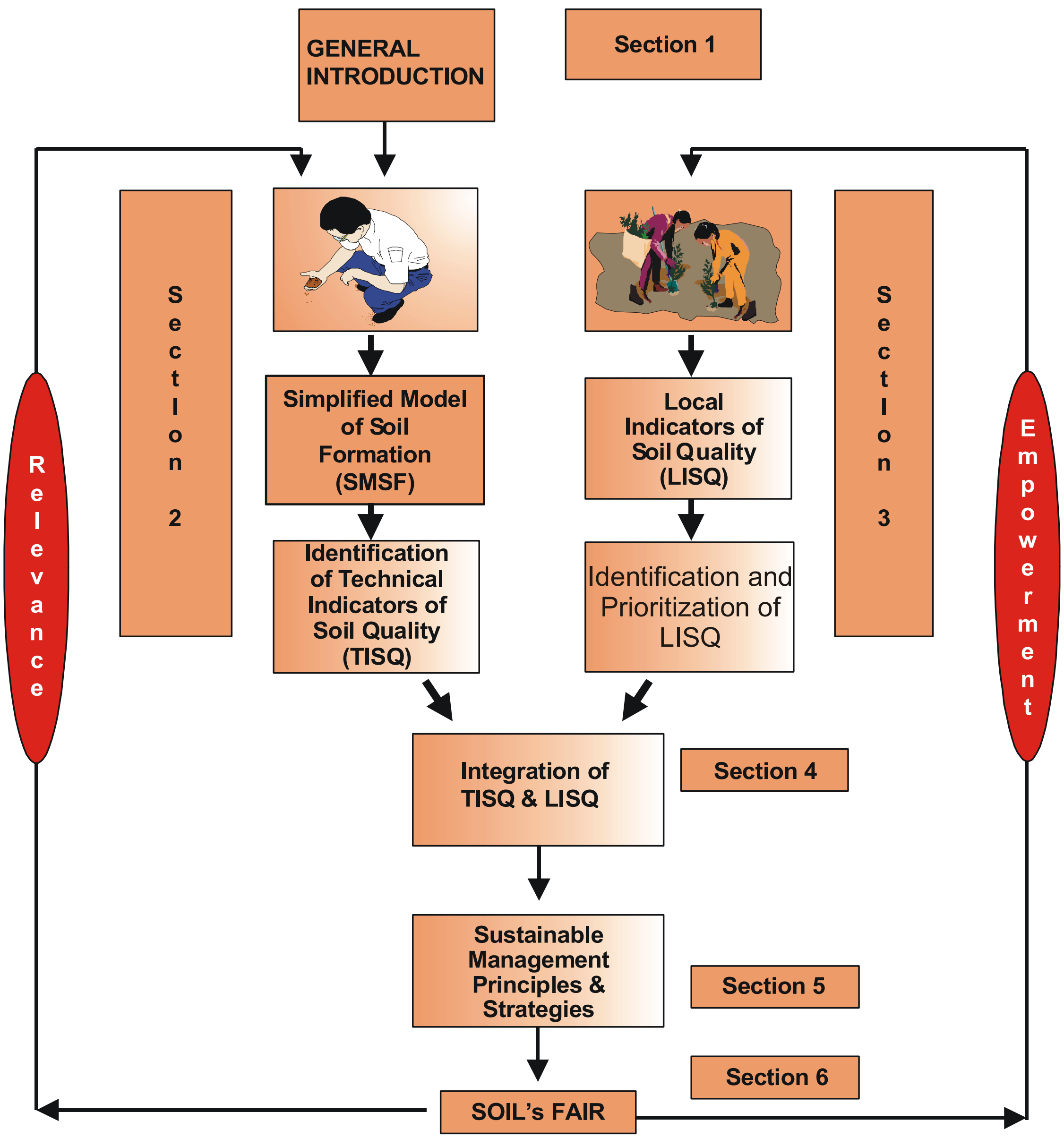
The appendices at the end of the text, designed to help participants deepen in some aspects presented in several sections as well as the exercises, can be adapted or substituted by practices on problems relevant to the local audiences. We also recommend including local, regional or national data both in the feedback sessions and in the appendices. The evaluation instruments (posttest, evaluation of the instructor, evaluation of the event, evaluation of the guide, etc.) can also be adapted to the style in which these activities are carried out in each country.

Finally, an idea to be emphasized is the importance of practice as a learning tool. Therefore, the training sessions are to be assigned the time necessary for participants to have the opportunity to develop the abilities, skills and attitudes expressed in the learning objectives. This way we can improve the chances that training has the expected impact on those who make decisions in soil management practices.

5. STRUCTURE OF THE GUIDE

The following scheme shows the various components of the guide, as well as their mutual relationships.

Structure of the Guide



This training guide is made up of six sections: The first section provides a general introduction about the management of the soil resource in the African context and the ISQ. The second section presents a technical conception of the soil through a Simplified Model of Soil Formation (SMSF) and introduces the technical indicators of soil quality (TISQ). The third section describes the methodology to identify and prioritize local indicators of soil quality (LISQ). The fourth section provides a methodology to construct an effective channel of communication by finding equivalences between TISQ and LISQ which permit a better Extension officier, NGO - farmer communication. The fifth section is concerned with management principles behind potential strategies to solve constraints at the short, medium and long term. The sixth section is devoted to the Soil's Fair which provides a practical exercise to highlight the complementary nature of technical and local indicators of soil quality.

One clear outcome of using this methodological approach is that technical research and development activities would have local relevance as they are related to local demands and perceptions and this will likely increase their adoption rate. On the other hand, there should also be positive impacts on the local knowledge base and community empowerment, as it provides a way for it to be widely understood, assessed and utilized, as well as by building an effective communication channel together.

The approach summarized in the preceeding sections provides the tools to conduct a technical-local classification of the soil, based on modifiable and permanent soil properties, which has the flexibility to work in the plot/farm/landscape (watershed) continuum, while also having the potential to take the stakeholder groups and gender issues dimensions into consideration. This guide then provides a valuable tool to evaluate the impact of the land use change across various spatial scales and social actors.

6. Opening Questions

Self-evaluation

Orientation for the Instructor

The instructor that employs a training participatory methodology starts with a small questionnaire allowing the participants to: (a) be acquainted with the main topics to be approached in the guide; and (b) explore what they know about such topics.

To administer the self-evaluation:

Give each participant or small group of participants the questions listed below.
Give 20 minutes to answer.
Share with the participants the responses given in the feedback information
Allow a brief discussion on each question, without going to deep into each topic.

Questions

1. What is the soil for you?

2. What do you think is the importance of the soil as a natural resource?

3. Could you mention some soil properties and indicate how they are useful to determine its quality?

4. ¿ Could you mention some soil properties that could be modified through management?

5. Which are some of the non-modifiable properties of soils?

6. What methods do you know to evaluate the quality of a soil?

Self-evaluation Feedback information

Orientations for the Instructor

Discuss each question with the participants; to do this, you can ask three participants to give their opinion on each question, before the instructor presents the right answer.

Consider that the responses can be very open; therefore, every opinion is very valuable and must be focused on the topics to be dealt with. Also, at the end, make a summary of all the responses, having as the main objective, to induce the participants to what is expected to be developed with the objectives and outcomes of the present guide.

Sample Answers

To question 1

The soil is a product from rock fragmentation into very fine particles, combined with organic materials that constitute an adequate medium for plants to grow and favorable for the biologic activity.

To question 2

The soil constitutes the basis for fiber and food production on earth and limits the impact of human activities to the environment.

To question 3

Soils have properties that distinguish them from rocks. Such properties can be divided into external and internal properties. The external properties refer to the characteristics of the surrounding landscape in which the soil has been formed (e.g. slope, climate, organisms, time). The internal properties refer to soil profile properties, which are divided among physical, chemical and biological properties. Some soil physical properties are: texture, structure and color. Some of the chemical properties are pH (acidity or alkalinity), organic matter content and the availability of nutrients required by plants. The biological properties are related to the activity of the soil organisms. Soil quality is a relative concept involving the evaluation both of the external and the internal characteristics. For example: a good quality soil in a highland area might be not such a good soil when compared with a good soil in a valley bottom area.

To question 4

Organic matter, pH, nutrient content, presence of organisms.

To question 5

Slope, climate, texture

To question 6

The evaluation of soil quality starts by identifying soil properties which are constraining agricultural production or other potential land use and then monitoring the benefit or not of management practices designed to correct such constraints.

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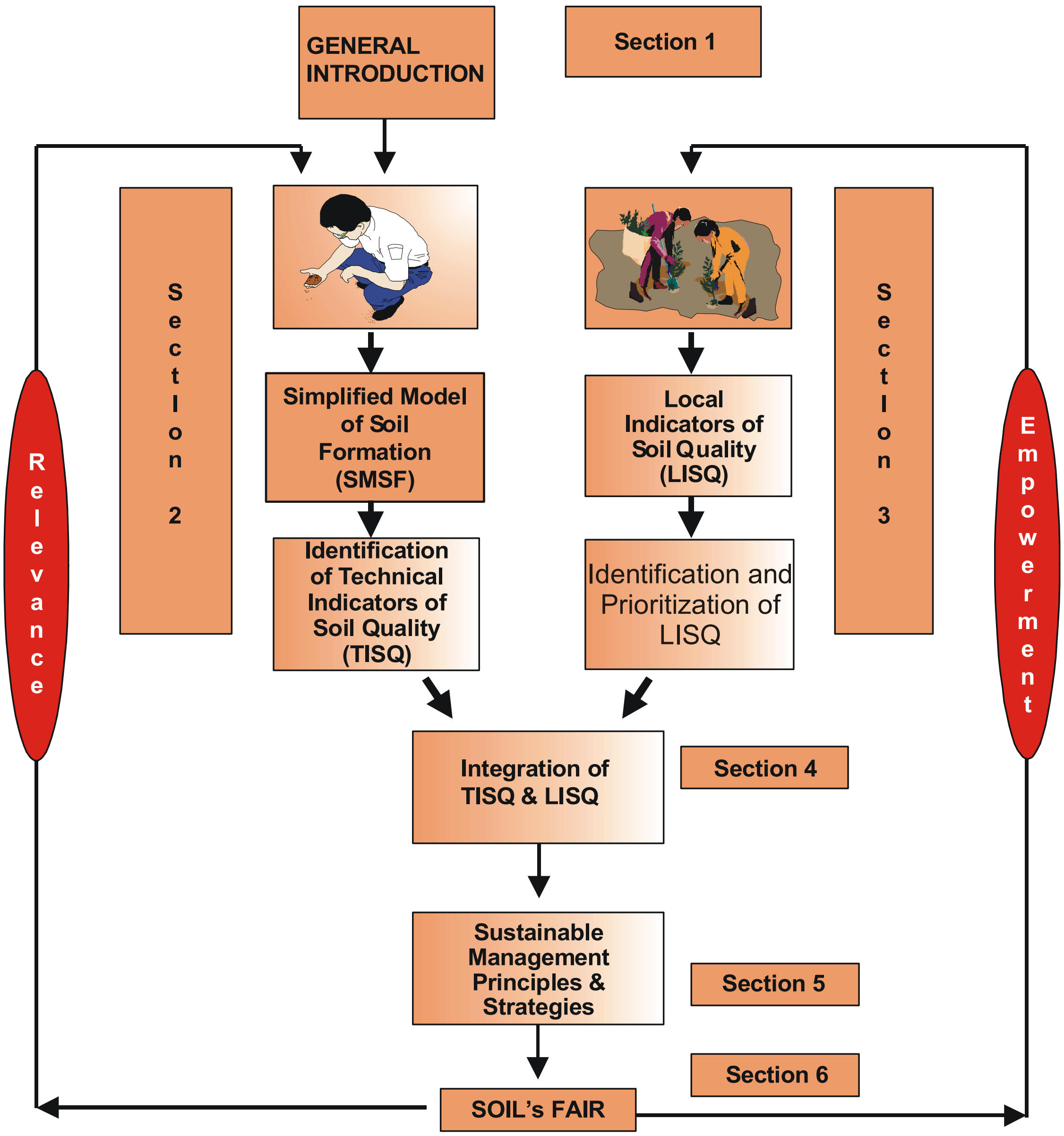
Originals for Overheads

Structure of the Guide



General Objective

Participants will be able to integrate local indicators of soil quality with the diagnostic properties of soils.

Specific Objectives

Differentiate factors and processes that take part in soil formation, using a simplified model.

Describe soil formation factors and processes.

Identify and prioritize local indicators of soil quality in a given area .

Specific Objectives

To identify soil physical properties (texture, colour, structure, depth), chemical properties (pH, nutrient content, organic matter) and biological (organisms) that are related to local indicators of soil quality, as they are prioritized by a community.

To match local indicators soil quality with the diagnostic properties soils.

Self Evaluation

What is a good definition for soil?

How important is soil as a natural resource?
Could you mention a few soil properties and describe their use as soil quality indicators?

Can you mention a few properties of soil that can be modified?

Do you know of properties of soils that can not be modified?

Do you know any methods that are good to evaluate the quality of soils?

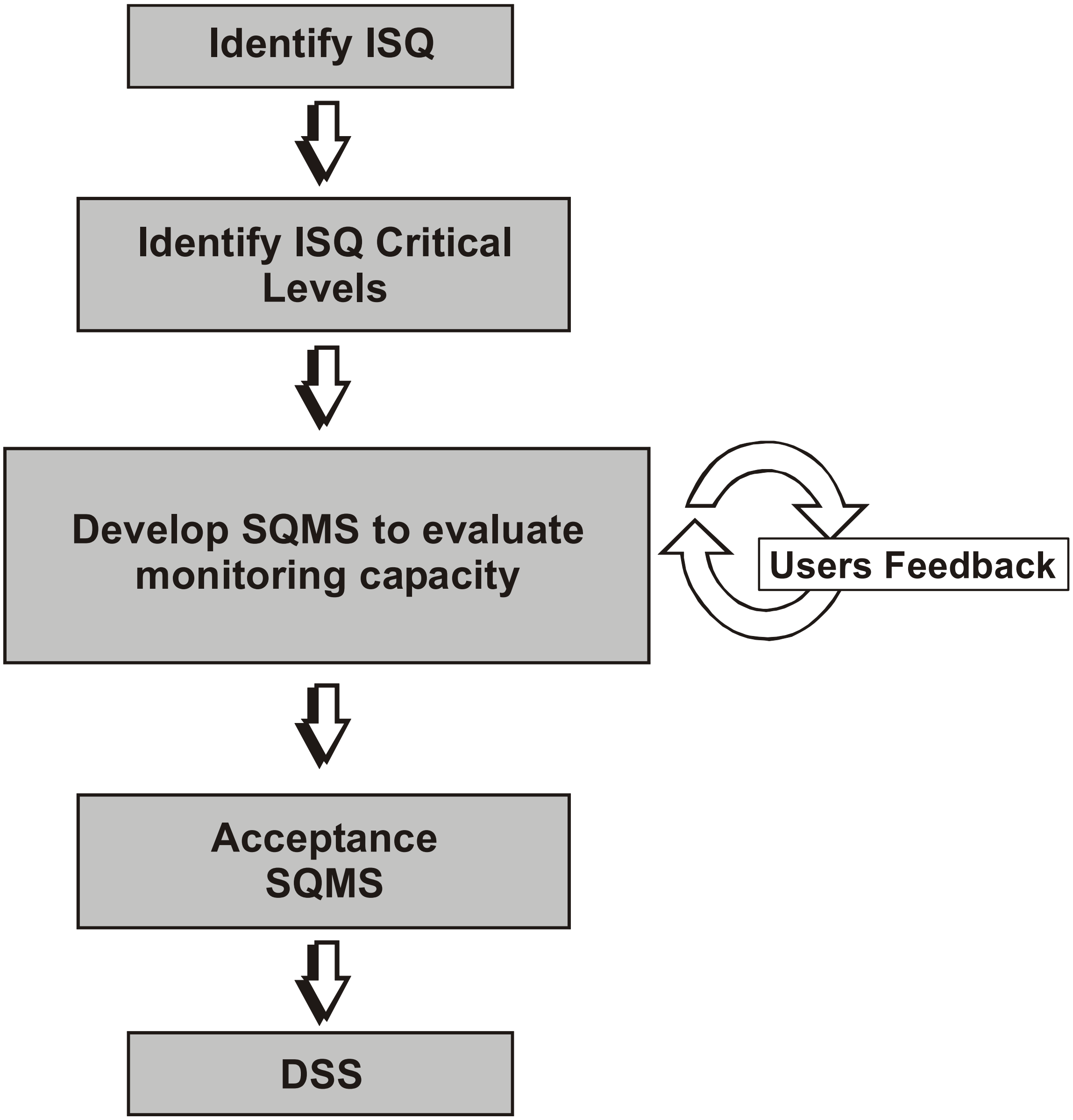
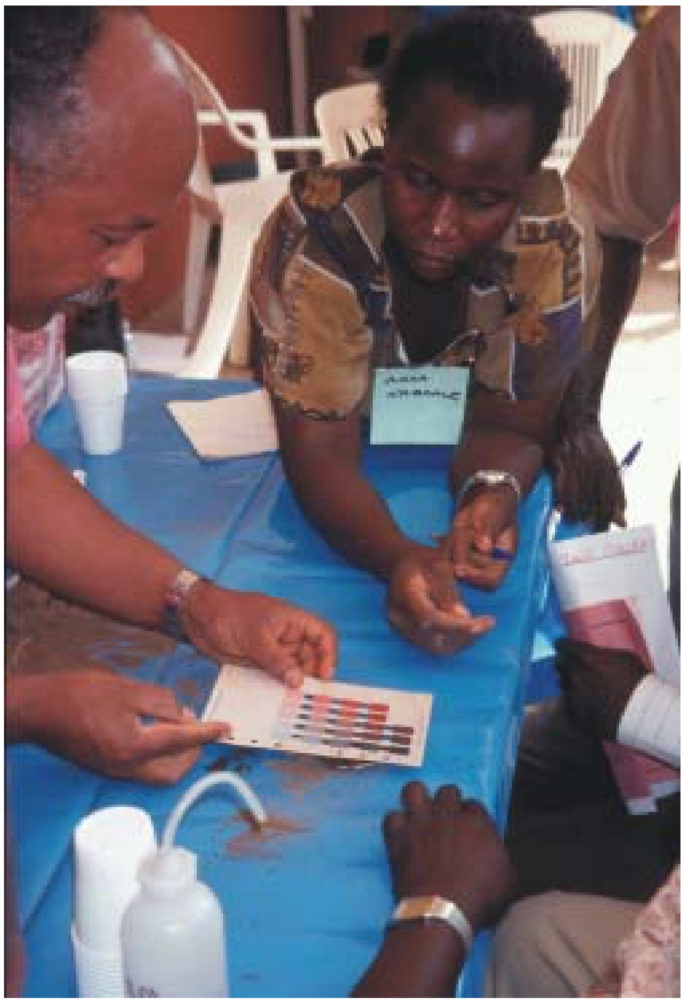


Fig.1 Process leading to the development of a Soil Quality Monitoring System

SECTION 2

Technical Indicators of Soil Quality



he soil shall continue to be the most important natural resource for mankind, who shall always need food and fibers to survive.

Section 2: Technical Indicators of Soil Quality

2.1 Introduction

Soils are natural bodies on the earth's surface consisting of solid, liquid, gaseous and biotic components in variable combinations. The variations are generated by natural and human-led processes, and affect the quality of the soil. Assessment of the quality of the soil varies depending on the appreciation of its various users. According to Brady (1974), the evaluation of modern concepts on soil involves two basic sources of knowledge. First, the practical knowledge accumulated over time, and which constituted the only information available before the advent of modern science. This indigenous knowledge has not been sufficiently appreciated, although it is a valuable alternative source of information about soils and their management. Second is the knowledge acquired through the application of the scientific methods, through edaphology (the study of soil properties and their relationship to the function of the soil), and pedology or soil classification.

The manual promotes the knowledge about agricultural use of the soil through both technical terms and the farmer's experiences, so that the producer and the technician share their knowledge, understand and analyze the origin, evolution and distribution of soils. In this section of the manual, a theoretical framework is presented, using a simplified model of soil formation that applies modern concepts of pedology and edaphology.

2.1.1 Objectives

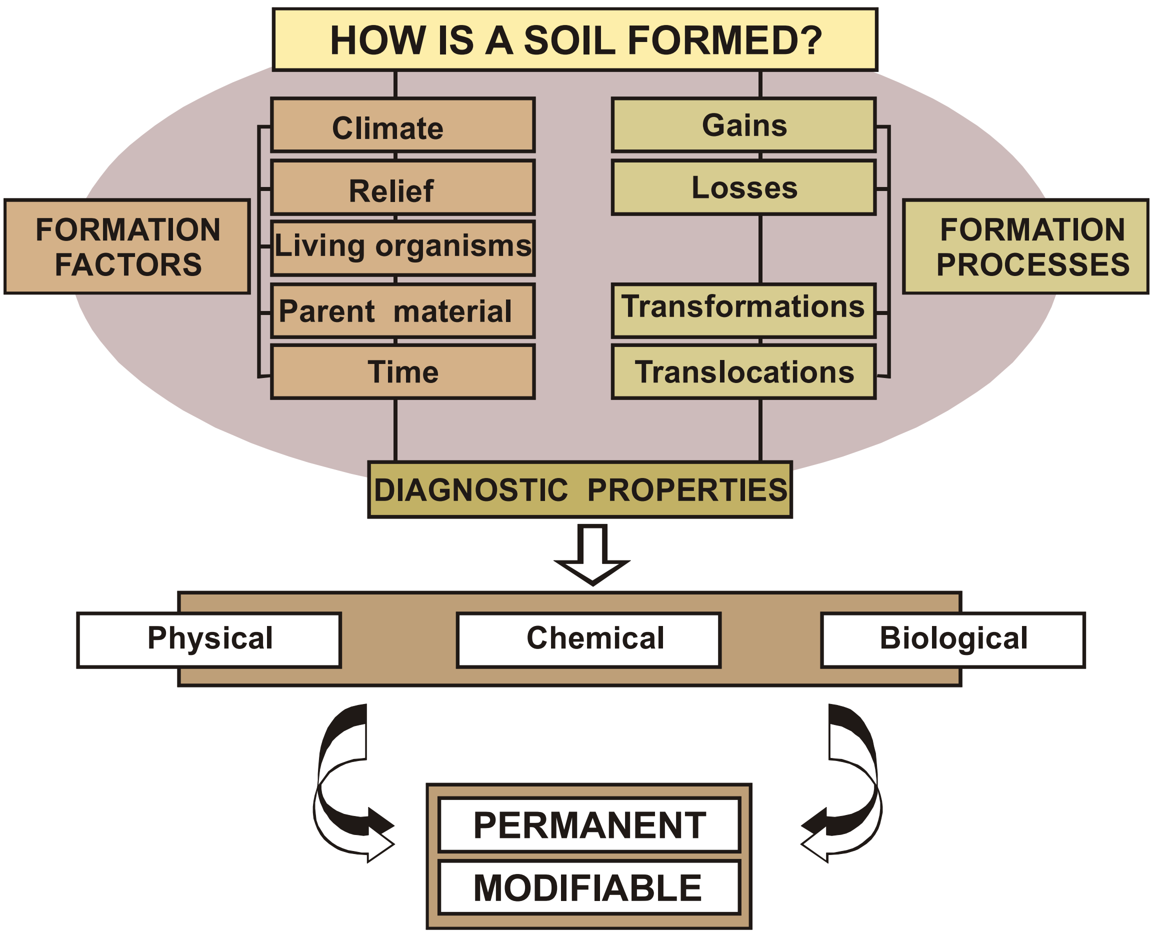
At the end of this section the trainees will be able to,

- Differentiate among the various soil formation factors and processes through the Simplified Model of Soil Formation

- Describe the factors and processes affecting the formation of a soil.

- Identify soil physical, chemical and biological properties, and differentiate between those that are permanent and modifiable.

2.1. 2 Section Structure



2.1.3 Orientating Questions

1. How do soils affect our daily lives?

2. How is a soil formed?

3. What is a soil formation factor?

4. What is a soil formation process?

5. What is a soil permanent property, and a modifiable property?

2.2 Importance of Soil

Soil is important as a natural resource and medium for plant growth because it,

- constitutes the basis for renewable natural resources (flora and fauna)
- provides food for the population, and constitutes the basic resource for the survival of the poorest population
- is a filter of wastes from human activities, as well as a water reservoir for crops
- is not a renewable natural resource.

As a medium for plant growth it:

- serves to anchor plant roots
- supplies water to the plants
- provides air for plant root respiration
- provides minerals for plant nutrition

2.3 Factors and Processes of Soil Formation

As soils naturally develop on the landscape, distinct "soil layers" called horizons may form. The horizons differ from each other in their physical, chemical and biological properties. Soil formation is the evolution of soil horizons through various processes and several soil-forming factors. An understanding of soil formation processes is useful in interpreting soils for specific uses.

2.3.1 Soil-forming factors

A soil-forming factor is an element, element part or agent favouring a given outcome. In this case, soil formation factors are those elements participating as soil development-causing agents; they are climate, parent material, relief, living organisms and time.

Put simply, the type of soil developed depends on the period a parent material on a specific topography is exposed to the effects of climate and living organisms. For instance: in an arid, cold climate with an uneven topography, the evolution of the soil is determined by the relief, moisture availability and low temperatures resulting in a less favourable substrate for the development of organisms, including plants and animals. Another example is of soils formed on flat relief where the main characteristic favouring soil evolution is the tendency to accumulate sediments from the surrounding slopes, as a result of erosive processes.

Climate

Climate is considered to be the most important factor of soil formation and evolution, with temperature and rainfall being the most influential components. Their effects are closely related to the control of physical, chemical and biological (especially organic matter production and decomposition) process rates. In general terms, it is considered that if the climate is very variable and contrasting, it becomes a factor of utmost influence, and tends to determine the formation of a soil.

Relief

Relief is sometimes referred to as topography. It contributes to soil formation largely through its influence on soil erosion and drainage (these accelerate or delay the soil formation process). For example, soil profiles on steep slopes are shallow because of the high rates of soil erosion. On the other hand, drainage on slopes and uplands is good and allows faster formation of soils than in lowlands where poor soil drainage will result in slow soil formation and high organic matter accumulation due to slower decomposition.

Parent material

This is the substrate or materials from which soils develop. Approximately 99% of the soils have developed from mineral parent material that was derived from the weathering of bedrock. The rest have developed from organic deposits, mainly of plant origin, formed in swamps and marshes. Therefore, parent materials differ in their composition and resistance to degradation.

Parent materials have influence on the soil physical and chemical characteristics, but the best correlation is with texture. Those materials with high quartz content tend to weather into very sandy soils while basic rocks and fine grained sediments weather into fine textured soils. But the same type of parent material can give rise to different soils depending upon the nature of the other factors, particularly climate. For example, basalt may develop into a highly weathered red soil (Ferralsol) in the humid tropics or a black cotton soil (Vertisol) in the semi-arid tropics.

Living organisms

Every organism living on earth has the potential to affect development of soils. Those with direct influence can be grouped as higher plants, vertebrates, macro-organisms and micro-organisms. The major contribution of higher plants is through the addition of organic matter, which varies in amount and quality according to plant communities. The roots of higher plants may bind and prevent erosion, physically disintegrate solid materials, extract and recycle nutrients within horizons, and leave a network of passages after death and decay. Some vertebrates, including rabbits and moles, burrow into and mix soils. Macro and micro-organisms exert a strong influence on soil formation due to the role they play in organic matter decomposition, nutrient redistribution and cycling, and the transformation of such nutrients into forms necessary for plant nutrition.

Time

The extent to which the other soil-forming factors express their effects is a function of the time during which they have operated. In general, the soils developed on alluvial deposits have not had enough time to evolve, as is the case of soils developed in other landscapes. Older soils, like those in tropical humid areas, generally have deeper soil profiles, are more weathered, contain thick horizons and have lost their plant nutrients due to leaching.

2.3.2 Soil-forming processes

These are conditioning processes that might cause the same group of soil-forming factors to generate different types of soils from a given parent material. The formation of soil horizons is a result of differential gains, losses, transformations and translocations (these constitute soil-forming processes) that occur over time within the profile of the parent material; these are natural and/or human-led processes (see box).

Soils gain from all types of depositions, both beneficial (e.g. mineral fertilisers) and detrimental (e.g. toxic wastes) to their development. The depositions may be in liquid, gaseous or solid forms, and mineral or biological in nature. There is a relationship between the gain and loss processes such that agents affecting one of these processes affect the other. For example, wind and water erode (loss) and deposit (gain) soil materials. Transformation refers to the modification of soil mineral and organic fractions through biophysical and chemical processes, while translocation is a process involving physical movement of soil constituents in the profile, such as clay illuviation.

Examples of natural and human-led processes

Natural processes

Movement of soil particles and nutrients down a slope through water erosion and deposition

Wind erosion and dust deposition

Fertility enrichment and depletion in the soil due to water movement

Movement of clays within soil

Uptake of nutrients by deep-rooting species

Biological nitrogen fixation

Mycorrhizal phosphorus accumulation

Human-led processes

Importing mineral and organic fertilisers

Transporting manures and residues to fields

Transporting farm products to homes, towns and other settlement areas

Burning vegetation and residues

2.4 Properties of Indicators of Soil Quality

Soil quality indicators relate to the fitness of use and ease of management of soils, and may be regarded as pre-requisites of soil fertility. Their properties are physical, chemical and biological in nature.

2.4.1 Physical properties

These are properties that add to the appearance and feel of the soil. By observing soil colour, for example, one may estimate its organic matter and iron content, and drainage. By feeling the soil, one may estimate the type and size of the particles present. Soil physical properties are largely controlled by the relative abundance of the different sized soil particles, and may be grouped into two:

- Primary properties: texture, structure, colour, consistency, density & temperature.

- Derived properties: porosity, air retention capacity, water retention capacity, compaction and effective depth.

Texture

The weathering of rocks and minerals results in a range in the size of particles; from stones through gravel, sand, silt and clay. Soil texture refers to the relative proportion of sand, silt and clay in the soil. The texture is responsible for the potential fertility, aeration, permeability, effective depth and moisture characteristics of soils. For example, a sandy soil will absorb and release water very easily, i.e. permit more rapid water intake or filtration. It also has lesser capacity for nutrient adsorption. A clay soil retains water and nutrients for long, but is not well aerated. A loam soil falls in between the sandy and clay soil and is suitable for plant growth.

Structure

Soil particles are typically arranged into secondary particles called aggregates. The shape, size and arrangement of the aggregates define the soil structure. Structure formation is influenced by the composition of the organic matter, iron oxides and hydroxides, and clay fractions. It affects water intake, drainage, aeration and root development. Soil structure, especially in the topsoil, can be changed by ploughing or cultivation.

Colour

Soil colour is, perhaps, the most obvious soil property, yet it has little actual effect on the soil. Soil colours vary from black to nearly white, and from red to yellow. They are an indirect measure of other important soil characteristics such as organic matter, temperature, moisture, and parent material.

Consistency

Consistency is the resistance of the soil to deformation under specific moisture conditions. It is determined by the cohesive and adhesive properties of the soil mass. It is a soil quality indicator closely related to the type of clay in the soil, and has noticeable influence on soil tilth and depth of rooting.

Density

This refers to the mass (weight) per unit volume of soil. Distinction is made between particle and bulk density. The former considers only volume of solid soil particles while the latter is the volume of solid and enclosed pore space. Soils differ in density because of their differences in texture, types of clay minerals and amount of organic matter. Properties such as water retention and gaseous exchange are linked to density, as it is related to the amount and shape of the pores.

Temperature

Soil temperature is a reflection of the solar energy reaching the surface of the earth. The soil chemical processes and activities of soil organisms are temperature dependent. In the tropics, very high or very low temperatures, as well as sudden temperature changes during the daytime influence the rate of soil formation.

Pore space

Pore space, also known as porosity, is the portion of the soil not occupied by solid soil particles, it is occupied by air and water. The arrangement of solid soil particles determines the amount of pore space. It is considered that soils have about 50% porosity which is important for water movement and retention, gas diffusion, root penetration, temperature regulation and soil biological activity. Pore spaces occur in soils in macro (large) and micro (small) pores.

Air retention capacity

This soil property is determined by the amount of macro-pores (>0.05 mm) in the porous space, facilitating the movement of the gases used or released during the activities of soil living organisms.

Water holding capacity

This relates to the amount of water "available to the plant" that a soil can hold. It is the difference between soil retained water, available to be used by the plants (field capacity) and the water retained but not available for the plants (permanent wilting point). This property is related to the nature of the surfaces and pores of the soil. Micro pores retain or hold soil moisture.

Compaction

Compaction is the result of altering the soil porosity caused by the long-term effects of cropping and tillage. Compaction decreases the total pore space and increases bulk density. Ploughing and other tillage operations usually increase pore space and decrease bulk density. Farm machinery have great potential to compact soil.

Effective soil depth

This indicator refers to the depth that roots can reach without confronting any physical or chemical obstacles. Deep soils allow penetration of roots downwards and sideways, and offer greater potential of the soil supplying the plant with the required nutrients and water. It is, therefore, one of the most important properties that determine the potential of the soil for crop production.

2.4.2 Chemical properties

Soil chemical properties indicate the levels of the soil organic and inorganic components, and their influence on crop production and productivity. The most important indicators are pH, organic matter content and cation exchange capacity.

pH

Soil pH is the measure of the quantity of acid or alkali in the soil. A pH scale that extends from 0 to 14 indicates this soil property. The pH values below 7 are acidic and those above 7 are basic or alkaline. Soil that has a pH of 7 is a neutral soil. Soil pH has a direct influence on physical, chemical (nutrient availability) and biological (microbial activity) characteristics that affect crop growth. The pH of most agricultural soils ranges from 4.5 to 8.5. Alkali soils have pH values above 8.5.

Soil organic matter

Soil organic matter consists of roots, plant residues and soil organisms in various stages of decomposition. It has great impact upon the chemical, physical and biological properties of the soil. Organic matter in the soil gives the soil good structure, and enables the soil to absorb water and retain nutrients. It also facilitates the growth and life of the soil biota by providing energy from the carbon compounds, nitrogen for protein formation, and other nutrients. Some of the nutrients in the soil are held in the organic matter, comprising almost all the nitrogen, a large amount of phosphorus and some sulphur. When organic matter decomposes, the nutrients are released into the soil for plant use. Therefore, the amount and type of organic matter in the soil determines the quantity and availability of these nutrients in the soil. It also affects the colour of the soil.

Cation Exchange Capacity

One of the properties of humus and clay minerals (colloids) in soil is that they have negative charge which allow them to "magnetically" hold positively charged nutrient elements (cations, eg. K^+, Ca^{++}) on their surfaces. This is important for reducing losses of nutrients through leaching. These nutrients can be exchanged with those dissolved in the soil solution surrounding the colloids.

Because of variations in the colloid structure, soils have widely differing abilities to hold (adsorb) the cations. Cation exchange capacity is a measure of the ability of the soil to adsorb cations, or of the negative charges of the soil arising from its clay and humus content.

In contrast, negatively charged nutrient elements (anions, eg. NO_3^-) are repulsed by the negative charge of humus and clay minerals and remain in the soil water solution and are therefore prone to leaching.

The process of adsorbing nutrients from, and releasing them into the soil solution is called cation exchange. This process is important for the nutrition of the plants. When soil is unable to release the nutrients required by the plant, natural or artificial fertilisers must be applied. The added fertilisers dissolve; some of the cations are taken up by the plant while some may be adsorbed on the colloid surfaces. Exchangeable cations affect soil structure. The presence of sufficient Na^+ on the colloidal surfaces disperse the soil while Ca^{++} flocculate and aggregate the soil.

2.4.3 Biological properties

The biological properties of the soil are related to the activity of the organisms living in it. Soil organisms (e.g. earthworms, termites, ants, fungi, bacteria, etc.) play a very important role in decomposing soil organic residues, as they fragment, ingest and excrete them, and affect their physical and chemical characteristics. The biological activity easily observed is the one performed by some larger organisms (earthworm casts, ant nests, etc.), while in most cases the activity of micro-organisms is not so easy to observe. There also are some other beneficial micro-organisms, such as nitrogen - fixing rhizobia which live in association with legume plant roots and cause the formation of rounded, easy-to-detect structures (nodules) on the roots of the plant.

The biological processes are either directly or indirectly affected by other soil properties, such as temperature, moisture, aeration, pH, organic matter and nutrient availability. The activity of soil and plant organisms tends to be more intensive in high temperature and moisture conditions, rather than in low temperatures and drought conditions.

2.4.4 Permanent and modifiable properties

An alternative way to group soil quality indicating properties is their own change through agricultural, livestock and/or forest management. The properties can be permanent or modifiable. A permanent property is the one that has been determined by the parent materials and by some formation factors which may not change in the short-term. The texture of the soil is regarded as a permanent property, as it is difficult to change the relative distribution of the particles size making up a fine fraction (< 2mm). Likewise, in the short term, it is difficult to change a pronounced slope in the hillside.

A modifiable property is the one that can be noticeably altered through management actions regularly applied to the soil. An example is the reduction in the content of organic matter in the superficial part of the soil (0-15 cm), which can be modified through the stimulation of greater mineralization caused by practices such as periodic burns, continuos tillage, erosion, etc.

Exercise 2.1: Identifying Soil Formation Factors and Processes

- ✓ ***Objective***

At the end of these exercises, the participants shall be able to identify the processes and factors involved in soil formation.

Guidelines for the Instructor

1. Depending on the number of participants, make four to six member groups and give each group a copy of the instructions to do this exercise.

2. Give 30 minutes to each group, to discuss and analyze the questions and possible responses. Ask the participants to apply the examples to their own smallholdings or their own micro-watershed.

3. Ask them to appoint a co-ordinator to present their responses. They can use the flip chart, the overhead projector or any other aid available.

4. At the end of the presentations, give some examples and suggestions to help the groups to broaden their knowledge on the topic.

Necessary Resources

- Instructions sheet for each group
- Flip chart and paper
- Overhead projector
- Washable overlays and markers

Suggested time: 45 minutes

Exercise 2.1: Identifying soil formation factors and processes

Worksheet No. 1: Soil formation factors and processes

Based on the knowledge you have acquired during this training, mark an X in the blanks against a soil formation factor or process you can identify e. g.: indicate which are factors and which are processes.

	Factors	Processes
1. Climate		
2. Soil losses		
3. Temperature		
4. Rainfall		
5. Wind speed		
6. Cloudiness		
7. Soil gains		
8. Translocation		
9. Relief		
10. Parental material		
11. Organisms		
12. Flora		
13. Fauna		
14. Moisture		
15. Luminosity		
16. Slope		
17. Valley		
18. Hill-foot		
19. Mountain		
20. Geology		
21. Erosion		
22. Burning practice		
23. Flood deposits		
24. Stubble incorporation		
25. Transformations		
26. Movements of clays		
27. Mineralogy of clays		
28. Micro-organisms		
29. Evolution		
30. Washing		
31. Forest		
32. Pastures		

Exercise 2.2 Identifying factors and processes in soils formation

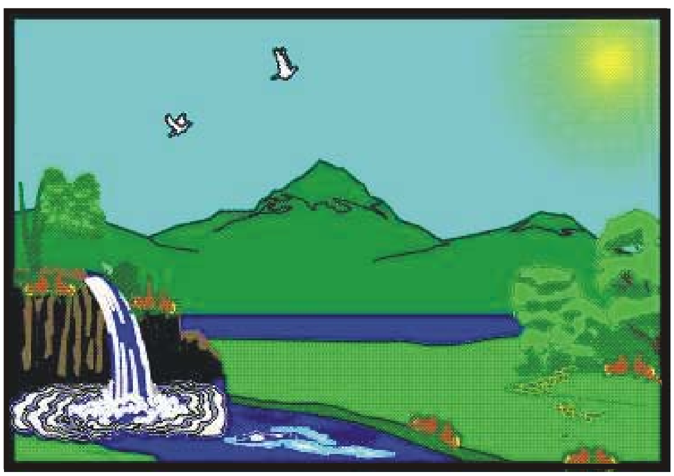
Worksheet No. 2: Formation factors

Taking as reference the drawings in the left margin of this worksheet, write on the line below each drawing, the soil formation factor you relate it to. Then, write on the right hand column, three or more elements involved in the formation factor identified.

Formation factors

____

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________



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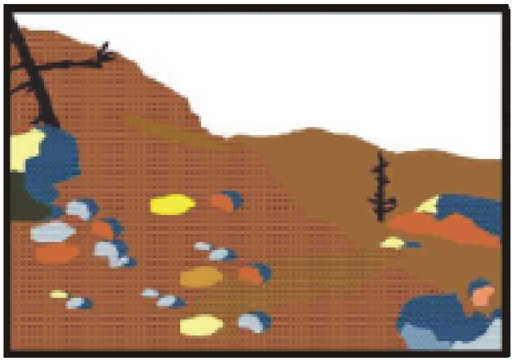
1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________



1. ______
2. ______
3. ______
4. ______
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1. ______
2. ______
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5. ______

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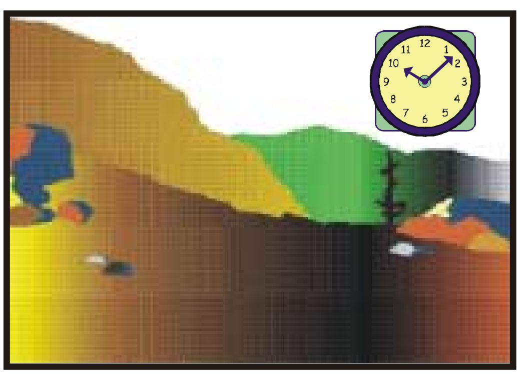


1. ______
2. ______
3. ______
4. ______
5. ______

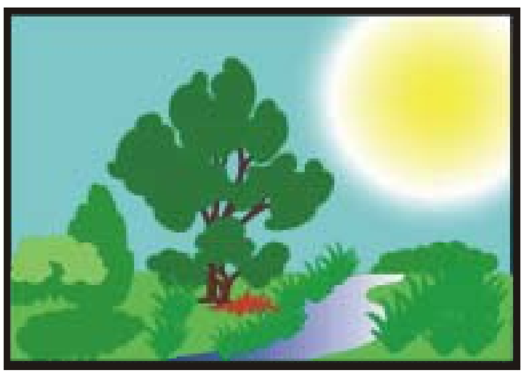
______

Exercise 2.3 Identifying soil formation factors and processes

Worksheet No. 3: Formation processes

Taking as reference the drawings in the left margin of this worksheet, write in the right side of each drawing, the soil formation process you relate it to. Then, write on the right hand column, three or more elements involved in the formation process identified.

Formation processes



1. ____________________

2. ____________________

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1. ____________________

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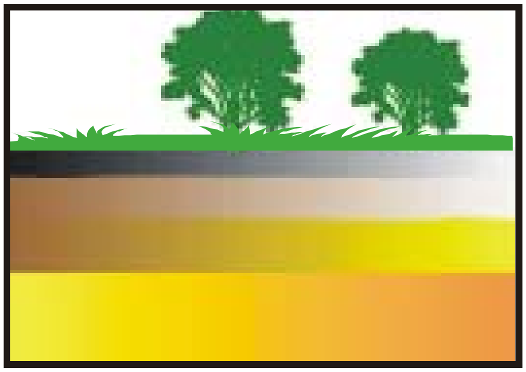
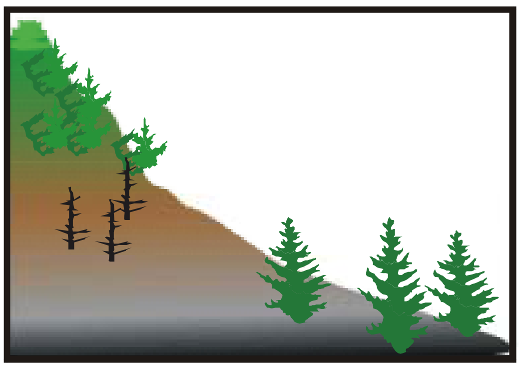


1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________



1. ______________________
2. ______________________
3. ______________________
4. ______________________
5. ______________________

Exercise 1.1 Identifying soils formation factors and processes Feedback information

	Factors	Processes
Climate	X	
Soil losses		X
Temperature	X	
Rainfall	X	
Wind Speed	X	
Cloudiness	X	
Soil Gains		X
Moisture	X	
Relief	X	
Parental Material	X	
Organisms	X	
Flora	X	
Fauna	X	
Translocation		X
Luminosity	X	
Slopes	X	
Valley	X	
Hill-foot	X	
Mountain	X	
Geology	X	
Erosion		X
Burning Practice		X
Flood Deposits		X
Stubble Incorporation		X
Transformations		X
Movement of clays	X	
Mineralogy of clays	X	
Micro organisms	X	
Evolution	X	
Washing		X
Forests	X	
Pastures	X	

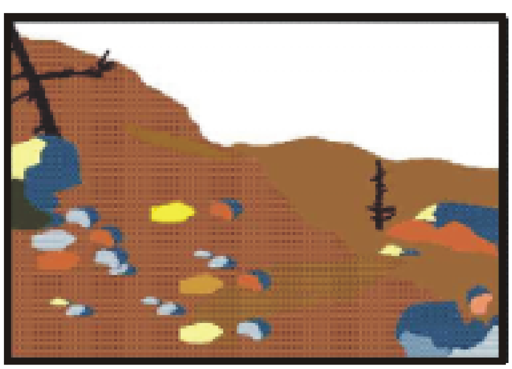
For Worksheet No. 2

Climate

1. Temperature
2. Rainfall
3. Luminosity
4. Cloudiness
5. Wind
6. Fog

Relief

1. Mountains
2. Valleys
3. Hill foot
4. Slopes
5. Hills
6. Plains

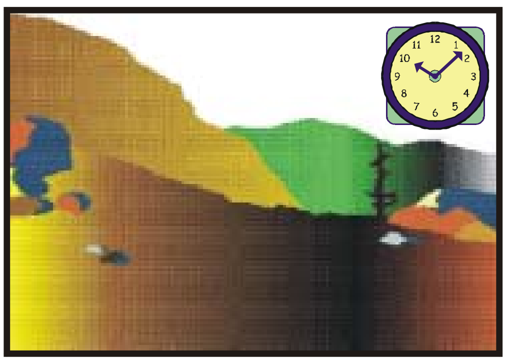


Parent Material

1. Rocks
2. Limestones
3. Tuffs
4. Lutites
5. Disintegration
6. Weathering

Organisms

1. Animals
2. Plants
3. Bacteria
4. Fungi
5. Earth Worms
6. Lichens



Time

1. Evolution
2. Transformation
3. Geological Ages
4. Development
5. Change

For Worsheet No. 3

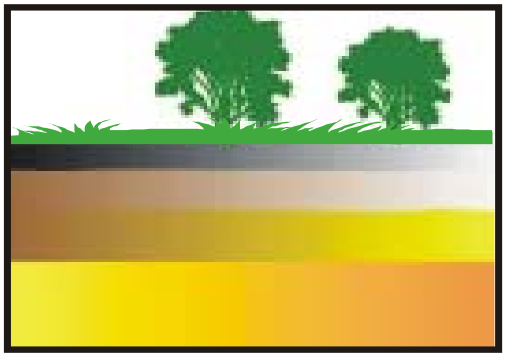
Formation Process

Gains

1. Flood Deposits
2. Incorporation of Stubble
3. Fertilization
4. Liming
5. Mineral
6. Biological

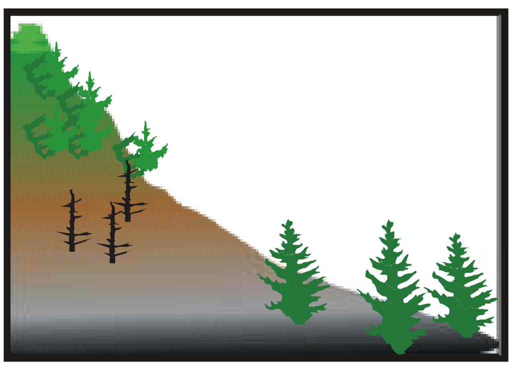
Losses

1. Erosion (wash out)
2. Burning Practice
3. Landslide
4. Crawling
5. Acidification
6. Slope



Translocation

1. Movement of clays
2. Movement of salts
3. Descendent movement
4. Oblique movement
5. Ascendant movement
6. Humus



Transformation

1. Minerals
2. Meteorization
3. Weathering
4. Organic Matter
5. Humus
6. Clays, Oxides

2.6 Summary

In this section we saw how to differentiate among the various soil formation factors and processes, how to describe these factors and processes and to identify soil physical, chemical and biological properties.

In the next section we will identify local indicators of soil quality and in Section 4 these local indicators of soil quality will be integrated with the technical indicators of soil quality that were derived during the exercises in this section. This integration will allow the development of a common language between farmers and researchers which will be essential to allow information exchange and sharing of knowledge.

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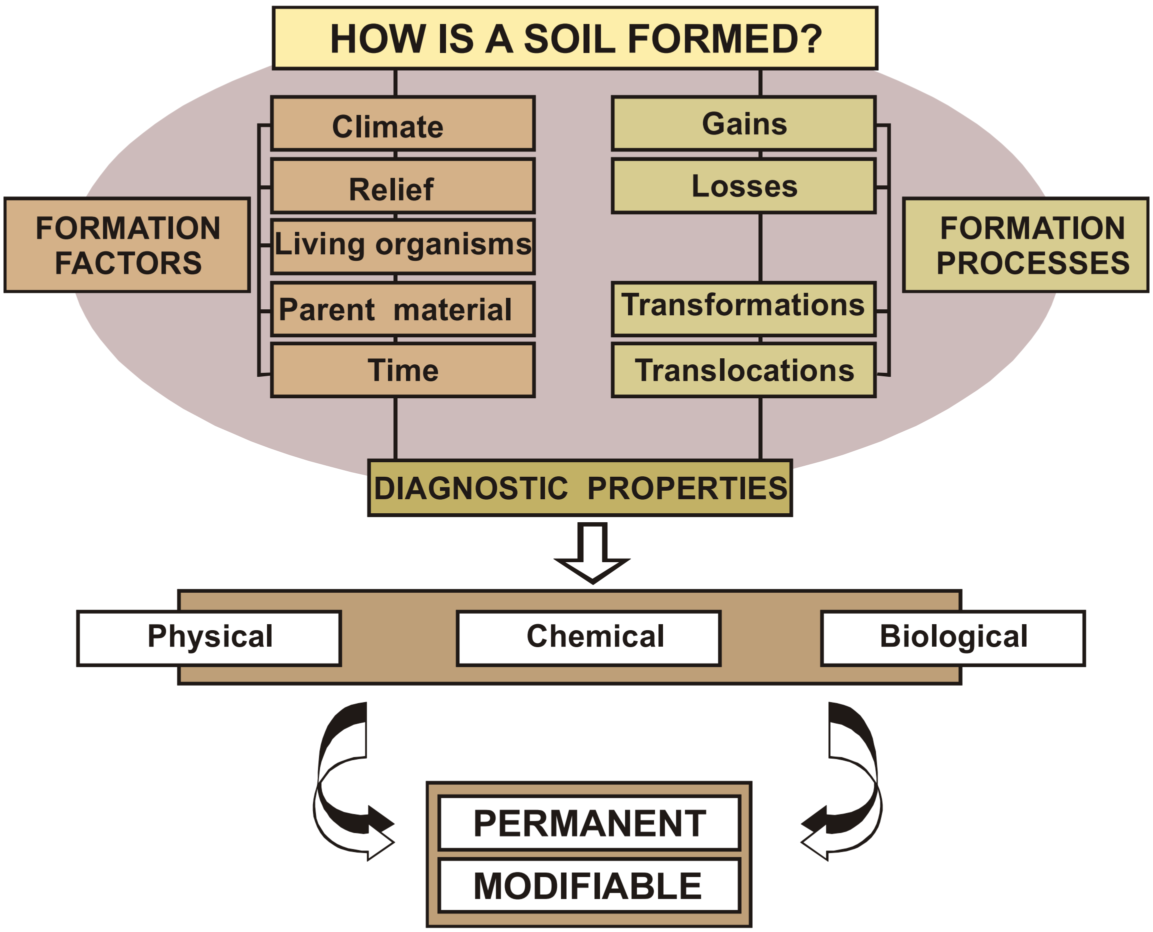
Originals for Overheads

Section Structure



Section objectives:

- Diferentiate among the various soil formation factors and processes

- Describe the factors and processes affecting the formation of a soil.

- Identify soil physical, chemical and biological properties, and differentiate between those that are permanent and modifiable.

Orienting questions:

- how do soils affect our daily lives?
- how is a soil formed?
- what is a soil formation factor?
- what is a soil formation process?
- what is a soil permanent property, and a
- modifiable property?

Soil is a natural resource:

- constitutes the basis for renewable natural resources (flora and fauna)
- provides food for the population, and constitutes the basic resource for the survival of the poorest population
- is a filter of wastes from human activities, as well as a water reservoir for crops
- is not a renewable natural resource.

Soil is a medium for plant growth:

- serves to anchor plant roots
- supplies water to the plants
- provides air for the breathing of plant roots furnishes minerals for plant nutrition

Soil forming factors:

These are soil development causing agents.

- climate
- parent material
- relief
- living organisms
- Time

Soil-forming processes - natural processes:

- Movement of soil particles and nutrients down a slope
- Wind erosion and dust deposition
- Fertility enrichment and depletion in the soil
- Movement of clays within soil
- Uptake of nutrients by deep-rooting species
- Biological nitrogen fixation
- Mycorrhizal phosphorus accumulation

Soil-forming processes - human-led processes:

- Importing mineral and organic fertilisers
- Transporting manures and residues to fields
- Transporting farm products to homes, towns and other settlement areas
- Burning vegetation and residues

Indicators of soil quality:

- Physical properties eg texture, colour, porosity, effective soil depth
- Chemical properties eg pH, organic matter
- Biological properties, related to organisms living in the soil
- Permanent properties do not change in the short-term
- Modifiable properties are noticeably altered through regular soil management actions

Appendices for Section 2

Appendix 2.1 - Answers for Worksheet No. 1: Soils formation factors and processes

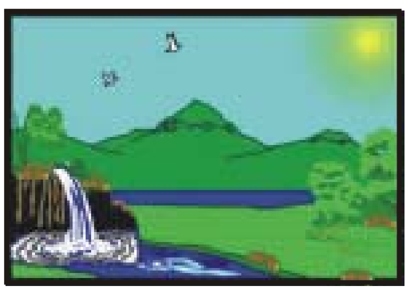
	Factors	Processes
1. Climate	X	
2. Soil losses		X
3. Temperature	X	
4. Rainfall	X	
5. Wind speed	X	
6. Cloudiness	X	
7. Soil gains		X
8. Translocation	X	
9. Relief	X	
10. Parental material	X	
11. Organisms	X	
12. Flora	X	
13. Fauna	X	
14. Moisture		X
15. Luminosity	X	
16. Slope	X	
17. Valley	X	
18. Hill-foot	X	
19. Mountain	X	
20. Geology	X	
21. Erosion		X
22. Burning practice		X
23. Flood deposits		X
24. Stubble incorporation		X
25. Transformations		X
26. Movements of clays	X	
27. Mineralogy of clays	X	
28. Micro-organisms	X	
29. Evolution	X	
30. Washing		X
31. Forest	X	
32. Pastures	X	

Appendix 2.2 - Answers for Worksheet No. 2: Formation factors

Climate

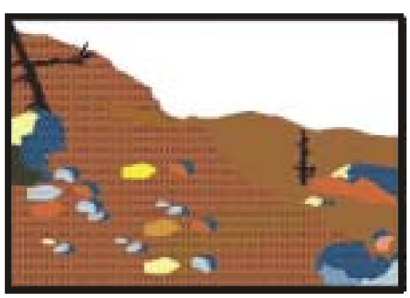
1. Temperature
2. Rainfall
3. Luminosity
4. Cloudiness
5. Wind
6. Fog

Relief

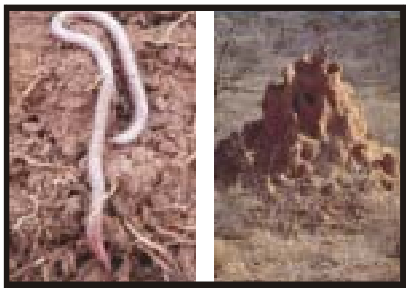


1. Mountains
2. Valleys
3. Hill foot
4. Slopes
5. Hills
6. Plains

Parent Material

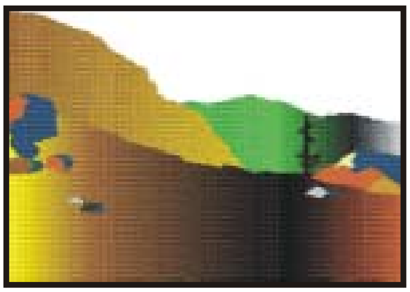


1. Rocks
2. Limestone
3. Tuffs
4. Lutites
5. Disintegration
6. Weathering



Organisms

1. Animals
2. Plants
3. Bacteria
4. Fungi
5. Earth Worms
6. Lichens



Time

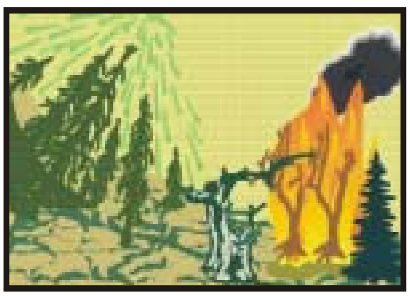
1. Evolution
2. Transformation
3. Geological Ages
4. Development
5. Change

Appendix 2.3 Answers for Worksheet No. 3: Formation processes

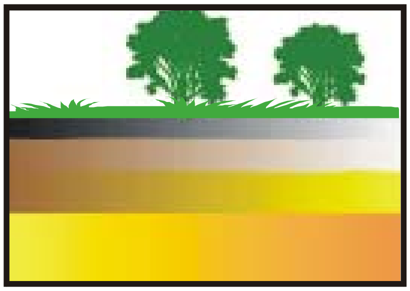
Gains

1. Flood Deposits
2. Incorporation of Stubble
3. Fertilization
4. Liming
5. Mineral
6. Biological

Losses

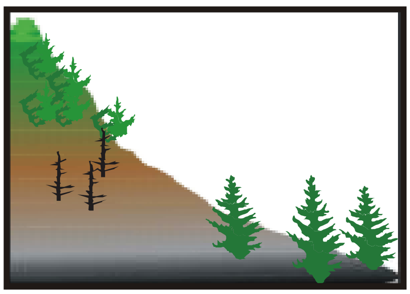


1. Erosion (wash out)
2. Burning Practice
3. Landslide
4. Crawling
5. Acidification
6. Slope



Translocation

1. Movement of clays
2. Movement of salts
3. Descendent movement
4. Oblique movement
5. Ascendant movement
6. Humus



Transformation

1. Minerals
2. Meteorization
3. Weathering
4. Organic Matter
5. Humus
6. Clays, Oxides

SECTION 3

Identifying and Prioritizing Local Indicators of Soil Quality

Section 3. Identifying and Prioritizing Local Indicators of Soil Quality

3.1 Introduction

Farmers traditional knowledge comes from an intuitive integration of the response of the agricultural systems through time, to factors affecting agricultural production like management, fertility, climate, pests, etc. (Barrios et al., 1994; Barrios 1995). Farmers' knowledge on soils is a valuable resource that is being lost with time. The aim is to combine the best soil science with the best local knowledge on the part of the farmers. The word best is used here to make reference to the methods used to solve problems and the basic knowledge, on the one hand, and to specific technological advances, on the other hand. The objective is to use both knowledge systems to prevent and solve local soil management problems in order to improve efficiency of each individual system.

From the above, it is clear that the integration of farmers' experience with technical-scientific knowledge allows both groups of stakeholders to have a better understanding of the soil and therefore it will be possible to make better management decisions. There are many management practices that farmers' know, experiment with, and can adopt to improve and maintain crop yields. Understanding the importance of such practices and their adoption will be improved, if effective communication is achieved through a common language between the farmer and the technician.

In Section 3 we will present a methodological approach to work with farmers in order to identify their local indicators of soil quality and then show how these indicators can be grouped according to soil property and prioritized in order of importance.

3.1.1 Local Indicators

Local indicators correspond to a language traditionally adopted by a community of farmers, to describe soil characteristics by using words they easily understand. The agreement between technical and local indicators is one of the objectives of the methodology contained in this Guide. The goal is to make the technical and scientific language compatible with the local language so that researchers and extensionists, on one hand, and the farmers on the other hand, share a common language about the soil and its management.

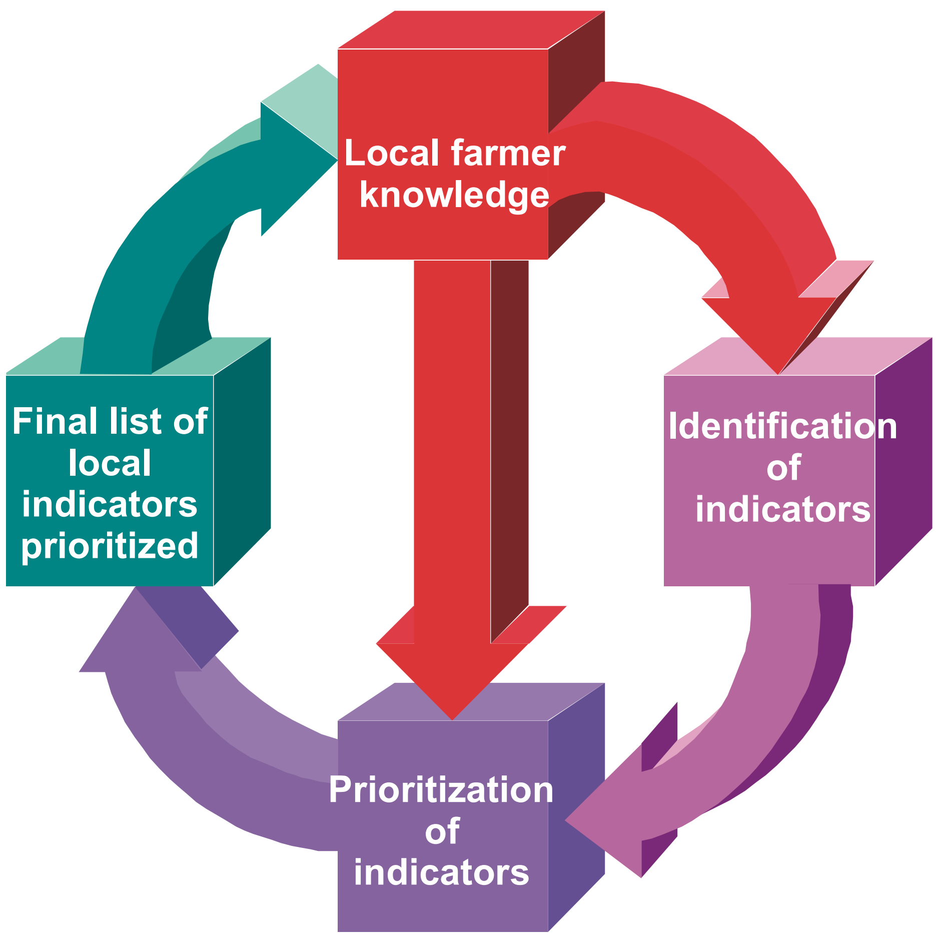
3.1.2 Objectives

At the end of this section the trainees will be able to,

- obtain the local indicators of soil quality.
- group local indicators according to soil properties.
- prioritize local indicators of soil quality.
- describe the methodology used to obtain the local indicators of soil quality.

3.1.3 Section Structure

This section consists of an introduction on the importance of local farmer knowledge about soils and local indicators of soil quality for sound soil management. This is followed by identification of local indicators of soil quality. The farmers assisted by technicians then prioritize and group the indicators according to soil properties and produce a prioritized list. At the end of the exercise the trainees will be able to describe the methodology used to obtain and prioritize local indicators of soil quality.



3.1.4 Opening Questions

1. What are the differences between a good and a bad soil?

2. How do you know if a soil is excellent, fairly good or bad for production?

3. Do you think that there are different types of soils on your farm?

4. Can you indicate the limits of the soil types on your farm?

3.2 Methodology to Identify and Prioritize Local Indicators

This methodology facilitates the identification and prioritization of local indicators commonly used by farmers in their smallholdings to evaluate soil quality. Through this process, the criteria used to identify and judge the soils, and determine which factors or indicators are more important, are also identified.

A methodological process developed by Burpee and Turcios (1997) is described below. In summary, there are two steps: group analysis (a brainstorming session) where farmers have the opportunity to judge their soils, in order to determine the differences between a good and a bad soil, and secondly prioritize the identified local indicators.

3.2.1 Group Analysis

The farmers attending the group meeting (brainstorming session) are requested to mention the indicators or characteristics they know to determine if a soil is good, fairly good or bad, for the various landuse practices. The farmers should be grouped according to gender/stakeholders. Then, all those indicators expressed with different words (local indicator) but with similar meanings, are grouped as descriptors of the same characteristic. Every indicator is written down on cardboard cards.

3.2.2 Prioritizing indicators

At this stage, two procedures can be used: The first one is the 2-entry matrix (Geilfus, 1997), as shown below;

Indicator	Water retaining soil	Black soil	Deep soil	Indicator $_n$
Water retaining soil				
Black soil				
Deep soil				
Indicator $_n$				

The following is the procedure to fill in the matrix:

- Explain to the farmers that what you want is to determine, from all the indicators identified, which are the most important, and get a list of prioritized indicators.

- Prepare a 2-entry matrix, with the same number or rows and columns as the identified indicators. Write on the first row and first column one indicator per cell, always following the same order.

  - Begin with the cell corresponding to indicator number 1 (second column) and indicator number 2 (third row). Ask the trainees which indicator (number 1 or number 2) they deem the most important. Or which of them is to be taken into consideration at the moment of judging the soil. After reaching an agreement, the most important indicator is written down in the cell. For instance:

Indicator	Water retaining soil	Black soil	Deep soil	Indicator $_n$
Water retaining soil		Black soil	Deep soil	
Black soil			Black soil	
Deep soil				
Indicator $_n$				

- Repeat the exercise by comparing the indicators with one another. At the end, half of the matrix must be filled in.

- For every indicator, attention must be paid to how many times it appears in the matrix, so that they can be ordered by frequency. The indicator most frequently appearing is the most important. This comparison by pairs is less subjective than other prioritizing methods. An example of frequency analyses based on the previous chart, could be:

Indicator	**Frequency**	**Priority Order**
Water retaining soil	0	3
Deep soil	1	2
Black soil	2	1

This method is recommended to be used with groups or farmers having a low level of schooling, since, as seen further on, the alternative methodology requires a better mastering of reading and writing skills.

The second method is classification by cards.

Classification by cards

1. The farmers are divided in 3 to 5-member groups, depending on the audience.

2. As in the previous methodology, farmers' indicators are obtained and written down on cards.

3. Every farmer is to separate the cards in three groups, according to the importance assigned to each indicator (high, medium, and low) (Figure 3.1).

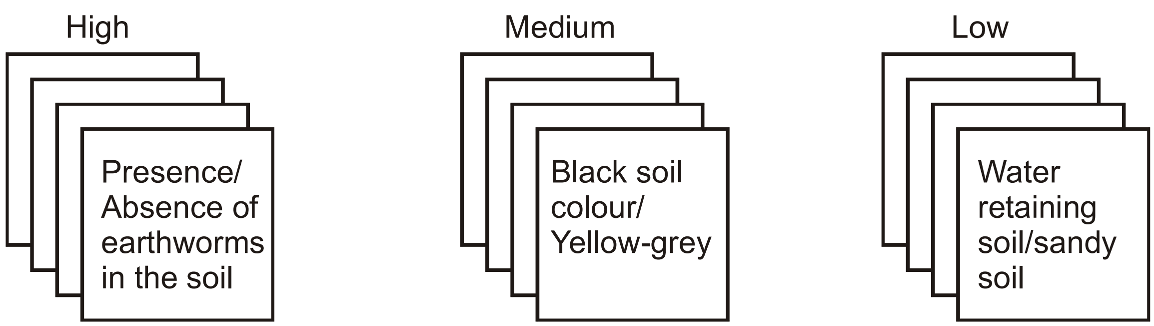


Figure 3.1 Farmer's card classification

- Then, every farmer is to individually assess each indicator in the group of cards, and is to give it a high or low importance, placing the most important one on top, followed by the others, in order of the importance (Figure 3.2).

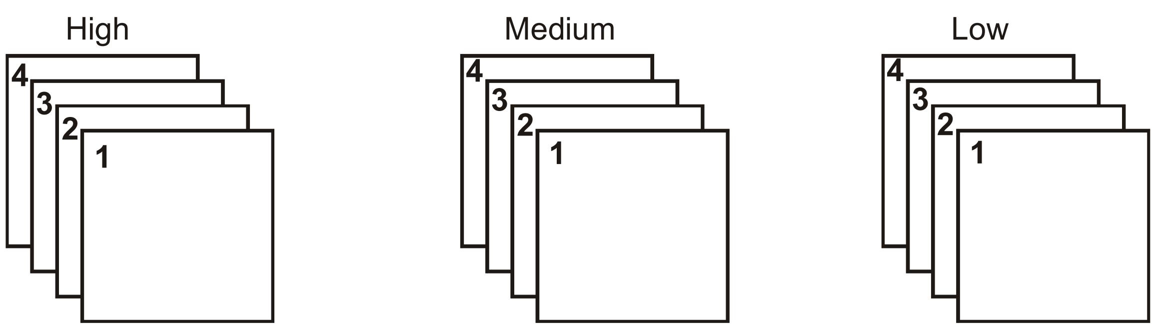


Figure 3.2 Assessing each card and assigning importance order, according to farmer's concept.

- Then, the narrator is to assign a numeric order to each indicator, according to the importance order assigned by the producer. The information generated by each farmer is recorded in the matrix shown in Table 3.1.

Table 3.1 Priority indicators matrix by farmers within each group.

Group:______________________ **Farmers' name**

Narrator:____________________

1.______________________________
2.______________________________
3.______________________________

Indicator (number and title)	Farmers			Total	Priority (see average value*)
	1	2	3		
1					
2					
3					
X_n					

- Average value = Total score divided by the number of farmers in each row.

Example:

If the group of high importance cards contains eight indicators, obviously the last indicator prioritized shall have the eighth place. When taking middle importance cards, already prioritized, the indicator assigned number 1 is to have the ninth priority place. If the total number of cards in this group is five, then the last card is to be located in the thirteenth place. For the last group of cards the same criteria are applied.

Every table is to contain specific information for each indicator. Based on this, the average score arising from the sum of the scores in each row, divided by the number of scores is established.

Finally, the matrix with all the indicators is submitted for its validation in a plenary session with all producers. The aim is to find out if all participants agree with the priorities established for the indicators in order to reach a group consensus that is fed back to the farmer community.

An example of several farmers answers is shown on table 3.2, for three indicators. If Farmer 1 thinks that "muddy/too much sand/ loamy soil" indicator is the third most important one, the narrator writes '3' in the appropriate cell, under Farmer 1, right in front of "muddy/too much sand/loamy soil" indicator. Likewise, if the farmer thinks that the "deep or thick soil/ thin soil" indicator is the seventh in importance, and that "gentle slopes/slope" indicator is number 1, the narrator writes 7 and 1 in the cells corresponding to these two indicators.

Table 3.2 Example of priority Matrix for three indicators and three farmers.

Indicator	Farmer			Total	Priority (average value*)
	1	2	3		
Loamy/muddy, too much sand	3	1	2	6	2
deep or thick soil/ thin soil	7	10	4	21	7
gentle slope/ foothill	1	2	6	9	3

* Average value = Total divided by the number of farmers in each row.

- Then, the narrator writes in the matrix the priority number corresponding to each indicator, per farmer consulted; these values are added to the "Total" column. The number in this column is divided among the number of farmers in the group (in this case, the number is "three") to find out the average priority value for this indicator and for this group.

The last column, to the right, in Table 3.2 shows that for these three farmers, the "muddy, too much sand/loamy" indicator is the first one in importance when judging if the soil is good or bad. The "gentle slope/foothill" indicator is the second one, and the "deep or thick soil/thin soil" is the third.

Finally, the individual value assigned by each group to each indicator is added, and the total is divided by the number of groups, which is the final indicator of priority (Table 3.3).

Table 3.3 Final Matrix of Indicators Priority by group, with average figures calculated for each indicator.

Indicator	Groups Average						Total	Final Priority (Average Value*)
	1	2	3	4	5	6		
Loamy/ muddy, too much sand	2	3	5	1	9	5	25	5.0
Deep or thick soil/ thin soil	7	10	8	4	7	11	47	9.4
Gentle slope/ foothill	3	4	1	6	5	2	21	4.2
Burns/ does not burn								
Presence/ absence of earth worms in the soil								
X_n								

* Average value = Total divided by the number of groups.

As in the previous example, the conclusion can be drawn, as per Table 3.3, the most important indicator, according to the "average value" column, is: "gentle slope/foothill", followed by " loamy/muddy,too much sand” indicator, and by "deep or thick soil/thin soil" indicator.

3.2.3 Case studies

The methodology to study cases was designed to understand local soil quality indicators and the context in which they are used by farmers.

Once activities 3.2.1 and 3.2.2 are completed, choose farmers who are interested, and who have the knowledge and capacity to serve as key informers to conduct more detailed studies through a checklist for study cases on local soil knowledge and their management (Barrios et al., 1998). This checklist has been designed to be used during a field day in each farmer's farm. Through a series of informal conversations, the information mentioned in the checklist is gathered (Gracia, 1989). It is important to check the checklist carefully before visiting the farmer in order to incorporate the checklist topics in the conversation.

The checklist comprises the following issues:

1. Information about the farm: The length of time in use, land holding, area, etc.

2. Farmer participatory mapping: Preparation of a farmer/ interviewer-designed map, emphasising the types of soils and their limits, past and current use with regard to slope, etc. This information is confirmed during the next steps, when using the recently-made map to locate the identified soils and their past and current use.

3. Soils knowledge: The aim is to identify the descriptive properties of each soil type.

4. Soil management practices: The aim is to identify the distribution of crops, land preparation, fertilization, conservation practices, etc.

5. Soil organisms: The aim is to identify beneficial and harmful organisms in the soil.

6. Factors guiding management and the decision making process: the aim is to identify local integrative indicators (e.g.: soil colour, indigenous plants) providing important information on management and the decision making processes.

7. General issues: In this section, some examples are introduced, which simultaneously incorporate various aspects mentioned in the previous items, as they occur in nature. Through this section, gathered data can be corroborated.

8. Soils sample related to each study case: representative soil samples described by the farmer are collected (geo-reference, if possible).

It is worth mentioning that the participatory mapping at farm level, which allows for the definition of past and current uses of the soil, according to their position on the slope, is very important in studying watersheds. This activity is complemented by the information generated by guides 2 (Land use tendencies by Photo analysis) and 3 (Participatory mapping). The impact of soil uses, position with regard to the slope and the micro-watershed, has not been broadly studied. This methodological proposal pursues a systematic focus to allow the evaluation of the impact of new options and spatial/temporal arrangements, in the management of natural resources at the watershed scale.

3.2.3.1 Checklist to case studies on soils, local knowledge and their management.

Name of the farmer:____

Ethnic origin :____
Name of District/ Division:____
Village:____
Name of interviewer:____
Date of the interview:____

Information about the farm:

a. How long have you cultivated this farm? _______________________________
Is it all cultivated? You cultivate_____% Fallow ______%
History of the use of the various plots, as long as you can recall.
____
____
____

b. Land tenure : Owner_____ Rented______
Inherited______ Purchased ___________
Cultivates permanently_______________
Cultivates occasionally_______________
Other ________ (specify)

c. Head of the household: Name____________________ Age______________

d. Wife / wives name (s):___________________________Age______________
____
____

e. Number of children:_______________ Age____________________________
Boys _________ __________ __________ __________
____
____
Girls __________ _________ __________ ___________

f. Is there enough labour for the whole family or do you need to hire labor ?
____
____
____

g. What are the task of each of the family members of the farm:
Father:____
Mother:____

Child 1:____

Child 2:____

Child 3:____

Child 4:____

Child 5:____

Other family

members:____

h. Do you depend on charcoal to cook your meals? Yes__ No__ Heating?

____

What amount do you use per week?________________________________

Where do you get the charcoal from and how far it is from your farm?_______

____

What type of charcoal do you use?___________________________________

Which one do you prefer and why?_________________________________

____

____

Farm participatory mapping

Prepare a map with the farmer showing the various types of soils (good - intermediate-poor), indicating slope, soils which dry fast or slowly, past and current use with regard to their location on the slope, location of cropping or fallow areas (geo-reference the uses, if possible), presence of weeds, soil organisms (e.g.: ants, earthworms, etc.). Use this map to conduct the rest of the interview while observing and sampling the various soils types.

Knowledge of the soils

a. Are there various soil types in the region and on your farm?

b. How can you distinguish one soil from another soil ?. Repeat these comparisons covering all possible combinations, as well as the contrasting features and identification criteria.

c. Descriptive properties of each identified soil type.

- What colour is the soil when dry or wet?
- Does the soil need little or a lot of fertilizer and can you plant without fertilizer?
- How deep is the fertile soil layer?
- Is the soil hard or dusty in the dry season and does it have large lumps or stones?
- Is it sandy or sticky (clayey)? In case of rain, does the water accumulate on the surface, does it run on the surface or does it quickly penetrate? Does the soil dry quickly or slowly after the rains? Is it easy to plough?
- How steep is the plot? Rolling plain <10%, moderate 10-30%, steep >30%. When it rains, is the water brown, yellowish or transparent (e.g.: too much erosion)?
- Which plants grow in the soil (i.e. fertility indicating plants), a great variety of plants or a common or prevalent type? (define the plants and their relationship with the soil type). Age of natural vegetation in the soil.

Presence of earthworms, ants, termites, etc ?
Crops yield is : Low______ Medium_______ High _______ ?
Are crop yields decreasing______, pasture yields _______, animals weight gain_______,milk production per animal_______, taste_______?

d. Which are the best soils to cultivate?_______________________________
Has it always been good? Yes___ No___ Was it better before?____________
What happened?____
And the worst?____

Where they worse before? Yes_______ No________

e. Is the soil # better for a particular crop? (Repeat for every soil mentioned)

f. Can soil #, be cultivated for a longer period than soil #? Yes ______ No ______

(Repeat for every pair of soils) Do you think that soil # resists a longer cropping period ? One year ____ 5 year _____, 10 years______, 20 years______, more>20 years___________________

Soils management practices

Crop distribution

When choosing the farm area to be planted during the next season, how do you decide where to assign each crop and how much of the farm area do you use? Do you sow all the above mentioned soils in the same way? Give details.

Land preparation

How is the land prepared: not prepared ____, with oxen ____, hand/hoe ploughed ____, with a tractor ____.

If you do not prepare the land, do you use a traditional hoe to plant? What is the sowing depth?

If the land is prepared, in what direction do you prepare the land? Downward (along the slope?) _____ or across (perpendicular to the slope _____) Why?

Slash and burn
Yes ____ No ____

When do you slash and burn, who does it, and indicate the various methods?

____
____

____
____
____

Which is the best method and why?

____

____

____

Manure

Yes ____ No ____

a) What type of manure do you use? Chicken manure ____?, sheep manure__ __goat manure ___ pig manure ____, other manure ____ (specify ___) Where do your animals graze? Do you transport manure to some places in your farm?

Other organic fertilizers used ______?

For what crops or plots do you use the various kinds of manure? Why?

How do you apply the manure? Broadcasted? _____, in the crop furrows _____, to each plant? ____, depending on the crop?_____

Amount of manure applied by crop or plot?

How do you decide the necessary amount of manure?

What do manures do to the soil?

Chemical fertilizers

Yes ____ No_____

If not, Why?

____

____

____

You do not have knowledge on fertilizers ____, the cost is to high_____ (if the cost was low would you use them? Not available in the market _____, the results are not good ____ (based on your personal experience _____, or the experience and information from other farmers _____?

If you use fertilizers, why?, On which crops or plots are chemical fertilizers used? Why? What type of fertilizers do you use? (Urea ___, Super-phosphate ___, NPKs _____? Do you know the meaning of NPK grades (e.g. 20-20-20) fertilizers? How do you choose the grade or type of fertilizer to be used? Do you use various types or grades of fertilizers for the various crops or plots? How do you apply the fertilizer? Broadcasted _____,in the crops furrows ______, to each plant _____, depending on the type of crop or type of fertilizer?

Amount of fertilizer applied (bags per plot _____)? Kg _____?

How do you decide the necessary amount? What do fertilizers do to the soil?

Who tells you about the use of fertilizers? (type, amount, and how to apply)? Dealer ____. Extension agency (government) ____ Other farmers _____?

Green manure

YES ____ NO _____

Which plants help to enrich the soil? One type____ Several types_____

Which crops do you use them with?____

____

____

Why?

____

____

____

How much labour or time do you spend?_______________________________________

____

____

Who performs this activity?____

____

____

How long is the land under the green manure?

____

____

______

Residues Management

Yes_______ No______

Do you leave the residues on the soil and for how long? Yes ____ No_____

Are residues fed to livestock and what do you do to the manure?____________________

____

____

Are the animals allowed to graze on the residues?

____

____

____

Do you incorporate fresh or dried residues?____________________________________

____

____

When do you incorporate crop residues?_______________________________________

____

____

Before the first rains?

____

____

____

After the first rains?

____

____

____

Composting:

Yes ____   No _____

Types of compost? How do you prepare it and which ingredients do you use in your compost?

Do you apply compost selectively or just to some crops? Which crops?

Soil erosion control

Do you control erosion? YES _____ NO ______

Do you use barriers: YES ______ NO______

Types of barriers: live, trash, terraces?

____

____

____

Amount of labour required for each activity?

____

____

____

Soils and plots you use the barriers, on what slopes and what is the distance between barriers?

____

____

____

For which crops do you use the barriers?_______________________________________

____

____

Which plants do you use as barriers and are they fed to livestock as feed supplement and who is in charge of these activities?____

How important is the quality of the feed supplement?

____

____

____

Do you construct terraces and what type of terraces? YES____ NO______

Crops grown between the terraces, amount of labour required and who is in charge of these activities? ____________________________________

____

Weed control

Yes____ No ____

How do you control weeds and how often? Herbicides ____,handpulling?___ Panga/machete?____ , hoe/shovel?____

Which herbicide and at what rate?____

____

____

How long does it take to weed and who does the weeding?

____

____

Which crops do you weed more frequently and what do you do with the weeds?____

____

____

Which are the most common pests or diseases affecting each crop.

____

____

____

Pesticides

Yes__ NO __

If yes, indicate the types of pesticides:

herbicides _____, insecticides _____? What amounts, number of back pumps (20lts)/ ha _____ ? How much pesticide do you use per back pump _____? How often do you use the pesticide? One or more times per harvest? Do you apply it at the beginning, at midday or at the end of the day? What tells you that is the moment to apply a pesticide? Who applies the pesticide? What does the pesticide do to the soil? Does it crack it? Does it harden it?

Soil organisms

a. There are good soil organism and these must be preserved. Are there some soil organisms helping to enrich the soil?
b. Can you increase the number of organisms in the soil? How?

Factors guiding management and the decision making processes

a. In plot #, when do you decide to rotate the crops? Which? And in what order? What changes do you observe in the soil? For how long do you rotate?

b. When do you decide that a plot must be left fallow? Less fertility, less money, less time? Indicators: weeds (which, how much), soil structure, colour? How long do you let it rest? What tells you that the soil has rested and can be sown again? How do you estimate the age of the vegetation or the rest time?

c. What types of plants can be mutually associated within a plot? Why? Plant # and plant # would have mutual positive effects? Replicate, to try to define some probable competitive (allelopathy) or mutually beneficial relationships

d. Do you have natural forests on your farm? How much of the land is under forest? How useful is the forest? Did you plant the forest? Why did you plant the forest (trees)?

e. Are there some periods during the year when lack of water affects the crops? When? Is there anything that can be done to reduce the effects of lack of water?

f. Which crops are sensitive to the lack of rains?
Which crops have deep roots, and which crops have superficial roots? Which indigenous plants have deep roots or superficial roots? How dependent are

animals on animal feed supplements during dry season? What is the importance of drought-tolerant cultivars?

g. How do you know when the rains will start, and the best moments to burn, plant, etc.? Are there some constellations, plants, or animals that serve as indicators of this year's weather?

General

a. In a year with no weather problems (rain and temperature) out of every 100 seeds you plant in the soil, how many germinate? (do not germinate, uneven germination, all germinate). Is the crop or tree growth fast or slow? Vigorous? Do you observe any yellowing, stripes or spots on the crop or tree leaves? How about resistance to drought, pest and diseases and crop yield?

b. Which are the poorest soils on your farm, and also among the ones you know in your area, and where are they located? Do they require fertilizer, or they do not respond to fertilizer?

c. Which are the fertile soils on your farm, in your area, and where are they located? Indicate the soils that can be sown without fertilizer.

d. Can you identify two people that use little or no fertilizer, and they still have good yields?

e. Can you identify two people that use fertilizer and have good yields?

Sampling of soils associated to each case study:

Preparation of a composite sample: Locate a central region in each type of soil described by the farmer. Draw on the soil a 5-m line. Draw another 5 m line, perpendicular to the one above, so that an X is formed. Take samples from the end of the X, and at the intersection point (a total of 5 samples for each required depth). Finally, mix well the 5 samples corresponding to each depth, to give one compound sample for every soil depth (should you be able to geo-reference this sampling, use the intersection point of two lines to take a GPS reading).

1. Take a composite sample (0-5, 5-10, 10-20, 20-40 cm) from the soil types identified by the farmer as representative of the region.

2. Take a composite sample (0-5, 5-10, 10-20, 20-40 cm) from the soils identified by the farmer as the poorest one in his/her farm and in the region.

3. Take a composite sample (0-5, 5-10, 10-20, 20-40 cm) from the soil types identified by the farmer as the most fertile in his/her farm and in the region.

3.2.4 Results from a study case exercise: Local weeds as indicators of soil quality

The composition and abundance of weed species growing on agricultural soils is a useful indicator of the soil condition frequently used by farmers (Barrios et al., 1994).Studies conducted in South America (de Kool, 1996; Barrios and Escobar, 1998) and Central America (Trejo et al., 1999) also indicate the importance of native plants as indicators of soil quality. Biological indicators have the potential to capture changes in the soil quality because of their integrative nature; that is, they simultaneously reflect changes in the physical, chemical and biological characteristics of the soil.

In fig. 3.3 the process of local knowledge generation about native plants as indicators of soil quality is summarized. Certain plants mainly predominate in poor soils and ubiquitous plants develop with difficulty. On the other hand, certain plants mainly predominate in fertile soils and ubiquitous plants grown vigorously. Farmer observation of this phenomenon in several soils and farms through time constitutes his/her direct experience and constitutes the basis of their knowledge on this topic.

It is now important to introduce the ecological concept of natural succession. Natural and agricultural ecosystems respond similarly to degradation and regeneration processes through natural succession. During these processes, best adapted plants and soil organisms gradually replace those least adapted through a selection exerted by changes in soil characteristics (i.e. during soil fertility decrease or increase). Local knowledge collects observations about changes in plant populations generated by changes in soil quality.

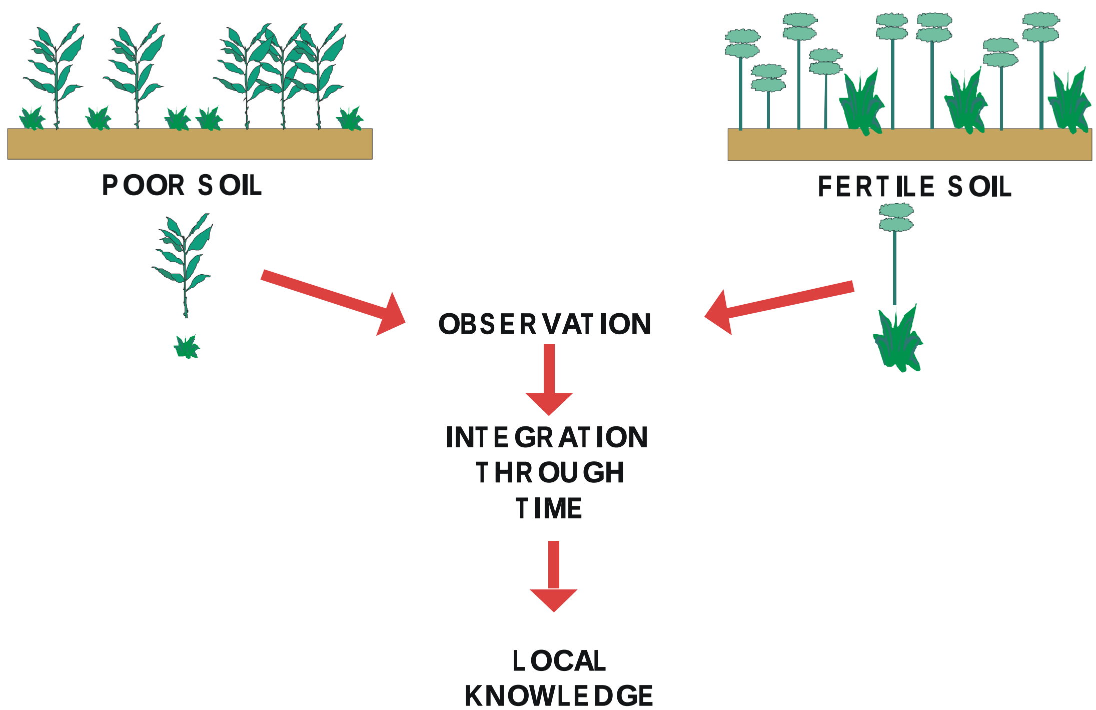


Fig. 3.3 Development of local knowledge about native plants as indicators of soil quality.

The study case approach allows exploration in more detail of certain aspects showing high importance. Ethnobotanical information related to the use of native plants as indicators of soil quality can thus be systematically collected. Results using this methodology in Colombian hillsides are presented as a list of indicator plants in Table 3.4 .

Table 3.4 Common plants as indicators of soil quality used by farmers in the Cabuyal Micro-watershed, Cauca, Colombia (Barrios and Escobar, 1998).

Common name	Scientific name	Botanical family	Soil type
Helecho marranero	*Pteridium aquilinum*	Pteridiaceae	Poor
Mangaguasca	*Braccharis trinervis*	Compositae	Poor
Escoba Lanosa	*Andropogon bicornis*	Gramineae	Poor
Siempre Viva	*Commelina difusa*	Commelinaceae	Fertile
Papunga	*Bidens pilosa*	Compositae	Fertile
Hierba de chivo	*Ageratum conyzoides*	Compositae	Fertile
Escoba Blanca	*Sida rhombifolia*	Malvaceae	Any soil
Caracola	*Koheleria lanata*	Gesneriaceae	Any soil
Margarita	*Chaptalia nutans*	Compositae	Any soil

The use of plant (weeds) dynamics as an integrative measure of changes in soil quality is based on the concept of natural selection mentioned above. Weeds are usually pioneer plants that grow on soils of different qualities and predominant weed populations often associate with a set of soil physical, chemical and biological characteristics. As soil characteristics change through time, for good or for bad, weed composition and abundance also changes. As mentioned before, local knowledge about native plants as indicators of soil quality is the result of cumulative farmer experiences. Therefore, a systematic monitoring of the changes in diversity and abundance of weeds while simultaneously monitoring changes in soil properties would permit the establishment of a practical relationship between local and technical indicators (i.e. pH, total C, etc.) of soil quality.

Exercise 3.1 Identifying and Prioritizing Local Indicators of Soil Quality

Objective

In a simulation situation, the trainees will identify and prioritize local soil quality indicators in farms belonging to a group of farmers.

Orientations for the Instructor

1. Select the group of trainees who are to play the role of "technicians", and another one that is to play the role of "farmers", in a proportion of one technician per five farmers.

2. Give the group of farmers the corresponding work agenda. The technicians must not know the farmers' agenda.

3. Provide the technicians with instructions to accomplish the following assignment:

- Conducting group analysis ("brainstorming session"), as described in the text.
- Grouping the indicators with the same meaning, according to the soil properties previously described.
- Preparing the cards with the indicators, and selecting the method of prioritization.

Prioritizing.

- Getting the averages for each group and for the group total.
- Validating, in a plenary session with the farmers, the indicators and the corresponding priority.
- Explaining the relationships between local indicators and soil properties.

Resources required

- cardboard cards.
- Thick tip markers (various colours)
- Paper for the flip chart
- A roll of masking tape
- Work sheets:

Indicators priority matrix by farmers in each group (Worksheet No. 1)

Final indicators priority matrix by the group (Worksheet No. 2)

List of trainees

Suggested time: 60 minutes

Exercise 3.1 Identifying and Prioritizing Local Indicators of Soil Quality

Orientations for the trainee

Agenda for the "Farmers"

You have been selected to play the role of a farmer during this exercise. Follow the instructions below:

1. You are a member of a 5-member farmer group who know how to read and write.

2. During the group analysis ("brainstorming session"), mention at least three soil quality indicators belonging to a local language; e.g.: washed land, cracked soil, weeping land, the land becomes waterlogged, the soil breaks, the soil is brittle; mild slope, mildly porous, sandy, lumpy, etc.

3. For the rest of the exercise follow the instructions given by the "technician" who will work with this group.

During the validation of the indicators and the corresponding priority, accept or reject the outcomes, depending on how you think they match or do not match with your opinion.

Exercise 3.1 Identifying and Prioritizing Local Indicators of Soil Quality - Worksheet No. 1

Group:________________ Narrator:___________________________________

Farmers names':

____

Local Indicator (Number and title)	Farmers			Total	Priority (average value *)
	1	2	3		

Exercise 3.1 Identifying and Prioritizing Local Indicators of Soil Quality - Worksheet No. 2

Local Indicator	**Groups Average**						Total	**Final Priority (average value*)**
	1	**2**	**3**	**4**	**5**	**6**		
1								
2								
3								
Xn								

- Average value = Total mean among the number of groups

Exercise 3.1 Identifying and Prioritizing Local Indicators of Soil Quality Feedback Information

The instructor, as part of the feedback information, is to show the trainees a case where indicators were identified as in the case of trainees in the stakeholder/soil quality indicator tool analysis workshop held in March 2000 in eastern Africa (Uganda). In this exercise, trainees in 3 groups were asked to play the role of farmers. Each group of "farmers" wrote down on cards 5-10 indicators of good soil and 5-10 indicators of poor soil and stuck these on a flip chart. The "farmers" presented and explained their indicators in a plenary session as shown below(The letters in brackets show indicators that are specific to the various countries: E = Ethiopia; K = Kenya; M = Madagascar; T= Tanzania and U = Uganda).

GROUP 1

GOOD	BAD
Gives good yield (T/K/E)	Sloppy shallow soils
Well drained	Rocky (water - logged) (E)
Udongo tifutifu (workable)	Lunyu (salty) (U)
Rhotuba (high fertility) (K/T)	Digitaria (indicator plant) (E)
Deep soils	Cracking soils (vertisols) (E)
Virgin soils	Kichanga (sandy soils) (T)
Valley bottoms alluvial soils	Tincha (story) (E)
Kossie (E) (High Organic Matter)	Striga infested
Sama (E) (indicator plant)	Fern (indicator plant for acidity) (T)
Serdo (E) (indicator plant)	Tindiga (swampy) (T/K)
Amaranthus (indicator plant) (T/K/U)	Litosi (clay for pottery) (K)
Soil with worms	

GROUP 2

GOOD	BAD
Colour of the crop green - good	Yellow/light grey soils
Deep soils	Poorly drained soils
Presence of certain weeds e.g. commelina, galinsoga	Presence of certain weeds e.g. striga/ferns
Black colour	Shallow soils
Growth vigour of the crop / vegetation	Stoniness
Anti hills	Limited worms
Water retaining	Excessive run off/ gullies, erosion
Easiness to cultivate	Poor growth/ stunted
Smell of rotting materials	Colour of the crop yellowish/purplish
Sedimentary Rock “Musimbi” W/Uganda	Difficult to cultivate hard pan
Presence of worms	
Well drained soils	

GROUP 3

GOOD	BAD
Wet/ retains water in dry season	Reddish/ brownish steep slops
Presence of earth worms	Bracken fern
Presence of Tithonia plants	Presence of striga
Can support many crops	Water logging
Workability	Stunted Plant growth
Vigour crops	Sick soils
Presence of obengele	Murram soils
Cool soils	Presence of couch grass
Black/ Dark	Sticky clay soil
Valley/ flat/ gentle plots	Thin/ shallow soil
Many diverse weeds	Ebeija
Deep soils	

Making compatible similar indicators

List of indicators, grouped around the same meaning.

Local Indicator	
Good crop vigour / Stunted growth Easy to cultivate / hard to cultivate Deep soils / Shallow soils Dark green plant colour / yellow purple e.g. ebeija Black soil colour / Yellow - grey, red - brown Weed species e.g. *Commelina* / Weed species e.g. Bracken fern, *Striga, Digitaria* Water retaining, well drained / water logged, sandy soils Presence of earth worms / Absence of earth worms salty e.g. visible at surface / Not salty Smell of rotting material / no smell	

Indicators priority matrix by "farmers" in each group.

Trainees as "farmers" in their groups prioritized the local indicators they had identified (1=highest priority and 10=lowest priority).

Local indicator	Group 1[a]	Group 2[a]	Group 3[a]	Total [b]	Average [c]
Good Crop / Stunted growth	3	2	4	9	3.0
Easy to cultivate / hard to cultivate e.g. hard pan	9	6	9	24	8.0
Deep soils/ shallow soils, erosion	2	5	5	12	4.0
Dark green plant colour	4	4	3	11	3.7
Black soil colour / Yellow purple e.g. ebeija	6	9	6	21	7.0
Weed species e.g. commelina / weed species e.g. Bracken fern , Striga, Digitaria	8	9	8	25	8.3
Water retaining, well drained / water logged, sandy soils	10	8	10	28	9.3
Presence of earth worms / Absence of earthworms	1	1	1	3	1.0
Salty e.g. visible at surface / Not salty	5	6	2	13	4.3
Smell of rotting / no smell	7	2	7	16	5.3

a The score in each cell is the result of the previous exercise to classify the cards into low, medium and high importance, individually by each "farmer", and writing it down on Table 1 Matrix.
b Is the sum of the rows, corresponding to each indicator.
c Is the average of the scores obtained for each indicator

A list of prioritized local indicators of soil quality.

Order of importance	Local indicator

3.3 Summary

In this section we saw how to work with farmers in order to identify their indigenous knowledge of local indicators of soil quality. Following the classification and ordering of local indicators farmers used a card classification system and a 2-way matrix table to prioritize these local indicators of soil quality.

In the next section these local indicators of soil quality will be integrated with the technical indicators of soil quality that were derived during the exercises in Section 2. This integration will allow the development of a common language between farmers and researchers which will be essential to allow information exchange and sharing of knowledge.

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Originals for Overheads

Section Objectives

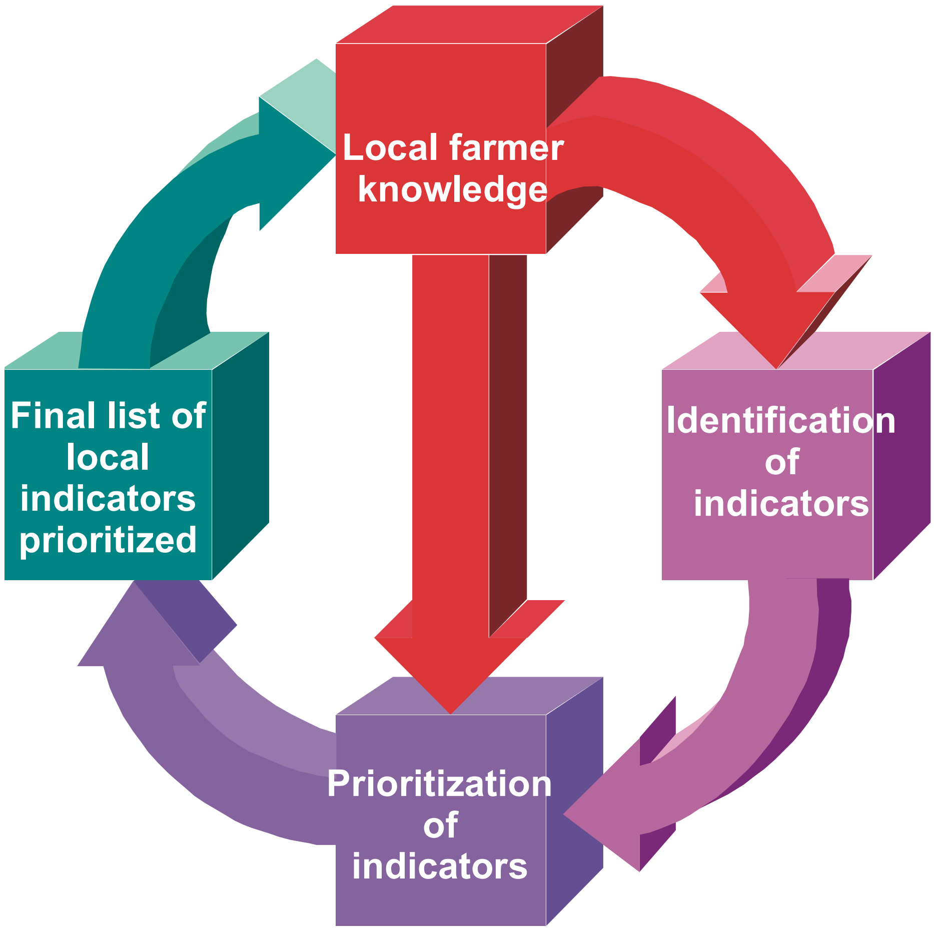
- ✓ The trainers will be able to obtain the local indicators of soil quality.

- ✓ The trainees will be able to group local indicators according to soil properties.

- ✓ The trainees will be able to prioritize local indicators of soil quality.

- ✓ The trainees will be able to describe the methodology used to obtain the local indicators of soil quality.

Section Structure



Opening Questions

1. What are the differences between a good and a bad soil?

2. How do you know if a soil is good, fairly good or bad for production?

3. Do you think that there are different types of soils on your farm?

4. Can you indicate the limits of the soil types on your farm?

What is the meaning of an "Indicator"?

Technical

Soil quality indicators are physical, chemical, and biological properties, processes, and characteristics that can be measured to monitor changes in the soil.

For example:

- **Slope**
- **pH**
- **Texture**
- **Organic matter**

What is the meaning of an "Indicator"?

Local

This describes soil quality using the language of farmers in a given community. It is the traditional, local terminology for soil characteristics.

For example:

- **Water retaining soil**
- **Black soil**
- **Deep soil**

Why do we need to incorporate farmers knowledge about soils?

- **It is the result of hundreds of years of trial and error and accumulated experiences**
- **It is valuable knowledge that tends to fade away with time**
- **It facilitates both actors (farmer and technician) to have a shared understanding of soils**
- **It is the farmer who knows and experiments with soils**

Methodology

Group analysis (brainstorming) to identify indicators

Prioritization of indicators

a.Two way matrix

b. Classification using cards

Case studies

Steps

Group analysis (Brainstorming session)

Farmers are asked to mention the characteristics they use to determine whether a soil is good, fair or bad

Local indicators are grouped with the list of characteristics

Prioritizing indicators

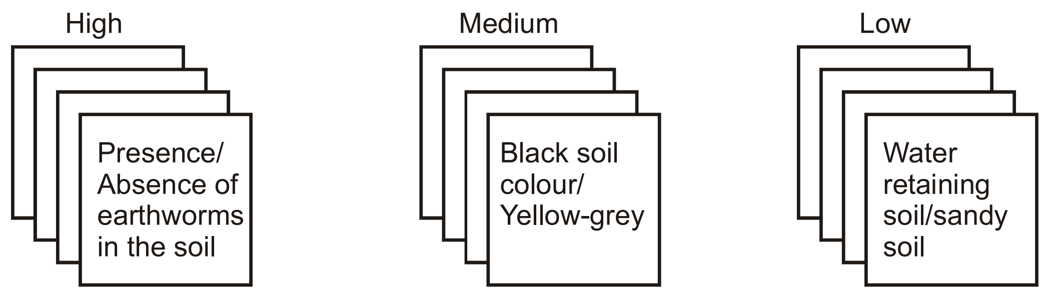
a. Two way matrix

Indicator	Water retaining soil	Black soil	Deep soil	Indicator $_n$
Water retaining soil				
Black soil				
Deep soil				
Indicator $_n$				

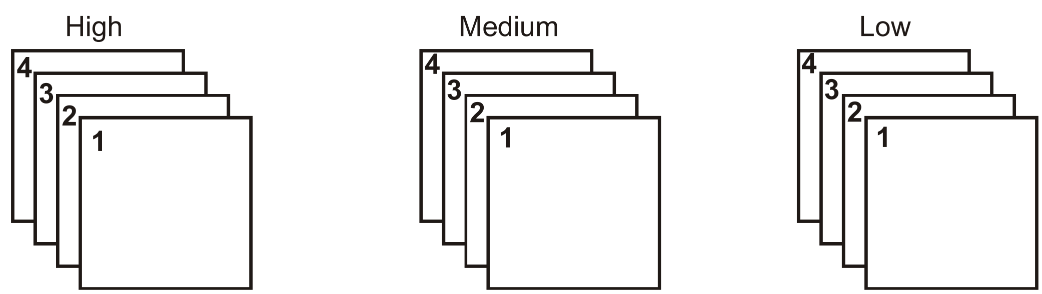
Indicator	Frequency	Priority Order
Water retaining soil		
Black soil		
Deep soil		

Classification using cards: Importance of indicators

Importance assigned by farmers



Value of each card



Indicators Prioritization Matrix for each Farmer within each Group

Group:_______________________ **Farmers' name**

Narrator:_____________________ **1.________________________________**
2.________________________________
3.________________________________

Indicator (number and title)	Farmers			Total	Priority (see average value*)
	1	2	3		
1					
2					
3					
X_n					

*** Mean value = Total score divided by the number of farmers in each row.**

Example of a Prioritization Matrix for three indicators and three Farmers

Indicator	Farmer			Total	Priority (average value*)
	1	2	3		
Loamy/muddy, too much sand	3	1	2	6	2
deep or thick soil/ thin soil	7	10	4	21	7
gentle slope/ foothill	1	2	6	9	3

*** Mean value = Total divided by the number of observed scores.**

Final Indicator prioritization Matrix, Group Means Calculated for each indicator

Indicator	Groups Average						Total	Final Priority (Average Value*)
	1	**2**	**3**	**4**	**5**	**6**		
Loamy/ muddy/ too much sand	2	3	5	1	9	5	25	5.0
Deep or thick soil/ thin soil	7	10	8	4	7	11	47	9.4
Gentle slope/ foothill	3	4	1	6	5	2	21	4.2
Burns/ does not burn								
Presence/ absence of earth worms in the soil								
X_n								

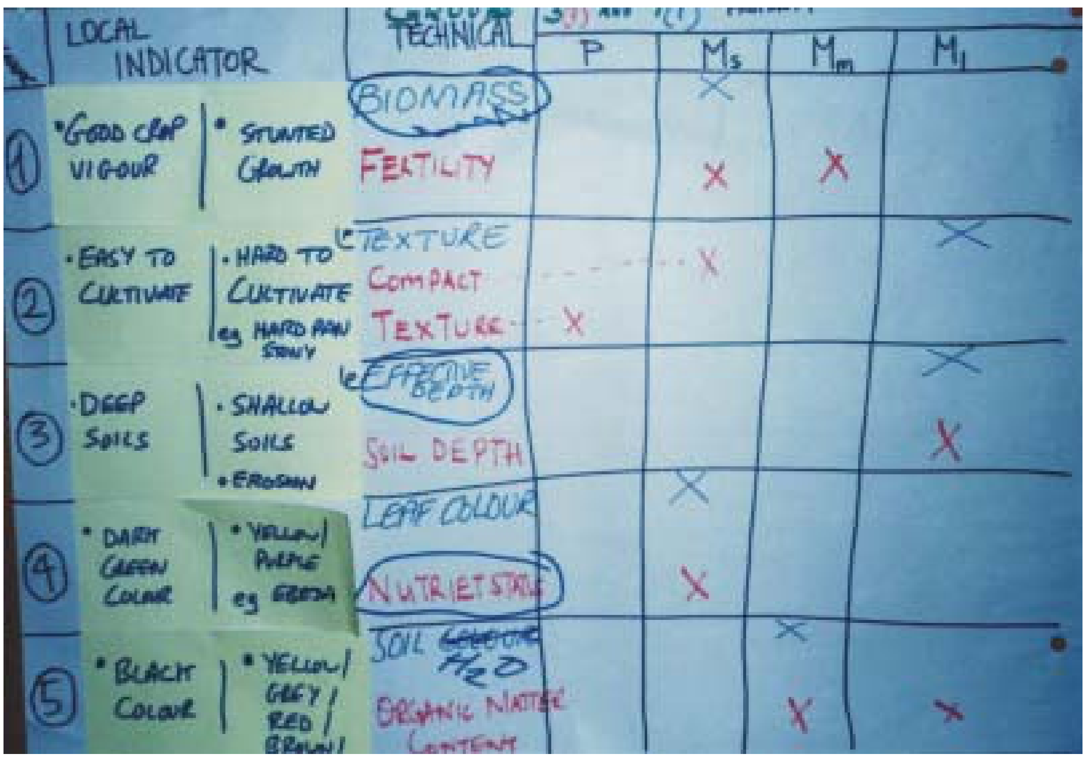
- **Mean value = Total divided by number of observed scores.**

Final List of Prioritized Indicators

Order of Importance	Indicator
1	Gentle slope/Foothill
2	Loamy/ Muddy, too much sand
3	Deep or thick soil/ Thin soil

SECTION 4

Integrating technical and local indicators of soil quality



Section 4: Integrating technical and local indicators of soil quality

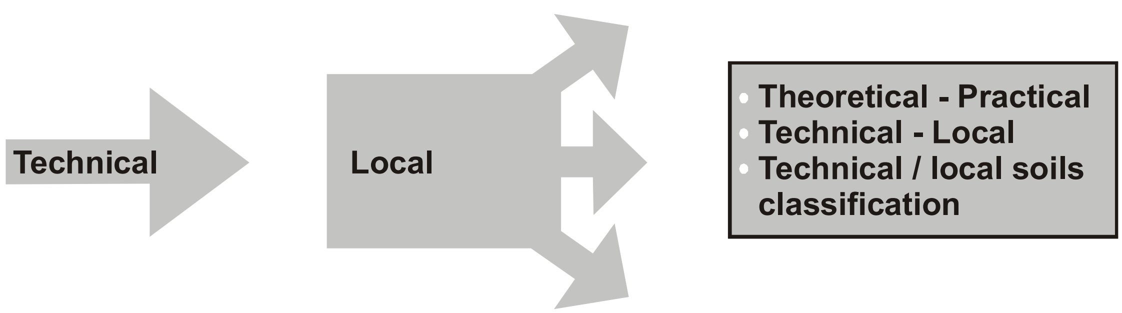
4.1 Introduction

In the previous sections we identified and categorized TISQ (Section 2) and we saw the methodology for the collection, classification and prioritization of LISQ (Section 3). In this section we will compare these two sets of indicators of soil quality and classify local indicators in technical terms and differentiate between permanent and modifiable properties

4.1.1 Objectives

- At the end of this section the trainees will be able to,
- Relate local indicators with soil properties.
- Relate technical indicators of soil quality with local indicators of soil quality.
- Differentiate between indicators of soil quality associated to soil properties that are modifiable or permanent.

4.1.2 Section structure



4.1.3 Opening questions

1. Do you know what "soil texture" is?

2. Do you know what "soil acidity" or "alkalinity "is?

3. How are the following conditions locally known (local terminology)?

    - Frequently flooded soils
    - Easy-to-plough soils
    - Good soils

4. What is a permanent soil quality property or indicator, and what is a modifiable property?

4.2 Relationship between TISQ and LISQ

The theoretical framework to compare local and technical indicators is based on the premise that the soil is a natural body organized as a continuum through the landscape, instead of being a discreet unit at smallholding or farm level. This concept is fundamental to understand how the intrinsic properties of a soil are more related to the environment in which the soil was formed (factors and processes), than to the agronomic management and its use.

If the soil is regarded as a resulting product (see the simplified formation model Section 2), and if its properties are broken down into permanent and modifiable, the process of comparing both local and technical knowledge about soils becomes easier. This is because the attributes and characteristics inherited from soil formation factors tend to become permanent properties, while the attributes conditioned by the environment (e.g. processes of nutrient lose and gain) tend to become modifiable properties. For instance, farmers frequently regard the slope as an attribute conditioning soil quality. On the other hand, farmers consider soil fertility as a quality attribute (very fertile land vs. washed land) and, in fact, in general terms soil fertility is an attribute considered to be something that can change through amendments (for example: fertilizers, incorporation of green manures).

The above discussion proposes a simple system to integrate local knowledge with technically recognized attributes and properties. This integration is done once after the prioritization of local indicators (Table 4.1 from Section 3).

Table 4.1 Example of prioritized LISQ from the training workshop held in Kampala in March 2000.

Order of importance	**Local indicator of Soil Quality**
1	Presence of earthworms/absence of earthworms
2	Good crop/stunted growth
3	Dark green plant colour/yellow,purple plant colour
4	Deep soils/shallow soils: erosion
5	Not salty/ salty i.e. visible at surface
6	Smell or rotting vegetation/no smell
7	Black soil colour/yellowish or greyish
8	Easy to cultivate/hard to cultivate e.g. hard pan
9	Presence of good indicator weed species e.g. *Commelina*/ presence of bad indicators e.g. Bracken fern, *Digitaria*
10	Good water retention-well drained/water logged, sandy soils

During the process of integration the objective is to make comparable the local knowledge with the technical knowledge, not vice versa. To do this technical terms are decided on that best capture each LISQ that the farmers use to classify their soils (Table 4.2).

Table 4.2 Example of the Integration of LISQ with LISQ from the training workshop held in Kampala in March 2000.

Indicator	
Local	**Technical**
Presence of earthworms/absence of earthworms	Biological activity
Good crop/stunted growth	Fertility
Dark green plant colour/yellow,purple plant colour	Leaf colour or nutrient status
Deep soils/shallow soils: erosion	Effective depth
Not salty/ salty i.e. visible at surface	Electrical conductivity and pH
Smell or rotting vegetation/no smell	Redox potential
Black soil colour/yellowish or greyish	OM content
Easy to cultivate/hard to cultivate e.g. hard pan	Texture or compaction
Presence of good indicator weed species e.g. C*ommelina*/ presence of bad indicators e.g. Bracken fern, *Digitaria*	Soil fertility or weed diversity
Good water retention-well drained/water logged, sandy soils	water holding capacity or infiltration

The last step in this integration exercise is to classify each of the TISQ into one of two groups, permanent properties and modifiable properties. In section 2 we saw that a permanent property is something about the soil which is unchangeable with time, for example, the slope of the land or the type of clay. In contrast, a modifiable property can be altered given time. The types of modifiable properties will be discussed further in Section 5. Table 4.3 shows an example of integration and classification for each group of prioritized indicators generated during from the training workshop held in Kampala in March 2000.

Table 4.3 Example of the final integration of TISQ with LISQ and classification of property type from the trainees during the training workshop held in Kampala, March 2000.

Order of importance	**Indicator**		**Type of property**	
	Local	**Technical**	**Permanent**	**Modifiable**
1	Presence of earth worms/absence of earthworms	Biological activity		X
2	Good crop/ stunted growth	Fertility		X
3	Dark green plant colour/yellow, purple plant colour	Leaf colour or nutrient status		X
4	Deep soils/ shallow soils: erosion	Effective depth		X
5	Not salty/ salty i.e. visible at surface	Electrical conductivity and pH		X
6	Smell or rotting vegetation/no smell	Redox potential		X
7	Black soil colour/ yellowish or greyish	OM content		X
8	Easy to cultivate/ hard to cultivate	Texture	X	
9	Presence of good indicator weed species e.g. *Commelina* presence of bad indicators e.g.Bracken fern, *Digitaria*	Soil fertility or weed diversity		X
10	Good water retention-well drained/water logged, sandy soils	water holding capacity or infiltration		X

4.3 Exercise 4.1 Classifying local indicators in technical terms and differentiation between permanent and modifiable properties.

Objectives

After completing this exercise the trainees will be able to:

Relate local indicators with soil properties;
Make compatible local language elements with the technical language;
Differentiate between permanent local indicators of soil quality and modifiable local soil quality indicators.

Orientations for the Instructor

Using Worksheet No. 1, review the list of prioritized LISQ

Using Worksheet No. 2, insert the list of LISQ from Section 3, divide the trainees into 3-5 groups and ask them to decide on a TISQ to match each LISQ. Return to plenary to summarize the findings

Using worksheet No. 3, in the same groups decide which of these TISQ are permanent and which are modifiable properties of soil. Return to plenary to summarize the findings

After this second summary, group the results and discuss differences and discuss the result in terms of time span and management options (leading into Section 5)

Resources necessary

- Thick tip markers (various colours)
- Flip chart paper
- Masking tape
- Overhead projector

Suggested time: 45 minutes.

Exercise 4.1 Classifying local indicators in technical terms and differentiation between permanent and modifiable properties.

Worksheet No. 1

Prioritization of LISQ

Order of importance	Local Indicator of Soil Quality
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	

Exercise 4.1 Classifying local indicators in technical terms and differentiation between permanent and modifiable properties.

Worksheet No. 2

Integration of LISQ with LISQ

Indicator	
Local	**Technical**

Exercise 4.1 Classifying local indicators in technical terms and differentiation between permanent and modifiable properties.

Worksheet No. 3

Order of importance	Indicator		Type of property	
	Local	Technical	Permanent	Modifiable
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

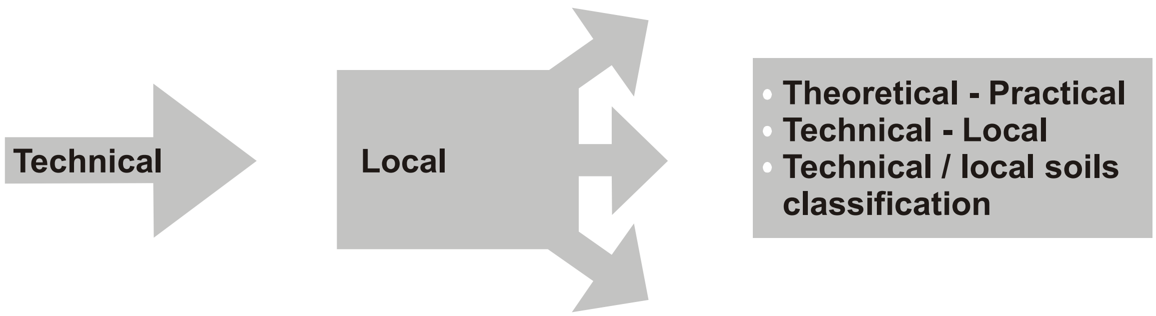
4.4 Summary

In this section we saw how to integrate the farmer classification of LISQ with TISQ to design a common language. This common language will be invaluable to enable the trainees to discuss with farmers their soils and the problems and constraints they face on their farms. In addition we developed the common language further to help us understand which of the problems and constraints faced by the farmers are modifiable and those that are not given a reasonable length of time and effort

In the next section we will look at the modifiable properties in more detail and group them into three classes depending on the time it will take to overcome the constraint short-term (0-2 years), medium-term (2-6 years) and long-term (more than 6 years). The final part of the program is then to define soil management principles and strategies that can be used to overcome the different constraints that farmers have identified.

Originals for overheads

Integrating soil characterization properties with local soil quality indicators



Objectives

At the end of this section the trainees will be able to,

- relate local indicators with soil properties.
- relate technical indicators of soil quality with local indicators of soil quality.
- differentiate between indicators of soil quality associated to soil properties that are modifiable or permanent.

Integrating soil properties with local indicators of soil quality

- During the process of integration the objective is to make comparable the local knowledge with the technical knowledge, not vice versa.

- To do this technical terms are decided on that best capture each LISQ that the farmers use to classify their soils

- The last step in this integration exercise is to classify indicators associated with permanent or modifiable soil properties

Table 4.1 Example of prioritized LISQ from the training workshop held in Kampala in March 2000.

Order of importance	Local indicator of Soil Quality
1	Presence of earthworms/absence of earthworms
2	Good crop/stunted growth
3	Dark green plant colour/yellow,purple plant colour
4	Deep soils/shallow soils: erosion
5	Not salty/ salty i.e. visible at surface
6	Smell or rotting vegetation/no smell
7	Black soil colour/yellowish or greyish
8	Easy to cultivate/hard to cultivate e.g. hard pan
9	Presence of good indicator weed species e.g. *Commelina*/ presence of bad indicators e.g. Bracken fern, *Digitaria*
10	Good water retention-well drained/water logged, sandy soils

Table 4.2 Example of the Integration of LISQ with LISQ from the training workshop held in Kampala in March 2000.

Indicator	
Local	**Technical**
Presence of earthworms/absence of earthworms	Biological activity
Good crop/stunted growth	Fertility
Dark green plant colour/yellow,purple plant colour	Leaf colour or nutrient status
Deep soils/shallow soils: erosion	Effective depth
Not salty/ salty i.e. visible at surface	Electrical conductivity and pH
Smell or rotting vegetation/no smell	Redox potential
Black soil colour/yellowish or greyish	OM content
Easy to cultivate/hard to cultivate e.g. hard pan	Texture or compaction
Presence of good indicator weed species e.g. C*ommelina*/ presence of bad indicators e.g. Bracken fern, *Digitaria*	Soil fertility or weed diversity
Good water retention-well drained/water logged, sandy soils	water holding capacity or infiltration

Table 4.3 Example of the final integration of TISQ with LISQ and classification of property type from the trainees during the training workshop held in Kampala, March 2000.

Order of importance	Indicator		Type of property	
	Local	Technical	Permanent	Modifiable
1	Presence of earth worms/absence of earthworms	Biological activity		X
2	Good crop/ stunted growth	Fertility		X
3	Dark green plant colour/yellow, purple plant colour	Leaf colour or nutrient status		X
4	Deep soils/ shallow soils: erosion	Effective depth		X
5	Not salty/ salty i.e. visible at surface	Electrical conductivity and pH		X
6	Smell or rotting vegetation/no smell	Redox potential		X
7	Black soil colour/ yellowish or greyish	OM content		X
8	Easy to cultivate/ hard to cultivate	Texture	X	
9	Presence of good indicator weed species e.g. *Commelina* presence of bad indicators e.g.Bracken fern, *Digitaria*	Soil fertility or weed diversity		X
10	Good water retention-well drained/water logged, sandy soils	water holding capacity or infiltration		X

SECTION 5

Appropiate management of the soil will ensure sustainable use of this valuable resource for present and future generations.

Section 5: Integrated Soil Management Strategies

5.1 Introduction

In Section 4 local and technical indicators of soil quality were integrated to form a technical-local soil classification system. In addition, these indicators of soil quality were classified into two groups, permanent and modifiable properties.

Such a classification system takes into consideration the abundant knowledge farmers have on their soils and hence can be used as a tool to devise appropriate management strategies of identified constraints. Having involved the users and main beneficiaries of the soil in the identification and classification of the indicators of soil quality it is possible to devise management strategies that can easily be adopted by them. In this section we shall learn integrated soil management strategies that can be applied by farmers to address identified soil constraints with the overall aim of enabling them to choose between different options depending on their resource endowment. We shall differentiate between short, medium and long term modifiable soil properties as well as identifying short, medium and long-term management strategies for identified constraints.

5.1.1 Objectives

At the end of this section the trainees will be able to:

- ✓ Differentiate between short, medium and long term modifiable soil properties.
- ✓ Identify short, medium and long term management strategies for identified constraints.
- ✓ Devise soil management strategies to address identified constraints.

5.1.2 Section Structure

The section structure is given in Figure 1.

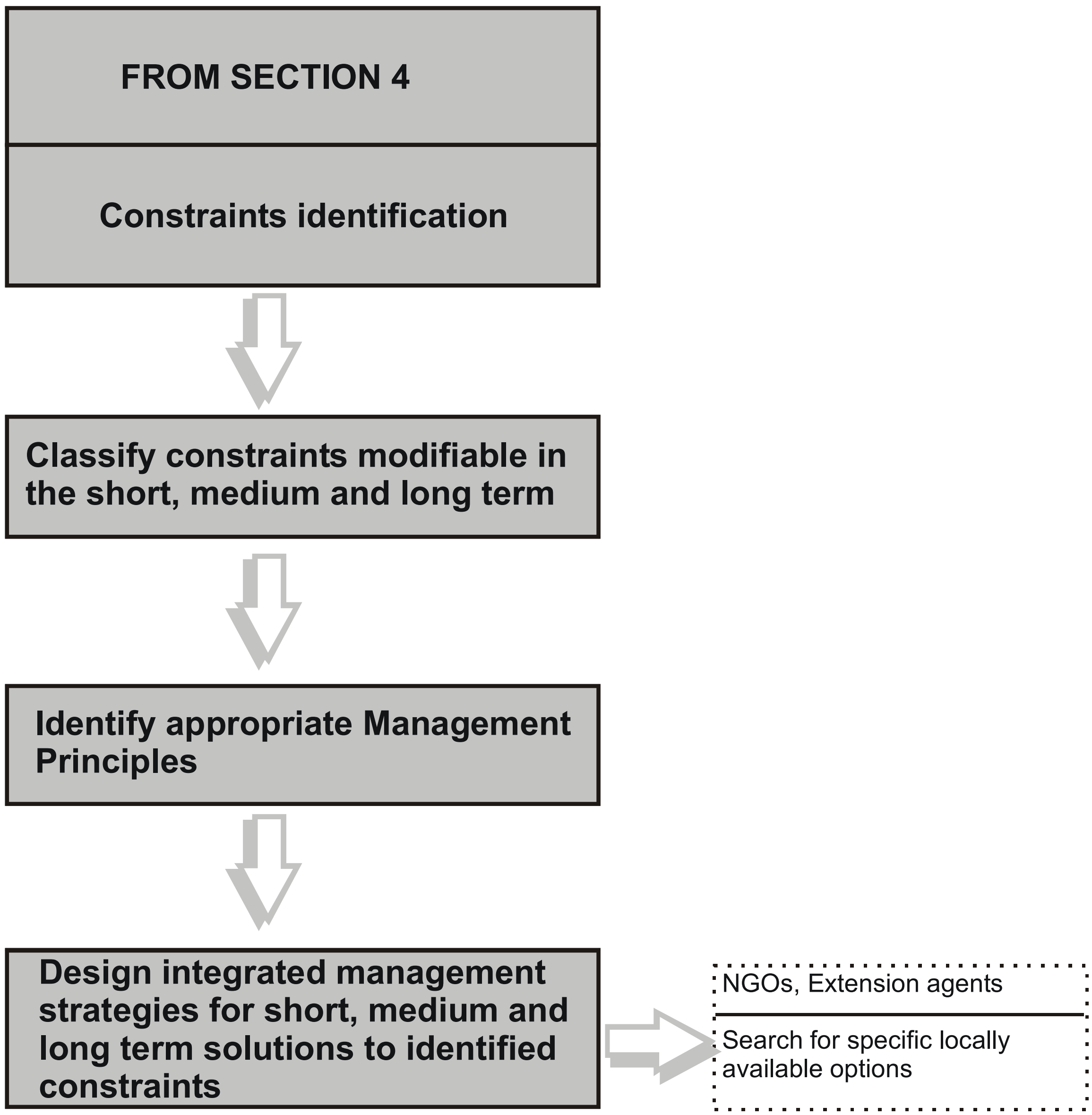


Figure 1 Outline structure of Section 5

5.1.3 Opening Questions

- Do you know any soil properties that can be modified through management.

- How do you know when you have a soil management problem?

- Once you know there is a soil management problem in a farm/plot what do you do?

- Do you know of any traditional soil management strategies (successful and unsuccessful) applied by farmers in your area?

- Do you know of any technical soil management strategies (successful and unsuccessful) applied by farmers in your area?

- Do you know three short-term soil management strategies?

- Do you know three medium-term soil management strategies?

- Do you know three long-term soil management strategies?

- Why is it important that farmers participate in the design of soil management practices?

5.2 Classifying Modifiable Soil Constraints

Modifiable soil constraints are those that can be overcome through management. Examples include low nutrient and water availability, low and high pH, soil compaction and low soil organic matter content. We distinguish between constraints that can be modified in the short, medium and long term depending on the time span required for an appreciable change to take place. Some constraints are not easily modifiable, like rooting depth which can be modified depending on the cause of that constraint such as chemical barrier and compaction. Further, all proposed solutions depend on resource endowment, mainly cash availability. Social and cultural factors can also limit or determine the duration in which a constraint can be overcome, for example, labour availability, distribution of resources, taboos attached to certain crops or consideration of manure as dirt. For the purpose of this manual the time span has been set as follows:

Short term = less than 2 years,
Medium term = between 2 and 6 years,
Long term = more than 6 years.

The separation between short, medium and long term is necessary to enable prioritization of management strategies, which are mainly dictated by resource endowment. A summary of soil constraints modifiable in the short term, medium and long terms and the soil management principles and strategies to overcome the identifiable constraints in the short, medium and long terms are given in Tables 5.1a, 5.1b and 5.1c respectively.

Table 5.1a Soil constraints, management principles and management strategies.

Table 5.1a Soil constraints, management principles and management strategies.

Soil constraints	Management principles	Management strategies
Constraints modifiable in the short term		
Low or limited nutrient availability	Replenish nutrients in depleted soils	Apply fertilizers. Soluble inorganic fertilizers like N and K applied each season offer short-term solution. Soluble P fertilizer offers both short and medium term solution (residual effect).
Low soil pH	Maintain soil pH between 5 and 7	Liming offers short, medium and long-term solution while phosphate rock apart from supplying P (Semoka, 1989; Mnkeni et al, 1991), modifies soil pH and hence offering short, medium and long-term solution. Adopt crops tolerant to low pH.
Some soil borne diseases and pests	Preserve soil biological integrity	Diversify cropping systems in time and space Application of pesticides directly into the soil
Weeds	Suppress weeds	Frequent weeding and the use of herbicides.
Low or limited water availability	Conserve soil moisture	In the short-term irrigation and rainwater harvesting and minimizing evaporation loss through mulching will address the problem.
Poor water infiltration	Avoid soil compaction	Deep tillage and avoiding using heavy machinery will address the problem.
Soil compaction	Avoid soil compaction	Breaking the compact layer using appropriate tillage machinery e.g. chisel plough will offer short-term solution.

Figure 1: Weeds: A short-term constraint that can be modified in the short term. Here bracken ferns are suffocating maize in Kwalei, Lushoto, Tanzania.

Figure 2: Application of fertilizer will address low or limited availability of nutrients. Bean treated with Minjingu rock phosphate + organics (farmyard manure or Venonia subligera shrub) (Right), versus untreated plot (Left) in Kwalei, Lushoto. Note that the treated plot has almost attained maturity.

Table 5.1b

Soil constraints	Management principles	Management strategies
Constraints modifiable in the medium term		
Low organic matter content	Optimize soil organic matter content	The use of organic residue, use of green manure and practicing no till systems.
Poor soil structure	Maintain optimum soil structure	Use organic manure, maintain improved fallow systems and practice minimum tillage.
Stoniness	Ensure stone free seedbed	Remove stones

Figure 3: Application of mulch will conserve soil moisture. Here the Venonia subligera shrub has been applied as a mulch on a bench terrace in Kwalei, Lushoto, Tanzania.

Table 5.1c

Soil constraints	Management principles	Management strategies
Constraints modifiable in the long term		
Nutrient depleted soils	Replenish nutrients in depleted soils	Use integrated management strategies aiming at reclaiming the soils. Apply fertilizers to restore soil nutrient reserve (e.g. for P recapitalization by applying phosphate rock), use organic manure/residue, integrate N fixing crops in the cropping system, institute improved fallows, appropriate rotation, use of crops not sharing the same niche in time and space (e.g. short and deep rooted crops, short duration and long duration crops) will ensure better distribution of nutrient exploitation.
High pH/Salinity	Maintain suitable soil pH (Between 5 and 7)	Improve drainage, flush salts with good quality water and use good quality water for irrigation.
Low effective rooting Depth	Protect soil against erosion	Construct soil conservation measures e.g. contour bunds, cut ditches, bench terraces and incorporate trees and grasses to ensure soil build up.
Culture of uncontrolled burning	Apply judicious burning practices	Create awareness among farmers on the negative effects of uncontrolled burning as well as enlightening them on the importance of practicing efficient organic residue management.

Figure 4: Soil conservation through use of appropriate structures can improve productivity. The maize in front of the woman was planted on an un-terraced plot 4 days Earlier than the maize behind the woman who is on a bench terrace.

Exercises in Identifying Soil Constraints and Devising Integrated Soil Management Strategies

Objectives

After completing the exercise the trainees will be able to:

Identify constraints to soil productivity
Devise soil management strategies to address these constraints

Orientation for the Instructor

Using the case studies work with the trainees to answer the questions, encourage the trainees to answer the questions before they see the answers. The answers are given in Appendix 1.

Guidelines for the trainee

Read carefully the information given for each case study and answer the questions that follow.

Resources necessary

A pen and a sheet of paper

Suggested time: 20 minutes for each case study

5.3.1 Case Studies

Tanzania. Kwalei catchment (Lushoto AHI benchmark site).

Kwalei catchment is located in Lushoto District, Tanga Region Northeast Tanzania. Lushoto District lies between 4 22' and 5 08' South and between 38 5' and 38 38' East in the Usambara mountain ranges. With an area of 3500 km2 and a population of about 471240, based on the 1988 census and a growth rate of 2.8 % (Lyamchai, 1998), it is the most populated district in the country.

Kwalei village is in Mamba ward in Soni division in the southern part of the district about 12 km south of Soni Township. The average altitude is 1300 m.a.s.l. with hilly steep slopes and medium tall mountains and narrow valley bottoms. Annual rainfall varies from 800 to 1700 mm. The area occupied by the catchment is about 5 km2 while the population is about 5274.

Major activity in the catchment is farming. The main crops are tea, coffee, maize (intercropped with beans or banana), vegetables and fruit trees. Livestock population is low and poorly kept and mainly comprises of cattle, goats and sheep.

Land ownership is restricted to men because they are the ones who can inherit it from their parents according to customary law. About 90 % of the land is acquired this way while the remaining 10 % is acquired through buying. Although women cannot inherit land they can own it as long as they can afford to buy but this is rarely done.

The household contributes about 90 % of the labour requirement while the remaining 10 % comes from hired labour. Almost all operations are done by all members of the family except pruning and spraying coffee, which is done by men and threshing and shelling of maize, which is done by women.

The major crop production constraints are low soil fertility, loss of topsoil through erosion, non-use or limited use of both organic and inorganic fertilizers, lack of opportunities for fallow, and pests and diseases. During a PRA conducted in 1998 (Lyamchai et al, 1998), farmers reported that there was virtually no soil erosion up to 1950's. Uncontrolled human activities including deforestation, cultivation of marginal areas and free livestock grazing are among factors responsible for increased soil erosion in the village. Others include lack of soil erosion control structures and cultivation along riverbanks and steep slopes. Pfeiffer (1990) reported a loss of about 100 tones per hectare in some steep areas of Lushoto, carrying with it about 370 kg N per hectare per year among other nutrients.

The use of inorganic fertilizers is limited by their high prices and unavailability while the limited use of organic manure is due to the low amounts produced because of the low livestock population. Due to poor storage of the organic manure its quality is also low. Farmers traditionally use a local shrub called "tughutu" (Venonia subligera) believed to enrich the soil. In a study by Wickama and Mowo (1999) the shrub was found to contain relatively high amounts of N, P and K. However, the amounts of the shrub produced are low..

Questions:

1. Mention the major soil constraints at Kwalei catchment.

2. How would you go about solving each of these constraints with the aim of rendering the soil more productive.

3. Given that land is limited suggest ways of improving soil productivity within the land and other resources available to Kwalei farmers.

Tanzania Lowlands of Masama division

Masama division is located in the central part of Hai district in Kilimanjaro region North of Tanzania. The area of the Division is about 418 km2. The foothills of Mt. Kilimanjaro to the north dominate the topography of the division. It stretches southwards to the lowlands of Sanya plains. Three divisions, the uplands, midlands and lowlands based on altitude, can be identified.

The lowlands covers an area approximately 312 km2 and maximum altitude if 900 m.a.s.l. Annual rainfall is about 580 mm. It is the least populated of the three altitude zones with a population density of 50 persons km2 against 250 and 650 in the mid and uplands respectively. The high population pressure as you go upward has forced out-migration to the lower slopes. There is a high risk of increased land fragmentation, overexploitation of soils due to absence of opportunities for fallow and bringing of marginal lands to arable agriculture.

Soils.

Predominant soils include Lithosols , Regosols and Fluvisols (USDA :Entisols) . The weakly developed Lithosols are shallow and stony and consists of black sandy loam's and sandy clays. They are mainly used for extensive grazing and recently for maize and beans. The Regosols are brown and reddish brown in colour, clay in texture and are shallow and stony. Extensive grazing is the most suitable land use although maize and beans are grown during the wet seasons. Irrigation is necessary to supplement the low rainfall. The Fluvisols are dark reddish-to-reddish brown alluvial soils occurring along rivers Sanya and Kikuletwa. They are deep, loam to clay loam in texture and highly fertile. They are mainly used for irrigation agriculture.

Socio-economics

The major enterprise is farming. There are limited opportunities for off-farm activities in the form of small rural trading centres, selling of vegetables along the main roads etc. There are two types of land tenure: the 'Kihamba' and 'Shamba'. 'Kihamba' is clan land to which the occupants have permanent freehold rights and are found in the uplands. In the lowlands, are 'shambas' and traditionally they used to be held on a yearly basis at the discretion of the chief. Today 'shamba' tenure is obtained by registering land with the local authorities through the village committee. This type of tenure is increasingly secure and can therefore be traded privately.

The household is composed of the core family (man, wife and children) and extended family and is mainly headed by men. Members of the family form the bulk of the labour and there is no strict gender division of labour. In some cases farmers hire tractors and/or labour. Decision making on land and livestock disposal is vested on men in male headed families while both men and women play role in deciding on land use issues.

The major production constraints include high prices and/or unavailability of inputs, recurrent drought, low quality of feeds, poor husbandry, predominance of stones, poor fertilizer application methods, limited use of manure due to lack of transport facilities and land shortage leading to frequent clashes between livestock keepers and crop producers.

Questions.

1. What are the major constraints limiting optimum soil productivity in Masama division?

2. How would you address each of these constraints in order to improve agricultural production in the Division?

Madagascar Fianarantsoa AHI site

The Fianarantsoa AHI site in Madagascar is located at an altitude of between 1100 and 1500 m.a.s.l. and 21 south. The site fall into what geographers call rejuvenated surfaces. There has been a general geomorphological action during the quaternary cycle, where erosion cycle restarted. This natural action was speeded up by human activities, such as deforestation, bush fires and cultivation. Slopes vary from gentle to steep. But the erodible soil material was washed away as soon as the protective cover disappeared. There are a lot of rocky areas in the site. The effects on water infiltration and surface water flows are tremendous.

Rainfall is uni-modal. The rainy season lasts from November to March. During the last few years, there has been a noticeable change in rainfall pattern, rains coming either late or stopping early. Rainfall averages 1100mm annually with maximum of 1500 mm and a minimum of 800 mm.

Major cropping systems are lowland rice practiced by all farmers except migrants who do not own paddy fields, upland crops such as cassava, grain legumes, maize (in the more fertile niches only) while at higher altitudes sweet potato replaces cassava. Rice is the staple food and the major cash earner.
Cattle keeping used to be an integral part of the farming system but the number of zebu cattle has diminished substantially since 1985 when organized banditry hit the area.

The major farming systems are:

·Traditional rice-cassava-grain legume system

·Intensified rice-sweet potato-grain legume system

Soils

The two farming systems have developed in different pedological environments.

Cassava: Oxisols (FAO: Ferralsols), rhodic (reddish)or ochric (yellowish) with medium to low fertility levels. The pH varies from 5.0 to 5.5.

Sweet potato: Ultisols (FAO: Acrisols), ochric with low fertility levels. pH varies from 4.5 to 5.0

In the valleys, there are waterlogged soils or alluvial soils. In some areas the soils are shallow where the organic matter enriched layer is less than 10 cm deep. Some soils are compacted hence experience lowered porosity and impaired infiltration. The average organic matter content is low to medium, soil pH is low, and especially in the ultisols, aluminium toxicity is frequent. The CEC is low because of the kaolinitic character of the clay and because of the iron coating on the clay. Most soils are deficient in N and P. Other soils may be deficient in Ca and K while micronutrient deficiencies (Bo, Zn and Mo) have been found in different places. Poorly drained paddy soils are mostly deficient in N and P and show Fe toxicity.

Questions:

1. Mention two soil chemical and two physical constraints of the soils at the Fianarantsoa AHI site.

2. How would you go about rejuvenating the soils at this site?

3. The change in rainfall pattern at Fianarantsoa was mainly caused by human activities. Explain.

4. How would you address the problems of low pH, low organic matter and low contents of N, P and K at Fianarantsoa in the short, medium and long term.

5.4 Summary

This chapter dealt with management strategies of soil constraints after both local and technical soil constraints were integrated in the previous chapters to give a common nomenclature that does not only reflect the real situation at the level of the farmer taking into account the enormous indigenous technical knowledge they have but also in a language that can be understood by both extension staff and researchers.

5.5 Bibliography

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Originals for Overheads

Structure of the Section

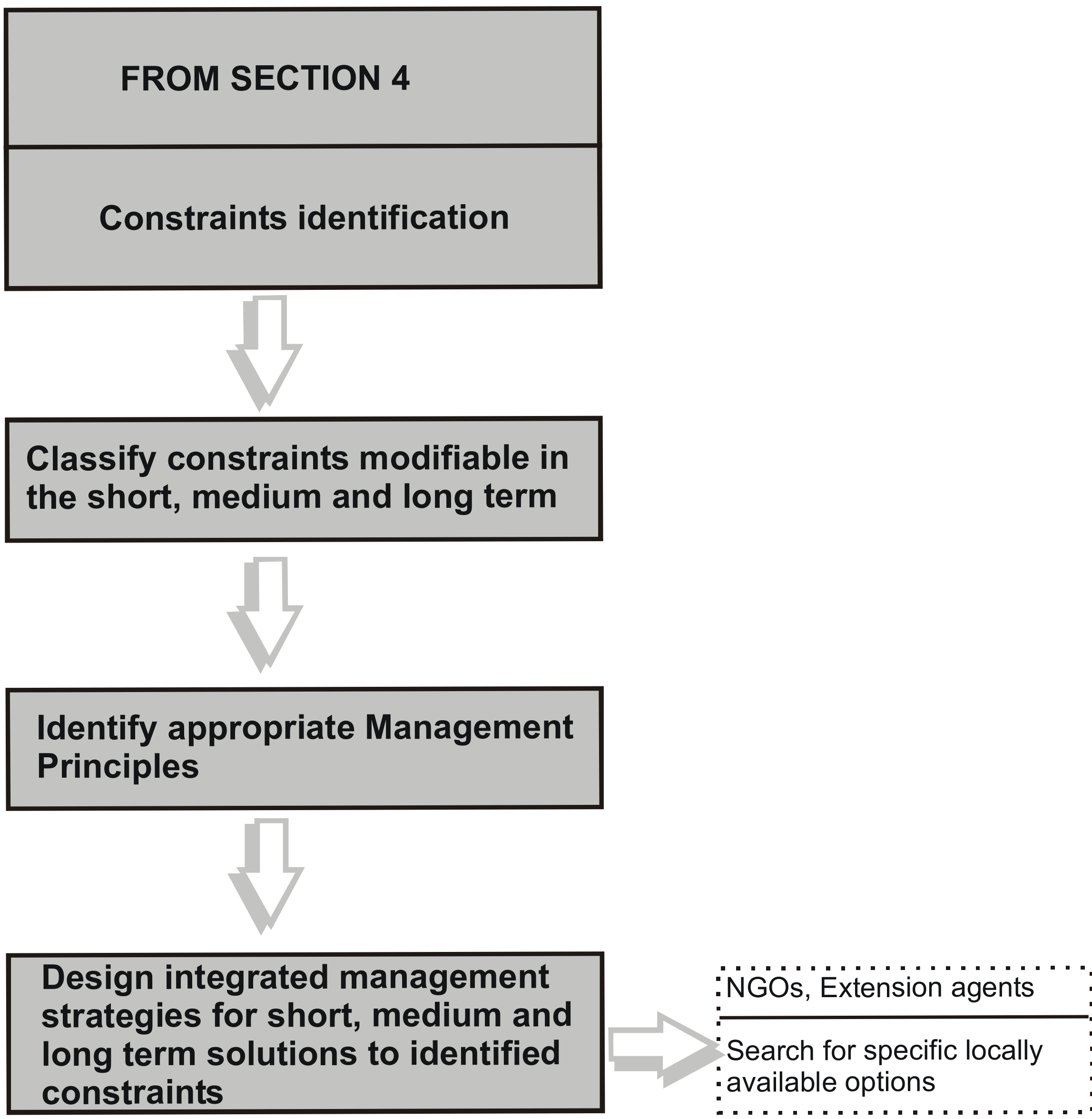

Figure 1 Outline structure of Section 5

Objectives

To enable trainees to:

- Differentiate between short, medium and long term modifiable soil properties.
- Identify short, medium and long term management strategies for identified constraints.
- Propose short, medium and long term management strategies for identified constraints.

Opening Questions

Aims at establishing how much do the trainees know about soil manageement

Examples:

- Do you know any soil properties that can be modified through management.
- How do you know when you have a soil management problem?
- Once you know there is a soil management problem in a farm/plot what do you do?

Modifiable Soil Constraints

'Those that can be overcome through management'

Examples: Low nutrient and water availability
Low and high pH
Soil compaction
Low soil organic matter content
etc.

We differentiate between:

Short term = less than 2 years,
Medium term = between 2 and 6 years,
Long term = more than 6 years.

This differentiation enables prioritization of management strategies according to resource endowment

Soil constraints, management principles and management strategies.

Soil constraints	Management principles	Management strategies
Constraints modifiable in the short term		
Low or limited nutrient availability	Replenish nutrients in depleted soils	**Apply fertilizers**
Low soil pH	Maintain soil pH between 5 and 7	**Liming** **Adopt crops tolerant to low pH.**
Some soil borne diseases and pests	Preserve soil biological integrity	**Diversify cropping systems in time and space** **Apply pesticides**
Weeds	Suppress weeds	**Weed frequently** **Use of herbicides**
Low or limited water availability	Conserve soil moisture	**Irrigate** **Harvest rainwater** **Minimizing evaporation**
Poor water infiltration	Avoid soil compaction	**Deep tillage** **Do not use heavy machinery**
Soil compaction	Avoid soil compaction	**Break compact layer**

Soil constraints	Management principles	Management strategies
Constraints modifiable in the medium term		
Low organic matter content	Optimize soil organic matter	**The use of organic residue, use of green manure and practicing no till systems.**
Poor soil structure	Maintain optimum structure	**Use organic manure, maintain improved fallow systems and practice minimum tillage.**
Stoniness	Ensure stone free seedbed	**Remove stones**

Soil constraints	Management principles	Management strategies
Constraints modifiable in the long term		
Nutrient depleted soils	Replenish nutrients in depleted soils	**Integrated management strategies aiming at reclaiming the soils** ***Examples:*** - Use organic and inorganic fertilizers - Integrate N fixing crops in the cropping system - Institute improved fallow - Apply appropriate rotation - Use of crops not sharing the same niche in time and space
High pH/Salinity	Maintain suitable soil pH (Between 5 and 7)	Improve drainage Flush salts with good quality water Use good quality water for irrigation
Low effective rooting Depth	Protect soil against erosion	Construct soil conservation measures Incorporate trees and grasses to ensure soil build up.
Culture of uncontrolled buming	Apply judicious burning practices	Create awareness Train farmers on efficient organic residue management

5.7 Appendix 1

Answers to the case study questions

Tanzania Lushoto Benchmark Site

Question 1

Major soil constraints at Kwalei:

- Low soil fertility coupled with limited or non-use of both organic and inorganic fertilizers.
- Loss of topsoil through erosion
- Absence of opportunity for fallow

Question 2

The problem of low soil fertility can be overcome in Kwalei through the use of both organic and inorganic fertilizers. Because inorganic fertilizers are expensive use can be made of the locally mined Minjingu PR in combination with farmyard manure or the local shrub (Venonia subligera). Since farmyard manure production and quality is low measures should be taken to increase the amount through improved feeding of livestock as well as in improving its quality by improving farmyard manure storage.

Question 3

Introduce improved fallow, judicious use of farmyard manure and the shrub Venonia subligera.

Tanzania Lowlands of Masama division

Question 1

Major soil constraints limiting optimum soil productivity in Masama division:

- Limited use or lack of farmyard manure
- Lack of simple transport facility for ferrying farmyard manure to the farms
- Lack of opportunities for fallow
- Poor fertilizer application methods
- High fertilizers price
- Stoniness

Question 2

These constraints can be addressed through:
Increase farmyard manure through improvement in livestock feeding and encouraging zero grazing to minimize wastage of farmyard manure

Local craftsmen empowered to manufacture simple transport tools using local materials

Introduce improved fallow

Extension staff demonstrates to farmers better fertilizer application methods

Encourage use of indigenous nutrient resources such as Minjingu phosphate rock

Collect stones and sell them to builders

Madagascar Fianarantsoa AHI site

Question 1

Chemical soil constraints:
Low soil pH
Micronutrient toxicity
Low CEC
Low content of major plant nutrients

Physical soil constraint:
Shallow soils
Soil compaction
Poor infiltration and impaired porosity

Question 2

Use light machinery, construct soil and water conservation structures, apply manure inorganic fertilizers and crop residues, address micro-nutrient (Bo, Zn, and Mo) deficiency, apply lime to correct soil pH and correct aluminium toxicity, improve livestock management including security.

Question 3

Through deforestation and bush fires and absence or minimum planting of trees rainfall amount and pattern has been altered.

Question 4

Soil pH Lime and apply phosphate rock (if locally available or if can be imported from near-by countries). Also one can introduce crops adapted to low pH.

Low organic matter Use crop residue and farmyard manure

Low contents of N, P and K Apply inorganic fertilizers (N, P and K), introduce crop rotation or intercropping involving crops not exploiting the same niche. Intercrop with legume crops capable for fixing atmospheric N.

SECTION 6

Soil Fair : Integration in Practice

Section 6: Soils Fair : Integration in Practice

6.1 Introduction

The Soils Fair demonstrates practically the integration (Section 4) of the technical knowledge gained on local indicators of soil quality (Section 2) with the technical knowledge of soil quality (Section 3), see Fig. 6.1.

This section develops the trainees understanding of soil physical, chemical and biological properties through the use of simple practical exercises. These exercises do not aim to go intoa detailed study of soil characteristics, instead, they aim to introduce some concepts and ideas to the trainees, so that they can relate technical and local indicators of soil quality with their permanent and modifiable characteristics. The soil characteristics that will be investigated during the Soils Fair are outlined in Table 6.1.

Table 6.1 Soil properties and methodologies used to determine those soil properties.

Properties	**Table number**	**Method**
Texture Consistency	**1**	Hand evaluation Hand evaluation
Organic matter Colour	**2**	Addition of hydrogen peroxide Munsell colour chart
pH Carbonates Indicator species	**3**	pH paper Addition of hydrochloric acid Participatory determination
Structure Macro/micro fauna	**4**	Visual examination Observation and counting

6.1.1 Objectives

At the end of the Soils Fair the trainees will,

- ✓ have developed their skills to be able to determine by using simple and easy methods, soil physical, chemical and biological properties.

- ✓ be able to relate these technical indicators to local indicators of soil quality
- ✓ be able to explain the relationship between technical and local indicators of soil quality to others

6.2 Organization of the Soils Fair

The outline of the preparation and organization of the Soils Fair is given in Fig. 6.2, the Soils Fair takes one day and occurs on the last day of the training workshop.

6.2.1 Before the Soils Fair

At the planning stage of the training workshop a coordinator needs to be appointed who is responsible for preparation and purchase of all materials required and for organizing the logistics to successfully run the Soils Fair.

Before the Soils Fair the order of planning is:

1. Conduct field day with local farmer community to collect LISQ.

2. Ensure that all materials required for the Soils Fair are purchased before the start of the training workshop.

3. During the training workshop agree on who (two trainers per table) is to demonstrate the soil property at each table

4. The appointed people are to prepare wallcharts for each Group to record the Soils Fair results as outlined in Appendix 6.1. These wallcharts

are to be displayed on the wall behind the tables and filled in by the people leading the demonstration.

Produce sufficient photocopies of the Farmer Worksheet (Appendix 6.2).

6.2.2 During the Soil Fair

During the Soils Fair the order of planning is:

The trainees are assigned to a starting Group, this starting group also contains at least two farmers who were involved in the identification of LISQ before the start of the training exercise. The farmers are given their Farmer Worksheet.

The opening questions are used to introduce the subject being demonstrated at that table. It is important for the audience to understand that this is not an examination but a method to know the starting point, in order to optimize the training event and at the end to be able to evaluate the benefit obtained by the trainees during the practice. Sample answers are given in Appendix 6.3.

Note: The questions are written to allow selection of the most convenient method of introduction and presentation to the trainees. For instance, give them the questions to be answered in groups (remember that they have these questions in the working material) and afterwards organize a plenary discussion to discuss the groups answers.

5. The practical should be developed according to the level of knowledge of the trainees.

Note: If chemical reagents are used in the practical, warn the trainees of the danger

6. The trainers demonstrating the topic should record on the wallchart the individual results for each farmer and the farmer should record their result on the Farmers Worksheet

7. After completing the practicals for that Group, the trainees are to pass to the next Group until all four Groups have been completed (Fig. 6.3).

6.2.3 After the Soil Fair

After the Soils Fair the order of planning is:

1. After the trainees and Farmers have completed all four Groups the wallcharts for each Group are correlated and transcribed into a table so that they can be discussed with the trainees and farmers during the following plenary session.

2. Hold the plenary session and explore the impact produced by the practicals on the trainees and farmers way of thinking (take as reference the responses to the questions at the end of the practice). Identify the strengths and weaknesses in the knowledge acquired.

3. In this plenary session the following key concepts should be addressed:

- ✓ why were the practicals grouped as they were
- ✓ what did you learn
- ✓ how can this knowledge be used in the field

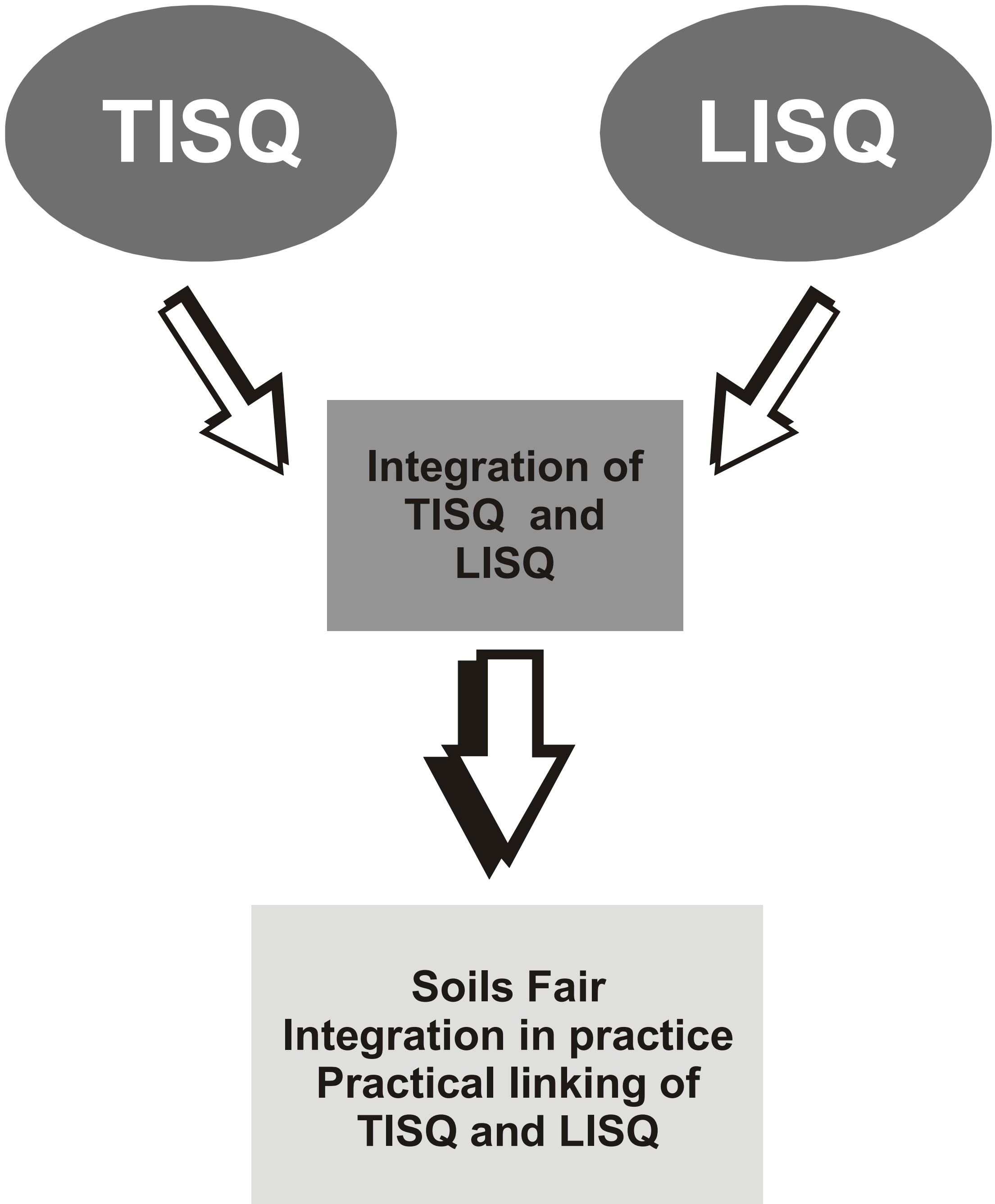

Fig. 6.1 How the Soils fair integrates technical knowledge with practical determination of soil quality

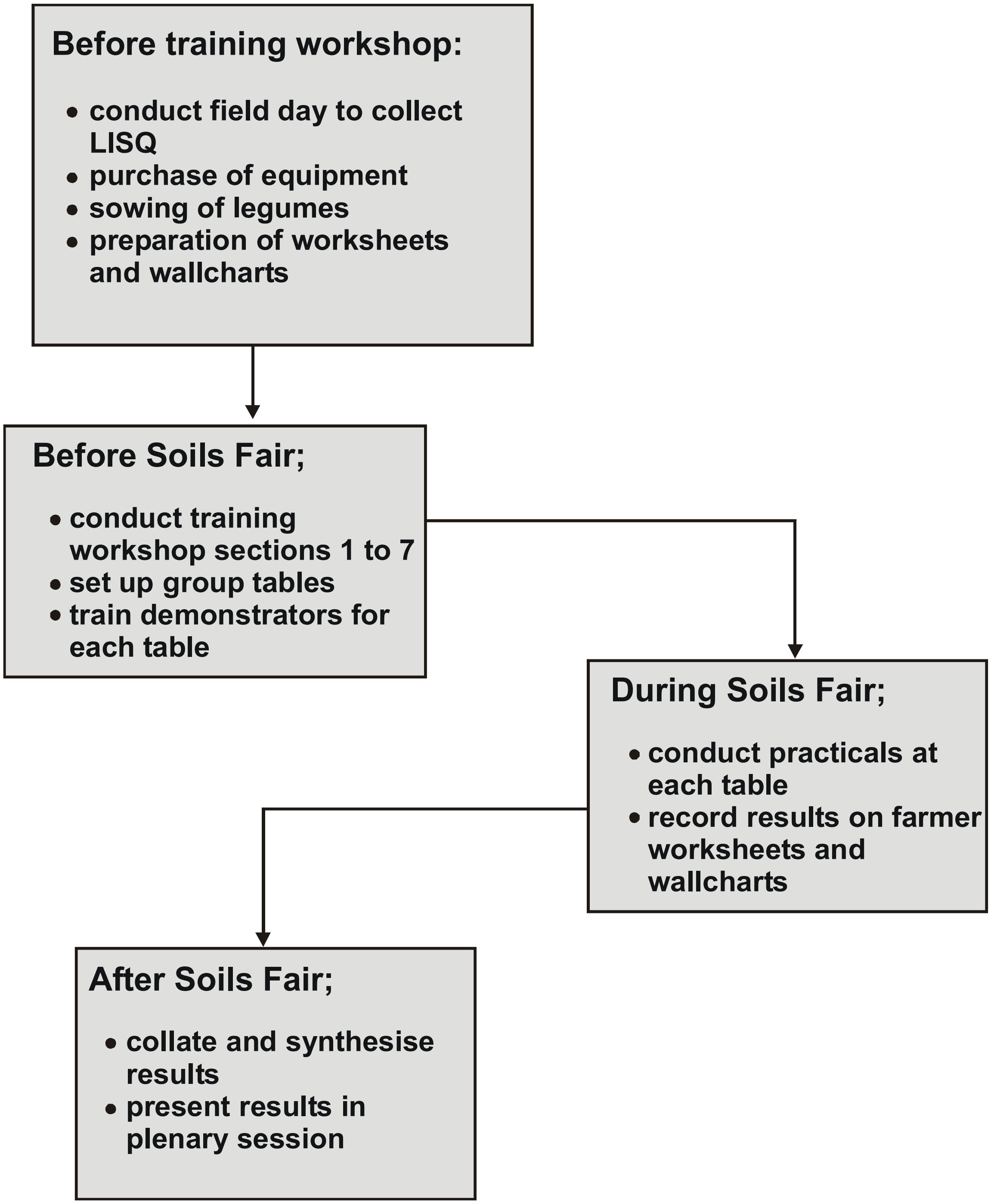

Fig. 6.2 Schematic diagram for the preparation and running of the Soils Fair

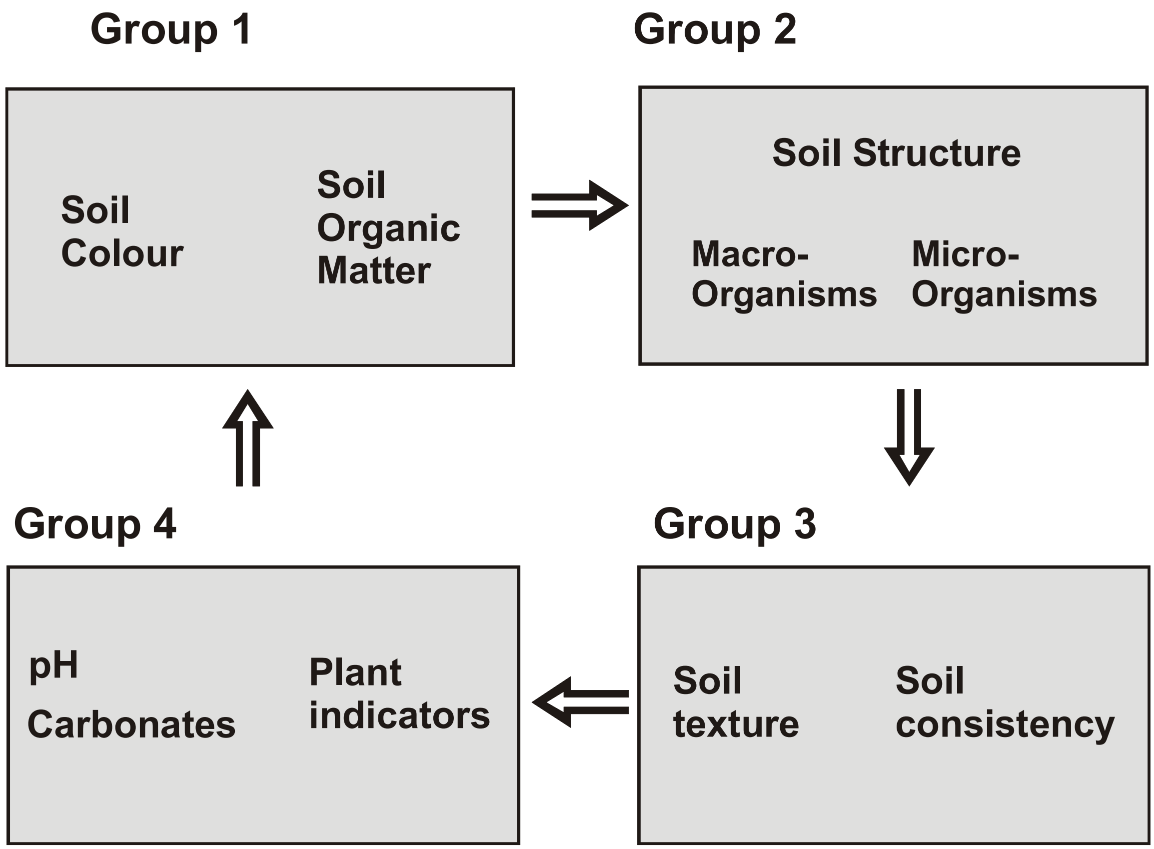

Fig. 6.3 Outline of the tables for the Soils Fair

Soils Fair exercises

6.3.1 Group 1: Practicals 1 and 2 - Determining Soil Texture and Consistency

Objectives

- ✓ To evaluate soil texture in different soil types
- ✓ To recognize the consistency of a soil as a physical characteristic related to its quality.

Resources Necessary

- Water dispenser
- Soil sample
- Measuring spoon
- Paper towels
- Worktable
- Chair
- Waste basket
- Waste bag
- Water container for hand washing

Suggested time: 40 minutes per group

Practice 1 - Determining Soil Texture - Worksheet

Opening questions to begin the practical

1. What do you understand by the term soil texture?

2. What do you understand by the term sand?

3. What do you understand by the term silt?

4. What do you understand by the term clay? What are its characteristics?

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Guidelines for the Trainee

1. Take a sample of the soil, about a spoonful.

2. Put it on your left hand.

3. With the aid of the water dispenser, gradually add some water (drop by drop) and with your right hand manipulate it to the point where a sticky consistency is reached and then make a 2- 5 cm ball (1 to 2 inches) diameter.

4. The point at which the wet soil becomes malleable is an indicator of its texture (Fig. 6.4).

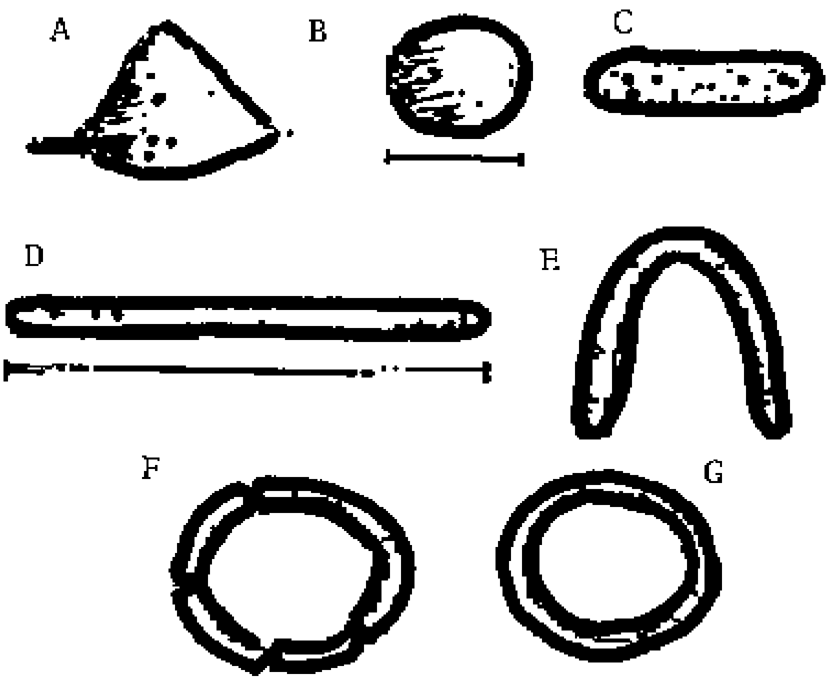

Fig. 6.4   Point at which the soil becomes malleable and can be hand-shaped, indicates its texture. (Source: Agricultural Compendium for Rural Development in the Tropics and Subtropics)

5. In order for you to identify the textural class the soil belongs to, compare it to the table and figures shown below:

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

Source: Agricultural Compendium for Rural Development in the Tropics and Subtropics.

6. Mark on the wallchart and the farmer's worksheet, the category corresponding to the soil analyzed.

Practice 2 - Determining Soil Consistency - Worksheet

Opening questions to begin the practical

1. What is soil consistency?

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2. What is soil adherence?

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3. What is soil plasticity?

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4. What is soil friability?

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Instructions for the trainee

Measuring the consistency of dry soil.

- Take a lump of soil and try to break it between thumb and index finger
- Write the result on the wallchart and the Farmers Worksheet

Soft	The lump is weak, brittle and breaks into powder or granules.
Slightly Hard	The lump is weakly resistant to pressure, and easy to break between thumb and index fingers.
Hard or very Hard	The lump is very resistant to pressure, can be hardly broken by hand, but can not be broken by applying pressure with thumb and index fingers.

2. Measuring the consistency of a moist soil.

If your sample is dry:

- To achieve the recommended moisture, add water (drop by drop). Allow the moisture to evaporate from the sample surface and then proceed to determine its consistency.
- Take a lump from the moist soil and try to break it by hand.
- Write the result on the wallchart and the Farmers Worksheet

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•

Friable	The lump is easy to break into pieces under a slight pressure of thumb and index fingers.
Firm	The lump breaks into pieces under a moderate finger pressure; it is weakly resistant to pressure, and is easy to break between thumb and index fingers, but resistance is
Very firm	The lump is very resistant to pressure, and difficult to break into pieces.

B.If the sample is moist, proceed as in the previous case, beginning with No. 2

3.Measuring the consistency of a wet soil

- To reach the recommended moisture, add water (drop by drop) to the soil.
- Take the wet soil lump and repeatedly rub it between your index finger and thumb.
- By doing this you are measuring two parameters, adherence and soil plasticity.
- Write the result on the wallchart and the Farmers Worksheet

Non-adherent	The soil does not adhere to thumb and index fingers.
Adherent	When manipulated, the soil sticks to your fingers.
Very adherent	When manipulated, the soil easily sticks to your fingers
Non-plastic	The soil does not take any shape when manipulated
Plastic	The soil forms a strand that breaks when a moderate pressure is applied by your fingers.
Very Plastic	When manipulated, a strand is formed and requires great pressure to deform the soil mass.

6.3.2 Group 2: Practices 3, 4 and 5 - Determining Soil Structure and the Presence and Activity of Soil Macro and Micro Fauna

Objectives

- ✓ To recognize and classify soil structure
- ✓ To recognize the presence and activity of soil fauna

Resources necessary

- Water dispenser
- Soil sample (lump)
- Paper Towel
- Work Table
- Chair
- Waste basket
- Waste bag
- Water container for hand washing

Suggested time: 40 minutes per group

Practice 3 - Determining Soil Structure - Worksheet

Opening questions to begin the practical

1. What do you understand by "soil structure"?

2. What is an aggregate?

3. What does "prismatic structure" mean?

Guidelines for the trainee

1. Take in your hands a lump of soil, trying to preserve the original shape

2. Add slight pressure at first and then, little by little, add more pressure until the soil lump breaks apart and reveals the shape of the aggregates.

3. Once the soil has broken apart, use the chart to identify the soil structure by:

- The shape it has taken
- The size and the shape obtained
- The hardness
- Write the result on the wallchart and the Farmers Worksheet

Without structure

Structured

Grade
Without Structure There is no visible aggregation or there is no ordering or natural fissure lines. If the material is coherent, an agglomerate is formed; if not, it is formed as a free grain.
Weak Poorly-formed or indistinct aggregates, very difficult to observe in the field.
Moderate Differentiated and well formed aggregates, moderately durable and visible.
Strong Durable and evident aggregates in non-altered soils. Mutual weak adherence, admit displacements and are easily separated in altered soils.

Source : Haluk, Y (1981)

Practice 4 Investigating the presence of Soil Macro-organisms Activity

Opening questions to begin the practice

1. What are soil macro-organisms?

2. What do soil macro-organisms do?

3. What is the importance of soil macro-organisms?

Instructions for the trainee:

Identify a tilled soil, adjacent to a forest or pasture soil and use them as examples of disturbed and non-disturbed soils, respectively.

a) Activity 1

The activity and presence of earthworms may be associated with the number of casts left on the soil surface. It is worth me
ntioning that this measure can vary considerably, according to the type of earthworms present. For instance, some earthworms do not deposit casts on the soil surface but in the soil, others deposit casts on the surface every time they are active. Thus, the counting of casts per area unit gives a first idea about the size of earthworms population and their activity in that soil.

1. Place a 50 x 50 cm grid at random on the soil, and count the number of earthworms casts within the area. Do this five times in each of the disturbed soil and undisturbed soil.

(Photo: A.F. Rangel)

b) Activity 2

Removing a soil monolith (lump) careful allows the macro-organisms and the structures produced by their action in the soil to be observed (Lavelle, 1988; Anderson & Ingram, 1989).

1. Remove a monolith (30 cm x 30cm x 30cm) from the soil.

2. Place the monolith on a plastic sheet on the table.

3. Using a knife, cut three 10-cm deep layers and place them in plastic bags labelled as 0-10 cm, 10-20 cm and 20-30 cm.

4. Empty the content of the corresponding bags into a plastic basin and label as 0-10 cm, 10-20 cm and 20-30 cm.

5. Break apart each layer.

6.Pick out carefully all macro-organisms and put them into glass jars with 5% formaldehyde for earthworms and 70% alcohol for other organisms.

7. Count the organisms and record the level of incidence on the wallchart and the Farmers Worksheet

–	**Null**	No organism is observed (only in exceptional cases)
+	**Low**	1 - 20 organism are observed
++	**Moderate**	21 - 60 organisms are observed
+++	**High**	More than 60 organisms are observed

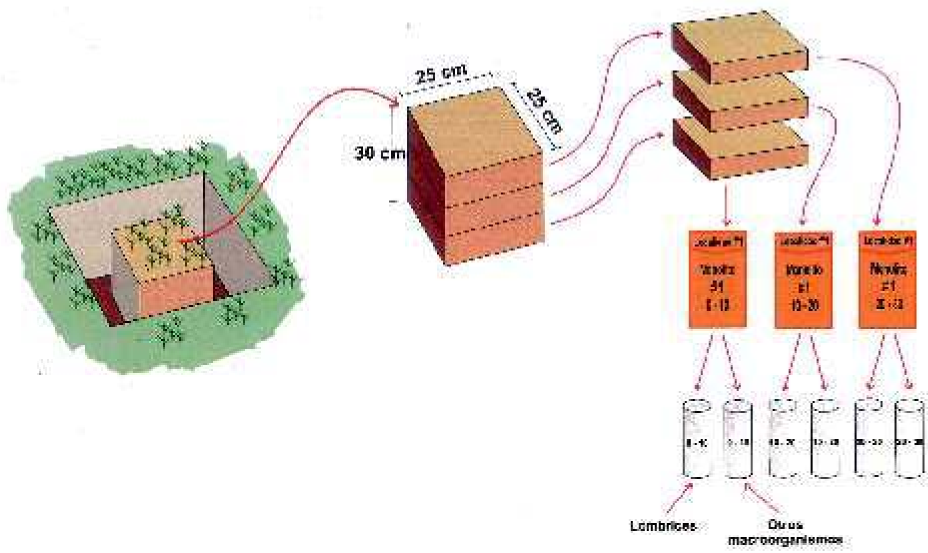

Figure 9.1   Estimating soil macro-organisms activity (Activity 2)

Practice 5 - Estimating Soil Micro-organisms Activity

Opening questions to begin the practice

1. What are soil micro-organisms?

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2. What do soil micro-organisms do?

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3. What is a symbiotic relationship?

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Instructions for the trainee

Identify a bean-sown area, where preferably little or no inorganic N fertilizers has been applied.

1. Select 10 plants at random and mark them with a white string to facilitate their identification.

2. Use a hoe to remove a monolith (30 x 30 cm and 30 cm) from the soil, including each of the 10 plants marked in step 1.

3. Place the monolith in a plastic container with water, and leave it there for 10 minutes. Carefully remove with water the remaining soil on the roots.

4.Identify the main root, the secondary roots and check the presence of nodules (small cylindrical formations adhered to the roots)

5. Count the number of roots in the nodules, and the total number of nodules in the entire root.

6. Separate10 nodules at random for each plant and cut them in half with a knife.

7. Check the internal colour of the nodules: whitish or beige (inactive), brown or reddish (active).

8. Record your result on the wallchart and Farmers Worksheet.

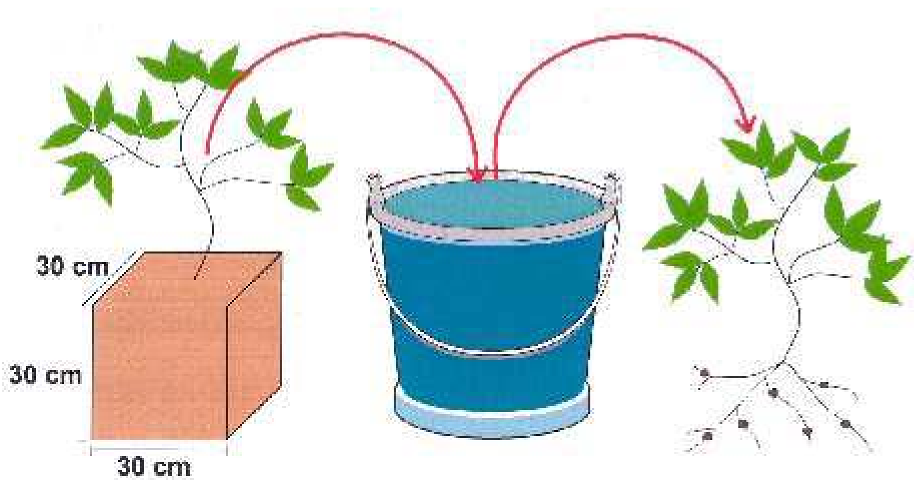

Fig. 6.8 Estimating soil micro-organisms activity (Rhizobia)

6.3.3 Group 3: Practice 6 and 7 - Determining Soil Colour and Organic Matter Content

Objectives

1. To identify the colour of soils

2. To identify variations in the content organic matter in soil

Resources necessary

- Water Dispenser
- Distilled water dispenser
- Soil sample
- Munsell Table to determine colours
- 35% hydrogen peroxide solution
- Droppers
- Paper Towel
- Work Table
- Chairs
- Waste basket
- Waste bag
- Water container for hand washing

Suggested time: 40 minutes per group

Practice 6 - Determining Soils Colour - Worksheet

Opening questions to begin the practice

1. What is soil colour?

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2. What do black, red and yellow colours indicate?

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Instructions for the Trainee

1. Measurement of dry soil colour

- Take a 5 cm (2 inches) soil sample; if it is part of a lump determine the colour in the part that was adhered to the lump (the part that has been exposed to air might be affected and have changed colour).
- Determine the soil colour by using a Munsell's colour chart.
- Record the colour on the Wallchart and the Farmers Worksheet

2. Measurement of the colour in moist soil

A. When your sample is dry:

- You may continue to use the previous sample
- To reach the recommended moisture, add water (drop by drop), allow the moisture to evaporate from the sample surface.
- Determine the soil colour by using a Munsell's colour chart.
- Record the colour on the Wallchart and the Farmers Worksheet

B. When your sample is moist:

- Take a 5 cm (2 inches) soil sample; if it is part of a lump determine the colour in the part that was adhered to the lump (the part that has been exposed to air might be affected and have changed colour).
- Determine the soil colour by using a Munsell's colour chart.
- Record the colour on the Wallchart and the Farmers Worksheet

Practice 7 - Determining Soil Organic Matter - Worksheet

Opening questions to begin the practice

1. What is soil organic matter?

2. What is organic matter decomposition?

3. What role does soil organic matter play?

Instructions for the Trainee:

Warning:

These reagents are dangerous and might cause skin burning; therefore, they are to be used with precaution and always in the presence of the instructor.

1. Take a soil sample (5 cm lump).
2. Use a dropper to apply a couple of drops of hydrogen peroxide
3. Observe the degree of effervescence (bubbling).
4. Classify the soil sample by following the table below
5. Record your result on the wallchart and Farmers Worksheet

Degree of effervescence	**Interpretation**	**Record as**
The soil does not show any effervescence	Very low OM content	Very low OM
The soil shows very little effervescence	Low OM content	Low OM
The soil shows moderate effervescence (many bubbles)	Moderate content of OM	Moderate OM
The soil shows great effervescence (lots of bubbles)	High OM content	High OM

6.3.4 Group 4: Practices 8, 9 and 10 - Determining Soil pH, Presence of Carbonates and Indicator Plant Species

Objectives

- ✓ To quantify the soil pH

- ✓ To identify the content of free carbonates in the soil.

Resources necessary

- pH measuring tape
- Colour pH comparative table
- Plastic cups (50 cc)
- Glass rods to stir the samples
- Plastic spoons
- Distilled water dispenser
- 10% hydrochloric acid jar and a dropper
- Soil Sample
- Paper towels
- Work table
- Chair
- Waste basket
- Waste bag
- Water container for hands washing

Suggested time: 40 minutes per group

Practice 8 - Determining Soil pH - Worksheet

Opening questions to begin the practice

1. What is soil pH?

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2. What is soil acidity?

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3. What is soil alkalinity?

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Instructions for the Trainee

- Put one spoonful of soil in a plastic cup
- Add 25 ml of water
- Stir the solution for 2 minutes with the glass rod.
- Dip the pH paper into the solution for a few seconds.
- Remove the pH paper and compare the colour to the standard pH colours provided with the pH paper.
- Record your result on the wallchart and Farmers Worksheet

Practice 9 - Determining the Presence of Carbonates - Worksheet

Opening questions to begin the practice

1. What is limestone?

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2. What are carbonates?

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3. What is the soil liming?

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Instructions for the trainee

Warning:
Reagents are dangerous and might cause skin burning; therefore they are to be used with precaution and always in the presence of the instructor.

1. Take a piece of soil approximately 5 cm in size

2. Use your dropper to apply a couple of drops of 10% hydrochloric acid drops.

3. Observe the degree of effervescence (bubbling) and determine the presence of carbonates, according to the following table.

Observation	Interpretation	Record as
The soil does not show any effervescence	No carbonate present	No carbonate

4. Record the colour on the Wallchart and the Farmers Worksheet

Practice 10 Use of Indicator Species to Identify Soil pH

Bracken fern (inside circle) is usually associated with acid soils

6.4 Summary

In The Soils Fair we developed our understanding of some of the soils physical, chemical and biological properties through the use of simple practical exercises. The intention was not to go into detail with these practical exercises, rather to give you the concepts and ideas so that you will be able to explain these different soil properties to other people during your work.

6.5 Bibliography

Anderson J.M. and Ingram J.S.I. 1989. Tropical Soil Biology and Fertility: A Handbook of Methods. 1ed.

Lavelle P. 1988. Assessing the abundance and role of invertebrate communities in tropical soils: Aims and methods. J.Afr.Zool.102: 275-283.

Munsell 1990. Munsell soil colour charts. Edition revised.

Originals for Overheads

Section 6

Soils Fair: Integration in Practice

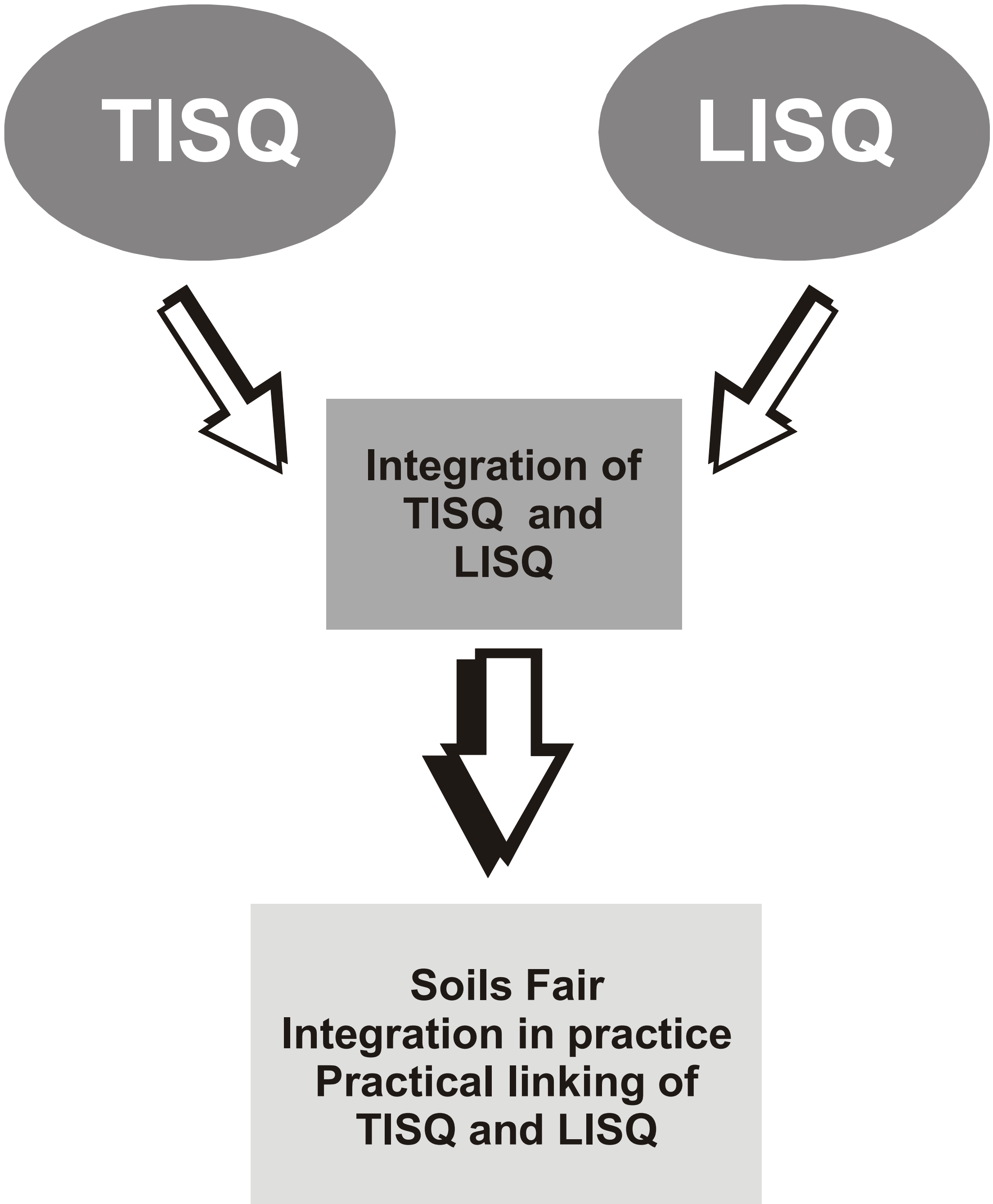
Objectives

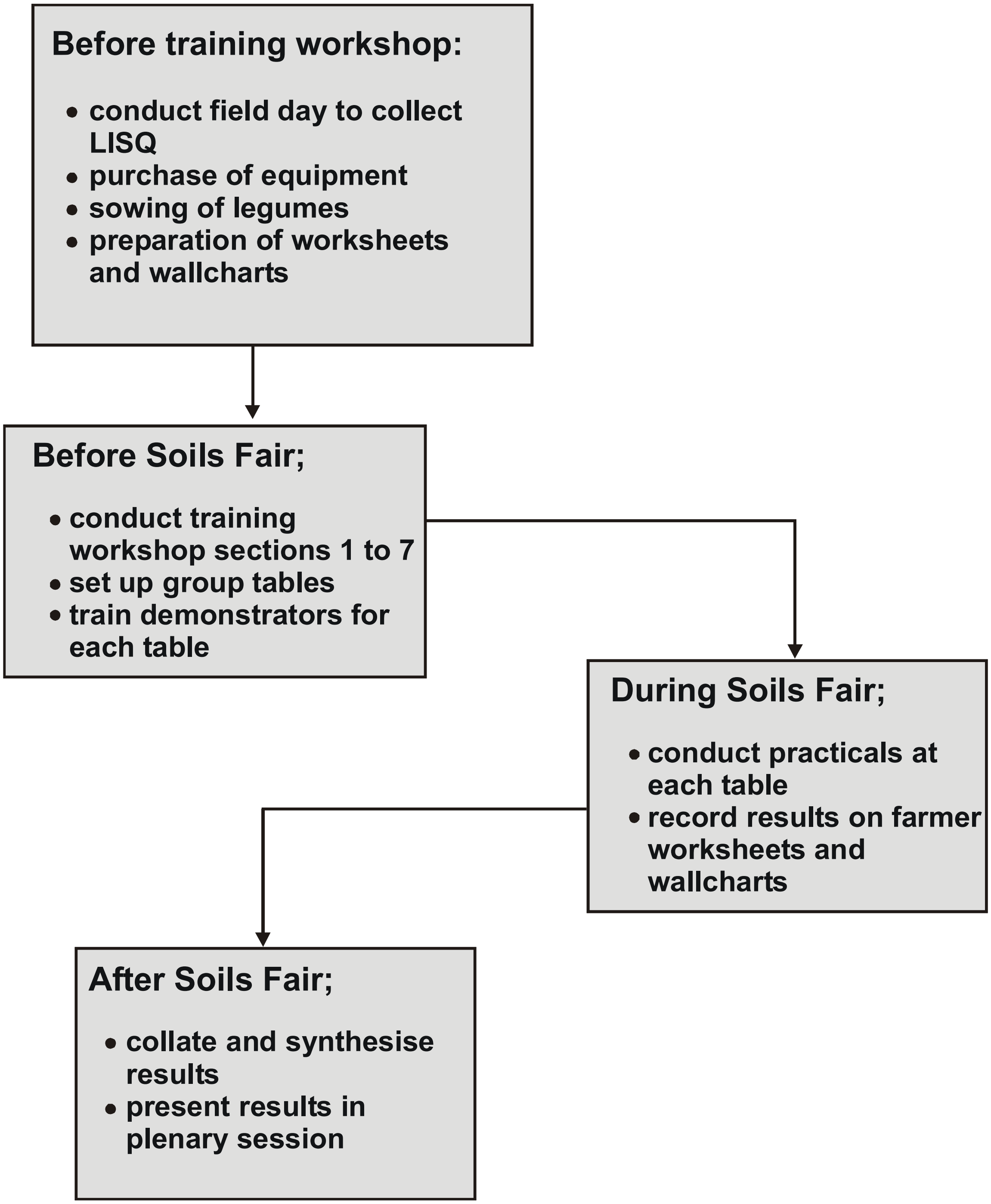
At the end of the Soils Fair the trainees will,

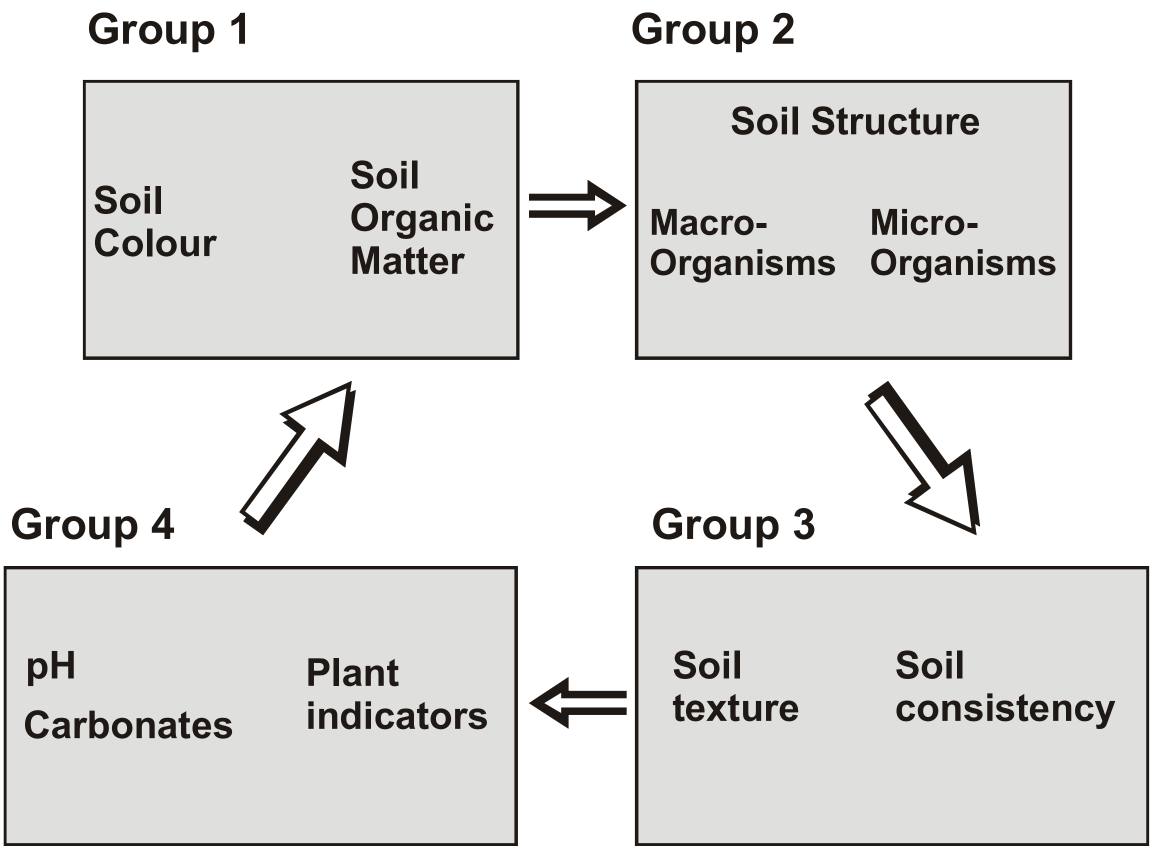
- have developed their skills to be able to determine by using simple and easy methods, soil physical, chemical and biological properties.

- be able to relate these technical indicators to local indicators of soil quality

- be able to explain the relationship between technical and local indicators of soil quality to others


TISQ
LISQ
Integration of TISQ and LISQ
Soils Fair
Integration in practice
Practical linking of
TISQ and LISQ


Before training workshop:
• conduct field day to collect LISQ
• purchase of equipment
• sowing of legumes
• preparation of worksheets and wallcharts
Before Soils Fair;
• conduct training workshop sections 1 to 7
• set up group tables
• train demonstrators for each table
During Soils Fair;
• conduct practicals at each table
• record results on farmer worksheets and wallcharts
After Soils Fair;
• collate and synthesise results
• present results in plenary session


Group 1
Soil Colour
Soil Organic Matter
Group 2
Soil Structure
Macro-Organisms
Micro-Organisms
Group 3
Soil texture
Soil consistency
Group 4
pH
Carbonates
Plant indicators

6.7 Appendices for Section 6

Appendix 6.7.1 - Wallcharts for the Soils Fair

Group 1: Texture Assessment

Farmer	Local soil name	Sandy	Silty	Loamy	Clayey

Group 2: Consistency Assessment (1)

Farmer	Local soil name	Dry soil			Wet soil		
		Soft	Slightly hard	Hard v. Hard	Friable	Firm V.	Firm

Group 2: Consistency Assessment (2)

Farmer	Local soil name	Non adherent	Adherent	Very adherent	Non plastic	Plastic	Very plastic

Group 3: pH Assessment

Farmers name	Soil name (local) description	pH		
		Acid	Neutral	Alkaline

Group 4: Biological Properties

	Macro-Organisms			
Farmersname	Earthworms	Ants	Beetles	Other i nsects

Appendix 6.7.2 - Farmer's Worksheet

Farmer's name: _________________________

Village: ____________________________

1. Information about the property or smallholding

Slope of land (%)	0-15	15-30	30-50	> 50
Soil depth (cm)	0-20	20- 50	50 100	> 100

2. Physical Properties

Property	1	2	3	4
Colour	Black	Brown	Red	Light
Texture	Loamy	Clayey	Silty	Sandy
Structure	Without	Weak	Moderate	Strong
Consistency: Dry	Soft	Hard	Very Hard	
Humid	Friable	Firm	Very firm	
Wet	Non-adherent	Adherent	Very Adherent	
	Non-plastic	Plastic	Very Plastic	
Infiltration	< 0.5 cm	0.5-1 cm	1-2 cm	> 2 cm

3. Chemical Properties

Property	-	+	++	+++
Organic Matter	None	Low	Moderate	High
Reaction to HCl	None	Low	Moderate	High
pH	------	Acid	Neutral	Alkaline

4. Biological Properties

4.1 Presence of soil macro-organisms

Property	-	+	++	+++
Earthworms	None	Low	Moderate	High
Ants	None	Low	Moderate	High
Beetles	None	Low	Moderate	High
Others	------	------	------	------

4.2 Presence of Soil micro-organisms

Rhizobia	None	Low	Moderate	High

Appendix 6.8 - Answers to introductory questions for the Soil Fair

Below is a list of possible answers to the questions posed to evaluate the trainees previous knowledge of each topic in the Soils Fair.

Practice 1 - Determining soil texture

To question 1

It is the physical characteristic of the soils, determined by the amount of each mineral component: clay, silt and sand.

To question 2

The coarsest fraction of soil mineral components; very coarse sands (not greater than 2.00 mm) up to very fine sands (not less than 0.02 mm) according to the ISSS (International Society of Soil Science) scale, can be found.

To question 3

Intermediate fraction of soil mineral components (less than 0.02 mm, but greater than or equal to 0.002 mm diameter)

To question 4

The finest fraction of soil mineral components with a diameter less than 0.002 mm. This is the fraction with the biggest responsibility in regard with the response to soil physical, chemical and biological processes.

Practice 2 - Determining soil consistency

To question 1

Consistency is defined as the resistance to the deformation offered by a soil mass, under specific moisture conditions.

To question 2

It is the consistency characteristic determined in a humid soil, and is identified by the capacity of the soil to adhere or stick to other surfaces.

To question 3

The characteristic of the soils, consisting of the possibility to take various shapes when moulded under humid conditions.

To question 4

Perturbation facility present in a dry condition soil**.**

Practice 3 - Determining soil structure

To question 1

This is how the various groups of soil components are called; it is influenced by the decomposition of organic matters, iron oxides and hydroxides, and clayey fractions.

To question 2

This is the minimum fraction determining the structure of a soil.

To question 3

This is the elongated soil structure, where most faces are flat.

Practicace 4 Investigating the presence of soil macro-organisms

To question 1

These are the organisms observable with a naked eye, such as earthworms, beetles and ants, who live in the soil.

To question 2

Macro-organisms fragment organic residues into finer pieces which, in their turn, are swallowed by these or other organisms that, further on, excrete them. The resulting excrete can, in its turn, be fragmented again, swallowed and excreted by other organisms; thus, the chain of events is replicated many times.

To question 3

The fragmenting capacity many of these organisms have, reduces the size of organic residues, and enables a faster decomposition. Earthworms' activity might reduce soils susceptibility to erosion and, moreover, their movement in the soil profile promotes an increased aeration and water infiltration into the soil.

Practicace 5 Investigating the presence of soil micro-organisms

To question 1

These are the micro-organisms that can not be observed with the naked eye, such as bacteria and most fungi.

To question 2

There are both beneficial and harmful micro-organisms for agricultural production. Some beneficial micro-organisms are bacteria, responsible for converting organic nutrients derived from the organic matter, into inorganic nutrients useful for crops.

There are also fungi and bacteria causing diseases and crops losses. The Biological management of soil fertility aims at increasing the impact of beneficial micro-organisms, and reducing the action of the harmful.

To question 3

This is a mutually beneficial relationship, where both the plant and the micro-organism live better together than separated. This is the case of rhizobia (bacterium) and mycorrhizae (fungi), which are able to supply additional nutrients to the crops, in exchange of being hosted in the plant roots.

Practice 6 - Determining soil colour

To question 1

The colour is a soil characteristic with a direct relationship with temperature, moisture, climate and organisms; it is commonly used as an indicator of soil fertility. The most common colours are black, reddish and yellowish.

To question 2

The black colour suggests the presence of organic matter; the reddish colour suggests the prevalence of iron oxides, and the yellowish colour suggests the prevalence of aluminium oxides.

Practice 7 - Determining soil organic matter

Answers

To question 1

These are all products derived from the disintegration of vegetal material and animal remains, being part of the soil.

To question 2

The action animal or vegetal compounds are subjected to by soil macro and micro-organisms.

To question 3

The organic matter influences soil structuring, nutrients release, cationic exchange and soil water retention processes.

Practice 8 - Determining soil pH

Answers

To question 1

It is the 0 to 14 scale, that serves to measure acidity or alkalinity levels. Soils with a pH 7 are neutral. Soils pH value, in most cases, ranges between 4 and 8; in general terms, crops show a better development in soils whose pH range between 6 and 7.

To question 2

All soils having a pH below 7 are considered acid.

To question 3

All soils with a pH above 7.0 are considered alkaline.

Practice 9 - Determining the amount of carbonates present

Answers

To question 1

Limestone is a rock lime can be obtained from, and is mainly made up of calcium carbonates.

To question 2

Carbonates are the chemical combination of carbonic acid and calcium or magnesium.

To question 3

Incorporating lime to the soil to raise pH level, and improve nutrients availability for the plants.

Practice 10 Use of indicator species to identify soil pH

7. Evaluation Forms

Appendix 7.1 Workshop Evaluation

Place:______________________

Date: ______________________

Dear Participant:

The worshop (course) organizers would like to know your opinions on the activities that have been carried out during this training event. You do not have to sign this form. We would like you to be very honest in your responses for the improvement of this activity depends heavily on your answers.

The evaluation includes two components:

a. You assign a value, chosen from a scale of 0 to 3, to each aspect being evaluated:

0 = Very poor, inadequate
1 = Deficient, just acceptable
2 = Good, needs little improvement
3 = Very good, highly satisfactory

b. We have left space after each question for you to write the comments you may have on the assigned score. Refer to positive and negative aspects. Leave blank those aspects you feel you don't have a clear opinion about.

Questions

1.0 Evaluate the objectives that we were to achieve according to items 1.1 and 1.2:

1.1 How well did the objectives correspond to the institutional and personal needs you brought to the workshop?

	0	1	2	3

Comments:

1) To the instructor: This form can be used on a daily basis throughout a workshop lasting one or more weeks.

How well do you consider the proposed objectives were achieved?

0	1	2	3

Comments:

2.0 What did you think of the following methodological strategies used?

2.1 Instructor's presentations	0	1	2	3
2.2 Group work sessions	0	1	2	3
2.3 Quantity and quality of materials delivered	0	1	2	3
2.4 Exercises carried out at the training site	0	1	2	3
2.5 Field practices with farmers	0	1	2	3
2.6 The time dedicated to the different activities	0	1	2	3

Comments:

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3.0 How do you rate the coordination of activities?

3.1 Preliminary information received by participants	0	1	2	3
3.2 Fulfillment of the training agenda	0	1	2	3
3.3 Daily coordination of activities	0	1	2	3
3.4 Logistic support provided (space, equipment, etc.)	0	1	2	3
3.5 Lodging (if applicable)	0	1	2	3
3.6 Board (if applicable)	0	1	2	3

Comments:

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5. Evaluate the applicability (usefulness) of what you have learned for the work you do now or may do in the future.

0	1	2	3

Comments:

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6.What activities will your institution carry out in the short term to which you could apply or transfer what you have learned ?

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7. Would you be interested in this training course being held at your institution? How could this be done?

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Thank you for your answers and comments!

Appendix 7.2 Assessing the Instructor's Performance

Date: _______________

Name of instructor: ____

Topic or topics addressed by this instructor____

Dear Participant:

Described below you will find a series of descriptors of sound training practices. These have been drawn from educational literature on characteristics of a good instructor or of a good facilitator.

Four dimensions of the trainer's performance will be analysed: (1) organization and clarity, (2) knowledge of subject matter, (3) interaction abilities , and (4) direction of practical activities and exercises. Descriptors are included for each dimension.

Mark X in the YES column if you are sure that this behavior was a part of the trainer's performance, regardless of how other participants may have evaluated it.

Mark X in the NO column if you are sure that such behavior was not a part of the trainer's performance.

The instructor is the main beneficiary of this self-evaluation test. It aims to help him improve his performance in future training activities.

The instructor will collect the completed forms and tabulate the answers, using the tabulation sheet on page A-14.

1. Organization and clarity

The instructor ...

	Yes	No
1.1 Presented and discussed with us the learning objectives	☐	☐
1.2 Explained the methodology needed to carry out each activity	☐	☐
1.3 Managed the activities within the established time limits	☐	☐
1.4 Handed out written material on his presentation	☐	☐
1.5 Followed an orderly sequence while presenting content	☐	☐
1.6 Used visual aids that improved understanding	☐	☐
1.7 Kept the participants' interventions relevant to the topic	☐	☐

2. Subject matter knowledge ☐ ☐

2.8 Am sure that he knows well what he is talking about ☐ ☐

2.9 He/she answered the participants' questions correctly ☐ ☐

2.10 He/she connected theory with practice ☐ ☐

2.11 Provided examples illustrating the topic discussed ☐ ☐

2.12 Focused the participants' attention on the most relevant aspects ☐ ☐

3. Interaction abilities ☐ ☐

3.13 Spoke according to the participants' level of understanding ☐ ☐

3.14 Acknowledged the participants' contributions ☐ ☐

3.15 Made sure that the participants understood ☐ ☐

3.16 Kept eye contact with the participants ☐ ☐

3.17 Asked the participants questions ☐ ☐

3.18 Invited the participants to ask me questions ☐ ☐

3.19 Provided immediate feedback to the participants' responses ☐ ☐

3.20 Maintained good interaction with fellow facilitators ☐ ☐

4. Direction of practice (i.e., in the field, laboratory, and classroom) ☐ ☐

As the person in charge of coordinating practical activities, he/she ... ☐ ☐

4.21 Made clear to course participants the objectives and procedures ☐ ☐

4.22 Showed how to carry out the practical activities ☐ ☐

4.23 Selected the appropriate site and equipment for practice ☐ ☐

4.24 Organized the audience so all could participate ☐ ☐

4.25 Had all the equipment and materials necessary for practice ☐ ☐

4.26 Provided immediate feedback to participants once the practice was ended ☐ ☐

Tabulation Sheet for Assessing the Instructor's Performance

1. The instructor hands out copies to 10 or more of the course participants before the activity starts so that they can observe and assess the instructor's performance during the activity.

2. At the activity's end, the instructor will pick up the forms and tabulate the results according to the tabulation sheet given below. Then he or she will transfer the scores to the performance profile to establish the difference between the score obtained and the ideal score.

	Areas to assess	***Affirmative answers tabulated***								**Score obtained**	**100% ideal**
1	Organization and clarity	**1.10**	**1.20**	**1.30**	**1.40**	**1.50**	**1.60**	**1.70**			
2	Command of topic	**2.80**	**2.90**	**2.10**	**2.11**	**2.12**					
3	Ability to interact	**3.13**	**3.14**	**3.15**	**3.16**	**3.17**	**3.18**	**3.19**	**3.20**		
4	Direction of practice	**4.21**	**4.22**	**4.23**	**4.24**	**4.25**	**4.26**				

A. Scores are based on a scale of 0 to 5

Performance profile

					1
					2
					3
					4

50 60 70 80 90 100

To establish the scores and the profile, the instructor should proceed as follows:

1. Add up the tabulations in every box and write the sum in the column 'Score obtained'.
2. Establish the "ideal" score corresponding to 100%; this will depend on the number of evaluators. For example, 10 evaluators scored for row 1, 'Organization and clarity'. The score obtained was 45, then the score corresponding to 100% is 70. In this case, the score obtained (45) is 64% of the ideal score. The instructor writes this score in the appropriate box of the 'Performance profile'.
3. For the 'Performance profile' graph, the points of each component (1, 2, 3, and 4) are joined .

Appendix 7.3. Evaluating the Training Materials

Training materials can be evaluated with the participation of:

Subject matter experts (scientists, researchers)

Communication experts

Technicians, facilitators, professors, etc.

Producers, farmers, members of community organizations, etc.

ASPECTS TO EVALUATE	Draw an X in the appropriate box	
Quality of content	**Yes**	**No**
The information presented is technically valid in the context in which it is used.		
The content is divided into segments that follow a clear and ordered sequence.		
The content is presented objectively, in other words, it respects accepted principles and methods.		
The content is appropriate for the level of understanding of the audience.		
The content is up-to-date from the scientific and technical viewpoints.		
Quality of presentation	**Yes**	**No**
The printing quality is excellent.		
The images (drawings, graphs, tables) are clear.		
The illustrations supported written messages.		
The icons are well selected (according to the meaning of the text).		
The distribution of information (diagramming) on each page is adequate.		
A good correspondence exists between images and text.		
Quality of instruction	**Yes**	**No**
The objectives are clearly established.		
The material facilitates audience participation.		
The relationship between objectives and content is excellent (the content reflects what is proposed in the objectives).		
The material facilitates both teaching and learning.		
The exercises and practices are innovative.		
The exercises and practices help the participants understand the topic.		