

AGL/MISC/27/2000

**GUIDELINES AND REFERENCE MATERIAL
ON
INTEGRATED SOIL AND
NUTRIENT MANAGEMENT AND
CONSERVATION
FOR
FARMER FIELD SCHOOLS**



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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

Land and Plant Nutrition Management Service

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Preface

Historically, land improvement schemes were based on encouraging, through financial incentives, land users to adopt specific soil management and conservation measures. Insufficient attention was paid to the constraints faced by farmers or to the policy, biophysical and socio-economic environment. In many cases such approaches have failed in restoring the natural resources and in increasing productivity in sustainable manner. For too long farmers have been the passive recipients of externally derived research and extension recommendations for soil management and conservation.

Recently soil management and conservation efforts have been moving toward a more *Participatory Approach*, in which both selection of management solutions and their implementation are decided upon and executed in cooperation with beneficiary groups. The participatory approach seeks to enhance farmers' inherent skills, knowledge and capability to develop and disseminate their own technologies.

It is evident that farmers will participate on a large scale in learning activities only if these will yield clear and significant benefits within a short time in return to their investment of time, effort and other inputs. Similarly, government agencies will only start, support and sustain the organization of such participatory learning activities if they recognize significant benefits to local communities and to the national economy, achieved at a lower cost than would be needed for other types of extension methodology that might yield similar benefits. Both the methodology and the subject matter used in the farmer field school (FFS) approach need to be validated for these requirements to be met and adopted for the country biophysical and socio-economic environment.

After a few years of subject matter development and several years of development and pilot testing of the training and learning approach, the FFS approach for integrated pest management (IPM) for various crops has been validated on a large scale in several countries in southeast Asia. On the basis of this successful example, efforts by FAO started in 1996, to adapt the FFS concept to other aspects of farmers' management, particularly integrated soil and plant nutrient management and soil and water conservation.

The FFS methodology on integrated soil and nutrient management (ISNM), through support of the FAO Farm Management and Production Economics Service (AGSP), and the Land and Plant Nutrition Management Service (AGLL) has been pilot tested in four southeastern Asian Countries. A Facilitator's Manual on the basis of this testing was developed, in 1998, by the FAO Farmer-centred Agricultural Resource Management Programme (FARM) in Asia.

On the basis of the above limited experience, AGLL has endeavoured to prepare this document for wider dissemination of reference material and practical exercises, from global perspectives, for the benefit of farmers and extension workers.

These Guidelines, of global nature, are aimed at developing and implementing FFS for better management and conservation practices on ISNM, with a view to sustaining the natural resource

base (mainly soil and plant nutrients) and enhancing productivity and income of small-scale farmers.

These guidelines provide a basic conceptual framework and supporting reference material which it is believed will assist in the development and implementation of effective FFS. They are intended for use by FFS facilitators; with an agricultural extension, agronomy, soil science, plant nutrition, soil conservation or land husbandry disciplinary background; for the production of country or local specific manuals and curricula. These should be adapted to the agro-ecological environment, the cropping/farming systems, and the socio-economic conditions and educational level of the farmers in the areas where the FFS are to be implemented.

The guidelines presented in this document on course structure and topics are intended to be of global applicability. Users of these guidelines must therefore select and adapt topics to make them relevant to the needs and circumstances of the farmers where the FFS is to be established.

The ultimate end users of these guidelines, once adapted to local field circumstances are expected to be:

- field based agricultural extension officers; crop, plant nutrition and land husbandry subject matter specialists; farmers' leaders; and field level community development workers wishing to facilitate the implementation of FFS;
- individuals and institutions interested in organizing FFS for integrated soil and plant nutrient management and conservation; requiring ideas and exercises on how to set up a school programme; and
- trainers or coordinators who will be training field-level facilitators using these guidelines.

The term Integrated Soil and Nutrient Management (ISNM) has been interpreted, in the document, in the broader and more holistic sense of "land husbandry", which embraces soil, nutrient, water, crop and pasture management, with the implied aim of sustaining productivity over the long term.

Additional elaborated training modules on "Soil and Water Conservation", "Tillage Systems" and "Water Management/Irrigation", are being finalized by the Land and Water Development Division (AGL) and will in due course be widely disseminated as complementary documents. It is hoped that these Guidelines and Reference Material will assist on-going projects and soil fertility management programmes, such as the Soil Fertility Initiative (SFI) and the Special Programme for Food Security (SPFS), in developing country-specific manuals and sound curricula for the implementation of FFS.

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The conceptual basis for learning about integrated soil and nutrient management through farmer field schools

THE PROBLEM TO BE TACKLED

Given escalating population growth, intensified cropping, widespread land degradation, shrinking agricultural land and increasing demands on limited water resources from the expanding urban and industrial sectors, sustaining agricultural production through improved soil management is critical to the issue of food security and poverty alleviation in most, if not all, developing countries. The challenge facing the research and extension services in these countries is one of how to increase output from their country's agricultural sector while sustaining and enhancing the productive potential of the available natural resources (notably the climate, soil, vegetation and water).

Few developing countries currently have the financial resources required to widely promote good soil management, through the traditional means of government extension services, with the aim of achieving food security at both the national and household levels. This is despite the considerable efforts put in by their research and extension services over the years. This lack of success, especially for small-scale resource-poor farmers, can be partly attributed to traditional extension methods which have not always focussed on farmers' priority issues, or have given recommendations that were inappropriate or with no immediate tangible benefits. The underlying reason for these failings is that farmers were insufficiently involved, or not involved at all, in identifying their problems, or in selecting, testing and evaluating the possible solutions.

Another factor that appears to have limited the success of traditional extension methods has been the assumption that farmers only need to be taught the technologies that experts have identified as the solution to their problems. This approach teaches farmers technological "recipes;" it does not allow them to learn the underlying principles and processes, and so does not enable them to cope with new situations or different problems. Farming is constantly changing; the prices and availability of agricultural inputs vary, the cost and availability of labour fluctuates, marketing opportunities change, and the incidence of pests and disease may sometimes preclude the production of certain crops. Thus, farmers are forced to change their farming system or management practices when the economic, technical or social conditions change. Providing farmers with technical packages or "recipes" which are only valid for specific situations, merely maintains their dependence on the extension service.

THE FARMER FIELD SCHOOL APPROACH

In contrast to the limited success achieved in past years by traditional extension methods, the farmer field school (FFS), based on an innovative, participatory, learning by discovery approach, has been the success story of the 1990s. The FFS approach was developed by an FAO Project in southeast Asia as a way for small-scale rice farmers to investigate, and learn, for themselves the skills required for, and benefits to be obtained from, adopting integrated pest management

(IPM) practices in their paddy fields. Subsequently the FFS approach was extended to several countries in Africa and Latin America. At the same time there has been a shift from IPM for rice based systems towards other annual crops, vegetables and cotton and the curriculum has been enriched with other crop management aspects. More recently farmer field schools on the principles and practice of integrated soil and nutrient management have been piloted in Asia¹. Where it has been found that the FFS approach, although originally developed for IPM purposes, provides a proven people centred learning methodology whereby farmers can learn about, and investigate for themselves, the costs and benefits of alternative soil management practices for sustaining and enhancing farm productivity.

The FFS approach offers an alternative to the traditional extension approach in which farmers are passive recipients of externally formulated extension messages that are demonstrated to farmers by the field assistant. The approach is aimed at exposing farmers to a learning process in which they are gradually presented with new technologies, new ideas, new situations and new ways of responding to problems. The knowledge acquired during the learning process can be used to build on existing knowledge enabling farmers to adapt their existing technologies so that they become more productive, more profitable, and more responsive to changing conditions, or to adopt new technologies. There is now a rapidly growing awareness that a much more participatory approach is required if extension recommendations are to be fully acceptable - technically, socially, environmentally and economically.

CHARACTERISTICS OF THE FARMER FIELD SCHOOL APPROACH

The characteristics of the approach are as follows²:

- **Farmers as Experts.** Farmers 'learn-by-doing' i.e. they carry out for themselves the various activities related to the particular farming/forestry practice they want to study and learn about. This could be related to annual crops, livestock/fodder production, orchards or forest management. The key thing is that farmers conduct their own field studies. Their training is based on comparison studies (of different treatments) and field studies that they, not the extension/research staff conduct. In so doing they become experts on the particular practice they are investigating.
- **The Field is the Primary Learning Place.** All learning is based in the field. The rice paddy, yam plot, maize field, banana plantation, coffee/fruit orchard, woodlot or grazing area is where farmers learn. Working in small sub-groups they collect data in the field, analyse the data, make action decisions based on their analyses of the data, and present their decisions to the other farmers in the field school for discussion, questioning and refinement.
- **Extension Workers as Facilitators Not Teachers.** The role of the extension worker is very much that of a facilitator rather than a conventional teacher. Once the farmers know what it is they have to do, and what it is that they can observe in the field, the extension worker takes a back seat role, only offering help and guidance when asked to do so.

¹ Through the regional Farm-Centred Agricultural Resource Management Programme (FARM) of eight Asian countries coordinated by the FAO Regional Office for Asia and the Pacific, Bangkok, Thailand.

² The notes in this and the following section are largely derived from material to be found in Indonesian National Integrated Pest Management Program, 1993. *IPM Farmer Training: The Indonesian Case*. FAO-IPM Secretariat, Yogyakarta, Indonesia.

Presentations during group meetings are the work of the farmers not the extension worker, with the members of each working group assuming responsibility for presenting their findings in turn to their fellow farmers. The extension worker may take part in the subsequent discussion sessions but as a contributor, rather than leader, in arriving at an agreed consensus on what action needs to be taken at that time.

- **Scientists/Subject Matter Specialists Work With Rather Than Lecture Farmers:** The role of scientists and subject matter specialists is to provide backstopping support to the members of the FFS and in so doing to learn to work in a consultative capacity with farmers. Instead of lecturing farmers their role is that of colleagues and advisers who can be consulted for advice on solving specific problems, and who can serve as a source of new ideas and/or information on locally unknown technologies.
- **The Curriculum is Integrated.** The curriculum is integrated. Crop husbandry, animal husbandry, horticulture, silviculture, land husbandry are considered together with ecology, economics, sociology and education to form a holistic approach. Problems confronted in the field are the integrating principle.
- **Training Follows the Seasonal Cycle.** Training is related to the seasonal cycle of the practice being investigated. For annual crops this would extend from land preparation to harvesting. For fodder production would include the dry season to evaluate the quantity and quality at a time of year when livestock feeds are commonly in short supply. For tree production, and conservation measures such as hedgerows and grass strips, training would need to continue over several years for farmers to see for themselves the full range of costs and benefits.
- **Regular Group Meetings.** Farmers meet at agreed regular intervals. For annual crops such meetings may be every 1 or 2 weeks during the cropping season. For other farm/forestry management practices the time between each meeting would depend on what specific activities need to be done, or be related to critical periods of the year when there are key issues to observe and discuss in the field.
- **Learning Materials are Learner Generated.** Farmers generate their own learning materials, from drawings of what they observe, to the field trials themselves. These materials are always consistent with local conditions, are less expensive to develop, are controlled by the learners and can thus be discussed by the learners with others. Learners know the meaning of the materials because they have created the materials. Even illiterate farmers can prepare and use simple diagrams to illustrate the points they want to make.
- **Group Dynamics/Team Building.** Training includes communication skills building, problem solving, leadership and discussion methods. Farmers require these skills. Successful activities at the community level require that farmers can apply effective leadership skills and have the ability to communicate their findings to others.

Farmer Field Schools are conducted for the purpose of creating a learning environment in which farmers can master and apply specific land management skills. The emphasis is on empowering farmers to implement their own decisions in their own fields.

SOME KEY CONCEPTS AND PRINCIPLES OF THE FARMER FIELD SCHOOL APPROACH

The following are some of the key concepts and principles underlying the FFS approach:

- **Communication.** Communications in extension have come to mean the marketing of informational packages. Messages are crafted to focus on a particular aspect, put on flip charts, the mass media, or on posters that are developed in central offices. In addition they may be disseminated to farmers via 'model' demonstration farms where the farmer is effectively serving as a labourer, merely following the instructions of the research or extension worker. This is not education and use of these communication approaches does not educate a farmer, they treat him or her as a target. The farmer is used by others to implement their decisions in his or her field.

Education is the most important thing that an 'extension' programme can do and the farmer is the most important person being educated. Within the educational approach, communication must take place at the field level, dealing with field issues in a dialogue with learners. The communications model cannot do this. However it can be done within the context of the Farmer Field School. The field school deals not only with the practice that farmers want to learn about but also with farmers as farmers. Such farmer field schools are conducted for the purpose of helping farmers to master and apply field management skills. The farmer implements his or her own decisions in his or her own field.

- **Problem-Posing/Problem-Solving.** Within this form of training problems are seen as challenges, not constraints. Farmers groups are taught numerous analytical methods. Problems are posed to groups in a graduated manner such that trainees can build confidence in their ability to identify and tackle any problem they might encounter in the field.
- **Field Based Education.** Put farmers in a classroom and if they have been to school, what they remember is the bad times they probably had in the classroom. Education in the classroom can only mimic the natural world. Putting the classroom in the field allows the field to be the learning material and the farmer to be able to learn from real live examples. Putting the classroom in the field means that the educator (extension worker) must come to terms with the farmer in the farmer's domain.
- **Principles not Packages.** Educational programmes should not promote packages in which are presented weekly atomized messages. Educational programmes should take a broad integrated approach to working with farmers, based on the belief that farmers want to learn to be better farmers and wish to optimize their incomes. The FFS approach teaches principles, any activity encompasses several principles, principles bring out cause and effect relationships, principles help farmers discover and learn, principles help farmers to learn so that they can continue to learn. Packages have nothing to do with learning and do not encourage learning, in the long run they are neither cost effective nor effective at improving the quality of farmers management skills. Skilled farmers can optimize yields independently of others. Packaged approaches increase the dependence of farmers on central planners.
- **Training Driven Research.** Research must be responsive to field needs. By and large researchers have got it backwards. Research programmes in agriculture drive the extension or education programme that the research should actually be serving. What farmers need to know to be able to operate sustainably, both environmentally and economically, should drive the research programme. In the FFS approach research is based on training needs or is a part of the training itself. Through their participation in the field schools farmers can become

a part of a wider programme of local, district and national research networks investigating agricultural production problems and developing local solutions for improving the sustainability and productivity of the country's farming systems.

THE CONCEPTS AND PRINCIPLES OF INTEGRATED SOIL AND NUTRIENT MANAGEMENT (ISNM)

In these guidelines the term ISNM is interpreted in the much broader more holistic sense of "land husbandry". It thus embraces soil, nutrient, water, crop, and vegetation management practices, tailored to a particular cropping and farming system, undertaken with the aim of improving and sustaining soil fertility and land productivity. ISNM aims to optimize the condition of the soil, with regard to its physical, chemical, biological and hydrological properties, for the purpose of enhancing farm productivity, whilst minimizing land degradation. There is now greater awareness that ISNM can, not only provide tangible benefits in terms of higher yields, but simultaneously and almost imperceptibly conserve the soil resource itself. The field level management practices considered under the heading of ISNM would include the use of farmyard manures, natural and mineral fertilizers, soil amendments, crop residues and farm wastes, agroforestry and tillage practices, green manures, cover crops, legumes, intercropping, crop rotations, fallows, irrigation, drainage, plus a variety of other agronomic, vegetative and structural measures designed to conserve both water and soil.

The underlying principles on how best to manage soils, nutrients, water, crops and vegetation to improve and sustain soil fertility and land productivity and their processes are derived from the essential soil functions necessary for plant growth. The following are fundamental to the approach outlined in these guidelines:

- loss of soil productivity is much more important than the loss of soil itself, thus land degradation should be prevented before it arises, instead of attempting to cure it afterwards - i.e. the focus for ISNM should be on sustaining the productive potential of the soil resource;
- soil and plant nutrient management cannot be dealt with in isolation but should be promoted as an integral part of a productive farming system;
- under rainfed dryland farming conditions soil moisture availability is the primary limiting factor on crop yields, not soil nutrients as such, hence ISNM requires the adoption of improved rainwater management practices (conservation tillage, tied ridging etc), so as to increase the effectiveness of the seasonal rainfall;
- with declining soil organic matter levels following cultivation, the adoption of improved organic matter management practices are a prerequisite for restoring and maintaining soil productivity (improved soil nutrient levels, soil moisture retention, soil structure and resistance to erosion);
- it is only after they have made improvements in the biological, physical and hydrological properties of their soils, that farmers can expect to get the full benefits from the supply of additional plant nutrients, in the form of inorganic fertilizer, to their crops.

At the farm field level ISNM therefore calls for an integrated and synergistic approach which involves:

- matching the land use requirements of individual agricultural enterprises with the land qualities present in the areas where they are undertaken - i.e. the biological, chemical and physical properties of the soil, the local climatic conditions (temperature, rainfall etc) and the areas

topographic characteristics (slope, aspect, altitude etc) should match the bio-physical requirements of the land uses followed;

- seeking to improve yields by identifying and overcoming the most limiting factors in order of their diminishing influence on yield;
- better plant management, especially: (i) improved crop establishment at the beginning of the rains, so as to increase protective ground cover thereby reducing splash erosion, enhancing infiltration and biological activity; and (ii) timely weeding to reduce crop yield losses from competition for nutrients and soil moisture;
- combinations of complementary crop, livestock and land husbandry practices which maximize additions of organic materials and recycle farm wastes, so as to maintain and enhance soil organic matter levels (ideally at levels of at least 50-75% of those under natural vegetation);
- land management practices that ensure soil moisture conditions are favourable for the proposed land use (e.g. moisture harvesting/conservation in low rainfall areas, drainage in high rainfall areas, impoundment for paddy rice);
- the replenishment of soil nutrients lost by leaching and/or removed in harvested products through an integrated plant nutrition management approach that optimizes the benefits from all possible on- and off-farm sources of plant nutrients (e.g. organic manures, crop residues, rhizobial N-fixation, P and other nutrient uptake through root mycorrhizal fungi infestation, transfer of nutrients released by weathering in the deeper soil layers to the surface via tree roots and leaf litter, rock phosphate, inorganic fertilizer etc);
- combinations of crop, livestock and land husbandry practices that reduce rainfall impact, improve surface infiltration, and reduce the velocity of surface runoff thereby ensuring any soil loss is below the 'tolerable' level for the soil type;
- conservation tillage, crop rotation, agroforestry and restorative fallow practices that maintain and enhance the soils physical properties through maintaining an open topsoil structure, and breaking any subsoil compacted layer (hoe/plough pan) thereby encouraging root development and rainfall infiltration (e.g. use of ox drawn chisel ploughs, double dug beds, pasture leys, interplanting of deep rooted perennial crops/trees and shrubs);
- reclamation, where appropriate (i.e. if technically feasible and cost effective), of farm land that has been severely degraded by such processes as gullying, loss of topsoil from sheet erosion, soil compaction, acidification and/or salinization.

SKILLS REQUIRED BY FARMERS FOR INTEGRATED SOIL AND NUTRIENT MANAGEMENT

By participating in a farmer field school, so as to learn what is involved in integrated soil and nutrient management, farmers can be expected to acquire a variety of different skills related to improved soil, water and plant nutrient management and related crop, animal and land husbandry and silvicultural practices. However, the precise skills needed by farmers (and thus to be learnt through the FFS) will depend on their particular cropping and farming systems, their physical environment, the scale of their production, and their access to machinery, inputs and advisory services.

The range of skills farmers might acquire through participating in a farmer field school for integrated soil and nutrient management (and conservation) could include:

- production of compost
- improved crop residue management
- storage of manures
- preparation of silage
- marking of contour lines
- establishment of grass barriers
- intercropping with cover crops
- growing of new grain legumes as intercrops or in rotation
- improved fallows (pasture leys, fast growing leguminous trees & shrubs)
- construction of hillside ditches
- construction of infiltration pits
- use of ox drawn rippers/subsoilers
- mulching
- fertilizer applications
- use of lime/rock phosphate
- soil sampling
- improved pasture management
- establishment of windbreaks
- establishment of live fences

It should be noted that a vast array of local variations in the types of soils, slopes, climates, crops and crop combinations can be expected. Consequently, the specific skills required by farmers will vary greatly from area to area. It is however beyond the scope of these guidelines to cover the full range of combined skills required and the specific variations needed to tackle local soil management problems. These guidelines will therefore focus on a limited number of skills with the aim of illustrating the underlying concepts and describing the procedures for conducting farmer field schools for integrated soil and nutrient management.

PROMOTING INTEGRATED SOIL AND NUTRIENT MANAGEMENT THROUGH FFS

The main objective of the FFS approach is to increase the capacity of farmers to respond adequately to changing farming situations. Farming circumstances are continually being transformed by periodic changes in technical, economic, social and environmental factors that force farmers to change their production and/or management practices. It is the farmer's ability to take advantage of new opportunities and to cope adequately with new problems that will determine his success in improving and sustaining the productivity of his farm. To achieve this, farmers need to become more experimental and innovative. A farmer's capacity to respond to changing circumstances becomes all the more important where farmers have no access to regular and reliable technical support from extension agencies. A second objective of the FFS approach is to increase farmer's knowledge and skills in improved soil and nutrient management practices.

As indicated earlier the FFS approach has successfully enabled farmers to learn about the principles of IPM and to take rational decisions on appropriate IPM practices, and it was believed that the same approach could be used to promote integrated soil and nutrient management. Preliminary experience from the pilot farmer field schools for integrated soil and nutrient

management conducted by the FARM programme in China, the Philippines, Thailand and Viet Nam has so far been encouraging.

Conducting a FFS for the purpose of enabling farmers to learn the principles and practices of integrated soil and nutrient management should be an essential part of a long-term and dynamic strategy for sustaining and enhancing agricultural productivity.

The focus should not just be on diagnosing the nature and extent of the various land degradation and fertility decline processes locally at work and seeking ways to combat them. The FFS should also focus on the rehabilitation, conservation and sustainable management of the land and water resources, leading to enhanced, simultaneous land productivity and improved living conditions at farm and community level.

Setting up and running a farmer field school

SOME PREREQUISITES FOR IMPLEMENTING FFS

The vast majority of professional extensionists have been trained in a traditional manner based on a “top-down” approach to farmers, which is contrary to the present emphasis on participatory approaches. Consequently, the attitudes and skills of most trainers will need to be radically modified, if they are to successfully change from being “instructors” to becoming “facilitators”. The role of the facilitator and his/her relationship to farmers contrasts significantly from that of the instructor or trainer. The instructor imparts knowledge to farmers who adopt a passive role of merely receiving information. In contrast, a facilitator creates conditions for farmers to learn, by arranging opportunities for farmers to observe and interpret differences in soil conditions and crop performance, to carry out simple tests and exercises, and through discussions. The facilitator encourages farmers to adopt an active role in the learning process.

The main features of the attitude and role of a facilitator are:

- to accept that there is no monopoly of wisdom or knowledge on the part of the facilitator
- to listen to farmers and respect their knowledge, experiences and perceptions
- to give farmers the confidence to share their knowledge and experiences
- to create suitable conditions and activities from which farmers can learn
- to be responsive to farmers’ needs and flexible in organizing the course
- to increase farmers’ knowledge, problem-solving ability, capacity for innovation and skills so that the facilitator becomes redundant

Political support, appropriate policies and assured sources of funding to organize and implement the FFS, train facilitators and produce specific ISNM manuals are essential if the FFS approach is to become successful, widespread and sustainable. A budget must be prepared with detailed costs of inputs, training & learning materials, refreshments, and transport. Moreover, decision-makers at both national and local levels will also need to become aware, and convinced, of the greater benefits and impact of these new approaches. The participation of local government institutions, NGOs, and the private sector together with farmers in the development and promotion of improved technologies which are productive, profitable, conservation-effective and socially acceptable is to be encouraged.

Promoting ISNM by means of the FFS approach will necessitate a “bottom-up” rather than a “top-down” strategy,” a flexible curriculum that can respond to farmers’ perceived needs and interests, and placing the emphasis on the learning of principles and processes rather than “recipes”.

GETTING STARTED

The way that a FFS programme is initiated in an area will vary depending on local circumstances. In some cases the initiative will come from within the farming community where farmers recognize that they have a problem of declining soil productivity and have asked for assistance

to solve it. Alternatively the problem may have been identified from within the research and/or extension services, and be seen as one that could be addressed through the mechanism of a FFS. Irrespective of where the initiative came from the common denominator would be recognition of the benefits that could be gained from bringing farmers together to learn through discovery based exercises about firstly, the nature of the problem, and secondly ways of solving it.

Initially broad target areas (i.e. in which districts, regions or provinces to mount a FFS programme) should be determined by the national government using criteria such as poverty indices, access to infrastructure and markets, land degradation problems, agricultural potential etc. The final selection as to the particular villages/communities in which to run farmer field schools would depend on local interest and the seriousness with which particular soil productivity problems need to be tackled. However the following two criteria should guide the final selection as to which communities to enlist in the FFS programme:

- firstly the community should be aware of the direct and wider implications of a declining natural resource base, and understand the importance of improving the management of their soil in an ecologically oriented and integrated manner so as to sustain their livelihoods;
- secondly within the community there should be sufficient scope for sustaining the FFS for as long as is needed (potentials for the development of adequate local leadership, no strong opposing factions that hamper action and organizational growth, etc).

PREPARATORY STEPS

A prerequisite for a successful farmer field school is that the participating farmers should have expressed their interest in the school's subject (in this case integrated soil and nutrient management), and that they are interested in actively participating in the identification of soil management problems and finding appropriate solutions. For this reason it is important for the FFS facilitators to begin the process by holding a series of formal or informal preparatory meetings with farmers, local government and non governmental organizations. The aim of such meetings would be to confirm that combatting soil productivity decline, through improved soil management, is one of their priority concerns and that they are sufficiently interested to attend at least a season-long course organized on the subject.

During the preparatory phase, and in part through the participatory meetings, the following matters would need to be addressed to facilitate the smooth running of the FFS programme:

- **Review of secondary information** - on farmers' expressed crop production constraints in relation to soil management. Such information to be obtained from the reports of previous participatory rural appraisal/diagnostic surveys, socio-economic/anthropological studies, benchmark surveys, etc. The review should focus on the characteristics of the existing farming systems, the agricultural practices pursued and the farming technologies available within the community, and specifically on the agricultural production constraints identified by farmers themselves. The information thus obtained should be discussed with farmers, which would also provide an opportunity for the facilitator to begin to focus their thinking on soil management issues and on identifying specific farmer interests in this area.
- **Review of existing data on soil types and soil fertility** - to obtain a general overview of the soils and soil management limitations and potentials. This to involve collecting and reviewing the secondary data (e.g. topographic maps, soil maps and relevant reports, soil fertility and land suitability surveys), typically available from such sources as the local area and district/

regional level offices of the Ministry/Department of Agriculture and regional/ national level soil research institutes. This information should be used to determine the potential content of the FFS curricula and for the preparation of simple hand outs that could be distributed to farmers during the school sessions where all, or the majority of farmers are sufficiently literate to be able to make use of them.

- **Review of existing soil management practices** - as already practised by farmers and/or recommended by the research and extension services. Where the recommended practices are not adopted the review should seek to understand why not so as to determine whether they are ones that should be tested in the school or whether alternative practices will need to be identified. The review should also note whether farmers indigenous practices have the potential to serve as the basis for the development of more cost and/or conservation effective practices.
- **Identification of farmers with the same interests and/or problems** - so as to form a group of farmers for whom the school approach, and topics to be investigated, could be considered as a worthwhile response and method, to tackling their problems. The group should contain no more than 25 farmers, all from the same village. Ideally the group should contain both male and female farmers, however in some traditional societies cultural and/or religious constraints may require that separate schools be run for men and women. Efforts should be made to ensure that everyone's interests are included. In particular attention should be paid to the different needs of men and women from within the same village. Timing of school sessions may be critical as due to their other commitments women may not have the same availability to attend as men.
- **Presentation of the objectives, principles and procedures of the FFS approach** - by the FFS facilitator(s) through formal meetings or informal discussions with those men and women farmers expected to attend the school. For most farmers the FFS approach will be new, and they will be unfamiliar with this method of learning. It is therefore important for the successful development of the FFS that the facilitator(s) let farmers know from the outset what they can expect from the school, and also what is expected from them, namely:
 - to learn
 - to exchange
 - to identify
 - to test
 - to evaluate
 - to explain and discuss their findings
- **Reaching agreement on a season-long participation in the school** - as active participation is expected from all the members of the school for at least one cropping season. Hence it is important to ensure at the outset that all prospective participants are committed to the full programme, once they have been briefed on what is expected from them.
- **Selection of a cropping system** - that is of common interest and which will be the specific focus of the school sessions. For practical reasons the school cannot address the problems of all of the crops grown by the participating farmers. Hence the curricula has to restrict itself to identifying and studying different soil, nutrient and water management options for a selected crop or intercrop mixture. Thus a common decision should be reached among farmers on the crop/crop mixture that they consider to be most relevant to their needs, are most interested in investigating, and where the present production problems are soil and nutrient management related.

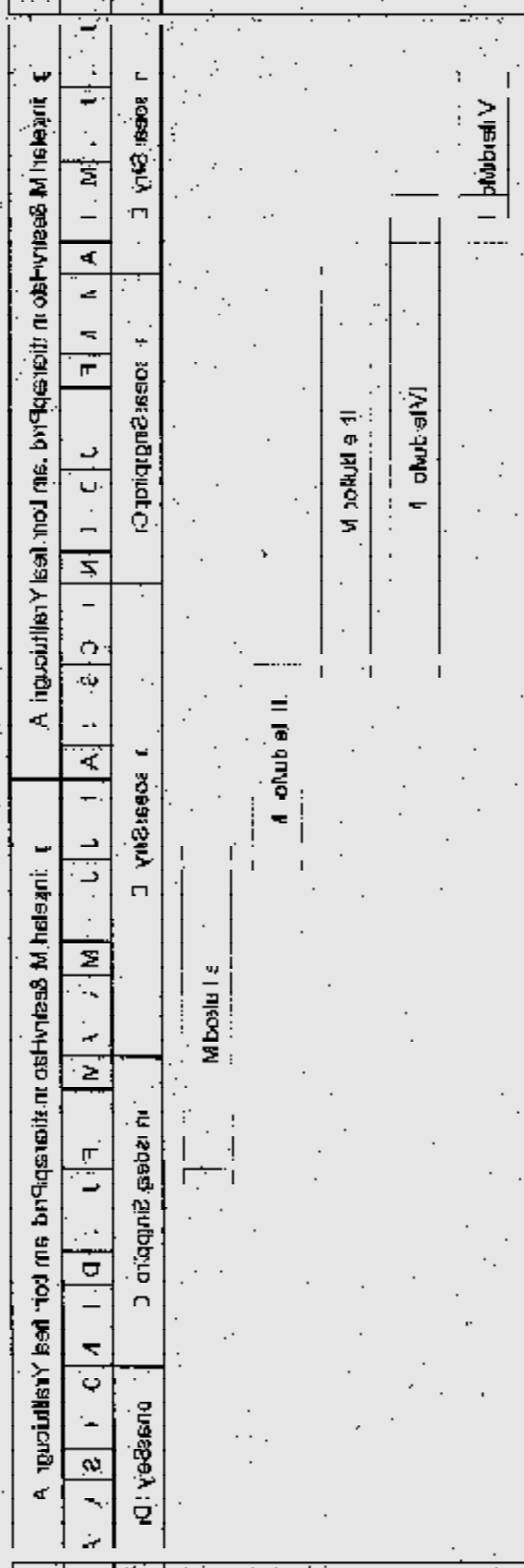
- **Agreement on the length and frequency of the school meetings** - as when scheduling the school's activities it is important to involve the participants in scheduling the meetings with regard to setting their time, length and frequency. It is rare for farmers to be able to spend a full day away from their farms and families, hence it is important to achieve a consensus amongst the participants as to how long each meeting should be. For most farmers this would be half a day (3-4 hours). Women in particular may not have the same time availability as men, and suitable times of day and duration should be identified to guarantee regular school attendance by women.
- **Agreement on the school's location** - by canvassing all participants' opinions so as to identify a suitable, and acceptable, field location where they would meet and jointly conduct the school's discovery based exercises.
- **Agreement on the school's start and end dates** - so that there is a consensus amongst the participants as to when the school will commence its learning activities and how long it should run. Whereas IPM farmer field schools have usually lasted one cropping season, for ISNM purposes there may be instances where farmers would wish (and may need) to continue the school for a longer period. In particular where specific practices have to be tested over several seasons to determine the variation in production levels associated with the degree of risk of crop failure (particularly where climatic variability is a key constraint) or where the full benefits may only be realizable after several cropping seasons rather than just one (e.g. improved fallows, alley cropping, restoration of organic matter levels, etc).
- **Preliminary field reconnaissance** - to familiarize the facilitator(s) with the bio-physical characteristics (e.g. soil types, topography, vegetation, water resources etc) of the village area and the land use enterprises and soil management practices used by the various households within the farming community prior to the commencement of the school.

TIMING AND SCHEDULING CONSIDERATIONS

The most convenient time to commence an ISNM FFS is usually just after the beginning of the dry season. Thus, learning modules dealing with the diagnosis of the farming environment, problems, causes and possible solutions and planning of on-farm trials, can be completed during the dry season when typically workloads are lighter. The testing of possible solutions by farmers would then be carried out during the following cropping season.

However, for annual dryland cropping systems the identification of soil and nutrient problems may be better accomplished during the latter part of the previous cropping season when crops are still in the field. This is a time when many soil related problems can readily be seen by farmers, for instance: (i) stunted crop growth and abnormal leaf colour indicating plant nutrient deficiencies/ toxicities; (ii) distorted tap roots of crops like tobacco and cotton indicating the presence of compacted subsoil layers; (iii) the presence of weeds like *Striga* and *Imperata* that are indicators of declining fertility; (iv) surface crusting or sealing restricting rainfall infiltration and seedling emergence; and (v) visible evidence of sheet and rill erosion that could be masked during subsequent cultivation. In such situations there would be considerable benefits to be gained by starting the ISNM FFS during the previous cropping season, so that some of the soil management problem diagnostic exercises could be undertaken at a time when the problems can be observed and their impact on yields noted. The ISNM FFS would then continue over the dry season, through the next cropping season and into the start of the next dry season (see Box 1).

BOX 1
Schematic illustration of the possible timing of ISM FFS modules in relation to the seasonal cropping calendar in a semi-arid unimodal climatic zone



- Key
- M1 - M1: Soil preparation, tillage, and sowing
 - M2 - M2: Planting, weeding, and irrigation
 - M3 - M3: Fertilization, pest control, and irrigation
 - M4 - M4: Harvesting, storage, and marketing
 - M5 - M5: Soil conservation, nutrient management, and irrigation

There are no fixed rules on when individual FFS meetings are held or on the duration of each meeting. This will depend in part on the farmers' and facilitators' availability and in part on the seasonal cropping calendar, the latter determining when specific tasks have to be done or when key issues should be observed and discussed in the field. The main requirement is that meetings be held on a regular basis with an agreed timetable so that all participants know when each meeting is due to take place. Typically meetings are held every 2-3 weeks during the cropping season, whereas the frequency may vary during the dry season. For instance several meetings may be held close together (e.g. daily) during slack periods in the agricultural and social calendar, with longer periods between groups of meetings. Typically meetings will last half a day (3-4) hours and scheduled for the morning or afternoon depending on what is most convenient for the participants.

FARMER FIELD SCHOOL MODULES

As indicated in Box 1 the curricula for an individual ISNM FFS can be broken down into a series of modules:

- **Module I** - aims to provide farmers with the skills to diagnose their farming environment and show them how to identify, primarily through field observation, soil management related problems. It is suggested that this should start during the previous cropping season when many soil management related problems can be readily seen in the field and continue into the dry season.
- **Module II** - focuses on diagnosing the causes of the problems and seeking ways to solve them. This should follow immediately after module I and be completed well before the start of land preparation for the next cropping season.
- **Module III** - focuses more specifically on discovering the principles of, and learning the skills required for, integrated soil and nutrient management. This should be initiated on the conclusion of module II and before the start of the next cropping season so that some of the discovery based learning exercises can be undertaken under dry season field conditions.
- **Module IV** - aims to allow farmers to learn from practical experience the skills required to plan and implement the field level testing of possible solutions, and how to monitor and evaluate the results of such tests. This module is expected to run in parallel to module III and would begin with land preparation and continue through to harvest.
- **Module V** - is a short concluding module that follows the completion of module IV in which the FFS participants and facilitator(s) evaluate: (i) the success of the school with regard to the change in the participants knowledge and field skills between the beginning and end of the training; (ii) the technical content of each module with regard to its relevance to the local agricultural production problems; and (iii) the way particular issues were dealt with (e.g. learning methods used) during schools meetings.

Note most of the activities related to the implementation and monitoring of farmers' tests would be carried out by farmers on their own farms in their own time, however several FFS sessions would be needed to guide and assist farmers in how to plan, establish, monitor and evaluate their tests (i.e. module IV). Individual sessions could treat the following as special topics: (i) how to plan and establish field tests; (ii) what indicators to look for and how to monitor them; (iii) how and what to measure when harvesting the crop; and (iv) how to finally evaluate the results of the test.

SELECTING THE VENUE FOR FARMER FIELD SCHOOL ACTIVITIES

Given that one of the key principles of the FFS approach is that learning is based in the field then the principle venue for FFS activities will be one or more fields selected from the fields of the participating farmers. When selecting a suitable FFS field in which to conduct the discovery based exercises and investigative field tests and demonstrations this should be a site where access is good, and the topography, soil type and cropping systems are representative of the area. In some circumstances one field may be designated as the FFS experimental area, much as in FFS for integrated pest management. However, there will usually be several soil types, slopes, cropping systems, and sometimes climatic zones within a community, and the full range of these situations is unlikely to be encountered in any one field. Consequently, several farmers' fields will usually be needed to fully reflect the different farming situations within the community.

In addition to the field site the FFS will require somewhere to meet out of the sun where the field findings can be reviewed, presented and discussed by the participants. To maintain the distinction between the conventional classroom based farmer training and the FFS approach, the non field based meetings and activities should not be conducted in a classroom setting. In the past a variety of alternative venues have been used by IPM and ISNM field schools, some have sat beneath a shady tree, others have used their local church or community hall, and a few have constructed their own simple roofed shelter. Within the chosen venue seating should be arranged in a circle so that all participants feel on equal terms with the facilitator and with each other. Experience has found that a flip board, paper and markers should be available to participants to assist the presentation and discussion sessions. Even illiterate farmers can make use of simple diagrams and symbols to assist in putting over their findings.

STRUCTURING AND RUNNING FARMER FIELD SCHOOL SESSIONS

Each session commences with one participant summarizing the findings of the previous session. The facilitator then introduces the activity for the present session, and explains what the participants will be doing and what they can expect to achieve. This effectively creates a "contract" between facilitator and participants.

For discussions, and if possible for field activities, it is beneficial to divide the participants into groups of 3-5 persons so that all participants are obliged to actively participate. One person is nominated to present the group's findings to the whole assembly, and the nominated person rotates within the group. It is often beneficial for women to be in separate groups to the men, as their perceptions of problems are frequently different, and they often feel more able to express their opinions in the absence of men.

To help participants feel less inhibited and more confident at expressing their opinions and relating their experiences within a group, various activities such as games, singing, plays and miming may be introduced, where the activities focus on ISNM problems and their solutions. In this way participants also become accustomed to working together as a group.

OPENING AND CLOSING CEREMONIES

The presence of dignitaries from the municipality and local communities at the opening and closing ceremonies of the FFS is important as it lends credibility to the FFS and attaches importance to ISNM. All participants who satisfactorily complete the course in ISNM should

receive a “Diploma in Integrated soil and nutrient management” at the closing graduation ceremony. This will provide recognition to the participants of the importance attached by the community to their achievements in ISNM, and will probably be the first time their skill as a farmer has been recognized.

COMPLEMENTARY FARM MANAGEMENT SKILLS

Since farming can only develop through an integrated approach to agriculture, there is scope for introducing modules on other farm management disciplines into the FFS curriculum. The selection and order in which these are presented will depend on farmers’ interests, needs and priorities, and the time they have available. The following are examples of such additional topics that could be included in a FFS:

- Integrated pest management
- Integrated crop and weed management
- Land reclamation
- Water harvesting
- Irrigation and drainage
- Credit management
- Farmers’ organizations
- Livestock production
- Alternative fuelwood and fodder sources

Module I: Diagnosis of the farming environment and observation of field problems

PURPOSE

The primary purpose of the first module of the FFS is to achieve a consensus amongst the participants as to the nature of their bio-physical farming environment, to share and assess the farming practices used in the area, to look for evidence of soil management related field problems, and to make a preliminary assessment of the effect of these problems on farm production. The field based activities would be expected to include direct observation, field transect walks and community mapping.

DIRECT OBSERVATION

Throughout the various field based activities that are engaged in during the course of conducting a FFS, direct observation will figure as the primary method used by the participants to make their field assessments. The role of the facilitator is to encourage them to use their eyes, to discuss what it is they can observe, and to explain to them what non observable soil properties they might be able to assess by using visual indicators.

When the school's participants are assessing their local farming environment direct observation can provide information on the different landforms, slopes, soils, water resources, vegetation, pests and diseases and the degree and extent of existing land degradation. It can also help in relating these factors to land use, crops, livestock and cultivation practices. Some factors may not be directly observable but rely on the use of observable indicators, such as indicator plants - the presence of the parasitic weed *Striga* or the grass *Imperata* in cultivated fields is a sign of declining fertility, likewise the presence of sedges in grasslands are indicators of regular waterlogging.

The following is indicative of the range of soil and nutrient management related problems and the types of indicators that could be observed by farmers during a discovery based field assessment exercise.

Soil Management Problem	Observable Indicators
Soil erosion by water	<ul style="list-style-type: none"> · exposed plant roots · pedestals, rills, gullies, accumulations of soil · reduced topsoil depth (seen in the side of gullies, or by digging or augering) · change in colour and/or texture indicating subsoil exposure
Wind erosion	<ul style="list-style-type: none"> · signs of wind scouring and exposure of plant roots · wind blown deposits accumulating at field margins or where the winds progress has been obstructed · in extreme conditions presence of mobile dunes · dust storms

Nutrient level - deficiency/toxicity	<ul style="list-style-type: none"> · pH (using a field pH metre) · relative nutrient levels (using a field soil testing kit) · leaf colour as an indicator of nutrient deficiencies · crop growth and vigour
Salinization/Alkalinity	<ul style="list-style-type: none"> · pH (using a field pH metre) · salt on soil surface
Waterlogging	<ul style="list-style-type: none"> · presence of indicator plants (e.g. sedges) · stunted & dying dryland crops · high water table · mottling within the topsoil and upper subsoil
Surface compaction/crusting	<ul style="list-style-type: none"> · thickness and strength of a soil crust · excessive surface runoff
Subsoil compaction	<ul style="list-style-type: none"> · uprooting and observation of the shape & distribution of the tap roots of indicator plants · number, size and distribution of roots per soil horizon as seen on the side of a profile soil pit
Lowering of the groundwater table	<ul style="list-style-type: none"> · drying of wells · deepening of boreholes · dying trees
Declining water quality	<ul style="list-style-type: none"> · discolouration of the water by sediment · algae · bad smell
Sedimentation of water reservoirs	<ul style="list-style-type: none"> · discolouration of the water by sediment · sediment deposition visible as water level drops
Degradation of grazing areas	<ul style="list-style-type: none"> · gullyng of livestock trails · poor ground cover (estimation in %) · signs of 'bush' encroachment · relative proportion of palatable to non-palatable pasture species · condition of grazing animals
Degradation of forest resources	<ul style="list-style-type: none"> · stunted trees with limited regeneration · poor ground cover (estimation in %)

FIELD TRANSECT WALKS

A field transect walk is a walk and discussion undertaken by the FFS participants, usually in the company of a facilitator, along a transect (route) that enables the participants to observe, for their local area, the variations in the main landforms (e.g. hills, flat alluvial areas, terraces), soils, land-use, soil, water and crop problems and possible opportunities, and how these are related to the landscape. Transect walks are important activities, and are particularly useful where there is a range of land use types, and where soils vary over short distances.

Prior to undertaking a transect walk the participants, in consultation with the facilitator, should plan a route that will cover as much of the diversity of local land types, land uses and problems as possible. When discussing and selecting the route the participants should be encouraged to

prepare and make use of a map depicting the key bio-physical and socio-economic features of the community's land area (see next section). Once the route to be followed has been agreed on it could be plotted on such a map. The route need not be in a single straight line, or even in a straight line, and should not be confined to the most accessible roads, as this will often give a false impression of the area. In hilly terrains, the transect may start at a high point near to the hydrological divide between two catchments and move downhill towards a drainage line. In flat areas the transect should cross as many land uses and soil types (based on farmers' knowledge) as possible, and at least part of it should be aligned perpendicular to the direction of the main drainage course.

During the transect walk there should be regular stops as the landscape and land use patterns change. This is for the participants to observe the local features of the farming environment, and to provide an opportunity to discuss how and why these have changed from one part of the transect walk to another. The participants should be encouraged to record their findings at each stop in the form of a transect diagram, with different individuals being responsible for different aspects. Exactly how this is to be done will depend on the degree of literacy amongst the participants. It would not normally be the role of the facilitator to record such information however this could be necessary when working with primarily illiterate farmers. In such a situation the facilitator should assume the role of a scribe recording the information given to him/her by the participants. Subsequently he/she should prepare a simple visual transect diagram using visual symbols so that the diagram can be verified and discussed by the participants.

The type of information to be recorded at each stop could include:

- **Soils:** using the farmers' criteria for defining different soil types, if these are very simplistic (e.g. just a colour difference) the facilitator may to improve the descriptions by prompting for additional details on stoniness, depth, fertility or management requirements.
- **Crops/vegetation:** using local terms and criteria to describe the cropping system(s), pasture types, tree crops and vegetation.
- **Animals:** recording the different types and approximate numbers of livestock and whether they are stall-fed or free grazing.
- **Water supplies:** using visual evidence and local knowledge to record the permanence of rivers, streams, springs, incidence and source of flooding.
- **Problems:** using observable indicators and local knowledge to record problems related to soils, nutrients, crops and water, and especially if there have been changes in recent years, e.g. erosion, increasing need for fertilizers or manures, declining yields or pollution.
- **Management practices:** describing soil practices such as tillage, conservation measures, fallows; cropping practices such as rotations, burning or grazing of residues; nutrient practices such as manuring, composts, fertilization; water practices such as irrigation and drainage. As far as possible this should be based on what the participants can observe during the transect, however the time of year may affect what can be seen so information on management practices not pursued at that time of year should be noted, using the local knowledge of the participants or other farmers met during the transect walk.
- **Opportunities:** recording the participants and other farmers' opinions of the opportunities for increasing productivity and reducing land degradation in specific locations.

It may not be practical, or desirable, for all 20-25 FFS participants to undertake the walk together. In such a situation one option is for the FFS participants to select some five or six farmers, including a couple of women farmers, to accompany the facilitator and represent the group as a whole, with possibly other participants being met during the walk. An alternative option is to divide the group into two or three subgroups and have each subgroup undertake a transect walk across a different part of the area. If there is more than one facilitator then these subgroup walks could take place at the same time. If not then they would have to take place consecutively. The facilitator must ensure there is no bias in the collection of information by talking only to the better-off male farmers. Care must be taken to ensure that poorer farmers, wives and women farmers are involved and consulted for their information and opinions, as their knowledge and perceptions may be different. However the transect walks are conducted, the facilitator should ensure that there is an opportunity for the full group of FFS participants to meet immediately afterwards, to discuss and review the findings of each one.

COMMUNITY LAND USE AND NATURAL RESOURCE MAPPING

A recent participatory rural appraisal tool that can be used in a FFS for describing the farming environment is that of participatory mapping or modelling. This exercise would involve asking a representative sub-group of the FFS participants to draw a map or construct a model of the main bio-physical and/or socio-economic features of their village and its surrounding area. Separate subgroups might be asked to map or model different features. The technique can be used for diagnostic purposes with the maps and models being used as a means of characterizing the local farming circumstances, and as visual aids to describe these to the facilitator and other FFS participants. Preparing such maps or models during the initial sessions of the school is a particularly useful means for achieving a consensus, amongst the participants, on how they perceive the bio-physical resources and socio-economic situation within their community.

There are several types of maps and models that could be prepared, and many uses to which they can be put, as part of discovery based learning exercises during the course of a FFS. One such map that should be prepared would be a general community resource map showing the location of the participating farmers' fields, communal pastures and woodlands, catchment boundaries etc. A participant who is particularly knowledgeable may be asked to prepare a single topic map such as a soils map (classified according to the locally recognized soil types), or a map showing the distribution of groundwater resources (perhaps based on the knowledge of a local water diviner or the seasonal location of shallow wells). FFS participants may also use maps to record the severity and extent of problems such as pest incidence, soil quality and erosion severity. Whereas these maps may initially be prepared on the basis of the participants existing local knowledge they could be refined subsequently following further field investigations during the course of the FFS.

Maps and models could also be used to combine a historical view with those of the present and the likely future situation. FFS participants could be asked to prepare a series of maps/models - e.g. one that describes the situation 30 - 50 years ago, another the present situation, and a third how they expect the area to look 20 years in the future. Such time series maps/models can form the basis for lively and informative discussions between the map makers/modellers, the other FFS participants and the facilitator on the reasons for the past changes, and what can be done to prevent further adverse changes.

Normally the boundaries of the map would conform to the boundaries of the land in which the community pursues its various land use enterprises. However there may be occasions when

it would be necessary to prepare a broader catchment map, for instance when there are serious environmental problems (e.g. erosion caused by runoff from steep lands or roads, water pollution, deforestation or overgrazing) which require catchment-scale solutions such as the installation of physical soil conservation structures, interceptor drains, reservoirs, road realignment, reforestation or land and vegetation recuperation. Maps of the catchment will also be necessary when a significant proportion of the river water is to be used for irrigation. Where the upstream and/or downstream portions of the catchment extend beyond the boundaries of the community a catchment map could be used by the facilitator to draw attention to: (i) the way the land use activities of communities living upstream may affect the school's participants with regard to the way in which use their land and their choice of management practice; and (ii) how their own land use activities might have an impact on those of downstream farming communities. The subsequent discussion may highlight the need for inter-community collaboration/conflict resolution to solve and/or prevent particular problems.

CONSIDERATION OF SOIL FUNCTIONS IN RELATION TO LANDSCAPE AND SOIL TYPE

Following on from the transect walks and field observations the facilitator should ask the participants to reflect on the basic demands (needs) made by crops on the soil. This can be done by linking the basic needs of a human to those of a plant, i.e. both need to eat (plants absorb nutrients), to drink (plants take in water), to breathe (plants take in oxygen through their roots and leaves), the freedom to grow (plants need soils that are not excessively strong so that shoots and roots can develop), a stable environment (plants need to anchor their roots in stable sites protected against erosion, landslides and flooding), and a healthy environment (soil health is maintained by the biological processes of soil macro- and micro-organisms).

Therefore to satisfy the needs of crops, soils must fulfil various functions. The six most important functions for plant growth are:

- an adequate supply and retention of water;
- an adequate supply and retention of available nutrients;
- an adequate supply of oxygen (except for irrigated rice which receives oxygen at the roots by transfer from the leaves down the stem);
- favourable biological processes due to soil fauna (worms, ants, termites etc.) which create pores for root penetration and drainage of excess water, and soil micro-organisms (bacteria and fungi) which convert nutrients in organic materials into forms usable by plants;
- an absence of excessive soil strengths which hinder shoot or root growth;
- site stability so that the quality and usefulness of the site is not damaged by water or wind erosion, mass movements or flooding.

The facilitator in consultation with the FFS participants should select three representative soil profile pits of contrasting characteristics. Their selection being guided by information on the local soils gained from the preliminary review of secondary data, the transect walk and participants local knowledge. Once dug these pits should be used to discuss soil functions in relation to landscape and soil type. In hilly terrains the pits would usually be located in upper, middle and lower slope positions, whereas in flat terrains the pits might be located in light, medium or heavy textured soils, or in well, imperfectly and poorly drained soils, or in different land use types.

It is suggested that the participants be divided into three subgroups with each one being given the task of examining one of the three soil pits. The subgroup should be asked to discuss and describe the characteristics of their soil profile, in their own way, and using their own words.

Subsequently a representative of each sub-group should present their findings to the other sub-groups while visiting each of the three locations in rotation. The facilitator should encourage further discussion and probing to ensure that by the end of the exercise the participants will be familiar with the main physical characteristics of different soil types and be able to relate these to the different soil functions (water retention, oxygen and nutrients supply). In addition they should be able to identify the most limiting soil function at each location, and relate this to plant growth.

FIELD IDENTIFICATION OF SOIL AND NUTRIENT PROBLEMS

When introducing the subject of soil and nutrient problems the facilitator should advise that the ultimate effect of such problems is low crop productivity which arises when the soil in which the crop is growing does not satisfy the crop's needs. This should be related back to the previous topic with the participants reminded of the essential soil functions, and how soil and nutrient problems are related to inadequate soil functioning.

Specific soil and nutrient problems known to cause low soil productivity can be summarized as follows:

- insufficient supply and retention of water;
- insufficient supply and retention of available nutrients;
- insufficient supply of oxygen;
- low biological activity;
- presence of toxins;
- excessive soil strength restricting shoot emergence, root growth and ease of tillage; and
- site instability.

Soil and nutrient problems can often be identified by means of various soil, site and crop indicators. Since crop conditions are frequently useful indicators of soil and nutrient problems, this is a reason for conducting this part of the FFS during the cropping season, so that the participants can directly observe the indicators of various soil and nutrient problems. However even during the cropping season some indicators, e.g. wilting, low crop emergence, erosion and surface crusting, may have been evident prior to the field visit, but have since disappeared or been obliterated by subsequent crop husbandry practices, e.g. weeding. However the participants can ask the person farming the plot which, if any, of such indicators were previously evident, and whether the observed problems occur frequently or are of rare occurrence related to exceptional climatic, pest, disease or management events.

The facilitator in consultation with the FFS participants should identify two sites in close proximity within the same field or adjacent fields, but with contrasting crop performance, that can serve to highlight soil and nutrient problems, and their impact on crop productivity. The selection of representative sites requires knowledge of the area's soils and soil problems which should have been obtained from the preliminary secondary data review and the transect walk.

A comprehensive list of field indicators that could be used by farmers in a FFS, to detect specific soil and nutrient problems can be found in Annex 6.

Module II: Diagnosis of problems, causes and possible solutions

PURPOSE

Having identified the main soil management problems during the previous module the primary focus for the second FFS module is to diagnose the causes of these problems and to seek possible solutions to them. Getting the participants to identify the problems and their possible solutions should provide a clear indication of their interest in knowing more about specific soil management, or related crop management topics. This should serve as the basis for selecting the specific topics to be addressed by the school during the third module (principles and skills of ISNM), and the field trials to be undertaken in the fourth module (planning, testing, monitoring and evaluation of possible solutions). It is highly unlikely that all of the identified problems can be addressed by the field trials that would be conducted under the auspices of a FFS during one cropping season (module IV). However some of these could be covered as ‘special topics’ in the sessions covering the principles and skills of ISNM (module III).

IDENTIFYING THE CAUSES

The identification of the cause(s) of a particular soil management problem would be undertaken within the FFS through group or sub-group discussion. The starting point would be the previously prepared list of identified problems. The objective of the focussed discussions, is to identify the causes and effects, and the causes of the causes. Two alternative diagramming techniques can be used to help show the cause and effect linkages, namely “causal diagramming” and the inverted “problem-cause tree” (see annex 4 for detailed guidelines on, and examples of, both techniques). The facilitator should explain the use of one of these techniques and then ask the group or sub-group to use it to identify the various causes of one of the main soil and nutrient problems within the dominant land use system in the community.

The facilitator should be aware, and explain to the group that a lot of the identified problems may be causes or effects of other problems and each cause of a problem in itself can be a problem and an effect for which other causes can often be identified. The group/sub-group should jointly revise the causes and effects on the diagram, eliminating those that are duplicates or invalid, to arrive at a consensus agreement on the causes for the problem. The process is then repeated for the next “problem”. During the diagramming process it will often become clear that by solving one problem a lot of other problems will be automatically solved as well.

By dividing the group into sub-groups, and asking each sub-group to focus on a different set of problems, it should be possible for a larger number of problems to be assessed. Furthermore by having each sub-group then present their diagrams to the group as a whole it would be possible to stimulate further discussion and consideration of the various causes of the identified problems.

Many of the causes of the problems which contribute to low productivity will stem from the socio-economic, organizational, infrastructural, credit and marketing environment in which farming takes place. Such problems should have been identified from the transect walk as well as from

secondary data sources. The causes of these problems may also be considered in the diagramming exercise, though the emphasis would be primarily on the technical problems as these are the ones for which solutions can be tested in the field during the course of a FFS.

If there are any uncertainties, within the group or sub-group, about the main causes, a ranking procedure may be used in which each participant “scores” (i.e. assigns a value or a number of seeds out of a total of 20) to each of the causes according to his/her perception of the relative importance of that cause.

PROBLEM PRIORITIZATION

During the previous school exercises the participants will have observed and discussed their soil management practices, identified their soil management and crop production problems and determined the causes of these problems. In order to identify what the participants see as their most relevant soil management problems, and to decide what they would like to learn more about during the subsequent school modules, the identified problems need to be summarized and prioritized according to the participants assessment. Problem prioritization can be undertaken as a group exercise through “individual voting” or “pairwise ranking”. The former allows a large number of problems to be ranked whereas the latter is better where the number of problems is no more than 4 or 5.

With individual voting the facilitator or one of the participants would write on a blackboard or large sheet of paper the list of identified problems (by major categories). The group would then review the list and add additional problems if one or more of the participants wished them to be included. Following this a matrix would be prepared on the blackboard or large paper with the problems listed on the left of the matrix. Each of the participants would then go individually to the chart to record their priority rating against each problem (1 low priority, 2, 3, 4, 5 etc high priority). The preference scores would be totalled and the problems ranked accordingly. At this point the group would review the results of the exercise to ensure that there is a consensus agreement on the final priority listing. They would then discuss with the facilitator whether the problems represent the topics they would like to investigate further and learn about during the farmer field school. The same exercise could be undertaken with predominantly illiterate participants by using a symbol to characterize a particular problem, preparing the matrix on the ground, and having each participant place a number of stones or seeds, corresponding to their priority rating, against the problem.

With pairwise ranking the prioritization of problems takes place in a structured way which compares problems one with another. The same process as used for individual voting would be followed to arrive at the list of problems for prioritization. However when preparing the matrix the problems are written across the top and down the left of the matrix. To get the group’s preferences the participants would be asked to compare the problems one with another. The first problem on the left side of the matrix would be compared with all the problems listed across the top. The participants ranking can be assessed by a simple raising of hands. The process would be repeated until all the problems have been covered. The number of times each problem was assessed as being the most important would be noted, summarized and ranked accordingly. Again there would be a discussion to achieve a consensus that these are the priority problems that should be addressed by the farmer field school.

The following questions could be used to facilitate the group discussion:

- have all the problems identified during the previous exercises been listed?
- are there still some problems missing from the list?
- are there any problems on the list which are closely related to each other or may even be considered the same?
- are there problems which can be considered as specific for a certain area or group of farmers (e.g. on a slope, on a specific soil type, or farming system)?
- which is the most serious problem?
- what specific criteria are used to arrive at a priority ranking for each problem?
- is there agreement on the final problem prioritization list?

IDENTIFICATION OF SOLUTIONS

Having identified and prioritized the problems and determined their causes the next step is for the participants to identify possible solutions to the problems. The participants with the support of the facilitator and/or a technical specialist brought in for this FFS session, should initially identify which, if any, solutions are already being used locally. The school facilitator and/or the technical specialist may draw on their specialist knowledge to suggest new practices or technologies not currently known about in the area, with potential for solving particular local problems¹. Similarly the appropriate solutions may be found within the farmers' indigenous knowledge, either within the community, or in nearby communities. During this exercise all these possible solutions should be listed and discussed, first in small groups of 4-5 participants, with their conclusions and suggestions subsequently being presented and discussed in a plenary session. After the plenary presentations the facilitator should assist the group to note similarities and differences in the suggested solutions, and to cluster/regroup the solutions according to major categories, removing duplication so as to remain with a total of 3-4 solutions listed for each problem. The final discussion should seek to achieve consensus agreement amongst the participants on the final list of solutions.

ASSESSMENT AND SELECTION OF PRACTICES TO BE TESTED

Farmers use agricultural practices that are suited to their farming system and household circumstances, and are thus heavily influenced by the resources available. Thus to be able to choose appropriate solutions/practices to be tested, it is important for the school participants to assess correctly whether an identified improved soil management practice (solution) is appropriate to the problem they experience within their farming system. The participants should therefore be asked to make a simple assessment of the resources needed (labour, land, cash, on-farm materials, external inputs etc) and their availability within the household and/or community. This exercise would help the participants to identify from amongst the several possible solutions, the most promising practices to be experimented with during the school, and to identify what changes to the present household farming system may be required in order to adopt a particular practice or technology.

¹ A comprehensive list of possible solutions for a wide range of problems and causes is given in Appendix 5 of Annex 2. This could be used by a FFS facilitator for the preparation of a short list of locally appropriate solutions, i.e. ones that match the area's agro-ecological environment, farming systems, household socio-economic circumstances and level of production.

The exercise can be conducted with sub-groups (4-5 farmers in each) or through a plenary session. The previously identified solutions (practices) should be written up on a blackboard or large sheet of paper for all the participants to see. Discussion and exchange of opinions and information should be promoted by asking the participants to indicate all possible limitations and difficulties they foresee in testing and using the proposed practices (labour, availability of on-farm materials, cash for purchasing external inputs, land access, risks etc). Efforts should be made to ensure that everyone expresses their views, in particular the women who may see the labour and cash requirements from a very different perspective given their specific responsibilities for their household's social welfare. In a plenary session the results of the previous discussion should be used to re-write the list of solutions starting with the most promising (i.e. of most interest to the participants) and ending with the least promising. Care should be taken to ensure that the criteria used are not biased towards the views of the facilitator or the better off and more influential farmers within the school. Since only a limited number of solutions/practices (e.g. 2-3) can be tested during one cropping season the participants should be asked to select those they wish to test in the fields, and any additional special topics they would like to know more about.

The following questions could be used to facilitate the group discussion:

- what impact will the new practice have on family labour (*men may have different opinions to the women*)?
- is the necessary organic material available (*if more use of organic fertilizer has been identified as a solution*)?
- what changes might be needed in the system to produce more organic fertilizer and what effect will it have on the present system?
- what would be the labour requirement needed to adopt such a practice?
- is it available?
- what external inputs might be required (*if inorganic fertilizer and/or herbicides have been identified as solutions*)?
- are these available locally?
- how much would they cost and does the household have the cash to pay for them; and also is the cost:benefit ratio favourable?

For complementary information, reference is made to FAO/AGL *Guidelines for Participatory Diagnosis of Constraints and Opportunities (PDCO) for Soil and Plant Nutrient Management* (in press).

Module III: Principles and skills of integrated soil and nutrient management

PURPOSE

Whereas the previous two modules have been concerned with diagnosing the farming environment, determining the problems and their causes, and identifying possible solutions, this module focuses more specifically on discovering the principles of, and learning the skills required for, integrated soil and nutrient management. Although some of these will be learnt by conducting field tests of possible solutions in module IV, this module aims to provide the FFS participants with a broad understanding of their soils and why the way the soil is managed will affect the level of crop production that can be achieved. The module will involve a variety of discovery based field exercises, as well as a range of participatory diagramming sessions, group discussion and simple exercises modelling various soil degradation and integrated management processes.

POTENTIAL TOPICS

The specific topics to be covered in this module will have been agreed on by the participants in consultation with the facilitator during the previous module. It is likely that most, if not all, of the following topics will be covered during this module:

- **Why soil is important:** Soil is the part of the earth where plants grow and humans depend on plants for the bulk of their primary welfare needs, e.g. staple food (cereals, roots, grain legumes, vegetables fruits etc), clothing (fibre crops), fuel (firewood), shelter (timber, poles, leaves/grasses for thatching), medicines, as well as feeding livestock from which man gets a variety of other valuable products.
- **What are the characteristics for an ideal soil:** Most crops require soils that are: (i) deep with no impediments to root development; (ii) well drained and well aerated, with the capacity to store sufficient soil moisture to support good crop growth; (iii) capable of supplying adequate quantities of the essential plant nutrients to growing crops; (iv) neutral to slightly acid; and (v) located on gently sloping sites (1-5% slope).
- **How soils are formed:** The soil forming factors influence the action of particular soil processes (e.g. weathering and leaching) and it is these processes acting over time that produce the variety of different soil types that can be recognized today. The factors of climate, relief, hydrology and man directly affect the processes of soil formation. The time factor determines how long the processes have been active. The parent material factor supplies the mineral substance from which the soil profile is developed. While vegetation and soil organisms both supply organic substances and affects processes. Although some of this is theoretical most of these factors can be illustrated and discussed with FFS participants through field visits to sites showing different soil types where different factors and processes have been involved in their formation (e.g. old land surfaces, colluvial deposits, volcanic ash, weathered rock showing signs of decomposition alluvial waterlogged valley floors etc. A point to emphasize is the time it takes for soil formation and the need to ensure that soil is not lost through erosion faster than it is formed.

- **Understanding soil physical properties:** As adverse changes in a soils physical properties following cultivation can lead to reduced yields and increased damage from soil erosion. The soil's physical properties can generally be observed and assessed in the field so lend themselves to a variety of discovery based learning exercises. Farmers can learn the technique of hand texturing so as to be able to accurately recognize differences in texture between different soils. Comparisons can be made of the structure of two topsoil samples of the same soil type, one collected from a field that has been cultivated for several years, and the other from a forest or permanent pasture area, to show how tillage affects structure. The physical condition of the soil surface can be compared between different fields to show the effect of different forms of management and/or the susceptibility of different soil types with regard to the thickness and strength of a soil crust and its effect on rainfall infiltration. Soil pits can be used to look at subsoil physical conditions particularly differences between horizons with regard to texture, consistence, the size and abundance of soil pores, ease of root penetration, and presence of compacted layers (plough pan) or other limiting horizons.
- **Understanding soil biological properties:** With declining soil organic matter levels following cultivation, the adoption of improved organic matter management practices are a prerequisite for restoring and maintaining soil productivity (improved soil nutrient levels, soil moisture retention, soil structure and resistance to erosion). Discovery based learning exercises could focus on comparisons of colour, structure, feel, and faunal (worms, termites etc) activity between a forest soil and a cultivated one. Alternatively the FFS participants could undertake soil ecosystem observation to compare the diversity of living and non-living things of a well managed and poorly managed soil.
- **Understanding soil chemical properties:** Chemical degradation in the form of acidification and nutrient decline is indicative of poor soil management and a common problem in many agricultural areas. A variety of diagramming and modelling exercises can be used by the FFS facilitator to explain to the participants about the importance of soil nutrients, and nutrient flows within the farming/household system. If simple soil testing kits and/or pH metres are obtainable the facilitator should try to get hold of them and make them available to the school so that the participants can use them to compare levels of the key primary and secondary nutrients, and soil reaction (pH), in different soil samples taken from fields with different soil types and/or past management histories. The facilitator can also link these sessions with the transect walk/direct observation exercises, undertaken in module I, that looked for plant foliar indicators of nutrient deficiencies and toxicities, and visible evidence of salinity problems (indicator plants, surface salt deposits, taste etc).
- **Understanding soil hydrological properties:** The moisture properties of a soil are of considerable importance in assessing its agricultural potential. A range of discovery based exercises could be used to investigate differences between soils and management practices with regard to such soil hydrological properties as drainage, field capacity, wilting point, available water capacity and infiltration capacity.
- **Understanding soil erosion processes:** Water erosion may take different forms (e.g. splash, sheet, rill and gully erosion), wind erosion may be a problem in some areas and both can have detrimental on- and off-site effects. There are a variety of different factors that determine the risk and severity of erosion - notably rainfall pattern, slope steepness, slope length, soil type, ground cover, land management practices and in the case of wind erosion wind speed. Discovery based exercises can assess the type, nature and severity of current erosion damage within farmers' fields and several of the erosion processes can be modelled using boxes of soil and a watering can.

- **Production and use of organic fertilizers:** A variety of different organic fertilizers can be used to supply plant nutrients and improve the condition of the soil. Furthermore micro-nutrient and trace element imbalances can occur where farmers rely solely on inorganic fertilizers to supply the macro nutrients and one or two secondary nutrients. Organic fertilizer can be produced from the recycling of farm wastes such as crop residues, animal manure and kitchen waste. A range of green manures can be grown on farm to supply plant nutrients and organic matter for incorporation into the soil (e.g. herbaceous legumes grown in a crop rotation, or agroforestry systems where the leaves and stems of nitrogen fixing trees/shrubs are used to fertilize adjacent crops). Some farmers may have access to off-farm sources of organic fertilizer (chicken/pig manure from commercial producers, silt from fish/prawn ponds, sugar factory waste, urban refuse etc). The FFS participants could investigate the costs and benefits of alternative organic fertilizers e.g. making compost, using green manures, improved storage of farm yard manure, incorporation of crop residues.
- **Inorganic fertilizer:** There is frequently a variety of different types of inorganic fertilizer available to farmers and they may have a limited understanding of which are the best for their specific circumstances. There is therefore scope for the FFS participants to learn about the differences between compound and single nutrient fertilizers and how to compare fertilizer costs in relation to the amount of nutrients supplied, for instance a bag of Urea typically costs more than a bag of Sulphate of Ammonia but is usually cheaper per unit of nitrogen supplied. The participants can also test (perhaps as part of module IV) different amounts of, and ways to apply, inorganic fertilizer, plus comparing the costs and benefits of inorganic versus organic fertilizers and combinations of the two.
- **Tillage practices:** The form of tillage used for land preparation will have an impact on the productive potential of a soil. In parts of Africa there is evidence that tractor drawn disc ploughs, ox drawn mouldboard ploughs and even the annual splitting and reformation of crop ridges with a hand hoe have resulted in the formation of a compacted upper subsoil horizon that can affect yields by limiting the crops root development and ability to obtain nutrients and moisture from the lower soil horizons. FFS participants could investigate and compare through field trials or observation of existing differences in field practices, alternative tillage techniques to determine their impact on both crop germination, establishment, growth and yield, and the soils physical properties.
- **Crop rotation/intercropping:** Amongst the FFS participants there may be a variety of different cropping systems and crop rotations pursued and these may differ from neighbouring communities. Each cropping system and crop rotation will have its own advantages and disadvantages many of which will be related to the soil characteristics and/or availability of water in the area where they are practised. A variety of discovery based exercises can be used to explore the relationships between different crop combinations and rotations to see whether they are competitive for nutrients and moisture or beneficial (e.g. by raising nitrogen levels by including a legume in a cereal based cropping system). Likewise the relationships between the crops, soil types and/or water availability.
- **Improved fallows:** Fallowing has been a traditional practice used by farmers to restore the productivity of their soil. However as the farming population has grown and the amount of agricultural land available to each household has decreased, traditional fallowing practices (i.e. abandoning the land to weeds and leaving it to recover on its own) have ceased or the length of fallow period has become too short to restore the soil to its former condition. Where farmers still have sufficient land resources for fallowing to still be a potential technical option

there is scope for the FFS participants to investigate alternative improved fallow systems that would either: (i) reduce the length of the fallow period (e.g. by scattering pasture legume seed or planting short lived (2-3 years) perennial leguminous shrubs at the end of the cropping period); or (ii) provide a tangible economic benefit in its own right (e.g. including a 2-3 year pasture ley in the crop rotation and using this for livestock production).

Module IV: Planning, testing, monitoring and evaluation of solutions

PURPOSE

By participating in module IV of the FFS farmers have the opportunity to learn, from practical experience, the skills that are required to plan and implement the field level testing of possible solutions to their soil management problems, and how to monitor and evaluate the results of such tests. Furthermore by the end of the module the participants would have seen for themselves a range of alternative soil management practices tested under their local circumstances and assessed the potential of each to tackle specific soil management related farm production problems.

Usually the testing of possible solutions as a component of the FFS involves the participating farmers investigating, through field tests, one or more solutions that they themselves have identified and developed to solve specific problems. The purpose of their field “investigation” being to the effect of that solution when tried under their local circumstances. Sometimes appropriate “off-the-shelf” ISNM solutions may already exist, i.e. well tested and validated ISNM practices may have been used in another part of the country, by farmers with similar bio-physical and socio-economic circumstances, to solve similar farm production problems. However such practices may be unknown to the farmers within the FFS, in which case, the “testing” of possible solutions will in reality be local “validations” executed by the FFS participating farmers.

THE NUMBER OF FARMERS INVOLVED IN CARRYING OUT THE TESTS

Each possible solution to a particular soil or nutrient problem should be tested by several farmers, so that the suitability of the possible solution can be assessed for a range of soil, site and management conditions in different parts of the community area. If only 1 or 2 farmers are involved in testing a specific solution, the results can be misleading should those tests have been carried out on unrepresentative sites, been subjected to unusual attacks of pests or diseases, or were exceptionally well or badly managed. A further justification for many farmers testing possible solutions is that this encourages farmers to become more innovative. Thus within the FFS small groups of farmers (5-6) may be given responsibility for testing particular solutions with the test’s progress and results being shared during the FFS meetings with the other members of the FFS.

THE NUMBER OF POSSIBLE SOLUTIONS TO BE TESTED PER FARMER

The number of solutions tested by an individual farmer will vary from farmer to farmer depending on their interest, time and resources. To solve some problems will require the combination of several possible solutions because of their interdependent nature, e.g. leaving residues on the surface, applying pre-sowing herbicides, no-tillage and direct sowing. In general farmers should test no more than 3 possible solutions at any one time. This might limit the number of solutions the FFS can test in anyone cropping season, and would be a justification for the FFS to continue over a number of seasons rather than as with the IPM FFS lasting one cropping season.

SELECTION OF SITES

The FFS facilitator(s) should assist the participating farmers to select sites in fields where the soil type, and its previous management and cropping history are representative of the general conditions faced by the community. Likewise within the field the selected location of the test/demonstration plots should be typical of that field. Field observation, combined with the knowledge of the farmer whose field it is, should be used to: (i) avoid exceptionally stony, poorly drained or weedy areas which are not typical and where crops never yield well; (ii) avoid the borders and entrance of a field where there may have been severe compaction from the congregation of cattle, or the entrance of vehicles or machinery; and (iii) avoid atypical areas where crops always yield better than the rest of the field. The farmer's intimate knowledge of his/her field is obviously very important in deciding the preferred location however if there is any doubt, then one or more soil pits should be dug (a depth of 50 cm will usually be sufficient) to check that the soil type is typical of that of the rest of the field. In areas where runoff or flooding is a problem, the experimental site should be located away from the influence of such dangers. Likewise in areas where livestock roam freely and marauding animals can be a nuisance, the experimental site should be adequately fenced.

DESIGN AND LAYOUT OF THE TESTS

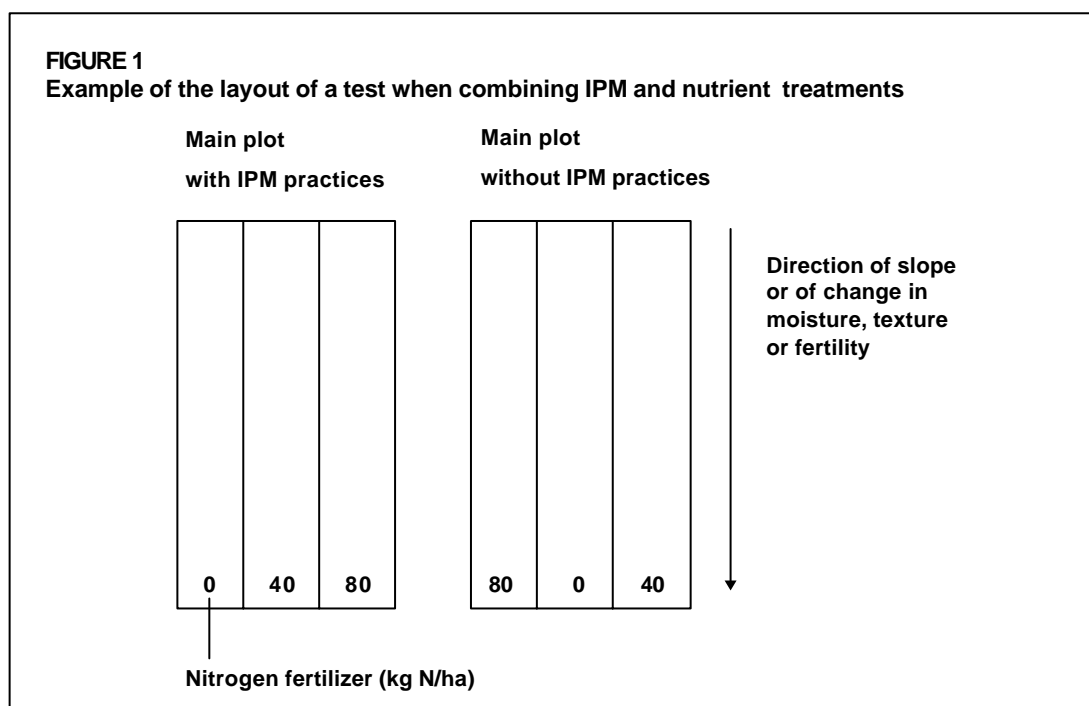
The size of the plots will vary with the nature of the "possible solution" that is being tested. In general, solutions to water and wind erosion, the control of runoff, water harvesting, and practices involving drainage or water interception require large experimental areas. Tests of conservation practices to control water erosion, such as vegetative barriers, hillside ditches or surface residues should use plots at least 20 m wide (in the cross-slope direction) and as long (in the downhill direction) as the length of the field. These dimensions will enable the influence of slope length on the generation of runoff to be fully expressed.

For those "possible solutions" where time, fuel, labour costs or water supplies may limit the acceptability of the practice, plots should be sufficiently large to permit the practice to be implemented on a field scale, so that realistic assessments of time, labour, fuel and water requirements can be made (FAO, 2000). Mechanized tillage trials need large plots so that the tractor and implement achieve the implement's optimal working speed at which its effect on the soil is fully expressed. For tillage trials, plot size should be at least 50 metres long (in the direction of tillage) and not less than 20 metres wide. When time and fuel considerations are important in a tillage trial, the plot size should equal the length of the field and be at least 40 metres wide so that time and fuel requirements can be realistically determined. For the testing of most other solutions, plots of 100-200 m² will normally be adequate for annual crops, and a minimum of 5 trees per treatment for perennial crops.

The design of the test is usually very simple, often involving just two plots - the "treated" plot (where the possible solution is implemented) and the "control" plot (the farmer's practice) against which the effect of the "possible solution" is evaluated. All of the area surrounding the "treated" plot is effectively a control, but to avoid problems of soil variability it is preferable to mark out a similarly sized "control" plot close to the "treated" plot. Where the possible solution involves several levels of the treatment, e.g. three rates of nitrogen fertilizer, there would be three "treated" plots and one "control" plot.

When a combination of ISNM and IPM solutions are to be simultaneously tested, a more complicated design, a split plot design, may be used. If the IPM solutions are the main treatments,

then both the plot to which the IPM solution is applied and that which receives no IPM treatment (the control) would be split into as many subplots as there are ISNM treatments. The allocation of the ISNM treatments within each IPM plot should be random and if there is a change in soil moisture, texture, or slope in a particular direction, the subplots should be marked out parallel to this direction as shown in Figure 1.



The number of replications should be restricted to one, i.e. one treated plot and one control plot on the same farm. However, if several farmers implement the same trial on their farms, the different locations can sometimes be considered as replications of the test. As appropriate the facilitator could verify this with a statistician. The procedures used in implementing the tests will vary according to the nature of the possible solutions, the farmer's resources and whether the farmer is mechanized or not.

MONITORING OF THE TESTS

There are a variety of soil, crop and site indicators (Table 1) that farmers could use to detect and monitor changes in soil conditions and crop performance, so that the effects of the possible solutions being tested can be evaluated by the FFS participants. The role of the facilitator would be to assist the farmers to select indicators that are capable of reflecting changes in the limiting soil or nutrient properties that the possible solution was intended to overcome. Thus, if the possible solution was intended to control water erosion, the selected indicator must be one that enables differences in the degree of erosion to be easily detected.

The indicators must also change sufficiently quickly to allow changes in soil conditions and crop performance to be detected over the period of the test, which is usually one cropping season. For example, differences in the number and size of rills between the treated and control plots will probably be sufficiently sensitive, whereas differences in thickness of the topsoil horizon, which changes very slowly, would not.

Not all of the changes in soil properties that occur following cultivation will be rapid. Many of these changes will be gradual and take place over a long period of time, i.e. it will be several years, before they become apparent. For this reason it is often difficult to detect the effect of some treatments on soil properties within just one cropping season. In these situations it is usually easier to monitor crop growth and yield which are frequently more sensitive indicators.

Some indicators may be quantified very easily, e.g. the height of a crop, whereas other indicators, e.g. soil moisture content by feel, can only be described in simple terms, such as very, moderately or slightly moist. Both forms of evaluation indicators are valid, and especially as farmers will be comparing the treated and control plots at the same time. The use of descriptive terms to monitor an indicator over time when there is no control plot with which to compare, is extremely difficult and would be inadvisable.

TABLE 1
Possible indicators for monitoring short-term changes in soil, nutrient and site conditions and crop performance

Problem	Indicators
Nutrient supply/soil fertility	Crop foliar deficiency symptoms, foliage colour, crop growth/yield (see below), weed diversity, weed density, weed species.
Water supply	Soil moisture by feel and soil colour, surface residue cover, surface crusting or sealing, surface porosity, crop wilting, rooting depth.
Oxygen supply	Depth to water table, soil moisture content by feel, rooting depth, weed species that love water, e.g. <i>Cyperacea</i> .
Toxicities	Foliar toxicity symptoms, salt deposits, deformation of roots, rooting depth.
Root restriction (excessive soil strength/presence of a compacted subsoil layer)	Root depth, root growth pattern, soil consistency, soil resistance to a spade, density of visible-sized pores,
Seedling emergence (excessive soil strength)	Thickness and strength of soil crust
Biological activity	Quantity of surface residues, numbers of worms, other organisms, casts, burrows, termite galleries, chambers, biopores
Water erosion (site stability)	Density and size of rills, soil pedestals, root exposures, accumulations of transported soil particles, splashed deposits.
Wind erosion (site stability)	Sand deposits, micro-dunes, exposure of plant roots, crop inclination
Crop growth/yield	Crop height, vigour, number of tillers, leaves, female flowers, number and size of fruit, cobs, length of panicles, crop yield, tree diameter, size of canopy.

The frequency with which individual indicators should be monitored will generally be once every 2-4 weeks, and should be undertaken as a part of the programme of FFS field activities. Soil indicators should be monitored when they are most likely to be evident. For instance when the problem is lack of water, the soil moisture indicator should be evaluated during dry spells and at the beginning of the dry season. For indicators of water erosion, the evaluations should be carried out immediately after intense rainstorms. When drawing up the schedule for the FFS individual sessions could be programmed at the time of year when such conditions can be expected to occur. Alternatively there may be occasions when the FFS participants would want to call an additional special meeting to observe the impact of a one off climatic event (such as a short intense rain storm, strong wind or severe frost) that occurred between the dates of the scheduled meetings.

The examples of indicators presented in Table 1 are for use in tests within a cropping season, and for farmers with few resources and no access to soil laboratory facilities. More sophisticated

indicators may be used when soil analytical facilities are available (e.g. the FFS is close to a research station or agricultural college with a soil laboratory). Once a new management practice has been introduced into a farming system, the effect of the practice should be monitored over much longer periods of several years so that the sustainability of the practice can be assessed. Indicators that change more slowly, such as soil colour, can then be used. If the FFS is to last only one cropping season then an alternative mechanism would need to be put in place to ensure that the results continue to be shared between the participating farmers.

EVALUATION OF TESTS

The results of the tests of possible solutions should be evaluated on the basis of whether they are technically, socially, economically and environmentally acceptable at the farm household level. In the case of environmental aspects, they should also be acceptable to the community at large. Whenever possible, the results and their evaluation should be recorded by the facilitator as this data may be invaluable when seeking assistance from funding agencies to promote more FFS.

Technical evaluation

The possible solutions must be evaluated as to whether they overcome or reduce the soil, water and nutrient problems for which they were intended, and whether they improve yields. This will be apparent from comparing the soil and crop indicators from the treated and control plots. If the possible solution “leaving crop residues” was tested, and the presence of rills and crop yield were used as indicators, the number and size of the rills should be significantly less on the treated plot compared to the control. The yield would also be expected to be greater, or no less, from the treated plot compared to the control.

Social evaluation

The most important aspects of the social evaluation of the possible solution compared to the normal farmer practice are:

- time and labour required;
- timing or seasonality of the labour (compared to other demands and interests of the farmer and his/her family); and
- degree of physical exertion.

Economic evaluation

This can be determined by comparing the profit (gross margin) obtained by applying the possible solution with that obtained from the normal farmer practice, but it is important that the data used are realistic of field conditions, and were obtained from sufficiently large plots. The profit (gross margin) is calculated from the difference between the income from the sale of the produce and the variable costs of production, i.e. labour, seed, fertilizer, pesticides, bags, transport etc. Recording the data on forms such as those given in annex 5 helps in remembering the costs, and helps with the calculations.

Environmental evaluation

The most important aspects to be considered during the testing of possible solutions are:

- the extent of possible toxicity or pollution;
- water and wind erosion hazards.

Other environmental aspects which usually become apparent over periods longer than one cropping season are:

- water supplies - water levels in rivers and wells;
- water quality - the sediment content and chemical composition (the colour, taste and smell are often good indicators);
- tree and vegetation cover.

Module V: School evaluation

EVALUATING THE IMPACT OF THE ISNM COURSE ON PARTICIPANTS

To evaluate the benefits to participants of attending the ISNM course by setting pre- and post-course tests is not considered acceptable. Written tests would not be culturally appropriate for many farmers, and practical tests on farming skills would be very limited in scope because of the time constraints. Moreover, such approaches are typical of traditional top-down, learning by instruction methods, and are contrary to the participatory, farmer-centred, learning by experience approach of FFS. It is also unlikely that tests could realistically assess a participant's ability to identify and solve problems within the constraints of his own farming environment, which is the key to farmers developing sustainable systems of agriculture.

An alternative approach is to evaluate the changes that occur in a farmer's property, and in particular, the change in yield and profitability of his/her cropping systems, and the change in health of his/her soils over a three to five year period after the completion of an ISNM FFS. This would provide a much more realistic and useful assessment of the benefits gained from FFS participation, whilst acknowledging that not all of the changes may be entirely attributable to the FFS.

Changes in profitability of a farmer's cropping systems may be evaluated by comparing the gross margins in the periods prior to, and 3-5 years after, completing the ISNM FFS. Because of inevitable yield fluctuations from year to year, the gross margin trend over a 3 year period will be more meaningful. These calculations are only possible if a farmer records his yields, production costs and income for each cropping system each season, using forms like that in Table 1 of Annex 5. An example of how to present yield and gross margin data is also given in Table 2.

TABLE 2
Presentation of yields and gross margins (GM) pre- and post-FFS

Cropping System	Pre-FFS		Post-FFS					
	Average		Year 1		Year 2		Year 3	
	Yield	GM	Yield	GM	Yield	GM	Yield	GM
Maize								
Beans								
Sorghum								

Soil health refers to the productivity of a soil, as influenced by land management practices, and may be considered comparable to the health of a person. To evaluate changes in "soil health" in a quantitative manner would require much data collection, a set of base line data or a control area, and would be time consuming. Such a quantitative assessment is unlikely to be satisfactorily carried out unless technical staff are involved - which would be costly. An alternative more participatory option is to evaluate changes in soil health by means of a multi-factor questionnaire which assesses whether various positive or beneficial features and practices have increased, decreased or not changed, and whether various negative features and processes have increased, decreased or not changed during the 3-5 years since the FFS. Such a questionnaire, adapted from Douglas (1996), is shown in Table 2 of Annex 5. By subtracting the

total number of “decreased” and “not changed” factors (indicated by Y and Z) from the total number of “increased” factors (indicated by X), an overall indicator of the change in soil health (indicated by J) can be obtained. This procedure can be implemented by participants, and gives a useful indication of the success of the ISNM course in improving soil health. A preliminary set of positive and negative factors that could be used for such an evaluation, should be drawn up by the FFS facilitator(s) with the aid of a soils specialist and then adapted to local conditions in consultation with the FFS participants.

EVALUATING THE ISNM FFS

Feedback from the participants on completion of an ISNM FFS is essential to improve the technical content, and mode of operation, of any future schools conducted in the area, to ensure they are more relevant to farmers’ needs and interests, and better adapted to the local environment. Participants should be asked to evaluate the usefulness and degree of understanding of the activities undertaken, the principles introduced, and skills learnt during the course of the FFS. In addition they should be asked to evaluate the way the organization of the FFS, and the ability of the facilitator.

The facilitator should make it clear that this exercise is designed to help the FFS organizers and facilitator improve the ISNM FFS for the benefit of future participants, and that by expressing their honest opinions they will be providing valuable assistance! Despite this comment, many participants may still feel unwilling to openly express criticisms of the FFS. In a farming community with a reasonable degree of literacy one way to overcome such reluctance, is to suggest to the participants that they write their opinions on separate cards for each subject that is to be evaluated, and place the cards in “ballot boxes” to preserve confidentiality. Opinions may be coded using numbers, e.g. 1 (very beneficial), 2 (moderately beneficial), 3 (not beneficial), 4 (needs to be improved), 5 (needs less time), 6 (needs more time).

An example of the questions used to evaluate the usefulness, quality, and level of understanding of the modules, principles and skills presented during a ISNM FFS is given in Table 3 of Annex 5. The names of the specific modules, principles and skills to be evaluated should be inserted into the table in place of 1, 2, 3, etc. An example of the questions used to evaluate the organization of the FFS and the ability of the facilitator is given in Table 4 of Annex 5, and the types of questions to be put to participants on how to improve the course is shown in Table 5 of Annex 5.

Once the results of each evaluation have been received they should be presented by the facilitator for further discussion, clarification and amplification by the participants. At this stage of the proceedings the participants may be less inhibited in their comments.

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Annex 1

Examples of discovery-based exercises and trials for use in farmer field schools on integrated soil and nutrient management

The following pages provide a number of examples of the type of discovery-based exercises and trials that could be undertaken by farmers during the course of a farmer field school to learn about the principles and skills required to practice integrated soil and nutrient management. Given that each farming community has its own unique set of bio-physical, socio-economic and cultural circumstances it would be the responsibility of the FFS facilitator to identify which discovery-based exercises would be locally appropriate, and to develop others as needed, to promote a farmer-centred learning approach to integrated soil management.

Note: additional examples of ISNM FFS exercises can be found in:

FARM Programme 1998. *Farmer Field School on Integrated Soil Management*. Facilitator's Manual. FAO-RAP Bangkok.

EXERCISE 1: CATCHMENT MAP OR COMMUNITY MAP**Aim:**

To produce a catchment map or community map to locate natural resources, like rivers and forests, different land uses, like roads, houses, cropping areas, communal areas, etc. and environmental problems, like land degradation and polluted areas. The map can be used for planning activities such as transect walks, experiments, land degradation control measures, changes in land use or improved management of communal grazing or forest areas.

Duration:

2-3 hours

Materials required:

Large sheets of paper and markers. Alternatively, if the map is prepared in the soil using sticks, stones and seeds etc., large sheets of paper will be required to make copies of the map.

Procedure:

1. Explain the objectives of the activity, and discuss the type of information that should appear on the map. In case of a catchment map explain the importance of crest lines (which determine whether rain enters this or a neighbouring catchment) and drainage lines (distinguish between rivers, permanent and seasonal streams and springs). Locate first the crest lines, drainage lines and roads to form the skeleton of the map, then details of the land use, housing and problem areas.
2. Divide the group into 2 or 3 subgroups
3. Make a list of the information to be presented, and help the group start by locating the main reference points (crest lines, roads and drainage lines) on a large sheet of paper, or in the soil. Then leave the group to elaborate the map.
4. At the end of the session, the group presents the map to the whole assembly for comments and suggestions.
5. Discuss the usefulness of the map in terms of the *Aim* of the activity.

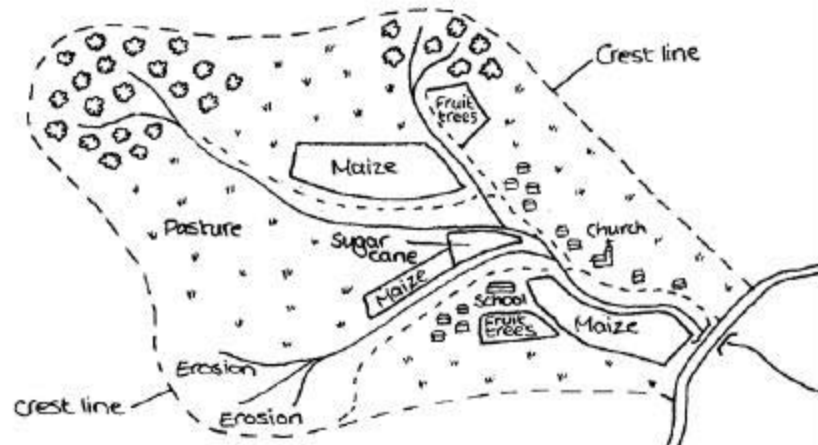
Expected output:

The participants would be able to produce a catchment or community map, identifying problems and opportunities in their environment.

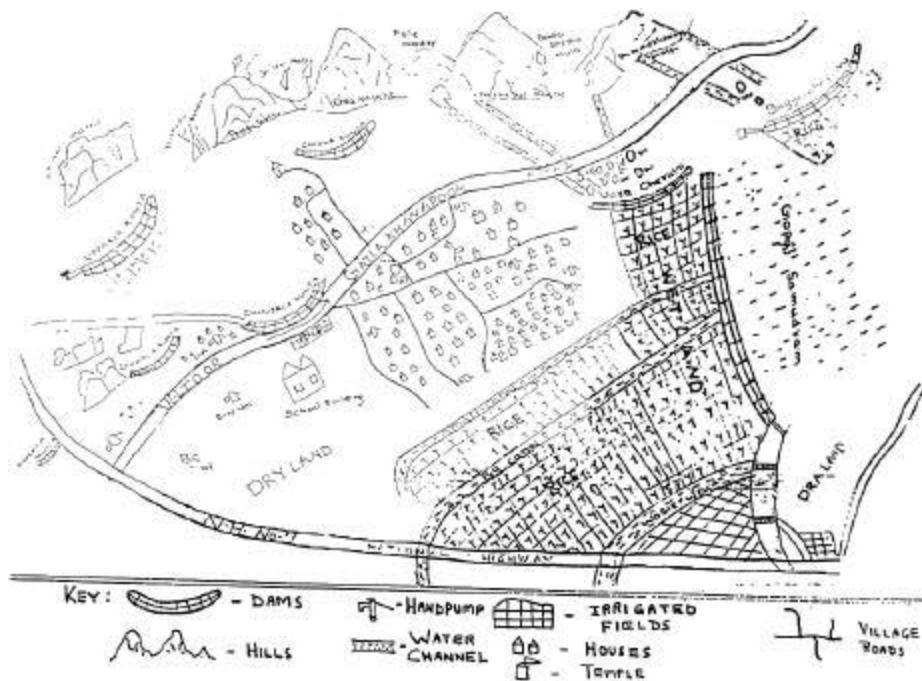
Questions to facilitate discussion:

- Why do problems occur in certain areas?
What, according to you, is the cause of these problems?

Example of a catchment map



Example of a community map from Andhra Pradesh (Source: Mascarenhas 1991)



EXERCISE 2: TRANSECT WALK**Aim:**

To obtain information on the relationships between landscape, forms of land use, farming systems, soil, water and crop problems. The activity serves to stimulate an initial discussion of the community's problems, possible solutions and potential opportunities.

Duration:

The transect should be completed in 3-4 hours within a morning, then allow an hour to finalize the transect diagram using a large sheet of paper.

Materials required:

Large sheets of paper, markers, pieces of plywood as supports for the paper.

Procedure:

1. Explain that before considering possible changes to farming practices, it is important to assess the current practices and problems, and the solutions that have already been tested.
2. Give the objective of the transect walk, the route on which was decided earlier and explain how to register the information.
3. During the walk, stop frequently at interesting places, and where there are differences in land use or soil type. Observe and record the position on the slope, or the distance from the main river at each stop, and consult with participants and others living nearby on the following: soil type, land use, livestock, water supply, management practices, problems and potential opportunities. The facilitator should ask questions to clarify or to obtain additional information on aspects which are overlooked.
4. At the end of the transect walk divide the participants into seven groups of 3-4 per group, and ask each group to discuss one of the 7 aspects, and to write on the blackboard a brief summary of the most important information recorded at each stop.
5. Initiate a general discussion on the information presented on the transect diagram, finalize the diagram and retain it in the FFS for future use.

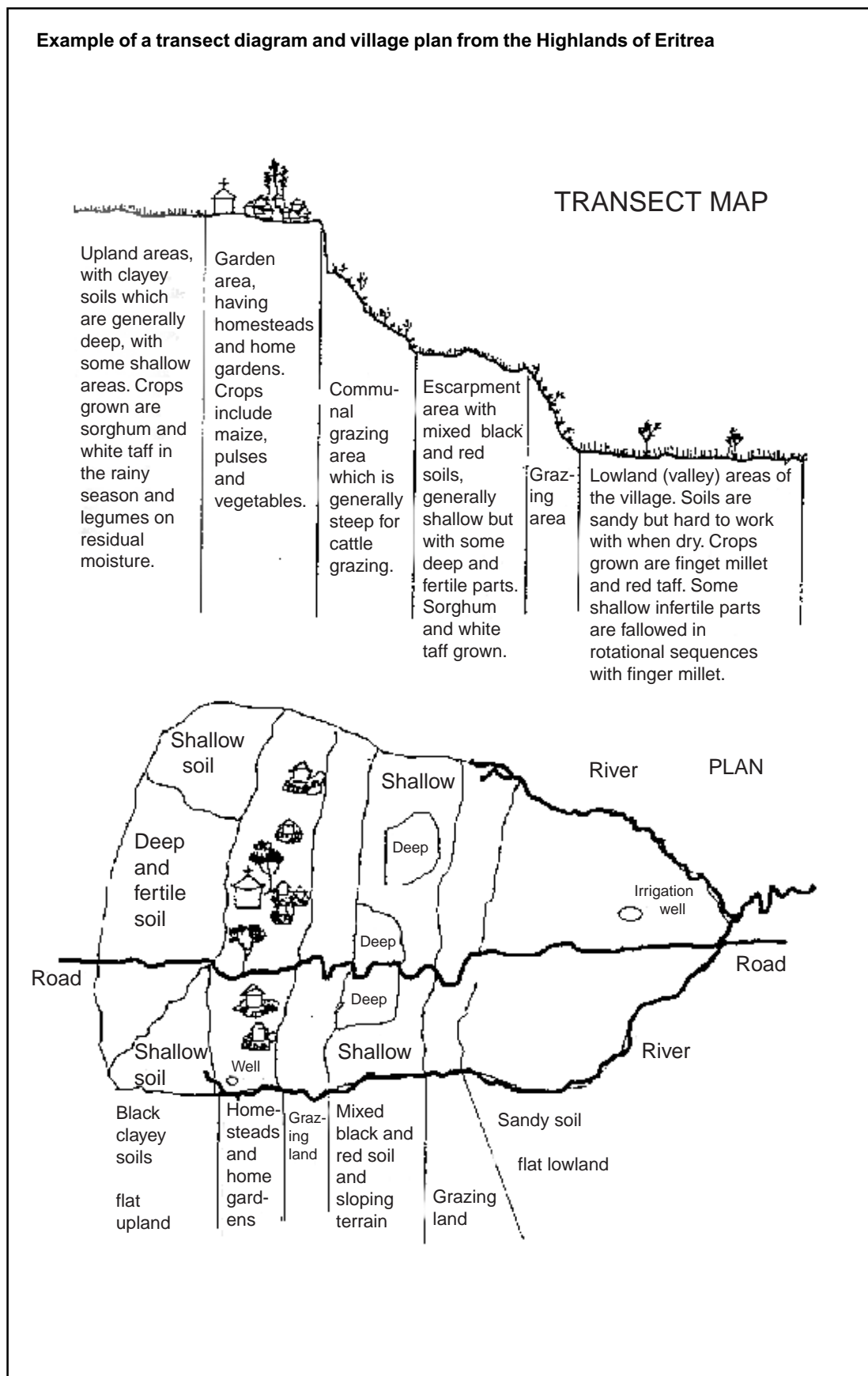
Expected output:

The participants would be able to produce a transect diagram for their local area depicting the relationships between landscape, forms of land use, farming systems, soil, water and crop problems.

Questions to facilitate discussion:

Are there differences in the type and properties of the soil which can be related to location?
How does the relationship between soil type and location affect the choice of land use and soil management practice?

Example of a transect diagram and village plan from the Highlands of Eritrea



EXERCISE 3: SOIL FUNCTIONS IN RELATION TO LANDSCAPE AND SOIL TYPE**Aim:**

To understand the relationships between landscape (topographical position, slope gradient), soil type (as indicated by colour, texture, hardness, pores, stoniness) and soil functions (the supply of water, nutrients, oxygen, site stability and biological activity) from a study of three contrasting soil profiles.

Duration:

4 hours

Materials required:

Spades or hoes, pick-axes, machetes or knives, tape measure, water in a water bottle, soil profile description forms, clip board, sheets of paper, markers

Procedure:

1. Dig soil pits to 1 metre depth, and preferably 1 m long and 0.7m wide. Where crops are present, one side of the soil pit should be orientated parallel and adjacent to the crop row to enable the crop's roots to be observed in the pit face. Place each soil horizon in separate heaps to facilitate refilling the pit. (This should be done beforehand)
2. Distinguish more than one topsoil or subsoil horizon if the differences are so marked that crop growth is likely to be affected. Delineate with a knife the different coloured horizons in the profile, the depth of penetration of the crop's roots, and the maximum depth available for rooting.
3. Introduce the concept of soil texture, and explain that texture refers to the proportions of sand and clay in a soil. As clay content increases, the texture changes from "very light" to "light" to "medium" to "heavy," and the soil becomes more difficult to till.
4. Show farmers how to assess soil texture in the field following the guidelines in Box 1. A simple classification of soil texture is summarized in Table 4.
5. Pass samples of the two horizons to each farmer in turn to see the colour and feel the moisture, texture, hardness or softness, presence of pores and cracks (porosity) and stoniness.
6. Ask the farmers to describe these characteristics for each soil horizon in turn, using simple terminology or their own terminology. Request one farmer to record the descriptions for the two horizons.
7. Discuss the soil function "water supply", unless the climate is so humid that water availability is not limiting to crop growth. Encourage farmers to think about and discuss the availability of water in soils on the basis of their own experience, and how this is related to soil depth, texture, organic matter, stoniness and root development. Same for nutrient supply and oxygen.

Questions to generate discussion:

What are the basic demands (needs) made by crops on the soil?
 What is the significance of the dark colour of the topsoil, and the depth of the topsoil to moisture supply in soils?
 How does this relate to soil fertility and the supply of nutrients?
 Is the soil very light, light, medium or heavy textured?
 How does the clay content of a soil affect its moisture supply?
 Do sandy, clayey, organic matter-rich or stony soils retain most moisture?
 Do the roots extend deeply? If not, why not?
 What is the advantage to crops of having deep roots?
 How do plant roots penetrate the soil?
 What types of horizons will stop roots from penetrating deeply?
 How does soil depth affect the ability of the soil to retain rainwater?
 What is the significance of biological activity?
 What is the significance of soil erosion to nutrient supply in soils and fertility maintenance?

EXERCISE 4: SOIL NUTRIENT SUPPLY AND DEMAND**Aim:**

To appreciate from an exercise in which N, P and K are depleted from a soil by successive harvests of maize, that the capacity of soils to supply different nutrients is limited and varies with the nutrient.

Materials required:

A bucket, 8 oranges, 5 limes and 15 palm kernels or similar numbers of other objects. Sheets of paper and markers.

Procedure:

1. Explain that a bucket is to be used to represent a soil, and different objects will be used to represent different nutrients. In this exercise oranges will be used to represent 10 kg N, limes to represent 10 kg P, and palm kernels to represent 10 kg K. Any other objects such as stones, coloured beads, different types of nuts or fruit may also be used.
2. Place 8 oranges, 5 limes and 30 palm kernels in the bucket, and ask the participants how much N, P and K the soil contains?
3. Explain that the grain harvested in 2.5 t maize/ha contains approximately 40 kg N, 10 kg P, and 20 kg K. Ask the participants to remove from the bucket 40 kg N (= 4 oranges), 10 kg P (= 1 lime), and 20 kg K (= 2 palm kernels) to represent the major nutrients removed in the first year's harvest of 2.5 t maize/ha.
4. Repeat the process by removing the same quantity of N, P, and K to represent the major nutrients removed in the second year's harvest of 2.5 t maize/ha.
5. Continue the procedure noting for how many years the soil would be able to supply the N, P and K removed in the grain harvests if no nutrients were added to the soil.
6. Stress that this exercise is merely to illustrate the principle, and that different soils will be able to supply the major nutrients for longer or shorter periods. If desired, two buckets could be used, one representing a sandy soil containing 40 kg N/ha, 30 kg P/ha and 100 kg K/ha, and the other bucket representing a clayey soil containing 120 kg N/ha, 60 kg P/ha and 360 kg K/ha. By carrying out the same procedure for the two soils, it would be apparent that the sandy soil would be more rapidly exhausted of nutrients than the clayey soil.

Questions to facilitate discussion

What would be the effect of not returning the maize stover to the soil?

EXERCISE 5: NUTRIENT FLOWS AND THE FARMING SYSTEM**Aim:**

To identify and portray the nutrient flows in the dominant farming system in the community.

Duration:

2-3 hours

Materials required:

Paper and markers, or if the diagram is prepared on the ground use sticks to draw or depict flow lines, stones, seeds, crop residues, dried manure etc materials that represent the products moving between different components of the farming system.

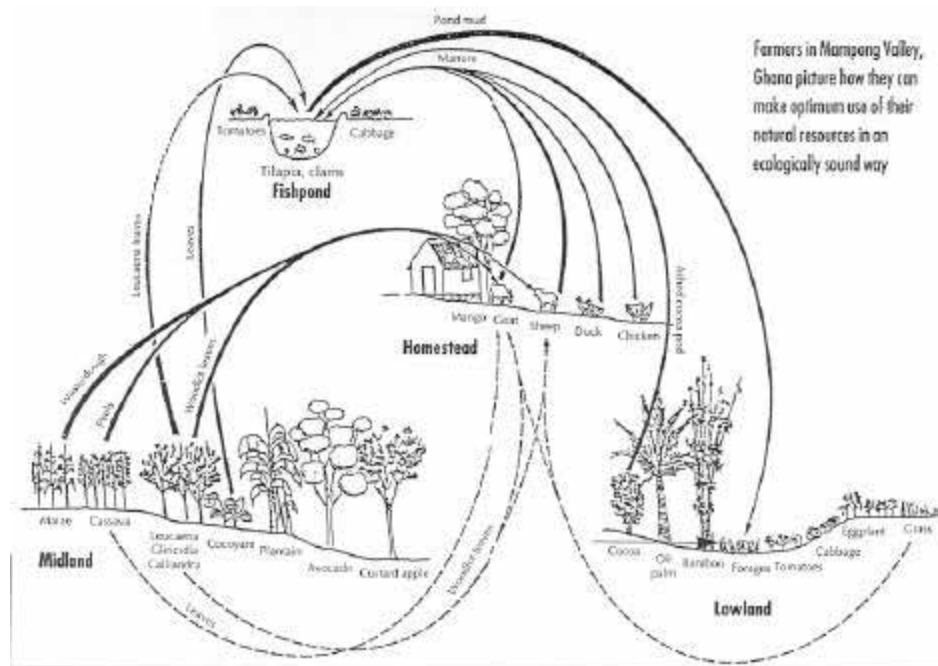
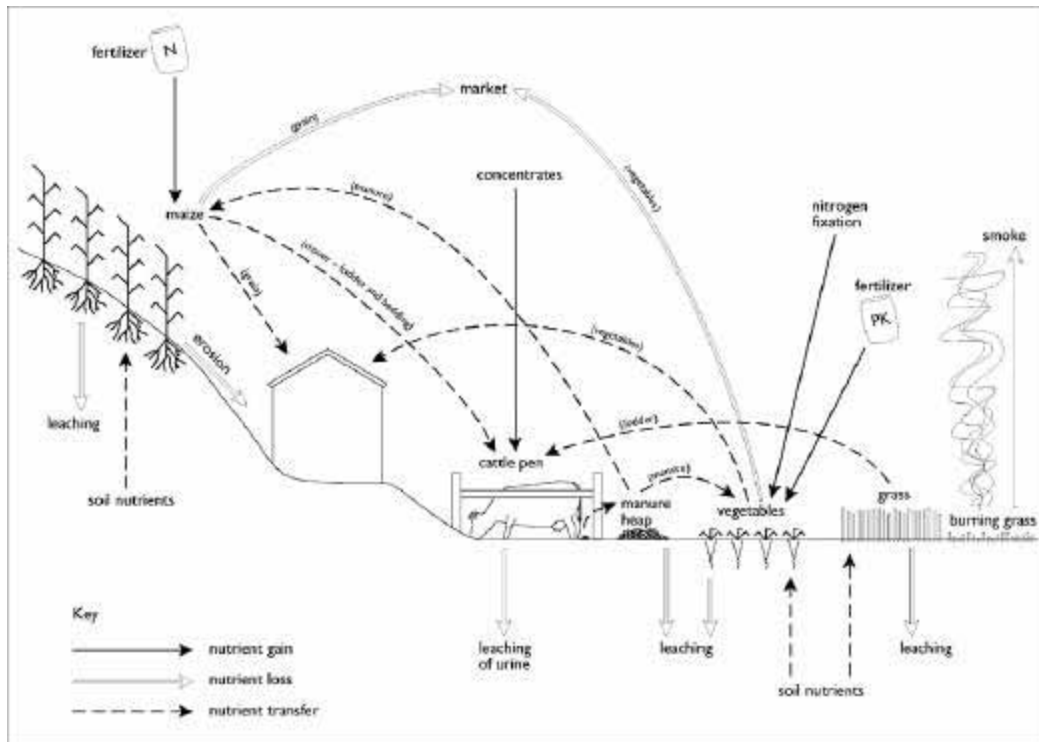
Procedure:

1. Select the farming system to be modelled in the flow diagram.
2. Start with the dominant cropping system and gradually build up the diagram by adding any other component cropping systems, the homestead plot, the livestock kraal/shelter, pasture/ grazing area(s), forests.
3. Identify the products which contain plant nutrients that move between the component elements of the household system (food crops consumed by the household, manure, crop residues, kitchen waste etc) and draw lines between them showing this movement.
4. Identify the products which contain plant nutrients that either leave the farm (eg. products sent for market) or are brought on to the farm (eg. purchased fertiliser, organic materials collected from off farm sources).
5. Discuss the movement of nutrients into, out of, and within the farming system, as each component of the system is introduced and arrows are inserted in the diagram to show the direction in which the nutrients flow.
6. At the end of the session the final flow diagram should be reviewed by the whole assembly for additional comments and suggestions.
7. Discuss the usefulness of the flow diagram in terms of the Aim of the activity.

Points to facilitate discussion

Discuss how to optimize the availability of nutrients to crops and livestock by reducing the outward nutrient flows, increasing the beneficial transfers of nutrients within the farming system, and by increasing the incoming nutrient flows. Consider only those actions, which the farmers consider to be economically and socially acceptable.

Example of nutrient flows in a mixed farming system (Source: van Veldhuisen *et al.* 1997)



EXERCISE 6: NUTRIENT CYCLING, BIOLOGICAL ACTIVITY AND LAND USE (CAN BE COMBINED WITH THE EXERCISE ON SOIL FUNCTIONS)**Aim:**

To appreciate how land use and soil management affect nutrient recycling, biological activity and soil characteristics.

Duration:

3-4 hours.

Materials required:

Hoes, spades, pickaxes, machete or trowel, sheets of plastic or paper, ruler, three 5 litre buckets, water source, watch, paper and markers.

Procedure:

1. Select two sites, where root growth can be observed.
2. For both the sites estimate the depth to which the crop and tree roots have penetrated the soil.
3. Examine for both sites the accumulated litter, biological activity and porosity of the topsoil. Collect samples from both sites for comparison. Observe colour, number of insects, presence of earthworms, and other fauna.
4. Observe the number of large pores in both sites. Illustrate their function to drain the water from the topsoil to deeper layers, using the exercise in Box 3 of the Reference material.

Questions to facilitate discussion

Why is there more litter at the forest site compared to the cropped site?

Why is there more faunal activity and a darker topsoil colour under forest than under annual crops?

What happens to leaves once they fall on the forest floor?

Why are there more (large) pores in the forest soil than in the cropped soil?

Why are large pores important?

What is their effect on soil erosion, loss of rainwater, loss of nutrients and fertilizers?

What happens to nutrients absorbed by roots?

What happens to nutrients in dead leaves lying on the soil surface?

What kind of practices would favour nutrient cycling?

What would happen to nutrients carried away as fodder?

What is the advantage of cultivating annual crops between dispersed trees or in alley cropping systems?

EXERCISE 7: FIELD IDENTIFICATION OF SOIL AND NUTRIENT PROBLEMS**Aim:**

To recognize soil and nutrient problems in the field through observations of soil, site and crop conditions.

Duration:

3-4 hours.

Materials:

Pick axes, hoes or spades, machete or trowel, water bottle.

Procedure:

1. Select 2 sites under the dominant land use of the area which are typical of the local topographical and soil conditions, and which show the commonly occurring soil and nutrient problems
2. Once suitable sites have been found, dig soil pits to 1 metre depth, 0.7 m in width, and 1 m long parallel and adjacent to the crop row to enable the crop's roots to be readily observed.
3. The farmer is invited to explain the cropping system, soil management practices applied and the yield expected. Ask him/her to discuss the different crops in his/her field, tillage, irrigation, crop management, fertilizers, etc.
4. Explain how to recognise those field indicators which can be observed on the day, explain the problems which they signify, how to assess the severity of the problems (using terms "very severe," "severe," "moderate," and "slight"), and the causes of the problems.
5. Ask the participants to identify any crop nutrient deficiency symptom which is apparent at the site.
6. If evidence of a nutrient toxicity exists at the site, request the participants to identify the toxicity using the foliar symptom descriptions provided, and to deduce possible causes.
7. Regardless of whether there are signs of wilting indicating crop moisture stress at the time of observing the crop, ask the land-owner if wilting occurred previously, and for how long the stress continued.
8. Assess the severity of the erosion problem at the time of observing the site in a qualitative manner according to the number and size of rills, soil pedestals, exposed roots, gullies or exposed subsoil, and deduce the causes of the erosion (e.g. lack of surface residues, too much cultivation, slow development of crop cover, excessively steep and/or long slopes, overgrazing, runoff from higher-lying steep lands, downhill footpaths or cattle tracks). Distinguish gully erosion as a separate problem because of the site stability and access problems it creates.
9. If dense layers are present the facilitator should invite the participants to force a spade vertically into the soil to experience the sudden increase in resistance at the upper boundary of the dense layer.
10. The participants should also be asked to assess which, if any, roots penetrate the dense layer and what happens to any roots that reach it but are unable to penetrate, do they stop, thicken, bend back up, or grow sideways and what would be the effect on the plants growth.
11. If numerous stones are present in the soil profile ask the farmers whether the stones occupy, for example, a half, quarter, an eighth, or less of the total volume of soil, are the stones a limiting factor?
12. Initiate a discussion on the main differences in soil and nutrient problems at each location.

Questions to facilitate discussion.

Are the problems observed related to soil management or other crop management activities?

Are these really constraints or not?

What would be the likely effect on crop yields?

Are the problems related and if so has one been the cause of another?

EXERCISE 8: IDENTIFICATION OF THE CAUSES AND EFFECTS OF SOIL AND NUTRIENT PROBLEMS**Aim:**

To determine from observations, deductions and focussed discussions the causes and effects of the soil and nutrient problems identified for the dominant land use system.

Duration:

1 ½ hours.

Materials required:

A large board, cards and markers, pins or adhesive tape.

Procedure:

1. Give a simple example using prepared cards of how to produce an inverted “problem-cause tree” (see Annex 4).
2. Make a list of the problems on a sheet of paper. Symbols may be used to represent each problem for illiterate participants.
3. Divide the participants into groups according to the main land use systems in the community and request each group to carry out the same exercise for their land use system. Groups may also be formed on the basis of those who farm hilly lands and flat lands.
4. Each group should identify the main problem(s), then discuss and identify the causes and effects, the causes of the causes, and so on for each of the problems in turn until an inverted problem-cause tree has been produced
5. Write the main soil and nutrient problems, which have been identified on a card, and fix the card to the board using a pin or adhesive tape.
6. Beneath this card attach other cards adjacent to each other giving the causes of the main problem and link the problem and the causes with arrows.
7. At the end of the exercise representatives of each group present their problem-cause trees, and a general discussion is opened to confirm or modify each group’s problem-cause tree.
8. Alternatively the participants could be shown how to prepare a simple causal diagram in which the main problem is placed on the left of the diagram and the various causal linkages are shown flowing from right to left (see Annex 4).

Questions to facilitate discussion

All questions starting with “Why” and “Because of what”.....

EXERCISE 9: IDENTIFICATION AND SELECTION OF POSSIBLE SOLUTIONS TO THE SOIL AND NUTRIENT PROBLEMS**Aim:**

To identify and select possible solutions to the soil and nutrient problems which were identified for the main land use systems.

Duration:

1 hour.

Materials required:

Copies of the problem-cause trees/causal diagrams already produced, a large board, cards, markers, pins or adhesive.

Procedure:

1. Give the possible solutions for the causes of the problem, which was used to explain the problem-cause tree/causal diagram.
2. Divide the participants into groups according to the main land use systems.
3. Request each group to identify possible solutions to the problems and causes given in their "problem-cause tree/causal diagram." The possible solutions should be based on their own experience and knowledge, their observations of practices seen during the field visit, and the adapted check list of possible solutions.
4. To identify possible solutions to a cause, each member of the group writes down what he/she considers to be the possible solutions to the cause, using a separate card for each possible solution.
5. The group jointly revises the "possible solutions," eliminating those that are duplicates or invalid, to arrive at agreed possible solutions. This process is then repeated for the next cause in the problem-cause tree/causal diagram, and so on.
6. At the end of the exercise group representatives present to the whole assembly the possible solutions to each of the causes in their problem-cause trees/causal diagrams for discussion and refinement.
7. Request the farmers to decide which of the possible solutions, which they identified, they would be willing to test on their own farms, and what inputs or assistance they would require.

Questions to facilitate discussion

What possible solutions for the problems listed have been mentioned in previous sessions?

What other solutions might there be?

Are these solutions realistic in the present farmers' situation and what is needed to implement them?

EXERCISE 10: MAXIMIZE SOIL COVER TO REDUCE EROSION**Aim:**

To demonstrate the beneficial influence of soil cover on enhancing rainwater infiltration and reducing runoff and erosion of nutrient-rich soil.

Duration:

1-½ hours

Materials required:

Two wooden boxes, sufficient air-dry well structured soil to fill two boxes to 8 cm depth, a watering can of 5 litres capacity with a coarse sprinkler head, chopped crop residues to cover 1 box completely.

Procedure:

1. Construct three open wooden boxes 30 cm wide, 40 cm long and 10 cm high with one end 2 cm lower than the other to provide a sill over which the runoff can flow. If it is not possible to make wooden boxes, two mounds of soil can be used with one of the slopes of each mound adjusted to about 25% and newspapers placed beneath the lower end of the mounds to absorb the runoff and collect the eroded soil. If a watering can is not available, a bunch of grass can be dipped into water and the water flicked onto the soil to simulate rainfall.
2. Remove stones and roots from the soil, and fill the boxes to 8 cm depth so that the soil at the lower end is level with the sill.
3. Place a layer of chopped crop residue of about 0.5 cm depth over the soil in one box.
4. Prop the boxes at an angle of about 25%, with the lower sill of the boxes in the downhill direction and place a bowl beneath each sill.
5. Holding the watering can about 2 metres above the first box, simulate a heavy rainstorm by sprinkling one complete can of water onto the box as uniformly as possible.
6. Note the amount and the colour of any runoff that accumulates in the bowl.
7. As soon as the runoff has ceased, excavate the soil at the downhill end of the box, and note the depth to which the water has penetrated.

Questions to facilitate discussion:

What changes have occurred to the soil surface and the surface pores?

In what other ways may surface pores be destroyed?

In which soil did more water infiltrate? And why?

What are the advantages to crops of a cover of residues on the soil surface?

What is the nature of the runoff from the bare soil?

What is being lost?

What evidence is there of soil erosion?

How does erosion affect the fertility of the soil?

What types of land use and cropping system (annuals, perennials, pastures, tree crops, fallows) would result in least runoff and least erosion?

EXERCISE 11: MAXIMIZE SOIL COVER TO REDUCE SOIL MOISTURE LOSSES**Aim:**

To appreciate the importance of crop residues and mulches in decreasing soil water losses by evaporation.

Duration:

1 hour on the first day, 30 minutes 2 days later, and then 1 hour a week later.

Materials required:

Stakes for marking out the two plots, buckets or a watering can for applying 30 litres of water, convenient source of water, mulch or crop residues to cover 1 m².

Procedure:

1. It is important that no rainfall occurs within 10 days of commencing the experiment, and so it is preferable to carry out this experiment during the dry season.
2. Select and mark out with stakes two plots of 1 m² within 5 metres of each other in a field with no crops where there is a convenient source of water nearby. To demonstrate the effect of tillage on increasing soil moisture losses by evaporation, a third plot may be included which is tilled after thoroughly wetting the soil and then left bare.
3. Remove any weeds, stones or residues from the two plots and gently apply 30 litres of water to each plot, preferably with a watering can so as not to degrade the surface structure.
4. Request participants to note the similarity of the topsoil moisture content in both plots.
5. Cover one of the plots with crop residues or mulching material so that the surface is completely covered, and leave the other plot uncovered.
6. Return two days later and note the difference in topsoil moisture between the two plots. Take care to minimise soil disturbance and to replace the surface residues after checking the soil moisture.
7. Return one week later, and compare the difference in soil moisture between the two plots.

Questions to facilitate discussion:

For which local soils and crops will these practices be most appropriate and feasible?

EXERCISE 12: MAXIMIZE SOIL COVER TO INCREASE BIOLOGICAL ACTIVITY**Aim:**

To demonstrate that surface residues or mulches can increase soil biological activity.

Duration:

1 hour

Materials required:

Spade or hoe, sheets of plastic or paper

Procedure:

1. Towards the end of the rains when the soils are still moist, ask the farmers to examine the soil under the crop residues or mulch, and to look for evidence of wide pores, i.e. biopores, that have been created by soil organisms.
2. Excavate an area of 30 cm x 30 cm to a depth of 30 cm using a spade or hoe. Place each layer of 5-10 cm onto a sheet of plastic or paper, sort through the residues or soil, and record the numbers of different soil organisms present, e.g. earthworms, ants, termites, millipedes, centipedes.
3. Repeat steps 1 and 2 for an adjacent control area that received no crop residues or mulch.

Questions to generate discussion:

What organisms can be seen?

How might their activities affect the soil (aeration, organic matter incorporation, nutrient provision)?

What would the soil be like if they weren't there?

EXERCISE 13: CALCULATION OF THE BENEFITS OF ORGANIC MATERIAL, FARM AND EXTERNAL AGRICULTURAL WASTES**Aim:**

To present the procedure for calculating the value of nutrients in organic material.

Duration:

1 hour

Materials required:

Fertilizer prices, nutrient composition data for plant materials, farm and agricultural wastes (see Appendix 6 Annex 2), calculator, paper and markers.

Procedure:

1. Calculate the value of the nitrogen in the locally available materials in terms of the cost of urea fertilizer that would supply an equivalent quantity of nitrogen (use units to which the farmers are accustomed).

Example:

1 bag (50 kg) of urea fertilizer costs \$10

Urea fertilizer contains 46% nitrogen (so 100 kg urea contains 46 kg of nitrogen)

1 bag of urea contains $0.46 \times 50 \text{ kg} = 23 \text{ kg}$ of nitrogen

So 23 kg of nitrogen costs \$10

1 kg N costs \$0.43

6 tonnes of cattle manure contains the equivalent of 36 kg of nitrogen (see appendix 6 annex 2)

Compared to the nitrogen in urea (1 kg N costs \$0.43)

36 kg of nitrogen cost $36 \times \$0.43 = \15.5

So 6 tonnes of cattle manure has a value of \$15.5

or equivalent to 78 kg or 1.5 bags of urea

2. Similar calculations can be made for phosphorus and potassium.
3. Present to the participants the nutrient contents of some of the plant materials, farm and external agricultural wastes. Compare these nutrient contents with the nutrient requirements of a maize crop yielding 2 t/ha of grain

Questions to generate discussion:

Which organic materials in the area could be beneficially applied to soils?

What happens if you burn the residues?

What will be the cost to replace it?

EXERCISE 14: MAXIMIZE ADDITIONS OF ORGANIC MATERIAL**Aim:**

To discuss practical ways of increasing the supply of organic material and the advantages to the farming system.

Duration:

2 hours

Materials required:

Sheets of papers and markers

Procedure:

1. Divide the participants into groups of not more than 3-5 persons.
2. Request each group to consider the different ways in which greater quantities of organic materials may be obtained for use in the farm, and particularly, how to reduce the use of crop residues and organic manures for fuel and fodder, so that crop residues remain in the field, and manures are applied to the soil.
3. If the local practice is to burn crop residues as part of land preparation ask the participants to consider what nutrients might be lost by this practice?
4. Give the groups up to 1 hour to discuss the topic, and request each group to nominate one member to present the group's findings to the rest of the participants for discussion.
5. Allow 1 hour for the general discussion on practices which are feasible and practical for increasing the supply and production of organic materials for the main cropping/farming system

Questions to facilitate discussion:

What organic materials are available on-farm?

Are these currently used as fuel, fodder or for other purposes that would prevent their use as an organic fertilizer?

Are there alternative sources of fuel or fodder that could be used in place of crop residues?

Are there organic materials available on-farm that are not currently used but could be used as source of nutrients and soil organic matter?

Are there organic materials that could be obtained from off-farm sources (grasses, forest litter etc)?

EXERCISE 15: OBSERVATION OF LEGUMINOUS PLANTS AND THEIR NODULES

Aim:

To learn how to detect if legumes are converting atmospheric nitrogen into plant nitrogen.

Duration:

1 hour.

Materials required:

Samples of local legumes (preferably in flower) with their roots and nodules intact, small sharp knife.

Procedure:

1. Demonstrate the presence of root nodules on samples of a range of local legumes collected at or close to flowering if possible.
2. Emphasize the need to exercise care in collecting legume root samples so that the nodules do not fall off whilst extracting the roots from the soil. It is advisable to dig around the base of the plant with a hoe or spade, and then carefully lift out the roots and soil. Carefully separate the soil from the roots by hand, and if necessary, by immersing the roots and soil in a bucket of water, or wash the soil off the roots with a stream of water directed from a plastic water bottle or hose.
3. Demonstrate how to cut open a nodule with a knife or fingernail to detect whether or not the nodules are actively fixing nitrogen.

Questions to facilitate discussion:

Which crop and tree legume species could be introduced into existing farming systems to improve the supply of nitrogen?

Which types of cropping systems (e.g. green manures, cover crops, strip crops, intercrops) will promote nitrogen fixation?

EXERCISE 16: BENEFICIAL EFFECTS OF LEGUMES ON A SUCCEEDING GRAIN CROP**Aim:**

To demonstrate the better performance of grain crops planted after legumes in a nitrogen-deficient soil.

Duration:

1 hour

Materials required:

keys and colour plates, if available, of nitrogen deficiency foliar symptoms.

Procedure:

1. Select a nitrogen-deficient soil sown to a grain crop, where the previous season one part was sown to a legume (the treated area), and another part to a non-legume or left under fallow (the control area). Apart from this difference, both areas must have been managed identically.
2. Visit the site when the grain crop has reached flowering or a more advanced growth stage.
3. Request the participants to observe any difference in colour of the foliage between the treated and control areas.
4. Encourage participants to look for evidence of nitrogen deficiency in the control area using the foliar deficiency symptoms given in annex 6.
5. Initiate a discussion on the advantages, disadvantages and feasibility of sowing legumes prior to grain crops in the existing cropping systems.

Questions to facilitate discussion:

Which crops show nitrogen deficiency foliar symptoms?

Have they observed any changes in leaf colour when the crop follows a legume crop?

How does this colour change compare to that seen when a nitrogen fertilizer has been applied to the same crop?

EXERCISE 17: CALCULATION OF NECESSARY NUTRIENT SUPPLY WITH MINERAL FERTILIZERS**Aim:**

To understand how to calculate the amounts of nutrients to be applied to a cropping system from mineral fertilisers to make up the deficit in nutrient supply from organic manures and N-fixing sources.

Duration:

1-½ hours

Materials required:

Data on nutrient requirements for cropping systems and soil types, and the nutrient contents of organic materials used in the area, paper, markers and calculator.

Procedure:

1. Explain how to calculate the additional mineral fertilizer required by a cropping system of inoculated beans, to which 2 t cattle manure/ha are applied, followed by rice to which 4 t cattle manure/ha are applied.
2. The recommended nutrient requirements for beans are 20 kg N/ha + 13 kg P/ha + 0 kg K/ha, and for rice 120 kg N/ha + 13 kg P/ha + 50 kg K/ha.
3. Insert the recommended nutrient requirements for beans and rice in a table.
4. Calculate the nutrients in 2 t cattle manure/ha applied to beans, and in 4 t cattle manure/ha applied to rice using the nutrient composition given in appendix 6 annex 2, and insert them in the table.
5. Include a residual N contribution of 20 kg/ha from the beans to the following rice crop due to nitrogen fixation by the inoculated beans.

Example	Beans			Rice		
	N	P	K	N	P	K
Nutrient recommendations						
Nutrients applied in manure						
Nitrogen fixed by beans						
Nutrients* to be applied by fertilizer						

* Nutrients in fertilizer material are usually expressed in terms of N, P₂O₅ and K₂O.

6. Calculate the nutrient deficits for each crop by subtracting the quantities of nutrients supplied in the cattle manure plus the residual N contribution from the beans, from the recommended nutrient requirements. These are the quantities of nutrients to be applied as mineral fertilizers.

Questions to facilitate discussion:

What types of materials available in the area would be most suitable as external sources of nutrients for the farm?

EXERCISE 18: USE LAND AS PER ITS SUITABILITY**Aim:**

To discuss how differences in soil properties, slope and landscape position will determine the suitability of a plot of land for particular land uses and crops.

Duration:

2 hours

Materials required:

Sheets of papers and markers

Procedure:

1. Divide the participants into groups of not more than 3-5 persons.
2. Request each group to draw on their local knowledge to consider why some crops grow better in some fields than others. Ask them to identify what those crops require to grow well and how might these requirements vary between different fields.
3. Give the groups up to 1 hour to discuss the topic, and request each group to nominate one member to present the group's findings to the rest of the participants for discussion.
4. Allow 1 hour for the general discussion on the optimum soil requirements for particular crops and how to match the most appropriate form of land use to slope and soil type.

Questions to facilitate discussion:

Why do different crops grow best in different soil types?

Which crops grow well in a wide range of different soil types, and which have much more specific requirements?

What affect does slope have on choice of land use?

What other factors should be taken into account in planning land use?

EXERCISE 19: OVERCOMING LIMITING FACTORS**Aim:**

To appreciate that yields are determined by the most limiting production factor.

Duration:

1- 2 hours

Materials required:

Diagrams of the broken barrels, paper and markers.

Procedure:

1. Ask the farmers to list the ten most important factors that limit the yield of a crop or cropping system.
2. Request the participants to rank the 10 factors.
3. Enter these limiting factors into the broken barrel, one factor for each plank of the barrel as shown in the following figure. Assign the most limiting factor to the shortest plank, the next most limiting factor to the second shortest plank, and so on.
4. Discuss the influence of the ten factors on crop yield.
5. Discuss on the basis of the limiting factors ranked in order of priority, the sequence of activities that should be carried out to improve yields for the dominant cropping system.

Questions to facilitate discussion:

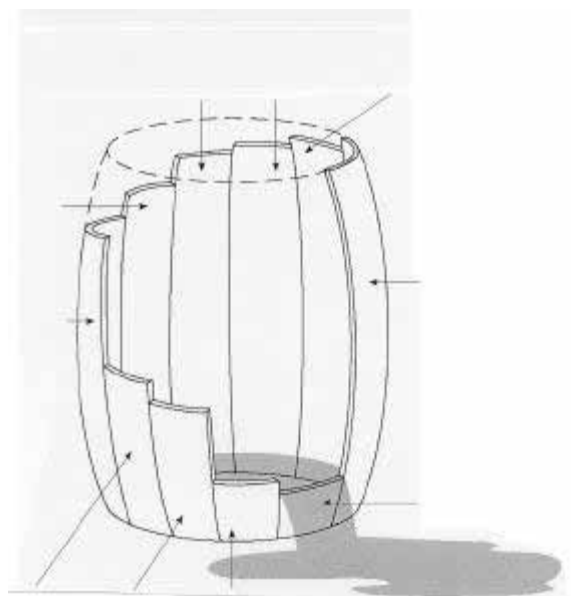
Which factors are likely to limit crop yields?

Which factor is likely to be the most limiting?

If this factor was to be overcome (eg. irrigation to overcome a water shortage) what other factors would still need to be overcome and in what order?

What would be the effect on yield of overcoming one limiting factor (eg. applying fertilizer to overcome nutrient deficiencies) if the most limiting factor (eg. inadequate soil moisture) had not been overcome?

Diagram of a broken barrel to be used by the FFS participants when discussing the principle of limiting factors. Each factor to be assigned to one of arrows linked to a barrel plank. The most limiting factor being assigned to the shortest plank, the next most limiting to the next shortest plank and so on in ascending order of their degree of limitation.



EXERCISE 20: CONDUCT FIELD OPERATIONS PARALLEL TO THE CONTOUR**Aim:**

To appreciate the necessity of conducting all field operations in sloping land parallel to the contour.

Duration:

1-½ hours

Materials required:

Sticks or stones, watering cans, hoes, machetes, source of water nearby.

Procedure:

1. Select a field with a gentle slope of about 10-15%, which has been recently cultivated prior to seeding, and where crops and crop residues are absent.
2. Mark out with stakes two plots (A and B) of 3 m x 3 m in size, separated by about 3 m.
3. Remove any surface stones or crop residues from the two plots, and smooth the soil surface with a plank of wood or broom to remove surface irregularities.
4. Place sticks or stones along the upper and lower boundaries of plot A to mark the positions of 7 imaginary rows of maize at 50 cm spacing in a downhill direction. Similarly place sticks or stones along the side boundaries of plot B to mark the ends of 7 rows at 50 cm spacing in a cross-slope direction.
5. Request the participants to imagine the 7 rows of maize planted in a downhill direction along the lines indicated by the sticks in plot A, and that each of 7 participants walks down the plot and pretends to sow one of the 7 rows with maize. A further 3 or 4 passes will be carried out to simulate the application of basal fertiliser, ridging up, the application of post emergence herbicide or weeding. Using implements to simulate the activity more realistically would be preferable.
6. Request the participants to imagine 7 rows of maize in a cross-slope direction along the lines indicated by the sticks in plot B, and repeat the same movements.
7. Observe the orientation, size and storage capacity of the ridges and depressions in plots A and B, and discuss what effect they would have on runoff.
8. Apply water from a watering can to each plot from the upper plot boundary, and observe the influence of the depressions and ridges formed by the traffic and field operations on the amount and velocity of runoff. Also note any differences in the turbidity of the runoff which would indicate the quantity of soil being eroded.

EXERCISE 21: FIELD GUIDE TO THE SIMPLIFIED ASSESSMENT OF SOIL TEXTURE**Materials required:**

Water bottle, smooth hard surface such as plywood or metal, ruler.

Procedure:

Add water to a volume of soil of approximately 2.5 cm x 2.5 cm x 2.5 cm until the soil is sufficiently moist to be very pliable. Crumble and press the soil between fingers and thumb to break down hard particles and remove stones, grit or roots until a smooth, soft, pliable mass has been formed.

1. If the soil feels gritty and lacks cohesion (i.e. does not hold together), the soil texture is **very light**

2. Form the soil into a round ball, and then press the thumb into the ball of moist soil to form a mould in the shape of a cup:

If no round ball can be formed, or the "cup" crumbles, the soil texture is..... **very light**

If a round ball can be formed, and the "cup" retains its shape, proceed to 3.

3. Roll the ball of moistened soil between the palms of the hands and then on a hard smooth surface to form a ribbon as thick as a pencil and about 20-23 cm long:

If no ribbon or only a short ribbon can be formed, the soil texture is **light**

If a long ribbon can be formed, proceed to 4.

4. Form the ribbon into a circle:

If a circle is formed with cracks, the soil texture is**medium**

If a circle is formed with no cracks, and the soil is very sticky, the soil texture is**heavy**

EXERCISE 22: COMPARISON OF THE CAPACITY OF CLAY, SAND AND ORGANIC MATTER TO RETAIN WATER**Previous preparation:**

Collect together quantities of at least 0.5 kg (or 1 lb.) of the following and leave in the sun to dry for at least 2 days:

- i) clayey subsoil which is poor in organic matter, i.e. has no dark colour,
- ii) a pure source of sand, perhaps from a river bed,
- iii) well decomposed organic manure or compost,

Duration: 1-2 hours.

Materials required:

Scales or spring balance accurate to within at least 50 g, 4 clean dry cloth or jute bags with a capacity of 1-3 kg, water barrel or water tank full of water.

Procedure:

1. Weigh 0.5 kg of each material and place in separate, but similar, cloth or jute bags,
2. Immerse the 4 bags simultaneously into a tank or barrel of water and leave for 10 minutes,
3. Remove the 4 bags from the water, stand on a clean dry surface, and wait until the excess water has drained out of the bags,
4. Weigh each of the 4 bags and record their weights,
5. Calculate the difference between the initial and final weights of each material which is equal to the amount of water absorbed.
6. Compare the weights of water retained by the four materials, and discuss the significance of the results to the suitability of sandy, clayey, stony and organic-matter-rich soils to crop growth, with emphasis on areas where dry periods are common.

EXERCISE 23: COMPARISON OF WATER INFILTRATION RATES UNDER FOREST AND ANNUAL CROPS

Aim:

To demonstrate the difference in water infiltration rate between a mature forest soil and a soil that has been under annual crops for many years.

Materials required:

Hoes or spades, three 5 litre buckets, water source, watch, paper and markers, machete or trowel.

Procedure:

1. At each site prepare a circular earth bund, 30 cm in diameter, of 15 cm height and 15 cm basal area without disturbing the soil surface. Subsoil is better than topsoil to make the bunds, and should be thoroughly moistened so it can be well compacted. Pay particular attention to the join between the earth bund and the soil surface, and use a mud seal to reduce leaks under the bund. If infiltration rings, oil cans or metal pipes are available, use these as they can be inserted 10 cm into the soil and the likelihood of lateral leakage will be less.
2. Carefully pour 5 litres of water into the banded area and record the time. Add the water from the other two buckets as the water infiltrates until 15 litres have been applied.
3. Record the time when the last of the 15 litres has infiltrated into the soil. Infiltration is likely to be very rapid in the forest soil.
4. Remove the residues and litter from the soil surface and carefully examine the surface for signs of biopores (created by earthworms or other insects). Excavate the surface soil and observe the porosity of the topsoil.
5. Initiate a discussion on the reasons for the difference in the time for the water to infiltrate into the forest and annual cropping sites, and the impact this will have on soil erosion, loss of rainwater, nutrients and fertilizers by runoff and deep drainage.

TRIAL 1: ZERO TILLAGE AND CROP RESIDUES TO REDUCE EROSION, AND INCREASE SOIL MOISTURE, BIOLOGICAL ACTIVITY AND CROP YIELDS IN SLOPING LANDS

Materials required: Machinery, equipment and supplies for land preparation, seeding, weeding, harvesting and the application of fertiliser, manure, herbicides and pesticides. Stakes, crop residues, spring balance, notebook.

Procedure:

1. Select a field of maize ready for harvest on gently sloping land, where the soil is typical of the area and is susceptible to nutrient losses by erosion and moisture losses by runoff and evaporation, is of low biological activity and low productivity.
2. Mark out with stakes two plots not less than 20 metres wide, which are, orientated parallel to the direction of maximum slope down the whole length of the field.
3. Harvest the maize following normal farmer practice. If this involves removing all crop residues, follow this practice for the control plot but leave all residues on the treated plot.
4. Prepare the land in the control plot according to normal farmer practice. Leave the treated plot undisturbed with a good residue cover and apply a burn-down pre-sowing herbicide to control weeds.
5. Sow the whole field with beans.
6. Control weeds following normal farmer practice for the treated plot, and apply herbicides to the treated plot. All subsequent management practices, such as fertilization, manuring, and pesticide applications, should be the same for both the treated and control plots.
7. At periodic intervals of 2-4 weeks during the growing season, and especially at periods of drought, compare the treated and control areas using the following soil and crop indicators:
 - crop appearance (foliage colour and plant wilting),
 - evidence of soil erosion and runoff (rills, soil pedestals capped by stones, exposed roots),
 - biological activity (presence of soil organisms, earthworm casts)
 - soil moisture (by feel and soil colour).
8. Harvest the treated and control plots separately, and record the yields.
9. Evaluate the possible solution by comparing the indicators of erosion, soil moisture, biological activity, crop yields and profit (gross margin) for the treated and control plots.

TRIAL 2: LEGUME COVER CROP TO INCREASE SOIL NITROGEN AND INCREASE YIELDS

It is assumed there are two cropping seasons per year, the legume is sown in the first cropping season, eliminated as a cover crop at the pod-filling stage, and the grain crop is sown at the beginning of the second season.

Materials required:

Machinery, implements, and inputs required for land preparation, sowing, fertilisation, manuring, weeding, and control of pests and diseases for the grain and legume crops, machete or contact herbicide, stakes, spring balance or scales.

Procedure:

1. Select a field which is typical of the soils, cropping and management history of the area, and which is known to suffer from nitrogen deficiency.
2. Prepare the land according to normal farmer practice, and mark out adjacent treated and control plots of 200 m² (10 m x 20 m) in a representative part of the field.
3. Sow the legume in the treated plot only at the recommended spacing, and sow the control plot to the same first season (non-leguminous) crop as the rest of the field.
4. If the soil is phosphorus-deficient, incorporate P fertilizer at the recommended rate to the whole field at the time of sowing so that N-fixation is not inhibited. Apply the usual fertilisation, manuring, weed, pest and disease control practices.
5. When the legume reaches the beginning of the pod-filling stage, observe the degree of nodulation, then eliminate it by cutting with a machete, mowing, rolling and cutting (using a rollofaca) or by applying a contact herbicide.
6. Harvest the crop in the control plot and the rest of the field following normal farmer practice.
7. Prepare the land for the subsequent grain crop in the control plot and the rest of the field following normal farmer practice. Leave the residues on the surface of the treated plot.
8. Sow the entire field including the two plots with a grain crop that responds well to nitrogen. A no-till seeder will probably be needed to sow the treated plot.
9. Apply the normal fertilization, manuring, pest and disease control practices to the whole field. Weed control in the treated plot will be by herbicide applications whereas either herbicides or mechanical control may be used in the control plot and the rest of the field.
10. During the growth of the grain crop, visit the site every 2-4 weeks, and monitor the following indicators for the treated and control plots:
 - crop appearance (foliage colour, nitrogen deficiency symptoms),
 - crop growth (height, vigour),
11. Harvest and record the yields of the grain crop from the treated and control plots.
12. Evaluate the legume cover crop treatment in terms of crop yield, profit (gross margin), and nitrogen supply. Discuss advantages and disadvantages of the practice and for what types of soil and crops the practice will be feasible.

Note: It is assumed that low levels of nitrogen fertiliser are applied; if optimum nitrogen rates are applied, the fertilizer applied to the treated plot may be reduced by about 40 kg N/ha depending on how much nitrogen the legume is expected to fix and release to the next crop.

Note: Darker green foliage in the treated plot should be taken as evidence of greater nitrogen availability. Encourage participants to identify nitrogen deficiency symptoms in the control plot using the key to foliar nutrient deficiency symptoms given in Annex 6.

TRIAL 3: COMPOST COMBINED WITH MINERAL FERTILIZER TO OVERCOME NUTRIENT DEFICIENCIES AND INCREASE YIELDS

Materials required: Machinery, implements, and inputs for land preparation, sowing, fertilization, manuring, weeding, and control of pests and diseases, compost for 200 m², stakes, spring balance or scales, paper and markers, blackboard and chalk.

The procedure presented here assumes that fertilizer recommendations exist for the cropping system, and so the treatments to be tested are:

- the recommended nitrogen application rate as inorganic fertilizer (Plot A),
- the recommended nitrogen application rate, part supplied by inorganic fertilizer and part by compost (Plot B),
- no fertilizer or compost (the control - Plot C).

The phosphorus and potassium fertilizers are applied at the recommended rates as a basal application.

Procedure:

1. Select a field which is typical of the soils, cropping and management history of the area, and which is used for horticultural crops. Decide which crop is to be sown for the test.
2. Prepare the land following normal farmer practice, and mark out with stakes three plots of 100-200 m² each, referred to as plots A, B and C, ensuring that all plots are representative of the dominant soil type, cropping and management history of the field.
3. Apply fertilizers and compost at the recommended rates and according to the treatments given above. Follow normal farmer practice in terms of the timing of application, i.e. how much of the inorganic nitrogen fertilizer is applied as a basal dressing, and how much as top or side dressings, and the method of applying the basal dressing, e.g. by broadcasting and incorporating or by placing in bands to the side of crop rows.
4. Sow the field, including the three plots, to the agreed crop.
5. Apply normal weed, pest and disease control practices.
6. During the growth of the crop, visit the site every 2-4 weeks, and monitor the following indicators for each plot:
 - the appearance of the crop (colour of the foliage, foliar deficiency symptoms, crop height, vigour, number and size of the fruits),
7. Harvest the plots separately, and record the yields.
8. Evaluate the two fertilizer/compost treatments by comparing the yields, evidence of nitrogen deficiency, and profits (gross margins) with those of the control.

TRIAL 4: DEEP CULTIVATION TO ENCOURAGE DEEPER ROOTING, GREATER SOIL WATER AVAILABILITY AND HIGHER YIELDS

Materials required: Spades or hoes, pickaxe, subsoiler or paraplough, machinery, equipment and inputs for land preparation, seeding, weeding, harvesting and the application of fertiliser, manure, herbicides and pesticides, stakes, spring balance, paper and markers.

Procedure:

1. Select a field where problems of restricted water availability due to dense subsoil layers impeding root penetration are known to occur. The soil should be representative of the soils of the area in terms of morphology, cropping and management history.
2. Confirm the presence of these dense root-restricting subsoil layers by digging a soil pit in the field. Examine the soil profiles and determine the depth to the upper and lower boundaries of the dense root-restricting layer.
3. Decide which crop is to be sown; it should be a crop that is sensitive to moisture stress and which responds well to deep tillage.
4. Select and mark out with stakes two similar plots - treated and control plots, of not less than 50 m x 20 m each, which are representative of the whole field in terms of soil characteristics, cropping and management history.
5. Prior to normal land preparation when the soil is dry to slightly moist, use a subsoiler or "paraplough" to loosen the subsoil in the treated plot only. The depth of penetration should be approximately 10 cm deeper than the lower limit of the dense root-restricting layer, and the spacing of the subsoiler shanks should equal the depth of subsoiling for narrow-spaced crops, or correspond to, and coincide with, the row spacing for widely spaced crops.
6. Prepare the land for the whole field using normal farmer practice, and avoid excessive tractor passes as this may cause compaction and offset the benefits of the subsoiling; greater benefits are likely to be obtained with minimum tillage for land preparation.
7. Sow the whole field with the agreed crop, and apply the same fertilisation, manuring, weed control, pest and disease management practices to both treated and control plots.
8. Visit the site at 2-4 week intervals during the period of crop growth and monitor the following soil and crop indicators:
 - the appearance of the crop (degree of wilting during dry periods, height, vigour),
 - depth of rooting * (determine at flowering and during pronounced dry periods),
 - soil moisture within and below the rooting zone (determine at flowering and during pronounced dry periods),
9. Harvest the two areas separately, and record the yields.
10. Evaluate the deep tillage treatment by comparing the depth of rooting, soil moisture contents during dry periods, yield and profit (gross margin) with that of the control plot.

* To observe the depth of rooting, dig a small 50 cm-deep pit of 1 metre length, parallel and close to the crop rows in both the treated and control plots. Compare the depths of rooting and soil moisture contents above and below the root-restricting layer in the plots.

TRIAL 5: LIMING ACID SOILS TO REDUCE ALUMINIUM TOXICITY, INCREASE P AVAILABILITY, PROMOTE DEEPER ROOTING, INCREASE SOIL WATER AVAILABILITY AND YIELDS

Materials required: Pick axe, spades or hoes, lime, machinery, equipment and inputs for land preparation, sowing, weeding, harvesting and the application of lime, fertilizer, manure, herbicides and pesticides. Stakes, spring balance, notebook.

Procedure:

1. Select a field where the soil type, cropping and management history are representative of the area, and where aluminium toxicity is known to restrict root development and depress yields. Detailed soil chemical analyses and recommendations on how to overcome the aluminium toxicity should be available.
2. Agree on the crop to be sown, which should be sensitive to aluminium toxicity.
3. Select and mark with stakes two plots of 100-200 m² which are typical of the whole field.
4. Apply lime at the recommended rate and incorporate to the recommended depth in the treated plot. The other plot will receive no lime and will serve as the control.
5. Prepare the land following normal farmer practice, and sow the whole field including the treated and control plots. Apply the same fertilization, weed, pest and disease management practices to both plots.
6. Visit the site at 2-4 week intervals and monitor the following crop indicators:
 - the degree of wilting - especially during dry periods,
 - crop height and vigour,
7. When there are differences in crop water stress between the treated and control plots, dig two small pits 60 cm deep and 100 cm long, parallel and close to the crop rows, within the treated and control plots. Examine the following crop and soil indicators:
 - depth of rooting,
 - health of the roots,
 - soil moisture within and below the rooting zone.
8. Harvest the two plots separately, and record their yields.
9. Evaluate the plot treated with lime by comparing the rooting characteristics, yield and profit (gross margin) with those of the control plot.

Note: Because of the long time often needed for lime to fully react with the soil, it is advisable to continue the monitoring and evaluation for at least the next two years.

TRIAL 6: INTERMITTENT CONTOUR GRASS STRIPS TO SLOW DOWN RUNOFF AND DECREASE SOIL LOSSES

Materials required: Machinery, equipment and inputs for herbicide application, sowing, weeding, harvesting and the application of fertiliser, manure, herbicides and pesticides. Stakes, A-frame or other device for contouring, grass seed or slips, spring balance.

Procedure:

1. Select a field where the slope gradient and length, soil type, cropping and management history are typical of the area, and where problems of runoff and erosion are known to occur.
2. Prior to the commencement of the rainy season, select and mark out with stakes two plots of at least 20 m width, which run downslope parallel to the direction of maximum slope from the top to the bottom of the field.
3. Mark out contour lines in the treated plot with stakes using an A-frame, hose or plank level. Space the grass strips at the recommended intervals according to the slope of the field. In the absence of local spacing recommendations, use 20 metre intervals.
4. At each contour line plant three rows of grass slips parallel to the contour line following local recommendations, or in the absence of local recommendations at 25 cm spacing between rows and 5-10 cm spacing within the rows. The grass may be planted at the beginning of the rainy season, or after harvesting the associated crop if sufficient moisture remains to permit the establishment of grass. Alternatively grass seed can be sown fairly densely in three rows parallel to the contour line at 25 cm spacing between the rows.
5. Weed the grass strips at about 21-30 days after planting or sowing, and then again when, and if, necessary. This would usually be done at the same time that the crop is weeded.
6. Sow the annual crop in both treated and control plots, and apply the same management practices of fertilisation, manuring, weed, disease and pest control to the whole field.
7. After the grass strips have become reasonably well established (which may take the first cropping season), observe the plots at about 2-4 weekly intervals during the next rainy season, and especially after heavy rainstorms.
8. Monitor the following indicators:
 - rills (furrows),
 - soil pedestals,
 - deposition of soil sediments, especially on the upslope side of the grass strips,
 - crop yield.
9. Harvest the crop from the two plots separately each season and record the yields.
10. Evaluate the effect of the grass strips by comparing the evidence for soil losses (assessed in descriptive terms) and crop yield between the treated and control plots over each season. Include the advantages, disadvantages and feasibility of establishing grass strips to control soil losses in annual crops, and the slopes, soil types and cropping systems for which this practice would be most suited.

Note: It may be necessary to continue monitoring for two seasons after the establishment of the grass barriers before convincing data are obtained.

TRIAL 7: RAISED BEDS TO REDUCE WATERLOGGING, INCREASE OXYGEN SUPPLY TO ROOTS, AND INCREASE YIELDS

Materials required: Machinery, implements and supplies for land preparation, construction of raised beds, sowing, harvesting, manuring, fertilization, weed, pest and disease control, stakes, spring balance, notebook.

Procedure:

1. Select a field with a poorly drained soil which is representative of the poorly drained soils of the area in terms of soil type, severity of waterlogging, cropping and management history, and where raised beds are, or could be, constructed.
2. Prepare the land in the conventional manner, and decide which crop is most suitable.
3. Mark out three plots, A, B and C, of at least 3.0 m x 2 m in size. Precise dimensions of the plots will depend on the dimensions of the raised beds, which in turn will depend on the crop, crop spacing and soil type.
4. Construct raised beds of the same width separated by graded furrows in each of the three plots, but with the height of the beds above the soil surface at 60 cm in plot A, 40 cm in plot B, and 20 cm in plot C.
5. Sow the three plots at the same time, and apply the same fertilisation, manuring, weed, pest and disease control practices to all the plots.
6. Observe the performance of the crop, the degree of waterlogging, and the crop's root development by digging a soil pit parallel to the middle row of the middle raised bed in each of the three plots. Monitor the following indicators at 2-4 weekly intervals:
 - depth to the water table from the top of the raised bed,
 - the zone of maximum rooting,
 - maximum depth of rooting,
 - crop vigour.
7. Harvest the three plots separately and record the yields.
8. Evaluate the influence of the height of the raised beds on the depth to the water table, the development of roots, crop vigour and yield. Include the reasons for the differences, and the advantages, disadvantages and feasibility of constructing raised beds to decrease the extent and duration of waterlogging on this soil. Consider alternative methods (i.e. drainage) that could be used to create a deeper rooting zone free from waterlogging.

Annex 2

Supporting reference material on integrated soil and plant nutrient management for farmer field schools

SOIL FUNCTIONS IN RELATION TO LANDSCAPE AND SOIL TYPE

A cross section of the soil is called a soil profile and each layer in the profile is called a horizon. Changes in the colour and general appearance of a soil can be used to determine different soil horizons. Many soils have three major layers of horizons: topsoil, subsoil and parent material.

- Horizon A: topsoil: dark colours, high organic matter, high biological activity, abundant roots
Horizon B: subsoil: below plough depth, brown or reddish coloured, more clay, fewer roots; even deeper in the soil yellowish coloured and less clay.
Horizon C: parent material: unconsolidated, slightly weathered rocky mass from which the soil developed, no biological activity, few roots.

It is not the aim of the ISNM FFS approach to teach farmers how to describe soil profiles in a precise systematic manner using standard terminology, but to record the most prominent features of practical significance to plant growth, in a manner that farmers can readily understand and use. The descriptions will serve as a record of the differences in soil characteristics between sites and between horizons. Both for topsoil and subsoil the following topics can be discussed:

- **rooting depth:** is the effective depth at which root growth of crops and trees is strongly inhibited. If the soil is too shallow the roots of the plants cannot explore the soil and will not develop in an optimal way, so the uptake of water and nutrients is limited. Soil depth is determined by compacted layers, hard rock or a high groundwater table. In case of a high groundwater table the roots cannot grow deeper because of lack of oxygen in the deeper layers. To describe rooting depth units that farmers are accustomed to can be used. Farmers can be asked to think about which crops require deep soils and which can grow well on shallow soils.
- **colour:** gives information about organic matter, biological activity and fertility. The drainage of a soil is also reflected in its colour, but usually in the colour of the subsoil (see Tables 1 and 2).
- **soil moisture:** varies with type of soil, climate and the amount of humus in that soil. The soil pores are usually partly filled with water. Soils which have larger pores can retain less water than soil with smaller pores. Terms like “very wet, wet, moist, dry or very dry” can be to describe soil moisture.
- **texture:** refers to the mixture of sand, clay and silt in the soil. If the mixture contains more sand the soil is said to be light and if more clay than it becomes heavier. Table 3 (and the section on the simplified assessment of soil texture in Annex 1) provide simple guidelines for assessing texture.

- **hardness:** of the soil can be observed when digging the soil pit. It not only determines the workability of the soil, but also the germination of seeds and the facility of roots penetrating the soil.
- **pores and cracks:** are either the result of the presence of earthworms and other soil fauna or the natural processes in the earth. Farmers should be directed to thinking about the need for spaces in soils to permit easy root penetration. Pores and cracks are also important to drain water from the topsoil to deeper layers. On the other hand they can drain also soluble fertilizers to deeper layers. Discussion should be focussed on horizons with no or very few pores that occur in the area, e.g. plough pans, gravel horizons, cemented layers (calcrete), gypsum or weathered rock, stones.
- **stones:** occupy spaces in the soil which then are no longer available for plant roots. Stones also do not permit a good exchange of nutrients and water towards the roots and make tillage more difficult.
- **roots:** indicate clearly if the soil is suitable for crops or not. Terms like “abundant, many, few and very few” can be used to describe the presence of roots.

TABLE 1
Soil colour in relation to soil function

	Dark (dark grey, brown to black)	Moderately dark (brown to yellow brown)	Light (pale brown, yellow)
Organic matter	high	medium	low
Erosion factor	low	medium	high
Aeration	high	medium	low
Available nitrogen	high	medium	low
Fertility	high	medium	low

TABLE 2
Soil colour in relation to drainage condition

Drainage condition	Subsoil colour
Water-logged soils, poor aeration	dull grey (in low rainfall areas)
Well drained soils	yellow, red-brown, black (if in forest soils)
Somewhat poorly drained soils	mottled grey (if in humid areas)

If the soil at one of the sites shows signs of light grey, bluish-grey or greenish-grey mottles or colours, farmers should be asked what could be the cause of this. Farmers will probably be unaware of their significance, so it can be explained that these colours indicate soils which are saturated with water and therefore lacking in oxygen for prolonged periods of time, usually from a few to several months. The saturation of soil pores may be due to the pores being too small to allow water to drain away and air to re-enter, or to the soil occurring beneath or close to a water table.

Farmers can be asked from where the excess water in the soil originates. Is it from groundwater that is flowing laterally and slowly into a river or stream? Is it from large quantities of water flowing in from surrounding higher-lying areas and accumulating in a lower-lying area? Or is it from rainwater which is retained in the soil by very clayey or cemented horizons which are lacking pores or channels sufficiently large to allow the water to drain through? Such a discussion is likely to be most relevant in flat land areas where waterlogged horizons lacking oxygen in the upper 1 metre depth are affecting crop growth.

Farmers' attention can be focussed on the differences between the soil profiles. For sloping lands, the soil at the lower slope position may be deeper and with a darker coloured top soil, or may possess a prominent stony horizon that is lacking in the soil at the upper slope position. Initiate a discussion as to why such differences occur. The discussion should be directed towards soil erosion, how topsoil has been lost from the upper site and deposited in a lower slope position. This may result in a shallower soil with a paler-coloured topsoil in the upper slope position and a deeper darker-coloured topsoil in the lower slope position.

TABLE 3
Soil texture determined by field tests*

Field test	Very Light (sand to loamy sand)	Light (sandy loam to loam)	Medium** (loam to sandy clay)	Heavy (clay)
Lacks cohesion	X			
Feels gritty	X	X		
Moulds into a cup		X	X	X
Forms no, or only a short, ribbon		X		
Forms a long ribbon			X	X
Ribbon forms circle with cracks			X	
Ribbon forms circle with no cracks				X
Feels sticky			X	
Feels very sticky				X

* Conventional texture classes are given in parentheses; ** Loam may sometimes be classed as light textured and sometimes as medium textured depending on the clay content.

SOIL NUTRIENTS, NUTRIENT FLOWS AND FARMING SYSTEMS

This is one of the few topics covered in a FFS that is likely to be based largely on teaching and discussion, because of the difficulty of perceiving nutrients and demonstrating their existence. The degree of detail in these FFS sessions should be appropriate to the farmers' knowledge of nutrients and their educational level. The emphasis should be on those nutrients that are deficient or present in unbalanced quantities, and any toxic substances, such as aluminium, sodium or salts, that occur in the soils of the area. The following presentation outline is suggested:

What are nutrients?

Like humans, plants need different types of food, or nutrients. There are 13 plant nutrients in the soil which are essential for plant growth. Of these, three nutrients, nitrogen (N), phosphorus (P) and potassium (K) are required in greater quantities and so are referred to as major nutrients. If any one of these nutrients is insufficient, plant growth is severely affected, although sometimes nutrients are required in very small quantities. Since the major nutrients are required in the largest amounts, it is often these nutrients (N, P and K) which are first to become deficient.

Note: Mention should be made by name of those secondary nutrients and micronutrients which are locally deficient, and their importance to good crop growth emphasized.

How do nutrients occur in the soil?

Soils are formed by the very slow weathering of rocks into small particles, some of which are the size of sand grains and others, so very small they cannot be seen with the naked eye,

referred to as clay particles. The remains of plants and animals also become incorporated, and are relatively rapidly broken down to form soil organic matter which gives soils their dark colour. Both rocks, plant and animal remains contain nutrients, and when soil is formed many of these nutrients are retained by the clay and organic matter particles. Soil organic matter is particularly important for the supply of nitrogen to plants.

Nutrient availability in acid and alkaline soils

In high rainfall areas many nutrients (especially Ca and Mg) are washed out of the soil and the soils are said to be “acid”. Very sandy soils are particularly prone to leaching. The continuous cropping of soils for many years without returning nutrients in the form of manures or fertilizers causes large quantities of soil nutrients to be “lost” in the harvests, thus enhancing acidification. Acid soils can also develop where certain types of nitrogen fertilizers (ammonium fertilizers) are applied at high rates over prolonged periods. Where there has been intense leaching of bases, like Ca and Mg, high levels of aluminium may accumulate which is toxic to plants, and the soils are said to be “strongly acid.” Aluminium effectively blocks the ability of plants to absorb phosphorus and so plants suffer from P deficiency.

In low rainfall areas where there is greater loss of water through evaporation, instead of nutrients being washed out of the soil, certain nutrients (e.g. sodium) often accumulate as salts in the soil from rising ground waters or from irrigation water. The salts can often be recognized as white deposits at the surface or within the soil profile. Such soils are said to be “saline/alkaline”, which may cause phosphorus and most of the micronutrients to be changed into forms that are unavailable to plants, causing crops to suffer from a deficiency of these nutrients. In alkaline soils the micronutrient boron may be present in relatively large amounts resulting in toxicity problems.

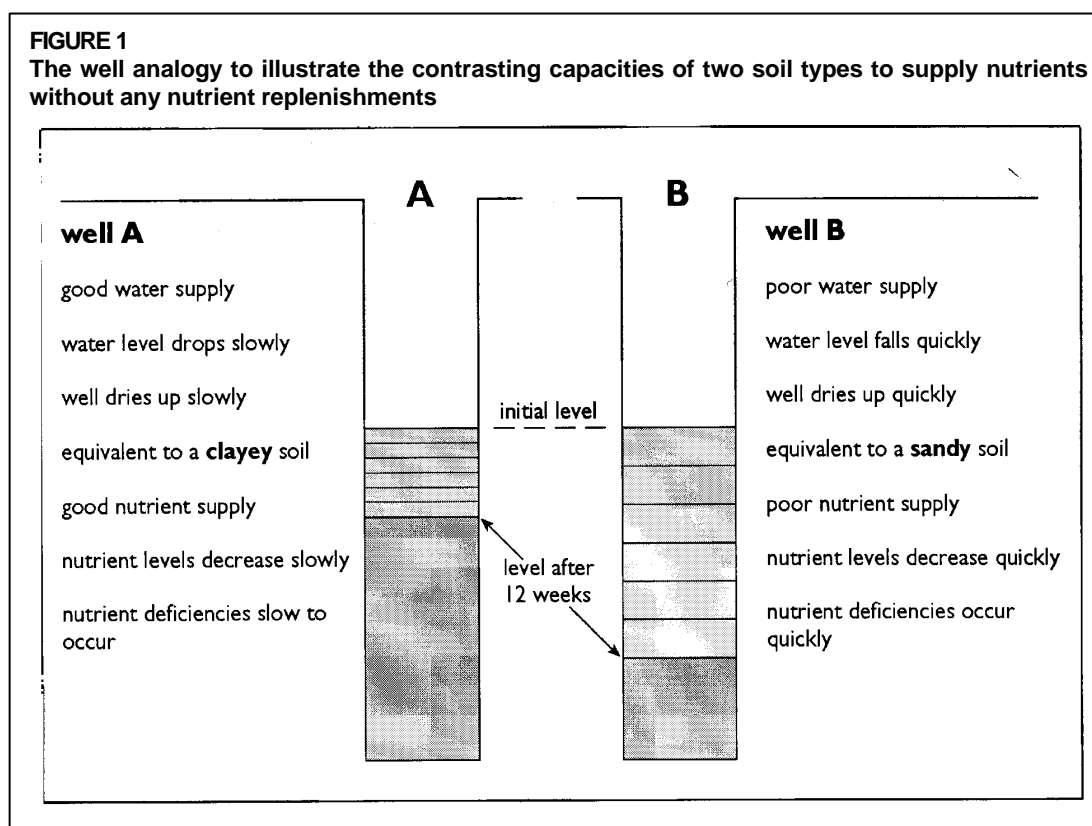
What quantities of nutrients are removed in crop harvests?

Crops require nutrients to produce leaves, grain and roots, that nutrients accumulate in the grain, and that every crop harvest leaving the field signifies a loss of soil nutrients. When continuous harvesting results in the rapid depletion of a soil nutrient, it will be necessary to apply this nutrient to avoid a deficiency. However, for those nutrients which the soil can continue to supply at a rate which satisfies crop demand, no nutrient additions will be necessary. In most soils it is likely that one or more of the soils’ nutrients will need to be replenished to avoid deficiencies and to satisfy crop requirements.

The table presented in Appendix 1 gives an overview of the quantities of nutrients removed by the different crops grown. In relation to the nutrients removed in crop harvests the following observations can be made:

- the largest quantities of nutrients removed are of N, K and P, followed by Ca and Mg,
- the quantities of nutrients removed in crop harvests vary with the type of crop and crop variety, and increase with increasing yield,
- very large quantities of nutrients are removed by cassava, sugarcane, bananas and grasses,
- large quantities of nitrogen are removed in grain crops, sugarcane and grasses,
- large quantities of potassium are removed in fruits, root crops, tobacco, sugarcane and grasses,

Note: Many farmers will be unaware of the meaning of the symbols used for nutrients (such as given on fertilizer bags) hence it is likely that it will be necessary to explain that: N = nitrogen, P = phosphorus, K = potassium, Ca = calcium, Mg = magnesium, etc.



Different capacities of soils to supply plant nutrients

The capacity of soils to continue supplying nutrients removed in harvests varies. For some soils it is possible to continue cropping for longer periods without applying nutrients than it is for other soils. The analogy shown in figure 1 can be used to compare the rate at which water levels fall when water is withdrawn from two wells and the capacity of two soils to retain nutrients for plant growth. The level of water in well (A) only falls very slowly as water is removed, and so water can be withdrawn from this well for a long time before the well dries up - this is equivalent to a soil that can continue supplying nutrients for several years without yields diminishing. In contrast, the water level in well (B) drops rapidly as water is withdrawn, and after a short time the well dries up - this is equivalent to a soil that can only supply sufficient nutrients for 1 or 2 years before yields become unacceptably low.

The participants should be invited to discuss, from their own experiences, which soil types can be cropped for several years without applying nutrients (e.g. clayey soils with high organic matter), and which soil types cannot be cropped for more than one or two years without applying fertilizers or manures (e.g. sandy soils with low organic matter).

Nutrient flows and the farming system

All biological and mineral materials contain nutrients, and so those materials brought into the farm and applied to crops (e.g. fertilizers) or fed to livestock or fish (e.g. animal feeds and concentrates) signify a flow (or movement) of nutrients into the farming system. When livestock graze outside the farm and defecate mainly within the farm, this also signifies a flow of nutrients into the farm.

The selling of farm produce (e.g. cattle, grain, eggs, vegetables), transporting waste materials outside the farm (e.g. crop residues, rice husks, manures), and natural processes such as leaching and erosion signify losses of nutrients out of the farm.

The transfer of vegetative materials from one production system to another within the farm (e.g. applying animal manures and compost made of farm and household wastes to vegetables, or grazing animals on pastures in the farm and applying the manure to arable land) signify a transfer of nutrients within the farming system.

Although nutrient cycling within a field returns nutrients to the topsoil, the recycled nutrients will still be deficient in the same nutrients as the soil. The only exception is with leguminous crop residues which enrich the soil in nitrogen. In poor soils there are few nutrients to be recycled, and so extra nutrients will have to be introduced from outside the farm - either as organic materials or mineral fertilizers.

When biomass is brought from outside the field or the farm, there is a transfer of nutrients from where the biomass originated to the field where the biomass has been applied. Similarly, when cattle graze on uncultivated land there is a transfer of nutrients from the grazing lands to the arable fields, through the application of manures to the arable land.

If the nutrient content of materials is known, the change in nutrient stock of the farming system can be monitored. There will be no change in the system when the same amount of nutrients that is brought into the system is also taken out. Degradation will occur when more nutrients are brought outside the farm than were previously imported.

Nutrient flow maps can be used to facilitate understanding of nutrient flows. When drawing a nutrient flow map this should be gradually built up, starting with the crop (e.g. maize plants), then the house, kraal, grass, vegetables, manure and so on. The movements of nutrients into, out of, and within the farming system as each component is introduced should be discussed, and the corresponding arrows inserted. A nutrient flow map presents a simplified overview of the farm as only the visible flows are demonstrated, thus resulting in a partial nutrient balance.

NUTRIENT CYCLING, BIOLOGICAL ACTIVITY AND LAND USE

Soil processes are important for maintaining normal nutrient cycling in all ecosystems. Soil decomposers (bacteria, fungi and possibly certain arthropods) perform one of the major nutrient cycling processes, nutrient retention, in the soil. In order for nutrients to become available once again to plants and animals, they must be mineralized by the interaction of decomposers and their predators (protozoa, nematodes, microarthropods and earthworms).

In healthy ecosystems, while nutrient cycling and productivity increases, nutrient loss is minimized. As total ecosystem productivity increases, biodiversity below ground also increases. The greater the interaction of decomposers, their predators and the predators of those predators responsible for nutrient cycling and the retention of nutrients within the soil, the fewer losses of nutrients from that system, the more tightly nutrients cycle from retained forms to plants, and back again. Without the soil organisms, plants would not obtain the nutrients necessary for growth.

What happens in the soil?

Bacteria break down easy to-use organic material, and retain the nutrients, like N, P and S in the soil. About 60% of the carbon in those organic materials are respired as carbon dioxide, but 40%

of that carbon is retained as bacterial biomass. The waste products bacteria produce become soil organic matter. This waste material is less decomposable than the original plant material, but can be used by a large number of other organisms.

Fungi break down the more difficult-to-decompose, organic matter, and retain those nutrients in the soil as fungal biomass. Just like bacteria, fungal waste products become soil organic matter, and these waste materials are used by other organisms

Protozoa are one-celled, highly mobile organisms that feed on bacteria and on each other. Because protozoa require 5 to 10-fold less nitrogen than bacteria, N is released when a protozoan eats a bacterium. The released N is then available for plants to take up. (Between 40 and 80% of the N in plants can come from the predator-prey interaction of protozoa with bacteria.)

Beneficial nematodes eat bacteria, fungi and other nematodes. Nematodes need even less nitrogen than protozoa, between 10 and 100 times less than a bacterium contains, or between 5 and 50 times less than a fungal hyphae contains. Thus when bacterial- or fungal feeding nematodes eat bacteria and fungi, nitrogen is released, making the N available for plant growth.

Microarthropods (insects) have several functions. They chew the plant leaf material, roots, stems and boles of trees into smaller pieces, making it easier for bacteria and fungi to find the food they like on the newly revealed surfaces. The arthropods can increase decomposition rates by 2 to 100 times, although if the bacteria and fungi are lacking, increased decomposition will not occur. In many cases however, the arthropods carry around an inoculum of bacteria and fungi, making certain the food they want is inoculated onto the newly exposed surfaces. Arthropods then feed on bacteria and fungi, and because the C/N ratio of arthropods is 100 times higher than the bacteria and fungi, they release nitrogen, which then is available for plant growth.

Larger soil organisms like earthworms and ants mix plant material into the soil. Earthworms also feed on microorganisms that decompose soil and have an important effect on the oxygen diffusion in the root zone, together with drainage of water from it. Their burrowing activity provides channels for ingress of air and exit of water. As casts contain up to four times more total nitrogen than the topsoil, N-availability from casts is apparently higher than from soil. Deposition of casts at the soil surface can generate a new soil layer, high in concentrations of organic C and nutrients. Dry casts also have a high resistance to mechanical disintegration by raindrops.

The greater production of foliage under forest compared to annual crops results in a higher population of earthworms, insects and micro-organisms, therefore greater biological activity, more humus formation, and hence a darker coloured topsoil. The greater leaf cover on the soil surface under forest creates a moister environment which is more conducive to activity by soil organisms. Because of greater numbers of worms, termites, ants, millipedes etc. due to greater litter production and less disturbance under forest there are more large pores present.

In contrast, under annual crops, leaf production is much less, the leaves are frequently removed, the soil is tilled several times each year and the soil is much drier. Consequently, less "food" and moisture are available for earthworms and other insects, and their habitat is constantly disturbed.

A simple discovery based exercise (see annex 1) can be used to demonstrate the difference in water infiltration rates between a mature forest soil and a soil that has been under annual crops for many years. Large pores quickly conduct large amounts of water through the soil after intense rainstorms, and also provide easy pathways for root penetration.

There is scope for a FFS facilitator to initiate a discussion that would enable farmers to understand the concept of nutrient cycling. He/she should focus the discussion on the accumulation of nutrients by tree leaves during growth, the death of the leaves, and their falling to the ground. Nutrients originated from deep in the soil and were transferred to the surface soil layer from where they can be taken up by plant roots again. This is referred to as nutrient cycling. Attention should be drawn to the different depths from which nutrients can be cycled with and without trees.

Discussion should be encouraged on the management practices that would favour nutrient cycling and those that would prevent nutrient cycling. Farmers can be asked to consider what would be the fate of the nutrients in crop residues if they are cut and carried to livestock for fodder, grazed by livestock, burned in the field (nitrogen and sulphur are lost), or left on the soil surface?

The depths of root penetration, leaf litter accumulation, biological activity, soil humus content, moisture content, and porosity are good indicators to investigate whether a soil is healthy or not. Particular attention should be paid to soil porosity and the presence of large pores or channels (referred to as biopores) formed by earthworms, termites and ants. Likewise fungal growths should be looked for on the surface of buried, decomposing leaves.

FIELD IDENTIFICATION OF SOIL AND NUTRIENT PROBLEMS

This section contains a comprehensive list of field indicators of soil and nutrient problems and discusses how they can be used in the determination of problems. A summarized list can be found in appendix 2.

Crop Indicators

Low or declining yields: This information should be obtained from the landowner. Evidence for low yields may sometimes be apparent from differences in crop performance between nearby fields. Better crop growth in localized patches in a field where there has been an accumulation of manures, ashes, crop residues or eroded sediments may also be indicative of overall low yields. Nutrient problems are most likely to be responsible, but the build-up of weeds, pests and diseases can also give rise to low or declining yields.

Low germination: Low crop density can be caused by low seed density, low germination or low emergence. A very heavy texture and a cloddy seedbed can be responsible for low germination. Other causes are an exceptionally wet season, excessively high temperatures, poor land preparation (heavy textured soil in a cloddy condition), untreated seed which suffered from pest or disease problems, or poor quality seed (farmer's own or purchased).

Stunted growth: Stunted crop growth can be due to excessively cold spells, pest or disease problems, low soil fertility, the lack of crop rotation, recent flooding or a high groundwater table. The cause may become more apparent when the site and soil indicators have been examined.

Non-uniform crop growth: If non-uniform growth is evident, this may be due to marked soil differences over short distances. To identify whether the cause of these differences is soil based, soil pits should be to 50 cm depth at sites where crop growth is good and where poor, and the soils compared. If the crop is deep rooting it may be necessary to dig the soil pits deeper. Differences in crop growth between the two sites may be due to differences in soil moisture or salt concentrations associated with an undulating topography, differences in soil depth due to parent material variability, differences in soil texture and nutrient content especially in alluvial

soils which frequently vary greatly over short distances. However it should be remembered that sometimes non-uniform growth might be due to variability in the planting material, for instance maize seed bought from the local food market could contain a mixture of recycled hybrid seed, composite seed and seed of local varieties which if planted could result in marked variations in growth between adjacent plants.

Nutrient deficiency symptoms: During a FFS, only the foliar symptoms of nutrient deficiencies known to occur in the area should be discussed. The facilitator can assist the discussion and identification of nutrient deficiencies by providing descriptions and supporting colour plates of the symptoms (see the descriptions and illustrated examples in annex 6). Acute nutrient deficiencies can often be identified from the colour of a plant's leaves, whether the older or younger leaves are first affected, whether the terminal bud is affected, and by the plant's growth pattern. Slight or moderate deficiencies seldom show up as foliar symptoms. Similar symptoms can also be caused by damage from machinery or wind. One deficiency symptom can also mask other deficiency symptoms.

Possible causes of nutrient deficiencies may be:

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

If a nutrient deficiency is suspected, the deficiency should be confirmed by sending a soil sample to a Soils Laboratory for analysis. Alternatively, a simple soil testing field kit can be used. The procedure for sampling soils is given in Appendix 4.

Sampling the crop's leaves for foliar analysis is very helpful in detecting trace element deficiencies, but precise details of which leaves and when to sample, will depend on the crop. Expert advice must always be sought, as only when the recommended sampling instructions are followed is it possible to interpret foliar analyses correctly.

Nutrient toxicity symptoms: During a FFS, only those nutrient toxicities known to occur in the area should be discussed. The facilitator can assist the discussion and identification of nutrient toxicities by providing the participants with descriptions of their foliar symptoms. Information on nutrient toxicity foliar symptoms is given in Appendix 3. Nutrient toxicities are mainly found in very acid soils, waterlogged soils such as irrigated rice fields, and in soils with high salt contents. The symptoms can be recognized by discolouration of the leaves, and whether younger or older leaves are first affected. In the case of aluminium toxicity the most obvious symptom is the deformation of roots.

Wilting: If the subsoil is light textured, or the profile is very stony or shallow, this could signify that it can only retain small amounts of water making the soil susceptible to drought. The crop's roots should be examined to assess whether rooting depth is restricted, and signs of excessive soil strength should be looked for within in the subsoil. Rooting and thus water uptake can also be restricted by very acid or alkaline subsoil conditions. However, to identify this requires soil chemical analysis.

Site Indicators

Bare patches: Bare patches often signify the presence of high salt concentrations which may be apparent by the presence of white surface deposits, and by livestock congregating and licking the soil surface. Bare patches may be caused by salt accumulation due to high evaporation rates and saline ground waters, or by irrigation with poor quality water and inadequate drainage.

Weeds: Weeds can be useful indicators of soil quality, and may sometimes indicate specific soil problems. In general, as soils become more degraded, i.e. more depleted in nutrients with lower infiltration properties and less biological activity, the weed population changes from many to few species, and from broad-leaved plants to grasses and other difficult-to-manage species. Certain weed species may indicate specific soil problems, e.g. *Imperata cylindrica* often indicates nutrient-poor soils, *Striga* (which is a parasitic weed on the roots of maize) becomes more abundant as soil fertility declines, many ferns (*Filicineae*) indicate acid soils, and *Juncaceae* and *Cyperaceae* (Figure 2) indicate inadequate oxygen supply in soils that are waterlogged or with low infiltration rates.

Surface ponding: Surface ponding is caused by low infiltration rates resulting in saturated soils and a lack of oxygen during wet periods. The cause is usually subsurface compaction caused by tillage with mouldboard or disc ploughs, traffic from heavy machinery or lorries, or excessive trampling by livestock in wet conditions.

Flooding: Evidence of flooding, such as debris lodged in crops or vegetation by receding flood waters, and non-humic sediments deposited on a dark coloured topsoil can rapidly disappear through cultivation and weeding practices. Causes of flooding can be high runoff due to deforestation or overgrazing.

Note: Site indicators related to water erosion, wind erosion and mass wasting (landslides) are covered in detail in annex 3.

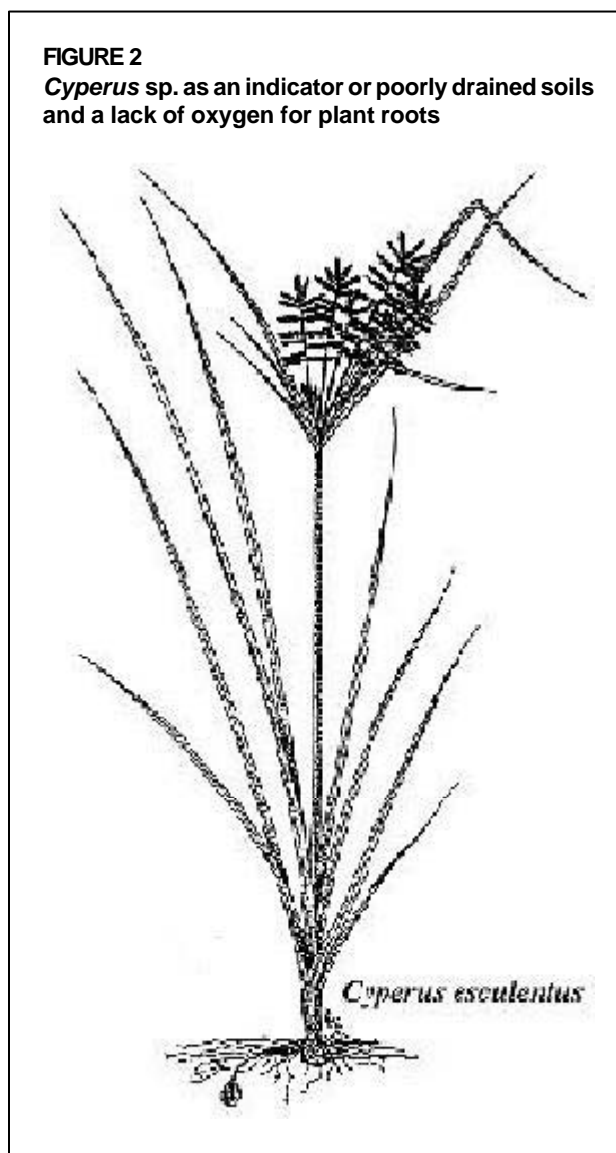
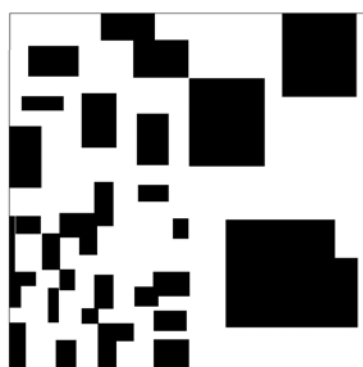


FIGURE 3

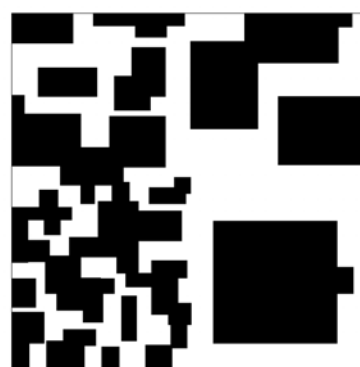
A high cover of surface residues on a steep slope of 45% controls erosion on a volcanic soil

**FIGURE 4**

Visual estimation of percentage cover from the area occupied by the black colour in any one of the four quarter squares



40%



70%

Soil Morphological Indicators

Lack of surface residues: A good cover of surface residues is important in crop production not only to protect soils from erosion, crusting and moisture loss by evaporation, but also to promote rainfall infiltration and biological activity. Thus, if erosion is the main problem, greatest cover would be required when rainfall is most erosive or most intense. Conversely, if loss of moisture by evaporation is the main problem, a good residue cover would be needed at the growth stage when water is most critical. To adequately control erosion on shallow slopes less than 10%, about 40% of the surface must be covered, whereas on slopes of 50%, about 70% cover is needed (Figure 3). Figure 4 can be used to recognize 40% and 70% surface residue cover from the proportion occupied by black in any one of the four quarter squares. Lack of cover can be caused through lack of water, nutrients or biological activity. However improving land cover in croplands may be difficult if crop residues are routinely removed because they needed for feeding livestock or for fuel, where there is uncontrolled post harvest grazing of residues in the

croplands, if the foliage of the crops grown provides little cover and/or is deliberately removed during the growing season (e.g. harvesting of tobacco leaves), and/or it is broken down very quickly due to excessive termite activity or very high rates of natural decomposition (as for instance occurs in humid tropical environments).

Surface salts: Salts can be recognized from white crusts or powdery deposits that usually occur as small sporadic patches on the soil surface, but sometimes as more extensive deposits. In the presence of high concentrations of salts, most plants experience difficulty in absorbing water, and so may suffer from water stress even though water is present in the soil! In addition there may be toxic concentrations of elements such as sodium, boron or chlorine. If feasible, soil samples should be taken for chemical analysis, so that the precise nature and degree of severity of the salt problem can be assessed. The cause of the problem can be rising ground waters or irrigation with inadequate drainage.

Dark coloured slippery surface which cracks in dry weather: Dark coloured slippery surfaces under moist conditions which crack under dry conditions often indicate soils of high sodium content. Sodium-rich soils (known as sodic soils) are characterized by poor structures that are impermeable to water resulting in a lack of oxygen to the crop's roots. High sodium levels can also result in sodium toxicity, and lead to nutrient imbalances causing a deficiency of other nutrients, such as calcium. As with saline soils, it is advisable to send soil samples to a Soils Laboratory for precise identification of the nature and severity of the problem. Rising sodium-rich ground waters or poor quality irrigation water are possible causes of sodic soils.

Surface rusty-coloured mottling and oily films on free water surfaces: If red- or rusty-coloured mottles are present at the soil surface and oily films occur on the surface of standing waters, this often indicates in very acid soils an iron toxicity. Soil samples should be taken for laboratory analysis, to assess the severity of the problem.

Hard surface layer: Recognition of hard surface layers is simple in dry conditions as they are hard and cannot normally be broken, or only with difficulty, by the hands. But in moist or wet conditions recognition is much more difficult. Hard surface layers may be cemented or naturally hard-setting,¹ and tillage is frequently difficult or impossible until after the soil has been wetted. This will delay planting and can lead to reduced yields. High soil strength may hinder seedling emergence and early growth as the soil dries out. Under wet conditions the poor structure may cause the surface soil to become saturated with water resulting in a lack of oxygen, poor infiltration, runoff and erosion. The cause is frequently natural, but may have been accentuated by intensive cultivation and the loss of soil organic matter.

Gravelly or stony surface layer: This is easily recognizable and the main problem is that tillage can be difficult if not impossible, and seedling emergence and early growth may be harmed. The problem is generally caused by natural soil forming processes.

Surface sealing: This is recognized by the presence of a very thin film-like layer, usually clayey, which forms a continuous impermeable layer over the soil surface, and which impedes rainwater infiltration. Surface seals promote runoff, which may accentuate water stress and cause erosion leading to the loss of soil nutrients. Surface seals may be caused by lack of cover or excessive cultivations.

Surface crusting: Surface crusts consist of several to many thin surface layers, usually made up of sandy or silty particles, to form a crust with a thickness ranging from a few mm to a cm or more (see Figure 5). Surface crusts are formed by the force of raindrops breaking down soil

¹ Hard-setting soils set to a hard, structureless mass during drying after being thoroughly wetted.

FIGURE 5
Surface crusts in a light textured soil impeding rainfall infiltration and seedling emergence

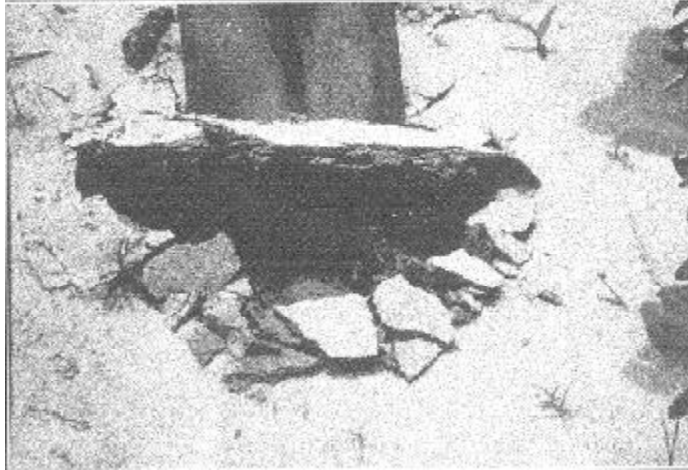


FIGURE 6
Differences in soil colour between a topsoil from a mature forest and from the same soil after four years cropping



aggregates into particles which clog the surface pores and build up a series of thin layers of sediments deposited parallel to the surface. Under dry conditions, crusts are hard with considerable strength and frequently inhibit seedling emergence. The impermeable nature of crusts drastically reduces rainwater infiltration, and so encourages runoff which may result in the loss of water and topsoil nutrients that could have been used by crops. Its causes may be loss of surface residues, excessive cultivations, deposition of eroded sediments or unusually intense rainfall.

Cloddy topsoil structure: Large, clayey aggregates are difficult to break down by tillage or with the hands, even when moist. The difficulty of reducing the aggregate size of coarse cloddy-structured soils makes it difficult to form a seedbed and so germination rates are often low. The cause is generally the very heavy texture of the soil itself.

Low soil organic matter: Low soil organic matter can usually be recognized by the pale colour of the topsoil, or in extreme cases by reddish or yellowish colours if subsoils are exposed at the

surface due to erosion. Soil organic matter contents can fall very rapidly to low levels when a forest soil is cropped to annual crops (See Figure 6). *Note:* The dark surface colours of black cracking clay soils (“vertisols”) are not reliable indicators of high soil organic matter contents.

Low soil organic matter may result in low structural stability leading to surface crusting and sealing, low biological activity, and low nutrient availability - especially of nitrogen. Therefore low soil organic matter may indicate problems of lack of water, lack of nutrients, and low biological activity. Soil organic matter contents less than 2% are generally indicative of poor soil health in subhumid to humid regions. Long or intensive annual cropping, little return of crop residues, no manure applications, excessive cultivations, or no fallow periods can be causes of low soil organic matter content.

Restricted rooting: Restricted rooting can be easily recognized in a crop at flowering or a more advanced stage of growth, by the pattern and depth of penetration of the crop’s roots.

Rooting may be physically restricted by very dense layers with very small pores which restrict root penetration. Dense layers can be formed by mechanized tillage, by animal traction and in some soils by hand-hoeing. The dense layers are formed immediately below the depth to which the soil is tilled each year, and are referred to as plough pans.

Other dense layers can be natural, such as those found in some heavy textured soils and those formed by chemicals which cement the soil into hard layers. Cemented layers are hard and difficult to break with the hands.

Root restriction can also be caused by toxic aluminium or manganese in very acid soils, by severe nutrient deficiencies, and by high salt levels; these causes can only be identified by soil chemical analysis.

When restricted crop rooting is present, the rooting depth of the soil is limited to the volume of soil above the dense layer. Plough pans often occur at 12-30 cm depth depending on the normal depth of tillage (see Figure 7), whereas naturally dense layers can occur at any depth. When dense layers *prevent* root penetration, the roots show an abrupt change of direction from vertical to horizontal or a corkscrewing pattern of growth at the upper boundary of the root-restricting dense layer. When a dense layer does not prevent, but *impedes* root penetration, roots may show a sudden kink or a localized thickening at the depth where soil resistance to root penetration has abruptly increased. Figure 8 illustrates the rooting patterns and growth habits that are indicative of root restriction by dense layers.

A restricted depth of rooting may diminish the supply of moisture and nutrients available to a crop, and the effect of diminished water supply will become more severe in areas where moisture shortage frequently limits productivity. Root restriction is far more important for annual crops which have only a short time in which roots can penetrate the soil to absorb nutrients and water, compared to perennial crops.

Dense layers of high resistance and low porosity: In the absence of a growing crop, the presence of a dense layer (plough pan, naturally dense layer or cemented layer) is often apparent from the sudden increase in soil resistance when forcing a spade into a moist soil profile. An abrupt increase in soil resistance can also be experienced if the topsoil is moist and the subsoil is dry. By excavating the looser soil above, the compact and often shiny upper surface of the dense layer can be exposed.

To assess whether a dense layer is likely to restrict crop rooting, the soil’s pores should be examined and an estimate made of the density of pores that are sufficiently large to be visible to

FIGURE 7
Recognition of dense layers which restrict root penetration due to very visible sized and larger pores

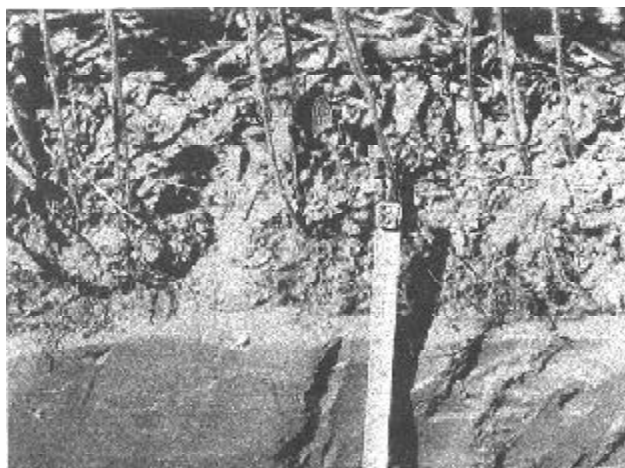
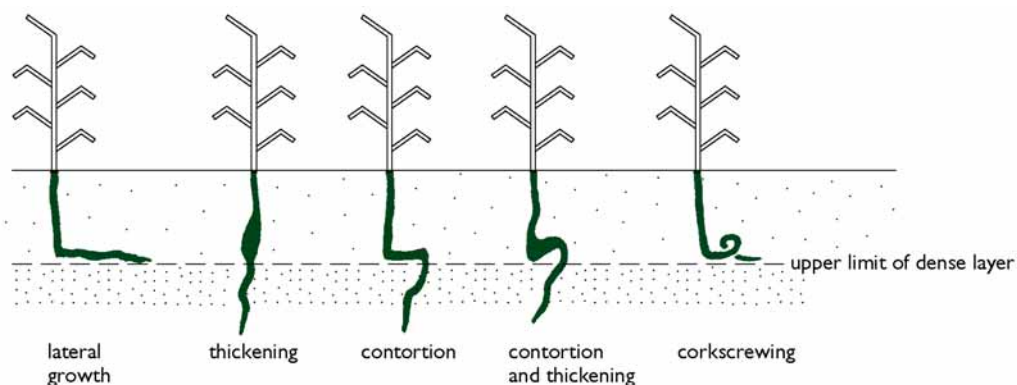


FIGURE 8
Examples of rooting pattern and growth habit which indicate the presence of dense-root restricting layers



the naked eye, i.e. > 0.3 mm in diameter. As a rough field guide, if the horizon contains less than 6 visible pores/100 cm² penetration problems for the roots of many crops may be expected. The nature and severity of the problem, and the probable cause of the dense layer, should be assessed.

Subsoil salts: The presence of salts is sometimes apparent by white powdery deposits in the subsoil. Salts may inhibit root development, so signs of root restriction, associated with salt deposits, should be looked for. The severity of the root restriction should be assessed and the probable cause of the salts established (e.g. irrigation with inadequate drainage, rising ground waters). If there are doubts about whether salts are inhibiting root growth or not, it is advisable to take a sample of the subsoil for chemical analysis.

Sandy to very sandy subsoil: Subsoils of very light to light texture may be easily determined by the field test described in annex 1. Soils of these textures will be very prone to drought because of their low capacity to retain water. They will also be low in plant nutrients, and susceptible to nutrient imbalances when inorganic fertilizers are applied. If the main problem is the low capacity

of the soil to retain water, the severity of the problem will obviously be greater where the seasonal rainfall is low than in high rainfall areas.

Very stony subsoil: If the soil's volume is occupied by stones plant growth will be influenced because the soil's capacity to retain water and nutrients is decreased, and root development may also be impeded.

Poor drainage mottling and colours: If the soil suffers from imperfect or poor drainage, light grey, bluish- or greenish-grey colours may occur as mottles or as the predominant soil colour. These colours indicate the problem of a lack of air (oxygen) in the soil caused by waterlogging for several months of the year.

Both plant roots and soil microorganisms (bacteria and fungi), need oxygen, and if there is insufficient oxygen these greyish colours usually develop. In very humic soil horizons, reddish-orange colours often develop instead of greys.

Poor drainage mottling and colours may be due to:

- the permeability of the soil being so low, as in many heavy textured soils, that the soil is saturated with water for long periods. This is particularly likely in low-lying areas where runoff accumulates.
- a high ground water saturating the soil. The presence of a ground water can be distinguished from low soil permeability by the increase in greyish colours from the highest limit reached by the ground water to the lowest limit where it is permanently present, and where the soil is dominated by grey colours. Ground waters usually fluctuate from shallow depths at the height of the rains to greater depths at the end of the dry season. The higher the upper limit, the more severe the problem.

Note: If low permeable soils and high groundwaters are common, both soil conditions should be noted.

SOME GENERAL PRINCIPLES OF INTEGRATED SOIL AND NUTRIENT MANAGEMENT (ISNM)

The principles of ISNM are the principal underlying ideas or “laws” on how best to manage soils, nutrients, water, crops and vegetation to improve and sustain soil fertility and productivity. They are derived from the essential soil functions necessary for plant growth. There are six principles of ISNM which have general applicability, and 17 other principles which have a more specific applicability. Both categories will be discussed in the following part.

Maximize Soil Cover to Reduce Erosion and Enhance Infiltration and Biological Activity

Soil is like a house with walls and rooms. The sand, clay and organic matter particles of soil represent the walls, floors and ceilings of a house, and the spaces in a soil represent the rooms in a house. It is in the rooms of a house where all the important activities occur - eating, drinking, sleeping, breathing, etc. Similarly it is in the soil spaces where all the important soil functions take place. Roots grow into the soil spaces, water enters and moves through the spaces, oxygen enters the soil through spaces, earthworms and other soil organisms live in the spaces, organic residues are pulled into the spaces, excess water drains out of the spaces, and moisture for plant use is retained in narrow spaces.

The pores at the surface of the soil which allow water, air, fertilizers and organic residues into the soil are similar to the doors and windows of the house which let people into and out of

the house. Therefore the surface pores of a soil must not be blocked or destroyed. Hence it is important to ensure that the pores in a soil remain open and are not destroyed.

The importance of soil cover in maintaining open spaces at the soil surface can be demonstrated by simulating rainfall with the aid of a watering can, and applying the 'simulated rainfall' to two inclined boxes of soil, one of which is bare and the other covered by crop residues (see Exercise 10, Annex 1 for details). Pronounced crusting or sealing and clogging of surface pores may occur in the bare soil due to the water drops destroying the surface structure, but with very little change to the soil surface protected by crop residues. Not only crop residues, but also crops and stones, can provide protection to the soil. More water will infiltrate because residues or crops protect the pores from disintegration by raindrops, so crops will suffer less from drought. Encouraging too much infiltration in some volcanic soils can increase the risks of landslides and mudslides, but this need only be considered in an ISNM FFS in areas where the problem arises.

If the sealing of surface pore spaces reduces infiltration then there will be more runoff increasing the risk of soil erosion. In this regard the colour of the runoff is a good indicator of what is being lost during a rainstorm. Soil, nutrients, fertilizers, even seeds and pesticides can be lost by erosion. Erosion selectively removes the darker, more fertile soil. The performance of crops growing in dark coloured top soils, where there has been little erosion or where eroded sediments have accumulated, should be compared to crops growing in light coloured subsoils where the topsoil has been lost. If further evidence of the effects of soil erosion on crop yield is required, an experiment can be established comparing crop yield in a plot where the topsoil has been artificially removed with that where the topsoil remains intact.

Leaving crop residues, mulches, prunings, weeds and stones on the soil surface, applying zero tillage, intercropping, relay planting, cover crops and higher plant densities will all increase surface cover and encourage infiltration. In contrast, burning, removing or grazing residues, excessive cultivation, wide spacing and poor stands encourage runoff. Identify methods of overcoming erosion and runoff problems that are applicable to the local situation.

The box experiment (Exercise 10, Annex 1) may be modified to demonstrate the effects of soil pulverization (simulating excessive tillage), different slope gradients, simulated trash lines, bunds and other conservation measures on soil erosion and runoff.

Evaporation refers to loss of moisture as a gas into the air due to the heat from the sun. Loss of moisture from a soil by evaporation is similar to a man losing water by sweating in the sun, and applying a mulch or leaving crop residues on the soil surface to reduce evaporation is similar to a man wearing a hat to feel cooler, and not to sweat. Advantages of leaving residues on the soil are less drought stress and higher yields; disadvantages are labour, availability of residues and cost of direct-till seed drills for mechanized farmers.

Simple field demonstrations can be used in a ISNM FFS to show the effects of cover on moisture loss (see Exercise 11 in Annex 1). Likewise field demonstrations can show the effect of crop residues or mulches on biological activity (see Exercise 12 in Annex 1). This can be most effectively demonstrated where there is an area where crop residues or mulches have been applied for two years or more (the treated area), adjacent to an area on the same soil type where no crop residues or mulches have been applied (the control area).

The activity of both soil macro- and microorganisms (bacteria, fungi, etc.) is stimulated by crop residues or mulch, and so helps to maintain a healthy soil. This is because soil organisms: (i) increase porosity which enhances rainwater infiltration from high intensity storms; (ii) incorporate organic residues into the soil; (iii) accelerate its decomposition and the liberation of nutrients; and (iv) contribute to the formation of soil organic matter - humus.

Maximize Additions of Organic Materials and Recycle Farm Wastes

Organic materials contain many plant nutrients (primary, secondary and trace elements) though in varying and often in small amounts, whereas mineral fertilizers usually contain only 1, 2 or 3 nutrients. Nutrient contents can vary considerably for the same organic material. For example, the nutrient composition of cattle manure will vary with the nutritional status of the livestock and the quality of the bedding straw. Similarly, the composition of maize stover will vary with soil fertility and local climatic conditions, and the higher the quality of the wastes used for compost, the better the compost.

For maize about 37% of the nitrogen, 33% of the phosphorus, and 54% of the potassium requirement remain in the stover. This highlights the importance of recycling crop residues. During a ISNM FFS the facilitator can point out the equivalent nitrogen fertilizer values of various organic materials and emphasize the savings in fertilizer costs by recycling waste products. The table in appendix 6 shows the nutrient contents of those plant materials, farm and external agricultural wastes which are, or could be, available to farmers.

Other benefits of applying organic materials to soils are the increased available water capacity and the stimulation of soil biological activity. Organic materials may also enhance the stability of soil structure so that infiltration rates and soil aeration are improved.

Practical ways of increasing the supply of organic materials and their advantages to the farming system can be discussed while visiting a farm where different types of organic materials are being produced.

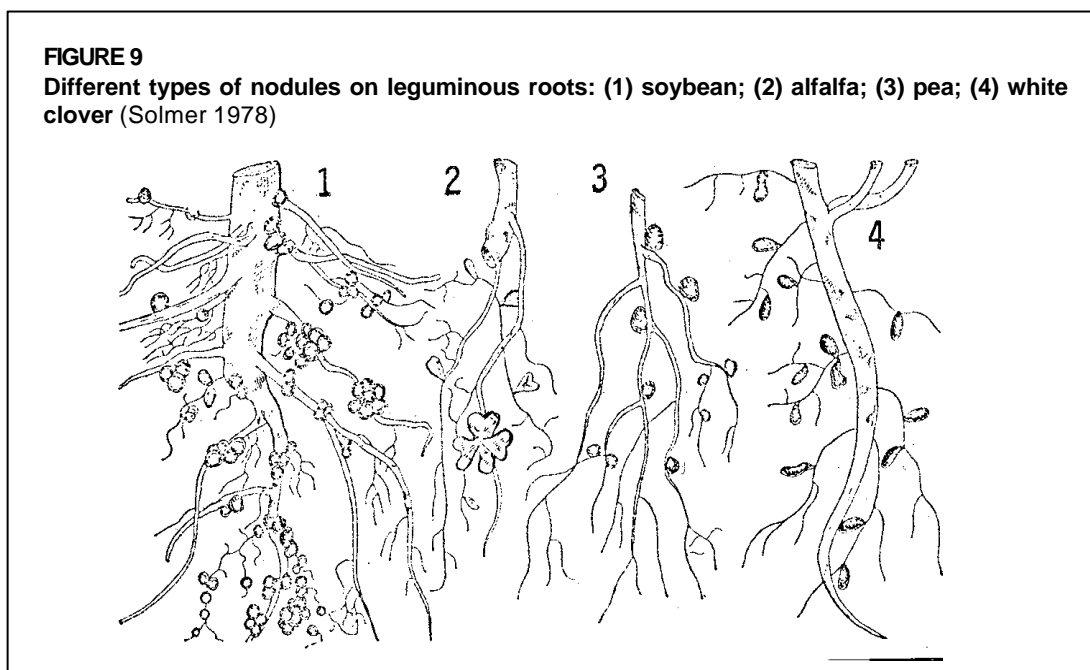
The following can be considered as sources for obtaining organic materials:

- on the farm from non-cultivated areas - forests, pastures, fallow and wastelands, rice-field bunds, terrace banks, farm and field margins and hedgerows. E.g. planting fast-growing leguminous and non-leguminous trees or shrubs for firewood, posts, fruit, nuts, forage and mulches, and by sowing grasses, cereals and legumes for silage, hay or mulching;
- on the farm from cropped areas, e.g. by sowing leguminous cover crops and green manures as intercrops, strip, relay and sequential crops within the same field as annual or perennial crops;
- by introducing new crops or varieties, e.g. which produce greater quantities of foliage, or which are better adapted to drought, acidity or salinity;
- by improving biomass production in fallow areas in or outside the farm. E.g. by enriching natural fallows with leguminous trees, shrubs, or cover crops;
- by production of *Azolla* or blue-green algae in irrigated rice fields;
- from external sources which are sufficiently cheap to buy and transport for the cost and effort to be worthwhile. E.g. waste products from oil processing plants, sugarcane factories, grain mills, coffee processing plants, large scale poultry and pig farms, grasses from roadsides, and litter from forests;
- by compost production from domestic and farm wastes; and
- by improving the collection and storage of animal manures.

Introduction of Legumes into the Farming System

Nearly 80% of the air consists of nitrogen, yet nitrogen is frequently the most limiting nutrient for crop growth. Nitrogen fertilizers are expensive and nitrogen in the air is free, but only

FIGURE 9
Different types of nodules on leguminous roots: (1) soybean; (2) alfalfa; (3) pea; (4) white clover (Solmer 1978)



leguminous plants can fix and use nitrogen from the air. Leguminous plants are characterized by pods and their flowers generally have five petals. Examples of locally important legumes (e.g. beans, pigeon peas, cowpeas, groundnuts, grams, chickpea, and soybean) could be discussed during an ISNM FFS along with any indigenous leguminous plants and trees that might occur naturally in the area.

Certain bacteria (microscopic organisms) found in the nodules on the roots of legumes are responsible for fixing the nitrogen, and that this is usually greatest at flowering. Generally the more nodules on a plant the greater the amount of nitrogen that is fixed (Figure 9), but not all nodules are active. If the internal colour of the nodule is rose-coloured, the nodule is actively fixing nitrogen, whereas if it is brown the nodule is inactive. By cutting open nodules of various species it is possible to determine if they are active or not.

The fixation of nitrogen by legumes depends on there being sufficient bacteria in the soil of the particular species, and strain, that can form nodules on that plant species. Only certain bacteria can form nodules on certain plants. For indigenous plants the appropriate strains of bacteria are invariably present in the soil, but for introduced crops the corresponding strain of bacteria is often absent. In such cases inoculation of legume seed with appropriate strains of *Rhizobia* bacteria will increase the amounts of nitrogen fixed. Appendix 7 gives details on the amounts of nitrogen fixed by a variety of legume species. Legumes require adequate phosphorus for nitrogen fixation to occur, and so soils deficient in phosphorus must be fertilized with phosphates.

Leaving legumes on the soil surface as a cover crop and practising zero tillage has the advantage of protecting soils from erosion, reducing weeds and moisture losses by evaporation, and moderating soil temperatures. The crop following a legume may benefit from an additional 20-40 kg nitrogen/ha from the legume. A higher expected yield and darker green foliage where the legume was sown the previous season, is field evidence of the benefit of legumes on succeeding grain crops due to nitrogen fixation.

However, for some legumes, such as soybean, the quantity of nitrogen removed in the harvested grain may be greater than the quantity of nitrogen fixed, and so continued harvesting of soybean may reduce soil nitrogen content.

To maximize the amount of nitrogen contributed to the soil by legumes, grown as cover crops and green manures, the plants should be incorporated at the mid-flowering or grain-filling stage. A minimum of 2-3 weeks should elapse after ploughing in green manures before grain crops are sown to allow for the initial legume decomposition to be completed.

The precise manner in which a legume may be best introduced into an existing cropping system, or the modifications of the cropping system necessary for this to be feasible, will frequently require considerable experimentation by farmers and researchers. In areas where two crops can be grown per year, it is preferable to sow the legume in the treated plot at the beginning of the first cropping season, eliminating it at mid-flowering or grain-filling stage, and then sow the grain crop in both plots at the beginning of the second cropping season. The control plot may be left in fallow, or sown to a traditional non-legume crop during the first cropping season. For areas where there is only one cropping season, the legume should be sown in the first year and the grain crop the following year.

The choice of legume will depend on the length of growing period and climatic conditions (expected rainfall, temperature and probability of frosts). It is important that the legume grows well, produces large quantities of biomass, and fixes substantial quantities of nitrogen if it is to provide marked benefits to the following grain crop. In some climatic environments large quantities of biomass can be achieved from fast growing legumes in only 4-6 weeks. Screening trials will need to be carried out (by researchers) to identify which legumes are most adapted to the soil and climatic conditions of specific areas.

Whether the legume is left as a cover crop or incorporated as a green manure would be decided by farmers based on local experience. In general, leaving the legume on the soil surface as a cover crop and practising zero tillage (on specific soils) is preferable to incorporating it as a green manure, because of the cover crop's added advantages of protecting the soil from erosion, reducing weed competition, moderating soil temperatures, and reducing soil moisture losses by evaporation.

Supplement Nutrients Supplied by Organic Sources with Mineral Fertilizers

The procedure of estimating nutrient deficits by comparing the nutrients removed in crop harvests with nutrient supplies from organic and N-fixing sources, is often difficult and inaccurate (and therefore may be inadvisable) because of a lack of reliable farming system specific data on such factors as the composition of organic manures, the N fixed by legumes and left as residual soil N, and the amounts of nutrients fixed by soils or lost by leaching.

Preference should always be given to maximizing the use of organic materials as sources of nutrients because they supply a wide range of nutrients and they give many physical benefits to soils. Nevertheless, the quantities of nutrients supplied by organic manures and legumes are frequently insufficient to satisfy the requirements of a cropping system with reasonable yields.

The whole cropping system must be considered, because some nutrients applied to one crop become available to subsequent crops by the slow release of nutrients, especially from organic manures. Nutrients should be applied to that crop in the cropping system which makes best use of them. The next crop will benefit from the residual effects.

In the situation of very infertile soils, the animal manures, crop residues and composts produced on the farm will all be deficient in the same nutrients as the soils. In such infertile soils even legumes may not be able to fix nitrogen because of the lack of phosphorus. This situation can be solved through the introduction of nutrients from outside the farm, either organic or mineral fertilizers.

Calculating nutrient budgets, and the proportion of the nutrients required that would need to come from mineral fertilizers, should only be undertaken as an ISNM FFS discovery based exercise if farmers are reasonably numerate, and if fertilizer recommendations exist for the local cropping systems and soils based on soil analyses and crop responses (see Exercise 17, Annex 1).

Allocate Land Use According to the Suitability of Land

When planning the optimum use of farmland, it is important that both the requirements of the crops, pastures and trees, and the nature of the soils are taken into account. Thus, the type of land use assigned to a particular field should be appropriate to the slope of the land and the type of soil present. To achieve a good matching between land use, slope and soil type, it is necessary to know what are the soil requirements of the crops to be grown. Appendix 8 provides information on optimum soil requirements for a range of crops.

Different crops grow better in different soils because they have different nutrient, water, oxygen, temperature and sunlight requirements. Pastures and forestry grow well in a wide range of soil types, whereas vegetables and coffee only grow well in fertile soils rich in organic matter. Some types of land use need to be allocated close to sources of water - for irrigation or drinking, or close to a road - for ease of transportation or the entry of machinery, or close to the house - for security and convenience of day-to-day management.

Sometimes it is impossible to satisfy the requirements of crops, and they have to be established on fields where the soils or slopes are not optimum. In this case it is very important that appropriate management and soil conservation practices are implemented to conserve and improve the soils so that they become less susceptible to degradation and more suitable for the proposed land use. An example of recommended soil conservation and management practices for grain crops, horticultural crops and fruit trees on different slope gradients is given in Appendix 10.

Improve Yields by Overcoming Limiting Factors in Order of their Decreasing Influence on Yield

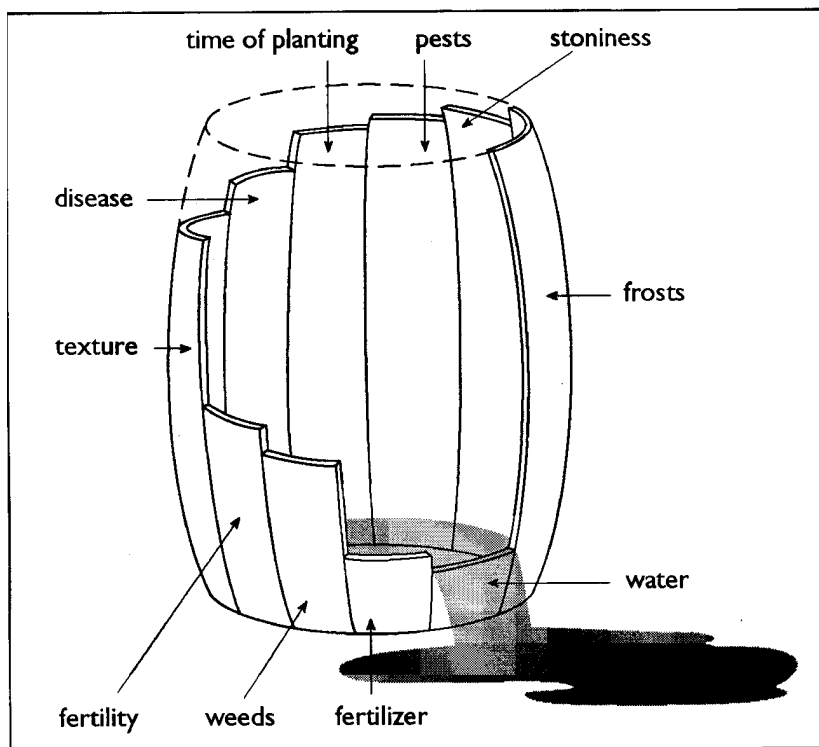
Yields are determined by the most limiting factor, and only when this factor has been overcome will yields increase until they become limited by the second most limiting factor, and so on. It is very difficult to demonstrate the principle of limiting factors by a simple demonstration, however this concept can be presented by using the analogy of a broken water barrel.

In the broken water barrel analogy the lengths of the barrel's planks vary (Figure 10), and the amount of water that the barrel can retain will depend on the height (length) of the shortest plank. The amount of water the barrel can retain may be thought of as being equivalent to the yield of a crop. Just as the amount of water the barrel can retain will be limited by the shortest plank, so the yield of a crop will be limited by the factor most limiting to yield.

If rainfall is the most limiting factor, i.e. is equivalent to the shortest plank, then the yield will be limited by the amount of rainfall that occurs. Once there is sufficient water available because irrigation has been applied for example, i.e. this, the shortest plank of the barrel, has been replaced by a full-length plank, the yield will then be determined by the next most limiting factor, i.e. by the next shortest plank, which in figure 12 is fertilizer application rate.

The same concept applies to the nutrients present in a soil. Thus, it is the most limiting nutrient which must first be overcome to improve yields. Once the most limiting nutrient has been overcome, the second most limiting nutrient will then limit yield until this deficiency has been overcome, and so on.

FIGURE 10
Diagram of a broken barrel to be used to illustrate the principle of limiting factors



Factors limiting crop yield				
rainfall	soil fertility	pests	soil texture	frosts
weeds	fertilizer	diseases	soil stoniness	time of planting

Other Principles

There are several other ISNM principles which have less general applicability, but may be just as important as, and sometimes more important than, the foregoing general ISNM principles, in certain situations. The ISNM principles listed here have been classified according to whether they relate primarily to the supply of nutrients, water or oxygen, or to the provision of biological activity, site stability, or lack of toxicities.

The soil specialists and extensionists/facilitators preparing the ISNM FFS curricula and field manuals should select only those principles which are relevant to the farming environment, cropping/farming systems and farmers’ socio-economic situations in the area where the FFS is to be implemented. Thus, the number of sessions required for a particular FFS will vary with the number of principles that are relevant to the participants.

The following ISNM principles may be presented during the main cropping season, or during the previous dry season. The time required will depend on the number of principles selected, but most require only about one hour, and so it is unlikely that more than 2-3 sessions would be required for a particular FFS.

ISNM Principles Related to the Supply of Nutrients

Split Fertilizer Applications

The benefits of splitting fertilizer applications so that the supply of nutrients to crops coincides more closely with the periods of greatest demand for nutrients can be introduced as a talk using an analogy to facilitate understanding. To illustrate the principle by means of a field demonstration would require a whole cropping season, and so would be very time consuming. However it could be done as part of a FFS fertilizer field trial that is monitored over the course of a cropping season by the FFS participants.

A crop is similar to a newborn child which has to be fed when it is hungry! Giving food to a child when it does not want food is a waste, and the food may easily be spilt and lost, whereas giving food when the child is crying for food means the food is well utilized and well appreciated. Similarly crops have periods when they need a lot of food (nutrients) and other periods when they need less. It therefore makes sense to apply fertilizer at those periods when the crop has a high demand for nutrients.

The primary nutrient which is most easily lost from soils is nitrogen because it is very susceptible to leaching by rainfall, and part of it may change into a gas which is lost into the air when some nitrogen fertilizers are applied to alkaline soils (the loss of nitrogen as a gas is referred to as volatilization). The need to split fertilizer applications is therefore most important for nitrogen fertilizers.

The demand for nitrogen by maize is very slow initially, but rapidly increases after about the third week from sowing to reach a maximum during the period from about 10 days before tasselling to about 25-35 days after tasselling. Therefore about 1/3 of the nitrogen and all of the phosphorus and potassium should be given at planting to satisfy the early growth needs. The remaining 2/3 of the nitrogen should be applied as a side-dressing when the maize is knee-high which corresponds to the beginning of the period of greatest nitrogen demand, which will attain a peak shortly before tasselling.

In high rainfall areas the risks of losing nutrients by leaching will be greater, and especially on light textured soils. For maize under these conditions, it is preferable to apply nitrogen more uniformly throughout the period of greatest nitrogen demand (i.e. from 10 days before tasselling to 35 days after tasselling) by applying the nitrogen in three applications:- 1/3 at sowing, 1/3 at knee-high stage, and 1/3 at silking.

For rice, the greatest demand for nitrogen is in the early tillering stage, and then at initial panicle formation stage. Consequently, nitrogen fertilizer should be split into three equal applications, 1/3 at sowing, 1/3 at 15-20 days after sowing (corresponding to early tillering), and 1/3 at panicle initiation.

The need to apply split fertilizer applications is greater for crops and varieties with long growing periods, because of the long period during which nutrient losses can occur, and because of the longer intervals between peak periods of nutrient demand.

Split nitrogen fertilizer applications are also more important when high levels of nitrogen are applied, because this increases the risk of large amounts of nitrogen being lost by leaching, unless the timing and split fertilizer applications supply nitrogen in quantities that coincide closely with the crop's demand for nitrogen.

Placement of Inorganic Phosphate Fertilizers in Acid (Phosphate-fixing) Soils

If phosphate fertilizers are applied to medium to heavy textured soils, which are also very acid, the phosphorus is often retained so strongly that it becomes unavailable, or is only available with difficulty, to the crop. In such a situation it is said that the soils “fix” phosphorus. To overcome this problem, the phosphorus fertilizer must be placed in the soil near to and below the seed, so that it will be in the vicinity of, and easily taken up by, the crop’s roots. Moreover, by concentrating the P fertilizer, less of the fertilizer phosphorus will be in direct contact with the soil, so less will be fixed and more will be available to the crop. This is similar to giving grain to a small chicken surrounded by many larger chickens. If the grain is broadcast evenly throughout the chicken pen the small chicken will receive very little. On the other hand, if a lot of grain is placed close to the small chicken, it is much more likely to obtain some of the grain.

When applying a basal dressing of phosphate fertilizer to a row crop in a phosphorus-fixing soil, it is much better to apply the phosphorus fertilizer 5-10 cm to the side of the seed, and about 5 cm below the seed, so that the roots of the crop will be able to easily intercept the fertilizer. By concentrating the fertilizer in this way, less phosphorus will be fixed compared to a uniform application by broadcasting and soil incorporation.

When applying a very slowly available P fertilizer, such as rock phosphate, it is better to broadcast and incorporate the crushed rock phosphate. With pastures and closely spaced crops it is not possible to place fertilizer and so must be broadcast.

Placement of phosphate fertilizer results in a greater amount of phosphorus being absorbed by the crop.

Application of Mineral Fertilizers Combined with Organic Manures Or Composts

A greater crop response is obtained to mineral fertilizers when they are applied in combination with composts or organic manures. This is an important principle, and the practice should be considered as a possible solution to the problem of low nutrient supplies. The principle can be presented as a talk, or it could be part of an ISNM FFS field trial conducted over the course of a cropping season.

The application of mineral fertilizer, and in particular phosphate fertilizer, combined with an organic manure or compost produces greater benefits than applying just mineral fertilizer, organic manure or compost on its own. The benefits are usually attributed to:

- the extra nutrient content, especially of trace elements, present in the organic material;
- higher soil moisture contents due to the organic material which cause the fertilizer nutrients to become more available;
- a more immediate release of nutrients from the chemical fertilizer combined with a slower longer-term release of nutrients from the organic material to give a more uniform supply of available nutrients over the whole growing period;
- an increased activity of soil organisms due to the organic material creating a more healthy soil with improved porosity, nutrient- and water-retaining properties, and hence better crop-growing conditions.

The compost or manure should be well decomposed and should have been well stored to avoid nutrient losses. Best results are usually obtained when both the inorganic fertilizer and the compost/manure contain at least 30% of the total nitrogen to be applied. In some acid soils optimum response is obtained with the combined application of manures, fertilizer and lime.

The combined application of organic manure or compost with mineral fertilizer is most relevant to horticultural crops, as there are seldom sufficient quantities of organic materials available for application to grain crops.

This topic can be introduced to an ISNM FFS by holding a discussion on the advantages, disadvantages and feasibility of applying a combination of organic manure or compost and mineral fertilizer, and for which cropping systems would this practice be most appropriate. Consideration should also be given to the changes in the farming system or farm household that would be necessary to permit greater quantities of organic materials to be produced, stored and used.

Maximum Use of Cheap Naturally-occurring Minerals

Various mineral materials contain plant nutrients, however these nutrients are usually released only very slowly. Rock phosphates are the most common naturally occurring minerals used as fertilizers. They generally contain 12-16% phosphorus and 35-38% calcium, though they have no liming effect. They are only usually effective on acid soils (pH less than 5.5), and when finely ground. The addition of sulphur or organic manure simultaneously with the rock phosphate increases soil acidity helping to slowly dissolve the rock phosphate, and so making it more reactive. The value of rock phosphates as fertilizers vary with crop type, but the best responses are generally obtained with perennial crops because of the slow rate of phosphorus release.

Finely-ground limestone, dolomitic limestone, gypsum, sulphur, and silt deposits from lakes, rivers and ditches, all contain plant nutrients and so may be used as fertilizer materials, but the rocks should be ground to speed up the rate of nutrient release.

Whether an ISNM FFS should include a demonstration of the value of naturally-occurring mineral materials, such as rock phosphates, limestone and gypsum, as sources of cheap nutrients would depend on the local need (known nutrient deficiencies), the availability of suitable locally-occurring mineral materials (at economically attractive prices), and when their value as a fertilizer has been proven for the crops and soils of the area. If a nearby demonstration exists on the benefits of applying naturally occurring mineral materials, one or more field visits could be made to this so the FFS participants can observe and discuss the costs and benefits of the practice.

Recycle Nutrients Through Deep-rooted Crops

Nutrients absorbed at depth by deep-rooting crops may have been released by weathering of parent materials, or have been leached to these depths beyond the reach of annual crops. If a soil sown to annual crops is deficient in a nutrient, the recycling of nutrients by deep-rooted crops is unlikely to introduce that nutrient into the topsoil, unless it occurs at depth within the soil profile beyond the reach of the annual crops' roots, and the deep-rooting crops have only recently been introduced.

It is difficult to demonstrate that deep-rooted crops absorb nutrients that have been leached and released by rock weathering from depths beyond the reach of annual crops' roots, and are then recycled to the soil surface through the accumulation of leaves and residues. However, an understanding of the concept of nutrient recycling by deep-rooted trees and crops can be gained from exercise 6 of annex 1 on nutrient cycling, biological activity and land use.

Within an ISNM FFS the discussion should be focussed on changes that could be made to existing cropping and farming systems to promote nutrient cycling. Consideration should be given to the benefits, disadvantages and feasibility of introducing deep-rooting crops in association with annual crops and pastures, (e.g. dispersed trees, alley cropping with trees or shrubs;

intercropping or sequential cropping with deep-rooted cover crops, pigeon pea or cassava; or rotations with tree or cover crop fallows). Likewise consideration should be given to which useful tree species (for fruit, firewood, timber or N-fixing) could be introduced.

Modification of Soil Acidity Through Amendments to Increase Nutrient Availability and Reduce Toxicities

The addition of soil amendments that change soil acidity can reduce toxicity problems and increase nutrient availability. A clear understanding of the precise nature of the problem is essential, i.e. whether poor crop growth is due to:

- a deficiency of phosphorus or a trace element (iron, manganese, zinc, copper, boron) due to soil alkalinity (high pH) which reduces nutrient availability;
- a deficiency of phosphate or molybdenum because of high soil acidity (low pH) reducing nutrient availability;
- A toxicity of aluminium or manganese caused by high soil acidity (low pH).

The exact nature of the problem will only be known from soil chemical analyses, and so access to a soil laboratory is necessary. Foliar analysis of the crop sampled in the correct manner and at the appropriate time will also give valuable information on crop nutrient deficiencies.

The type of amendment required for the problems indicated above will be:

- an acidifying material such as sulphur;
- an alkaline material such as lime or dolomitic limestone;
- a neutral material such as gypsum with a high calcium content to displace toxic aluminium;
- an alkaline material such as lime or dolomitic limestone to neutralize excess aluminium or manganese;
- a mixture of gypsum and lime, or large quantities of organic materials to disable and complex excess aluminium or manganese.

Advice on the most appropriate amendment that might be used to solve such problems, in a specific area, should be sought from the nearest soils research institute. If this is important to the area in which an ISNM FFS is conducted, a field trial should be established to demonstrate the effect of applying an amendment on crop growth and yield.

ISNM Principles Related to the Supply of Water

Loosen Root-restricting Dense Subsoil Layers

Crop water availability can be increased by loosening dense subsoil layers that impede root penetration so that crop roots are able to penetrate more deeply and absorb water from a greater volume of soil. Dense subsoil layers which impede rooting may be of natural origin, may be caused by mechanized tillage, by animal traction or even by hoeing when the depth of cultivation remains the same year after year. When the dense layers are impermeable and restrict both the percolation of water and the penetration of roots, loosening will encourage deeper rainwater percolation allowing oxygen to enter the rooting zone, encouraging deeper rooting, and increasing the quantity of water percolating to greater soil depths.

Demonstrating this principle in an ISNM FFS relies on the facilitator having previously prepared an area where the dense subsoil was thoroughly loosened prior to sowing the existing crop. The loosened area will correspond to the “treated area,” and the surrounding area that has not been

loosened as the “control area.” The loosened area may be quite small, and may correspond to where a soil pit was previously dug to demonstrate the effect of dense subsoil layers on depth of rooting. In this case it is important that the soil horizons removed from the soil pit were replaced in exactly the same order as they were found in the undisturbed pit. Alternatively, a loosened area may have been previously created by loosening an area about 3 m long and 30–40 cm wide aligned along a crop row.

In areas where dense subsoil layers are a major problem, the practice of “deep loosening” using tractor drawn subsoilers, oxen drawn chisel ploughs or hand hoes for double dug beds, could be tested in a field experiment. When the crop has reached flowering or a later stage, dig a small pit should be dug (50 cm-deep and 1 metre in length), parallel and close to the crop rows in both the treated and control areas. This will allow comparison of the depths of rooting and soil moisture contents within the upper and lower parts of the soil profile in the treated and control areas. Rooting depth would be expected to be greater in the treated plot than in the control area because of the deep loosening. In the control area the soil moisture would probably be higher in the lower part of the soil profile below the dense root-restricting layer, compared to the treated plot, because of the absence of roots at that depth, though with time even the moisture in the lower part of the profile will move upwards into the rooting zone. At harvest the yields of the treated and control areas can be visually compared. If the treated area is sufficiently large the yields may be harvested from the two areas separately and compared.

Such a trial would facilitate the initiation of a discussion on the benefits, disadvantages and feasibility of deep tillage on soils that have dense layers which restrict root penetration. The possibility of using biological tillage where crops with strong tap roots such as *Cajanus cajan* are used to penetrate the dense layer can also be considered.

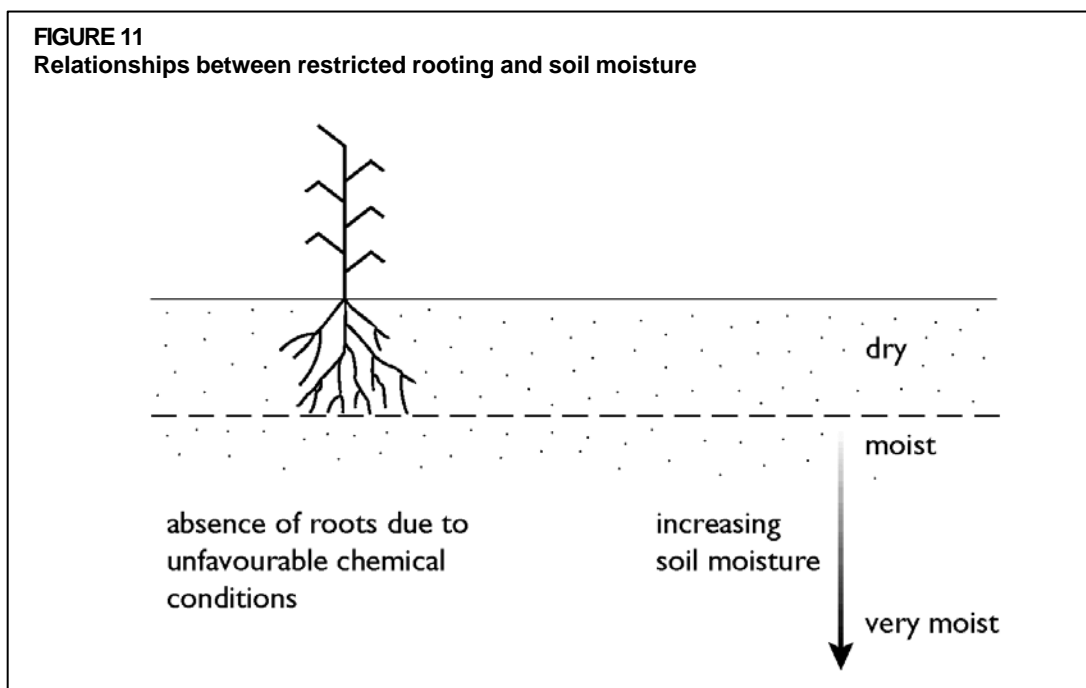
Overcome Chemical Limitations to Root Penetration

The application of an appropriate amendment to improve chemical conditions, which restrict the depth of rooting will increase the volume of soil available. There are many types of adverse chemical conditions that restrict rooting to shallow depths, e.g. aluminium, sodium, molybdenum and boron toxicities, high salinity, phosphorus and calcium deficiencies. Specialized knowledge and detailed soil, and sometimes water, analyses will be necessary to identify the precise nature of the problem, and to give specific recommendations on the appropriate recuperation, management or fertilization practices needed to overcome the problem. Therefore farmers will need good technical support to enable them to overcome this type of problem.

Examples of the types of practices that may be recommended are:

- lime, gypsum, or lime plus gypsum to overcome aluminium toxicity;
- gypsum (in non-calcareous soils) or gypsum plus sulphur or green manures (in calcareous soils) to overcome sodium toxicity;
- leaching, drainage and gypsum to overcome salinity and alkalinity problems;
- phosphate and calcium fertilizers to overcome P and Ca deficiencies.

If the problem of unfavourable subsoil chemical conditions limiting the depth of crop rooting and moisture availability is an important problem of the area, the appropriate recuperation practice to overcome this problem should be tested in a field trial (see Trial 5, Annex 1). Select a field with annual crops where restricted rooting is known to occur due to unfavourable soil chemical conditions. Send a sample of the topsoil and subsoil for detailed chemical analysis to confirm the nature of the unfavourable chemical conditions. Request recommendations on the required



amendment, management and/or fertilization practices with information on the type, quantity, form and timing of application of the amendment. Select a suitable time during the growing season when the lack of water in the shallow restricted rooting zone, and the presence of water at greater depths, can be clearly demonstrated (see Figure 11). This will be when:

- there has been sufficient rainfall during the cropping season to wet the whole soil profile;
- there would have been sufficient time for the crop's roots to penetrate well into the subsoil in the absence of unfavourable soil chemical conditions (may correspond to the flowering stage of growth);
- there has been sufficient time, (10-15 days) after the last significant rainfall for the crop's roots to thoroughly dry the soil in the shallow rooting zone.

A discussion should then be initiated on the problems of restricted rooting and how it influences a crop's susceptibility to drought. Where such a problem occurs, the necessity of sampling the soil properly for chemical analysis, and seeking expert advice on the nature of the problem, and the type of recuperation/management/fertilization practices required to rectify it, should be emphasized.

Create Level Soil Surfaces to Encourage Infiltration and Reduce Runoff and Soil Losses

Modification of the soil surface to form level areas (terraces) encourages rainfall infiltration and so reduces soil water loss as runoff and soil erosion. The same experiment as used to illustrate the beneficial influence of soil cover to reduce runoff can be modified to demonstrate the usefulness of terraces. Where appropriate a discussion should be initiated on the benefits, disadvantages and feasibility of constructing terraces to encourage rainfall infiltration, reduce runoff and reduce soil erosion. The discussion should consider for which crops, slope gradients and soil types in the area the construction of terraces is worthwhile, and the types of terraces that could be constructed.

Application of Supplementary Irrigation Water During Critical Periods

The application of irrigation water to supplement soil water supplies during critical periods is of particular importance in areas where crop yields are frequently reduced by lack of moisture and where the application of irrigation water is feasible, either by a rustic or a more sophisticated irrigation system, which could be manual, some form of surface, gravity-fed or powered sprinkler system.

Irrigation water is most needed during the critical periods of a crop's growing period. These are times when a crop is most sensitive to water stress, and any stress at these times will cause a lasting effect on growth and a reduction in yield. The critical periods for different crops are presented in appendix 9. Expert assistance would probably be needed to help participants select and implement the most appropriate system of irrigation should this be appropriate to the farming systems being investigated by the school.

Conduct Field Operations Parallel to the Contour

If field operations are carried out up-and-down slope, the depressions formed by traffic and implements will be in a down slope direction, and so will increase runoff losses as concentrated flow provoking increased risks of rill and gully erosion. In contrast, if all field operations in sloping lands are conducted parallel to the contour, surface irregularities formed as a result of these operations will create water storage areas that will detain runoff, give more time for infiltration, and so reduce water losses. Depressions and ridges can be formed specifically for the purpose of retaining runoff and promoting infiltration, i.e. furrows and tied ridges (or raised beds).

The practice of conducting field operations parallel to the contour is not by itself sufficient to avoid water losses by runoff (or erosion), and needs to be complemented with other good land husbandry practices that conserve water (and soil), like including operations such as pruning and leaving the prunings and loppings aligned parallel to the contour, and felling trees and crops so that the trees fall across the slope to form barriers.

This principle may be demonstrated for non-mechanized farmers by simulating field activities across slope and down slope on a sloping freshly cultivated site, where there is easy access to a source of water (see Exercise 20, Annex 1).

Create Intermittent Permeable Barriers Across the Slope

Permeable cross-slope barriers, such as vegetation strips and crop residues, located at intervals down the slope will disperse and temporarily slow down runoff leading to more infiltration in the vicinity of the barrier. Permeable barriers will be most effective in reducing runoff where the volumes of runoff are low and slope gradients are gentle, but they can still play a useful role of complementing other land husbandry practices that conserve rainfall.

The effect of permeable barriers in slowing down runoff and promoting infiltration is most pronounced in the vicinity of the barriers, and so will benefit only those crops that are immediately adjacent to, and downhill from, the permeable barrier. In a closely spaced grain crop with comparatively widely spaced permeable barriers, the majority of the plants will therefore gain little or no benefit from increased infiltration. In contrast, in coffee where permeable barriers of prunings and weeds are constructed adjacent to, and immediately above, each row of coffee bushes, the crop is likely to benefit much more from increased water infiltration.

When impermeable subsoils occur which divert percolating waters laterally in a downhill direction beneath the soil surface, the greater volume of water that infiltrates in a permeable barrier may benefit crops beyond the immediate vicinity of the barrier. The effect of permeable barriers in filtering out eroded soil particles carried by the runoff in the vicinity of the barriers, and so reducing soil losses, will often be more important than their effect of increasing infiltration. The continual filtering out of sediments may lead to the progressive formation of terraces.

The use of grass strips is likely to be successfully adopted only where farmers need grass for their livestock, or where the price of grass or hay in the area is attractively high. Grass strips can only be successful if livestock are excluded from the field whilst the grass strips are being established. This may take up to two years, during which time the field should be adequately fenced to restrict the entry of livestock. Select a grass species that is adapted to the agro-ecological environment, which can be cut and fed to, or grazed by, livestock, which is not a strong invader of the adjacent crop, and which forms a close, erect, dense barrier capable of filtering out soil particles transported in the runoff. Stoloniferous and rhizomatous grasses are seldom suitable because of their strong tendency to invade the neighbouring crop. Intermittent contour grass strips must generally be accompanied by other soil conservation practices, such as crop residues on the surface, to adequately control soil losses, especially on slopes steeper than 10%. For other farmers other types of permeable barriers, such as sugar cane or pineapples, may be more acceptable, provided the crop used as the permeable barrier has an economic value.

Impermeable barriers, such as hillside ditches and conservation banks, result in greater infiltration of water at the barriers which similarly gives little benefit of increased soil water to the majority of the crop in most situations. However, impermeable barriers can be important in retaining or safely diverting runoff to limit rill and gully erosion.

Demonstration of the effect of a permeable barrier on infiltration can be done by making use of inclined boxes of soil as described in exercise 10 annex 1 and lacing a 5 cm-wide trash line of crop residues across the slope in the middle of one of the boxes. Another possibility will be the design of a field trial. For further information see trial 6 annex 1.

When introducing this topic to the FFS the discussion should focus on which types of permeable barriers (crop residues and weeds, stones, prunings, closely spaced grass strips, and dense strips of other erect plants) could be used for different cropping systems, and their advantages, disadvantages and limitations. Their influence on soil erosion, and the formation of rills and gullies, can also be discussed.

Practice Zero Or Minimum Tillage

The practice of tilling the soil has in the past been seen as one way to increase fertility. Initially this may be true resulting from the mineralization of soil nutrients as a consequence of soil tillage. However continued tillage leads in the long term to a reduction of soil organic matter. Soil organic matter not only provides nutrients, but is also, more than anything else, crucial for the stabilization of soil structure. Therefore the physical properties of most soils degrade under long lasting intensive arable agriculture. This structural soil degradation results in the formation of crusts and compacted layers, and leads in the end to soil erosion. The process is particularly dramatic under tropical climatic situations.

In a soil that has not been tilled for many years, the crop residues remain on the soil surface and produce a layer of mulch. This layer not only protects the soil from the physical impact of rain and wind, but it also stabilizes soil moisture and temperature conditions in the surface

layers. Such favourable conditions enables the zone to become a habitat for a number of organisms, from larger insects down to soil borne fungi and bacteria. Those organisms macerate the mulch, incorporate and mix it with the soil and decompose it so that it becomes humus and contributes to the physical stabilization of the soil structure. At the same time this soil organic matter provides a buffer function for water and nutrients. Larger components of the soil fauna, such as earthworms, provide a soil structuring effect producing very stable soil aggregates as well as uninterrupted macropores leading from the soil surface straight to the subsoil and allowing fast water infiltration in case of heavy rain events. This process carried out by the edaphon, the living component of a soil, can be called “biological tillage”. However, biological tillage is not compatible with mechanical tillage and with increased mechanical tillage the biological soil structuring processes will disappear.

Engaging in agriculture with reduced mechanical tillage is only possible when soil organisms are taking over the task of tilling the soil. This, however, leads to other implications regarding the use of chemical farm inputs. Synthetic pesticides and mineral fertilizer have to be used in a way that does not harm soil life. As the main objective of agriculture is the production of crops, changes in the management of pests and weeds becomes necessary.

Burning of plant residues and ploughing of the soil is mainly considered necessary for phytosanitary reasons, i.e. to control pests, diseases and weeds. In a system with reduced mechanical tillage based on mulch cover and biological tillage, alternative methods have to be developed and used to control pests and weeds. One important way to achieve this is crop rotation, interrupting the infection chain between subsequent crops and making full use of the physical and chemical interactions between different plant species. Synthetic chemical pesticides, particularly herbicides, are for some minimum/zero tillage systems inevitable in the first years. However they have to be used with very much care to reduce the negative impacts on soil life.

Practise Good Weed Control

All plants take up water from the soil through their roots, and this water is later released through very small holes in the leaves into the air. The loss of water from plants’ leaves is known as “transpiration” and is an important process in growing plants.

This can be demonstrated during an ISNM FFS session by selecting a tall weed or clump of weeds that are growing in a moist soil, completely within the shade and enclosing the weed or clump of weeds with a plastic bag, tying the bag to the stems of the weed(s) so that the drops of water released by transpiration do not escape. Before tying the bag onto the weeds it is important to show the participants that the bag is completely dry. After 10-15 minutes, the bag can be removed and shown to the participants when they should be able to observe a quantity of water droplets in the bag.

Installation of Windbreaks to Reduce Soil-Water Losses

The installation of windbreaks will prevent the excessive use of soil moisture by crops through reducing wind velocity, in addition to reducing wind erosion. As wind velocity increases crops transpire more water. Strong winds cause excessive transpiration and the soil dries out more quickly. Consequently crops will suffer from moisture stress earlier than if there had been no strong winds and the crops had transpired at normal rates. The rapid loss of water by transpiration from crops in windy conditions is similar to the effect of wind on washing. Clothes hung out to dry will dry far more quickly in a windy position than in a protected situation.

During an ISNM FFS discussion should be initiated on the effect of windbreaks on crop water use and hence on the drying out of soils (based on the comparison with the rate of drying of clothes in protected and unprotected positions). Windbreaks can delay the onset of moisture stress in crops. The advantages, disadvantages and feasibility of establishing windbreaks should be discussed, as well as the soil types (e.g. droughty soils in particular) and crops or cropping periods which would most benefit from wind breaks.

In areas where wind erosion is problem it should be possible, during a ISNM FFS transect walk (Exercise 2, annex 1) to observe differences in wind erosion damage between land that is protected by a windbreak and land that is exposed. Conducting field visits when a strong wind is blowing and the topsoil is dry, would enable the participants to see for themselves the effect of wind protection on reducing wind erosion. Any discussion on wind erosion should emphasize the importance of direct sowing (zero tillage) and leaving crop residues on the surface, in soils susceptible to wind erosion, in addition to the need for windbreaks.

ISNM Principles Related to the Supply of Oxygen

Construction of Raised Beds to Reduce Waterlogging

Both human beings and plants require oxygen, and that whereas human beings breathe through their noses and mouths, so most plants “breathe” through their roots. Although some plants (notably irrigated rice, sedges and some grasses) take oxygen in through the leaves and transport it to the roots via the stems. To avoid confusion these exceptions need only be mentioned in an ISNM FFS if the subject is raised by the participants. Because human beings need oxygen to breathe we cannot stay under water for a long time. Just as a person cannot survive submerged in a river with his nose and mouth beneath the water, so most crops (with the exception of irrigated rice and some grasses) cannot survive with their roots submerged in water, except for short periods.

Waterlogging in the rooting zone of a crop drastically reduces root development because of a reduction in oxygen supply. The depth and duration of waterlogging may be reduced by the construction of raised beds, the installation of drainage ditches, or by diverting the sources of incoming runoff. Sowing on raised beds or ridges elevates a crops’ roots above the water table, allows greater oxygen supply to the crop’s roots and better root development. Comparison can be made of roots developed in waterlogged soil and those developed in drained soils.

When the construction of raised beds is considered to be a possible solution to the problem of inadequate oxygen supplies in an area, the practice should be one of those tested in the course of an ISNM FFS. Alternative practices that can create rooting zones free from waterlogging like implementing drainage ditches and diversion canals should be discussed and considered. Specialized knowledge would be needed to assist in the selection and design of appropriate drainage systems.

Application of Amendments to Sodic Soils

In soils with high sodium contents (sodic soils), the sodium produces an impermeable structure that is waterlogged during wet periods with a lack of oxygen. Application of chemical amendments to sodic soils, followed by leaching, will improve soil structural conditions leading to increased permeability, a greater supply of oxygen to plant roots, and higher yields. The type and quantity of amendment to be applied will depend on the degree of saturation of the soil with sodium, soil texture, the presence or absence of calcium carbonates, and the cost of locally available amendments.

The most common procedures used to reclaim sodic soils are:

- application of gypsum followed by leaching;
- application of sulphur (when free calcium carbonate is present) followed by leaching;
- sowing sodium tolerant crops such as irrigated rice plus the application of green manures and organic manures (when free calcium carbonate is present) - which is a low cost, slow-acting procedure.

Soil chemical analysis and expert advice based on experience from field trials will be necessary to determine the most appropriate reclamation practice for sodic soils.

Should there be a problem of sodic soils in the community where the FFS is located then a visit should be organized to an area where there has been a successful reclamation of sodic soils that are chemically similar. The farmers who implemented the reclamation should be asked to explain the procedure, the costs, the time involved (i.e. number of cropping seasons), and the benefits they have achieved. The ISNM FFS participants should be encouraged to ask questions, and to verify that the procedure would be feasible for their own situation.

Deep Till to Loosen Impermeable Soil Layers (see also the earlier section on *loosen root-restricting dense subsoil layers*)

Dense impermeable layers restrict water percolation and so inhibit the supply of oxygen to plant roots. By loosening this layer, rainwater percolation to deeper horizons is encouraged, oxygen enters the rooting zone and deeper rooting is enhanced.

The effects of loosening impermeable soil layers through deep tillage can be assessed by means of comparative ISNM FFS field trials. Such trials should be considered in areas where dense subsoil layers are a major problem. In the course of conducting such trials some of the observations should take place just after a heavy rainstorm, when it would be expected that the soil in the dense layer would be saturated in the untreated (control) area, but better drained in the treated plot due to percolation of the excess water into deeper layers allowing the entry of oxygen into the soil. Depth of rooting would also be expected to be greater in the treated plot compared to the control area.

At harvest time visual comparisons should be made of the yields of the treated and control areas. If the treated area is sufficiently large the yields may be harvested from the two areas and compared. The effect of deep loosening can be evaluated by comparing data from the two plots, with regard to the degree of waterlogging in the dense layer, the depth of rooting and crop yield.

ISNM Principles Related to Site Stability

Maximize plant and residue cover

It is usually mechanized farmers who face the most serious problems of wind erosion, notably when the soil is dry, strong winds are common, and when few crop residues remain on the land after the harvest. A good ground cover with crops or crop residues reduces wind velocity close to the soil surface and so reduces wind erosion. Ploughing and harrowing the strip of land parallel to the direction of the wind will almost certainly result, if a strong wind is present, in noticeable wind erosion from the bare land that is being harrowed, whereas no significant wind erosion should be evident on the land covered by crop residues.

Establishment of deep rooting tree crops

Mass movements refer to landslides and mudflows, i.e. the movement of land in mass. Mudflows are similar to landslides but instead of the land moving as a solid mass, the land flows as though it were almost a liquid. Saturating a soil with water leads to a rapid loss of its stability and the soil quickly becomes fluid. Landslides and mudflows most frequently occur during very heavy rains which saturate the soils.

Trees and all other plants take up water from the soil through their roots, and then release this to the air by transpiration through very small holes in their leaves. Deep-rooting tree crops in the farming system will reduce soil moisture by the absorption and transpiration of water, which will reduce the risks of mass movements and so physically stabilize soils. Trees which contain many more leaves than weeds, will absorb far more water than weeds from the soil and release it into the air. It is possible to prevent soils from becoming saturated, so that they become less susceptible to landslides and mudflow, not only by planting trees with deep roots that absorb large quantities of water from the soil, but also by not cutting the trees down in the first place.

The effect of water saturation of a soil can be illustrated, in an ISNM FFS, by giving each participant a small sample of dry soil from the subsoil of a soil known to be very susceptible to landslides or mudflows. The participants should be requested to add a little water to the dry soil and to mould it between the fingers and the thumb as if they were determining the texture of the soil. They should observe the effort needed to mould the moist soil. A greater quantity of water should then be added to another sample of dry soil and again moulded between fingers and thumb, with it being noted how much easier it is to mould the soil. Even more water should be added to another sample of soil, until the soil can be observed to become very mobile as though it could flow.

Annex 2, Appendix 1

Nutrients removal in crop harvests

Crop	Yield (t/ha)	Nutrient Removal (kg/ha)				
		N	P*	K*	Ca*	Mg*
Maize grain	1	25	6	15	3	2
	4	63	12	30	8	6
	7	128	20	37	14	11
Rice grain	1.5	35	7	10	1.4	0.3
	8	106	32	20	4	1
Wheat grain	0.6	12	2.4	3	0.3	1.0
	5	80	22	20	2.5	8
Sorghum grain	1	20	0.9	4	4	2.4
	8	65	4	13	18	12.8
Finger millet grain	1.1	17	5	59	-	-
Cassava roots	8	30	10	50	20	10
	16	64	21	100	41	21
	30	120	40	187	77	40
Sweet potato roots	16.5	72	8	88	-	-
Beans	1	31	3.5	6.6		
Soybeans	1	49	7.2	21	-	-
Peanuts (unhulled)	1	49	5.2	27	-	-
Sugarcane (2 year crop)	100	75	20	125	28	10
	200	149	29	316	55	58
	300	254	35	499	96	80
Rubber dry latex	3	7	1.2	4	4	-
Coffee dry beans	1	25	1.7	16	1	2
Tea dry leaf	0.6	31	2.3	15	2	-
Tobacco cured leaf	1	116	14	202	-	-
Cacao dry beans	0.5	10	2.2	5	1	1
Coconut dry copra	1.2	60	7.2	40	-	-
Oil palm fruits	15	90	8.8	112	28	-
Cotton seed	0.8	30	4.4	7	-	-
Banana bunches	10	19	2	54	23	30
	30	56	6	161	70	82
Pineapple fruits	12.5	9	2.3	29	3	-
Guinea grass (annual production from 6 cuts)	10	107	27	180	78	49
	23	288	44	363	149	99
	35	560	77	600	230	133

* To convert from P to P₂O₅ multiply by 2.29; to convert from K to K₂O multiply by 1.2; to convert from Ca to CaO multiply by 1.4; to convert from Mg to MgO multiply by 1.66.

Annex 2, Appendix 2

Comprehensive list of field indicators of soil and nutrient problems

<i>Crop indicators</i>	Inadequate soil functioning
Low or declining yield	Various
Low germination	Various
Stunted growth	Various
Non-uniform growth	Various
Nutrient deficiency symptoms	Nutrients
Nutrient toxicity symptoms	Toxic substances
Wilting	Water

<i>Site Indicators</i>	Inadequate soil functioning
Bare patches	Salt toxicity
Water erosion	Nutrients
Weeds	Nutrients, Oxygen, Toxic substances
Surface ponding	Oxygen
Gully erosion	Site stability
Wind erosion	Site stability
Landslides	Site stability
Flooding	Site stability

<i>Soil morphological indicators</i>	Inadequate soil functioning
Lack of surface residues	Water, Biological activity
Surface salts	Salt toxicity
Dark slippery surface & cracks	Oxygen, Sodium toxicity
Surface rusty mottles & oily films	Iron toxicity
Hard surface layer	Strength, Oxygen
Gravelly-stoney surface	Strength
Cloddy topsoil structure	Strength, Germination
Surface crusting	Strength, Water
Surface sealing	Water
Low soil organic matter	Biological Activity, Water
Restricted rooting	Strength, Nutrients, Toxicities, Water
Dense layers of high resistance & low porosity	Strength
Subsoil salt deposits	Salt toxicity
Light textured subsoil	Water, Nutrients
Very stony subsoil	Water, Nutrients
Shallow soil profile	Water
Poor drainage mottling (depth)	Oxygen

Annex 2, Appendix 3

Nutrient toxicity foliar symptoms

Iron: Iron toxicity usually occurs only in irrigated rice. The foliar symptoms first appear on lower leaves as small brown spots starting near the tips and spreading towards the base. The spots coalesce on interveinal areas, otherwise leaf colour normally remains green. In severe cases the entire leaf turns purplish-brown, and eventually the lower leaves die. Some rice varieties also turn yellow.

Manganese: The most prominent symptom is raised interveinal areas giving a puckered appearance and brown speckling of the older leaves. In irrigated rice brown spots develop on the veins of the leaf blade and sheath, especially on lower leaves. The plant is stunted and tillering is often limited.

Copper: Toxicity symptoms resemble iron deficiency symptoms, i.e. interveinal areas of youngest leaves turn yellow to almost white, but the points and margins retain their green colour longest.

Boron: In irrigated rice chlorosis (loss of green colour) takes place at the tips of the older leaves, especially along the margins, followed by the appearance of large, dark-brown elliptical spots in the affected parts which ultimately turn brown and dry up. *Note:* the margin between boron deficiency and toxicity is narrow.

Aluminium: The most obvious symptom is the formation of swollen, stunted and crooked roots, which may turn brown with black necrotic spots, and with few fine feeder roots. Aluminium toxicity may appear as manganese or iron toxicity or as calcium or magnesium deficiency. In irrigated rice orange-yellow colours develop in the interveinal leaf areas.

High salt injury: In irrigated rice the tips of the leaves become whitish and, frequently, some parts of the leaves also lose their green colour.

Annex 2, Appendix 4

Procedure for taking soil samples

The procedure for sampling soils for analysis should only be introduced to farmers who have access to laboratory facilities and can afford to pay for analyses, or to those with access to soil testing kits for use in the field.

Sometimes it is necessary to take more than one soil sample from a field if the soil conditions, crop performance or management history are markedly different in one part of the field to another. However, the separate areas must be sufficiently large to warrant managing them in different ways, e.g. applying different types or amounts of fertilizers. In general it is not worthwhile dividing fields into areas less than 0.5 ha for small-scale non-mechanized farmers, or into areas less than 5 ha for mechanized farmers. The farmer will normally know if marked differences in soil type or crop yield occur in his field, and whether the areas are sufficiently large to warrant managing them in different ways.

For areas that have not been previously cropped, fields may be divided on the basis of marked differences in topography (e.g. low lying and higher lying areas), colour (e.g. dark, light or red coloured soils), texture (e.g. light and heavy textured soils), drainage (e.g. well and poorly drained soils), cropping history (e.g. with legumes and non-legumes), or management history (e.g. with and without manure/fertilizer applications). Present Figure 1 as an example of how to subdivide a variable field into two areas for sampling.

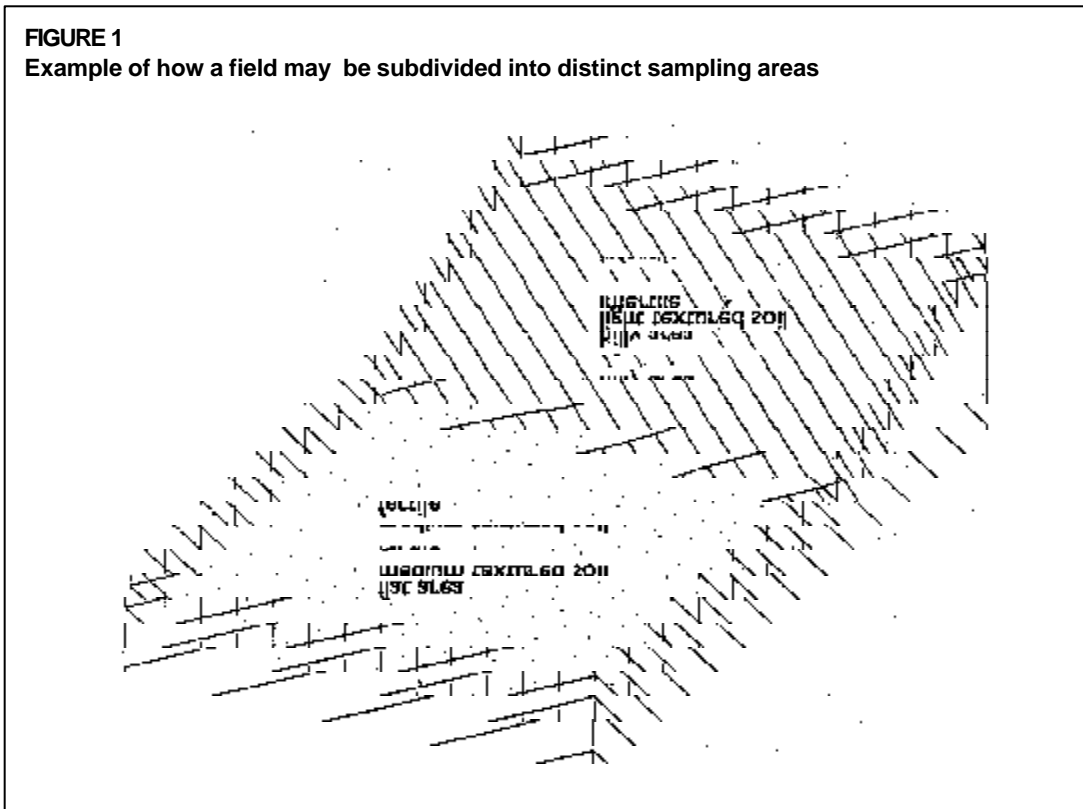


FIGURE 2
Taking soil samples using a soil sampler

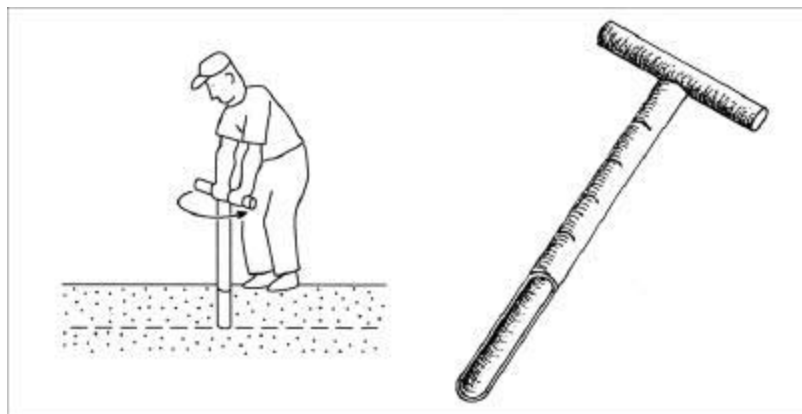
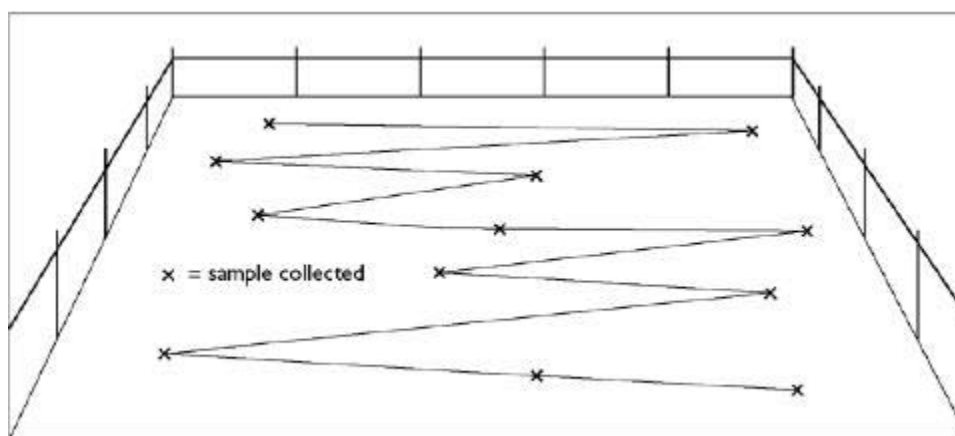


FIGURE 3
Illustration of how to collect subsamples in a zig-zag route



Since soils frequently vary considerably over short distances, even in a field that appears to be uniform, 15 subsamples taken from different locations in the field should be combined and thoroughly mixed to form a representative sample. Soil samples may be taken with a soil sampler, spade, hoe, trowel or auger. The use of a soil sampler is the best method, followed by a straight-sided spade.

If the soil is sampled using a soil sampler as shown in Figure 2, press the sampler into the soil to the required depth, give the sampler a half turn, then withdraw the sampler and transfer the soil sample into a bucket. The same procedure can be followed using a trowel, knife or machete, but great care must be taken to ensure that the subsamples are as wide at the soil surface as at the lower sampling depth.

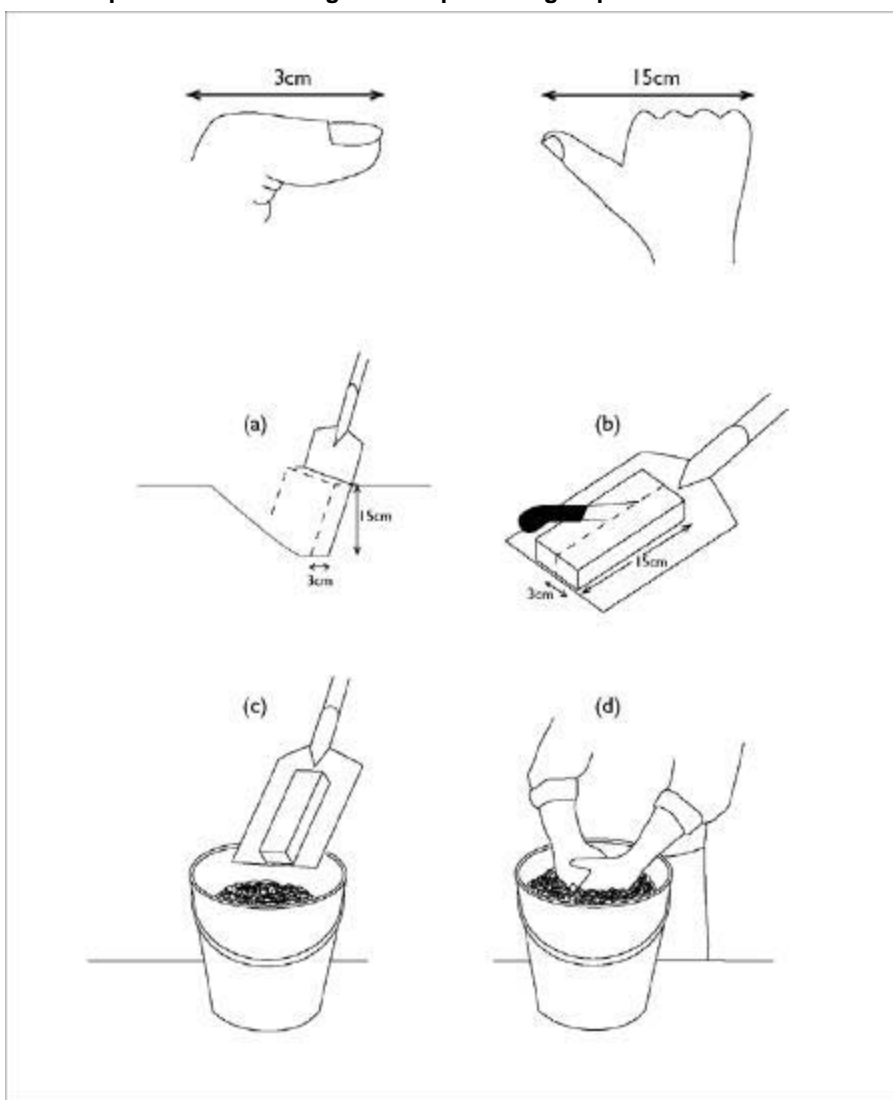
Procedure :

- Decide whether it is necessary and worthwhile to divide the field into two or more sampling areas.
- For each area to be sampled, subsamples should be taken from 15 points that are well distributed throughout the area, avoiding “exceptional” sites such as termite mounds, small

poorly drained patches, and accumulations of manures, ashes or crop residues. Demonstrate how to take samples by zigzagging across the field from one end to the other and taking a total of 15 subsamples uniformly distributed across the field (Figure 3).

- The recommended depth, which is generally 15 or 20 cm for annual crops, varies from country to country, and will depend on the depth of humic topsoil, depth of tillage, topsoil moisture content and the ease of rooting in the subsoil.
- Figure 4 demonstrates how to sample the soil to a depth of 15cm using a spade or hoe. Make an opening in the soil surface in the shape of a “V” of 15cm depth, then remove a slice of soil of 3cm thickness from one side of the “V” with the spade.
- Remove the soil from the outside of the slice so that a central slice of 3cm width remains on the spade as shown in Figure 4b. Transfer this remnant slice of soil to a bucket (Figure 4c). Field methods of estimating 15 cm and 3 cm using the hand are also shown in Figure 4.

FIGURE 4
Recommended procedure for taking soil samples using a spade



- Proceed in a zig zag manner across the field and collect additional soil samples in the same way until a total of 15 subsamples have been collected, mix them thoroughly in the bucket to obtain a uniform combined sample (Figure 4d), and then remove a sample of about 0.5kg and transfer it into a plastic or cloth bag, carton or tin container.
- Place a label in the container with the soil sample indicating the name and address of the farmer, the name or number of the field, the depth of sampling and the date.
- The soil samples may be sent to a Soils Laboratory for analysis, or may be analysed immediately in the field if a soil testing kit is available. Demonstrate the use of the soil testing kit to the participants, explain the significance of the values obtained, and how to convert them into fertilizer recommendations. No details are given here, as the use of soil testing kits and the interpretation of the values obtained will depend on the type of kit and the local fertilizer recommendations.

Annex 2, Appendix 5

Checklist of possible solutions for soil and nutrient problems

Problem	Cause	Possible Solutions
A. Low soil fertility	i) Nutrient deficiencies or imbalances	Inorganic fertilizers Fertilizer placement Split fertilizer applications Opportune timing of fertilizer application Non-acidifying fertilizers increase nutrient availability Inorganic foliar fertilization Rock phosphates FYM Composts Guano Addition of crop residues or forest litter Incorporation of green manures Legume rotations ¹ Legume intercropping Fallows Enriched fallows
	ii) Low nutrient retention capacity	Split applications of inorganic fertilizers Organic manures Composts Incorporation of plant biomass Leave crop residues and zero tillage ² Cover crop fallows
	iii) High leaching losses of nutrients	Deep rooting perennial crops Alley cropping Dispersed trees in annual crops Dispersed trees in pastures Tree-enriched fallows
	iv) Erosion of topsoil	Leave crop residues Zero tillage Mulches Higher plant density Cover crops Covered beans Intercropping

¹ Legume inoculation may be necessary.

² Controlled grazing of residues, live fences, hay or silage production, improved pasture species and better management of existing pastures may be required to enable the residues to be left in the field.

Problem	Cause	Possible Solutions
		Sequential and relay cropping Weed control with herbicides Controlled grazing Trash lines Vegetative cross-slope barriers Contour sowing, tillage and weeding Minimum tillage Strip tillage Tillage to break up surface crusts Tillage at the end of the rains Deep till to loosen impermeable layers Stone lines Stone bunds Fanya juu terraces Bench, orchard and platform terraces Diversion canals
B. Low crop productivity	i) Low crop yields	Improved varieties Crop diversification
	ii) Extensive use of land	Higher plant populations ³ Intercropping Sequential and relay cropping Alley cropping Kitchen gardens
	iii) Poor quality seed	Improved seed selection Seed treatment
	iv) Weeds	Herbicides Semi-botanical herbicides Integrated weed management Crop rotations Spreading crops such as <i>Cucurbitaceae</i> Cover crops
	v) Pests or diseases	Integrated pest management Inorganic pesticides Natural pesticides Insect traps Insect-repellent crops Crop rotations
	vi) Adverse micro-climate	Shade trees Wind breaks See I iii and iv
	vii) Low fertility	See A
C. Presence of toxic substances	i) Aluminium or Manganese toxicity	Acid-tolerant species Acid-tolerant varieties Lime or dolomitic limestone Gypsum application Gypsum and lime application
	ii) Iron toxicity	Drainage

3 Fertilizers or manures may also be required.

Problem	Cause	Possible Solutions
	iii) Salinity	Leaching Drainage
	iv) Sodium	Gypsum application Leaching
D. Insufficient supply & retention of water	i) Low infiltration	Leave crop residues and zero tillage Mulches Cover crops Leave stones on soil surface Trash lines Vegetative cross-slope barriers Contour sowing, tillage and weeding Strip tillage Minimum tillage Deep till to loosen impermeable layers Furrows with raised beds or ridges Tied ridges Stone lines Stone bunds Infiltration ditches Infiltration pits <u>Bench, orchard or platform terraces</u>
	ii) Strong winds	<u>Wind breaks</u>
	iii) High evaporation	Leave crop residues and zero tillage Mulches
	iv) Low ability of soil to retain water	Incorporation of organic manures Incorporation of cover crops Moisture-conserving fallows <u>Sprinkler or drip irrigation</u>
	v) Low or erratic rainfall	Drought resistant crops or varieties Moisture-conserving fallows Water harvesting Strip cropping with runoff areas Cropping within half-moon bunds or pits Water collection from roofs <u>Irrigation systems</u>
	vi) Restricted rooting	Loosen dense layers with deep tillage Add amendments to neutralize toxicities Fertilize to correct nutrient deficiencies <u>Drainage ditches to lower water table</u>
E. Insufficient supply of oxygen	i) Accumulation of runoff	Diversion canals <u>Safe discharge outlets</u>
	ii) High water table or impermeable soil layers	Raised beds and cambered beds Ridges Subsoiling Graded furrows Drainage ditches <u>Safe discharge outlets</u>

Problem	Cause	Possible Solution
F. Low biological activity	i) Lack of residues and soil organic matter	Leave crop residues and zero tillage Mulches Cover crops Organic manures Crops or varieties producing large quantities of slowly decomposing residues Higher plant populations
	ii) "Tired" soils	Crop rotations Rotations with pastures Organic manures and composts
	iii) Toxic pesticides	Natural pesticides Insect-repellent crops Insect traps Integrated pest management Integrated weed management
G. Site instability	i) Water erosion caused by runoff	Leave crop residues and zero tillage Leave stones on soil surface Cover crops Mulches Controlled grazing Vegetative cross-slope barriers Stone barriers Earth contour bunds Graded hillside ditches Roadside trenches Diversion canals Safe discharge outlets Bench terraces Orchard terraces Individual platform terraces
	ii) Wind erosion.	Leave crop residues and zero tillage Harvest crops well above ground level Mulches Cover crops Intercropping Sequential and relay cropping Higher plant populations Ridges and furrows Wind breaks
	iii) Mass movements	Tree crops Diversion canals
	iv) Flooding	Diversion canals Safe discharge outlets

4 Additional fertilizers may be required.

5 Fences, live fences, troughs and ponds may also be needed.

Problem	Causes	Possible Solutions
H. Restricted root growth	i) Excessive soil strength due to dense layers	Subsoiling (for recuperation) Vertical tillage with tined implements Periodic deep tillage Controlled traffic Biological "tillage" with tap-rooted crops
	ii) Lack of oxygen	See E
	iii) Lack of phosphorus	Phosphate fertilizers Rock phosphates Liming to reduce acidity
	iv) Toxic substances	See C
I. Poor seed germination	i) Lack of moisture	Leave crop residues and zero tillage Mulches Deep placement of seeds in dry conditions
	ii) Lack of oxygen	Raised or cambered beds Drainage ditches Diversion canals Safe discharge outlets Subsoiling Land levelling
	iii) Excessive temperatures	Leave crop residues and zero tillage Mulches
	iv) Very low temperatures	Ridge tillage Raised beds Wind breaks Drainage ditches Absence of residues
	v) Cloddy structure	Strip tillage Disc tillage Organic manures Rotations with grass fallows
J. Poor emergence	i) Excessive soil strength due to crusting	Leave crop residues and zero tillage Plant into cover crop residues Mulches Organic manures Plant on ridges Higher sowing density Shallower depth of seeding
	ii) Excessive soil strength due to dense topsoils	Vertical tillage with tined implements Organic manures Incorporate cover crops

Problem	Cause	Possible Solutions
K. High production costs	i) High labour costs	Manual seeders-fertilizers Animal-traction seeders-fertilizers
	ii) High machinery costs	Manual no-tillage Animal-traction tillage
	iii) High pesticide costs	Integrated weed management Systemic herbicides Crop rotations Cover crops Integrated pest management Natural pesticides Insect-repellent crops Insect traps Bulk pesticide purchases
	iv) High fertilizer costs	Legume rotations Organic manures Composts Economic applications of fertilizers Split applications Fertilizer placement Opportune timing of application Rock phosphates Bulk purchases
	v) High credit cost	Formation of communal banks
L. Low profits	i) Lack of diversification	Crop and livestock diversification Economic data for different enterprises Marketing information Credit access Improved availability of seeds and plants Farm planning
	ii) Low prices	Bulk sales through farmer organizations Silos to delay time of sale Farm processing to increase value
M. Environmental pollution	i) Toxic pesticides	Natural pesticides Integrated pest management Insect-repellent crops Insect traps Crop rotations Integrated weed management Monitoring of soil and water quality
	ii) Fertilizer contamination of waters	Split fertilizer applications Economic application rates Fertilizer placement Legumes to reduce N fertilizers Greater use of organic manures Greater use of compost Monitoring of water quality
	iii) Sediment contamination of water	See G i). Monitoring of water quality

Annex 2, Appendix 6

Nutrient contents of manures, crop residues, agricultural wastes and plant material

Source	Amount produced	Nutrient content (kg)		
		N	P	K
Manures				
Cattle manure (1)	6 t/animal (l.u.)/yr	36	8	30
Poultry manure (1)	1 t/40 broilers/yr	23	9	10
Pig manure (1)	3 t/animal/yr	15	5	13
Guano (6)	1 t	10	5	
Crop residues				
Maize stover (2)	3 t/ha	30	6	36
Rice straw (2)	1.5 t/ha	7	1	18
Wheat straw (2)	1 t/ha	3	0.8	14
Sorghum stover (2)	1.2 t/ha	6	0.4	2
Cotton stalks (4)	1 t/ha	13	3	23
Rural compost (3)	1 t	7	1	4
Agricultural wastes				
	(1 t)			
Sugarcane filter mud (4)		12	10	3
Sugarcane factory ash (4)		1	3	19
Coffee pulp (3)		15	1	30
Coconut oil cake (3)		31	8	14
Groundnut oil cake (3)		45	7	12
Groundnut shells (4)		10	1	9
Wood ash (4)		-	6	40
Cottonseed meal (4)		75	11	12
Plant materials				
Kudzu green manure (5)	8 t	60	4	33
Guineagrass green manure (5)	8 t	20	5	29
Cassia hirsuta (7)	1 t	29.8	1.8	12.8
<i>Lantana camara</i> (7)	1 t	26.9	1.6	8.7
Nutrients required by 3 t/ha maize		72	16	45

(1) FAO, 1987; (2) Sanchez, 1976; (4) Songambe, 1982; (3) FAO, 1995; (4) FAO, 1980; (5) Wade and Sanchez, 1983; (6) Cooke, 1982; (7) Kayizzi, 1998.

Annex 2, Appendix 7

Estimates of nitrogen fixation by legumes

Crop	Nitrogen fixed (kg N/ha)
<i>Glycine max</i> (soybean)	64-206
<i>Vigna unguiculata</i> (cowpea)	73-240
<i>Vigna radiata</i> (mung bean)	61-342
<i>Arachis hypogaea</i> (groundnut)	72-240
<i>Cajanus cajan</i> (pigeon pea)	96-280
<i>Cicer arietenum</i> (chickpea)	103
<i>Canavalia ensiformis</i>	49
<i>Cyamopsis tetragonolobus</i> (guar)	41-220
<i>Lens culinaris</i> (lentil)	88-114
<i>Pisum sativum</i> (pea)	52-77
<i>Vicia faba</i>	45-552
<i>Calopogonium muconoides</i>	370-450

(FAO, 1980).

Annex 2, Appendix 8

Soil requirements of crops, pastures and trees

Species	Max. slope (%)	Opt/Min depth (cm)	Opt/Min fertility ¹	Opt/Tolerable drainage ²	Opt/Tolerable texture ³
Basic grains					
Rice (dryland)	50	>50/20	H/M	W/P,I	H/M
Rice (flooded)	0.1	>50/20	H/M	VP-P/I	H-MH/M
Beans	50	>50/20	M/L	W/W	M/H,L
Maize	50	>50/20	H/L	W/W	M/H,L
Annual crops					
Groundnuts	20	>50/50	H/M	W/W	M/L,H
Tobacco	20	>150/50	M/M	W/W	L,M/H
Cowpea	50	>50/20	M/L	W/W	M/H,L
Tubers					
Sweet potato	20	>50/20	H/L	W/W	M/L
Cassava	20	>50/50	M/L	W/W	L,M/ML
Fruit trees					
Avocado	60	>150/50	H/M	W/W	L,M,H
Coconut	50	>150/50	M/L	W/W	M,L,ML
Guava	60	>50/20	H/L	W/P,I	L,M/H
Lime	60	>50/50	M/L	W/W	L,M/H
Lemon	60	>50/50	H/M	W/W	L,M/H
Mandarin	60	>150/50	H/M	W/P,I	L,M/H
Mango	60	>150/50	M/L	W/W	L,M/H
Cashew nut	60	>150/50	M/L	W/W	L,M/H
Bananas		>150/50	H/M	W/W	M/H,L
Orange	60	>150/50	M/L	W/W	L,M/H
Papaya	60	<150/50	H/M	W/W	M/L,H
Pineapple		>50/20	M/M	W/W	L,M/H
Grapefruit	60	>150/50	H/M	W/W	L,M/H
Other perennial crops					
Arabica coffee	60	>150/50	H/M	W/W	M/L,M
Sugarcane	15	>50/50	M/L	W/I	M,H/M,H
Pigeon pea	50	>150/50	M/L	W/W	L,M/H
Sisal	50	>50/20	M/L	W/W	L/L

Species	Max. slope (%)	Opt/Min depth (cm)	Opt/Min fertility ¹	Opt/Tolerable drainage ²	Opt/Tolerable texture ³
Horticultural crops					
Pumpkin	10	>150/20	H/L	W/W	M/L,H
Onion	10	>50/20	M/L	W/W	M/L
Cucumber	10	>50/20	H/H-M	W/W	M/L,H
Beetroot	10	>50/20	H/M	W/W	M,L,H
Cabbage	10	>20/20	H/M	W/W	M,L,H
Watermelon	10	>150/50	H/L	W/W	M/L,H
Tomato	10	>20/20	H/M	W/W	M/L,H
Carrot	10	>50/50	M/M	W/W	M/L,H
Improved Pastures					
Brachiaria decumbens	50	>20/20	M/M-L	W/W	L,M,H
Star grass (Cynodon plectostachyum)	50	>50/20	H/M	W,P,I	L,M,H
Stylosanthes guianensis	50	>150/50	L/L	W/W	L,M/L,M
Forage trees					
Leucaena leucocephala	60	>150/20	M/L	W/W	M,H/L
Mulberry (Morus nigra)	60	>50/20??	H/M	W/W	L,M,H
Timber trees					
Acacia mangium	70	20??	M/?	P,I,W	L,M/?
Eucalyptus camaldulensis	70	>50/50	M/L	P,I,W	L,M/H
Grevillea robusta	70	>150/50	H/L	W/W	L,M/L,M

(FAO, 1994).

¹ H= High; M= Moderate; L= Low.

² W= Well; I= Imperfectly; P= Poorly; VP= Very poorly.

³ H= Heavy; MH= Moderately heavy; M= Medium; L= Light.

Annex 2, Appendix 9

Critical periods for soil water stress for different crops

Crop	Critical periods
Alfalfa	Just after cutting for hay and at the start of flowering for seed production
Apricots	Flowering and bud development
Barley	Early boot stage > soft dough stage > onset of tillering or ripening stage
Beans	Flowering and pod setting period > earlier stage > ripening period. However, ripening period > earlier stage if not prior water stress.
Broccoli	During head formation and enlargement
Cabbage	During head formation and enlargement
Castor bean	Relatively high soil water level during full growing period
Cauliflower	Requires frequent irrigation from planting to harvesting
Cherries	Period of rapid growth of fruit prior to maturing
Citrus	Flowering and fruit setting stages: heavy flowering may be induced by withholding irrigation just before flowering stage (lemon).
Cotton	Flowering and boll formation > early stages of growth > after boll formation
Groundnuts	Flowering and seed development > between germination and flowering and end of growing season
Lettuce	Requires wet soil particularly before harvest
Maize	Pollination period from tasselling to blister kernel stages > prior to tasselling > grain filling periods; pollination period very critical if no prior water stress
Oats	Beginning of ear emergence possibly up to heading
Olives	Just before flowering and during fruit enlargement
Peaches	Period of rapid fruit growth prior to maturity
Peas	Start of flowering and when pods are swelling
Potatoes	High soil water levels; after formation of tubers > blossom to harvest
Radish	During root enlargement
Sunflower	Possibly during seeding and flowering - seed development stage
Small grains	Boot to heading stage
Sorghum	Secondary rooting and tillering to boot stage > heading, flowering and grain formation > grain filling period
Soybeans	Flowering and fruiting stage and possibly period of max. vegetative growth
Strawberries	Fruit development to ripening
Sugarcane	Period of maximum vegetative growth
Tobacco	Knee high to blossoming
Tomatoes	When flowers are formed and fruits are rapidly enlarging
Water melon	Blossom to harvesting
Wheat	Possibly during booting and heading and two weeks before pollination

(FAO, 1977).

Annex 2, Appendix 10

Example of a set of recommended soil conservation and management practices from El Salvador, Central America

Crop	Slope	Land management practices with emphasis on soil conservation
Horticultural crops	0-5%	Mulching, Contour planting, Strip cropping.
	5-10%	Mulching, Contour planting, Strip cropping, Contour bedding, Stone barriers, Bench terraces.
	>10%	Horticultural crops not recommended, but if it is inevitable, apply the practices given for slopes of 5-10%.
Grain crops	0-10%	No residue burning, Leave residues, No-tillage, Contour sowing, Controlled grazing, Contour live fences, Intercropped legumes.
	10-50%	No residue burning, Leave residues, No-tillage, Contour sowing, Controlled grazing, Contour live fences, Intercropped legumes, Live barriers, (Hillside ditches)
	>50%	Grain crops not recommended, but if they are inevitable, apply the practices given for slopes of 10-50%.
Fruit trees	0-10%	Mulching, Leguminous cover crops, Contour live fences.
	10-60%	Mulching, Leguminous cover crops, Contour live fences, Live barriers, Individual platform terraces, (Hillside ditches)?
	>60%	Fruit trees not recommended, but if they are inevitable, apply the practices given for slopes of 10-60%.

Note: Structural practices are only recommended if agronomic and vegetative practices cannot solve the erosion problem.

Lands subjected to runoff from steep slopes and roads will require interception canals for protection.

Annex 3

Supporting reference material on soil and water conservation for farmer field schools

As indicated earlier there is more to integrated soil and nutrient management than just meeting the nutritional needs of plants. The previous annex contains supporting reference material on the underlying principles, and the practice, of a wide range of integrated soil and nutrient management practices. This annex likewise provides supporting reference material, but concentrates specifically on providing details on the principles and practice of soil and water conservation. Although covered separately, soil and water conservation is an integral part of integrated soil and nutrient management.

BASIC CONCEPTS

An ISNM FFS would need to introduce to farmers the basic concepts of “soil erosion”, “erosion control”, “land degradation”, “soil and water conservation” and “watershed/catchment concept” as well as some related terms.

Soil Erosion

Soil erosion means the processes by which soil is removed from one place by forces such as wind, water, waves, glaciers, and human activities (construction and farming) and eventually deposited at some new place (Choudhury and Jansen 1997).

Soil aggregates can gradually break down into smaller particles. If this happens on sloping land these particles may be transported down the slope. The water which runs from a slope during a heavy rain is called runoff. Factors which affect soil erosion caused by water are the rainfall pattern, slope steepness (gradient), slope length, soil type, existing erosion control structures, cropping practices and time (see Box 1). The stronger the rain and the steeper the slope, the more and the faster water erosion occurs.

Erosion caused by wind may also happen on level land and additionally it depends on the strength of the occurring winds.

In contrast to natural erosion which happens slowly, human-induced erosion can happen fast with large amounts of soil being removed. If this happens, it can be a serious threat to agricultural production and the environment. Erosion always has on-site effects, i.e. consequences at the place from where the soil is removed and off-site effects, i.e. consequences at places which are affected by the transport of eroded soil or where the removed soil is deposited (see Box 2).

Erosion Control

Direct erosion control involves measures which aim at stopping or slowing down erosion processes. In the case of soil erosion caused by water it is based on the following principles:

BOX 1: Factors affecting soil erosion by water

- **Rainfall pattern:** The more rainfall and the higher the “force” of the rain (called the intensity, i.e. the amount of rain which falls per minute), the more erosion will occur.
- **Slope steepness:** The steeper the field, the higher the erosion risk.
- **Slope length:** Erosion increases with slope length.
- **Soil type:** Clayey soils show in general more resistance to erosion than sandy soils.
- **Erosion control structures:** Well-established and well-maintained erosion control structures can be very effective. But when such structures are poorly established or poorly maintained it is possible that they accelerate erosion.
- **Cropping practices:** Varying cropping practices have different effects on soil erosion.
- **Ground cover:** The greater the groundcover the greater protection of the soil surface from the impact of rainfall.
- **Time:** Soil erosion (as well as soil development) is a function of time.

(Source: van Keer et al. 1996, modified)

BOX 2: Effects of erosion**On-site effects:**

- Losses of water, fertilizers and pesticides (Immediate production loss)
- Loss of soil (Long-term productivity loss)

Off-site effects:

- Deterioration in water quality (e.g. pollution of rivers, death of fish, higher costs of drinking water, etc.)
- Sedimentation of transported soil (e.g. silting up of reservoirs, covering of crops, etc.)
- Flooding of inhabited areas (mud flows, sanded up ditches)
- Rise in peak flows of rivers (destruction of structural works, bridges, etc.)

(Source: FAO 1994, modified)

- protecting the soil surface from the forces of raindrops;
- increasing water infiltration;
- decreasing the speed (force) of runoff water;
- intercepting the transported soil.

Indirect erosion control, such as land use planning, aims at using land in ways that prevent and/or reduce the risk of erosion occurring.

Land Degradation

When land is degraded, its productivity is reduced and may continue to decline unless steps are taken to restore the lost productivity and prevent further losses. Unchecked land degradation may result in an almost total loss of the productive capacity of the land to produce anything of value to humanity. Concern with such an outcome has led to land degradation sometimes being defined as follows:

Land degradation is the loss of the productive capacity of the land to sustain life (IFAD 1992).

However such a definition is perhaps too broad and has somewhat emotive overtones. It ignores the fact that whereas the productive capacity of an area may have been reduced by land degradation, it may still be possible to use the land for productive purposes by adopting alternative land uses, although with an inherent lower productive potential. While land degradation will have taken place, it will not have progressed to the extent that the land can no longer sustain any form of life. It therefore may be more appropriate to define land degradation in a more focused manner as follows:

Land degradation is the reduction in the capability of the land to produce benefits from a particular land use under a specified form of land management (after Blaikie & Brookfield 1987).

Such a definition embraces not only the biophysical factor of land capability, but also such socio-economic considerations as the way the land is used and the products wanted from the land (the benefits).

Components of Land Degradation

There are a number of interrelated land degradation components all of which may contribute to a decline in agricultural production. The most important are:

- **Soil degradation** - decline in the productive capacity of the soil as a result of soil erosion and adverse changes in the hydrological, biological, chemical and physical properties of the soil.
- **Vegetation degradation** - decline in the quantity and/or quality of the natural biomass and decrease in the vegetative ground cover.
- **Biodiversity degradation** - decline in genetic, species and ecosystem diversity (with possible extinction of some species of fauna and flora).
- **Water degradation** - decline in the quantity and/or quality of both surface and ground water resources and increased risk of downstream flood damage.

In addition, at the local level, the following may contribute to declining crop and livestock production:

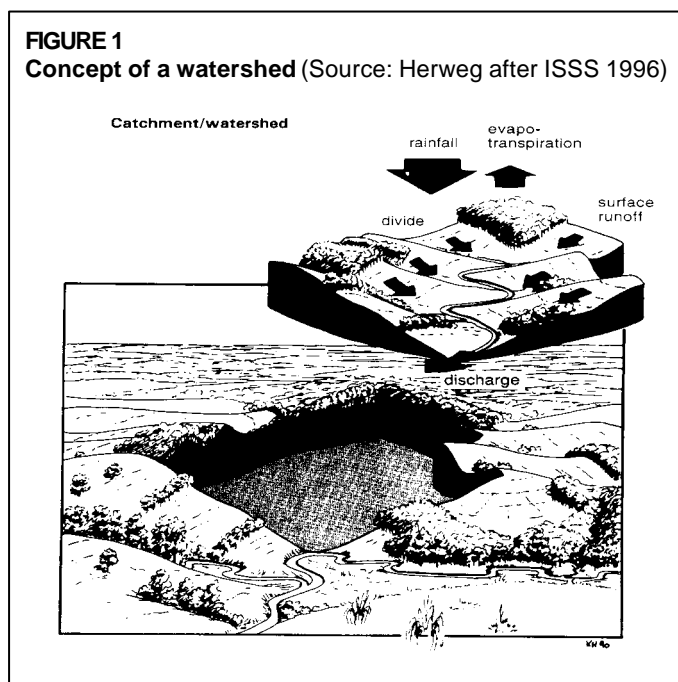
- **Climate deterioration** - changes in the micro climatic conditions that increase the risk of crop failure.
- **Land conversion** - decline in the total area of land used, or with potential, for crop and livestock production as a result of arable land and/or rangeland being converted to urban, industrial, water storage and infrastructural uses.

Soil and Water Conservation

In its narrowest meaning the term soil and water conservation is used for erosion control only. In its broader sense (as it should be understood in an ISM FFS) it refers to all efforts which aim at guaranteeing long-term soil productivity, i.e. using the soil and keeping the soil in a healthy

(physical, biological and chemical) condition as well as preserving it against deterioration and loss.

Soil and water conservation means using the land within the limits of economic practicability while safeguarding it against impoverishment or depletion by erosion, deposition, exhaustion of plant nutrients, accumulation of toxic salts, burning, waterlogging, improper cultivation or any other type of improper use. In the context of agricultural production, the terms “conservation farming” or “good/better land husbandry” are increasingly used as an alternative to soil and water conservation in order to show a change in emphasis from merely conserving soil to improving the sustainability and productivity of the farming system.



Watershed/Catchment Concept

As a topographic and hydrological unit a watershed or catchment can be defined as (see also Figure 1):

the area of land from which rainwater can drain, as surface runoff, via a specific stream or river system to a common outlet point which may be a dam, irrigation system or municipal/urban water supply off take point, or where the stream/river discharges into a larger river, lake or the sea.

Soil and water conservation should deal with all lands within the boundaries of a drainage basin. In the context of an ISM FFS it should not just be concerned with the agricultural lands under cultivation but also focus attention on the need to look at soil and water conservation within the area of the community as a whole, including its forest/woodland areas, range lands, settlement areas and roads/access tracks. The hydrology of a watershed/catchment depends on all its land. Therefore an understanding of the relationship between water movement and agricultural production is crucial for the planning of soil and water conservation efforts. Planning of soil and water conservation interventions at the farm and community level needs to conform to the principles of watershed management (i.e. water flows down hill) and this is a key component of integrated soil management.

FIELD ASSESSMENT OF THE TYPE AND SEVERITY OF SOIL EROSION

The type of erosion taking place as well as its severity and status has to be identified in the field before remedial actions can be determined and appropriate technologies are selected. The status

of erosion at a specific site can be classified as to whether it is active (i.e. still taking place), stabilized (i.e. erosion has taken place in the past but is no longer active), or partly stabilized (i.e. whereas there are some signs that erosion is still taking place there is also evidence that some previously active erosion features are stabilizing).

Water erosion is the most widespread form of degradation within the tropics and occurs widely in all agro-climatic zones. It includes processes such as splash erosion, sheet erosion, rill and gully erosion and mass movement. In arid and semi arid climatic zones wind erosion may also be as serious a problem if strong winds occur when the soil is bare and dry.

- **Splash erosion:** i.e. the spattering of soil particles caused by the impact of raindrops on the soil. The loosened particles may or may not be subsequently removed by runoff; splash erosion is an important component of sheet erosion.

Symptoms to be observed in the field: Poor soil structure at the surface (destroyed soil aggregates). Tendency towards surface sealing and crusting. (See appendix 1)

- **Sheet erosion:** i.e. the removal of a fairly uniform layer of soil from the land surface by runoff or wind.

Symptoms to be observed in the field: After a rainstorm, small heaps of loose soil material can be found between fine lines of sand. Severe sheet erosion results in soil profile removal and can be identified by uncovered roots of trees (see appendix 1).

- **Rill erosion:** i.e. the removal of soil by the cutting of numerous small, but conspicuous water channels by concentrated surface runoff. The marks of rill erosion may be obliterated by ordinary tillage practices.

Symptoms to be observed in the field: Rills (see appendix 1, not to be confused with furrows caused by tillage operations).

- **Gully erosion:** i.e. the removal of soil by the formation of relatively large channels (called gullies) cut into the soil by concentrated surface runoff. In contrast to rills, gullies are too deep to be obliterated by ordinary tillage practices.

Symptoms to be observed in the field: Gullies (see appendix 1). They may develop from deep rills which act as drainage channels or in unstable soil by tunnel formation by undercutting the bank until the overhang drops. Gullies progressively widen and deepen; the gully head moves slope upwards.

- **Mass movement:** i.e. movements of parts of the whole slope. Heavy and/or prolonged rains are usually the triggering factors of mass movements.

Symptoms to be observed in the field: Landslides, mudflows, rock falls and soil creep.

- **Wind erosion,** i.e. the removal of soil by the detrimental forces of wind.

Symptoms to be observed in the field: Wind induced scouring, transportation and deposition of soil, and wind damaged plants.

SOME GENERAL PRINCIPLES FOR SOIL AND WATER CONSERVATION

Water Erosion Control

The dominant soil degradation process faced by almost all resource poor small-scale farmers is water erosion. Whether or not water erosion occurs at a particular site will depend on the

erosivity of the rainfall received, the soil's infiltration capacity and erodibility, slope length and angle, and the amount of ground cover provided by surface litter and growing plants.

Rainfall Erosivity

Erosivity is a function of the physical characteristics of rainfall. As rainfall intensity increases, so in turn does raindrop size (up to certain high intensities), terminal velocity and kinetic energy. Thus, the higher the rainfall intensity the greater its capacity to cause erosion. There will be considerable variation in total annual rainfall between and within different agro-ecological zones from close to zero in desert regions to over 10,000mm in some humid highland tropical areas. Irrespective of the area, total annual precipitation in the tropics typically comes in the form of short duration high intensity rainstorms with maximum intensities associated with individual cyclone events and the occasional typhoon/hurricane. Within the tropics at least some 40% of the annual rainfall can be expected to be received at erosive intensities¹.

Rainfall erosivity is a factor that cannot be modified by man's actions. Given that rain will fall at erosive intensities it has to be regarded as a fixed constraint for integrated soil management purposes. The only options open are to reduce its impact by providing protective ground cover through appropriate crop management and revegetation practices. In an agricultural context the aim should be to ensure the least amount of bare soil at the time the most intensive rainfall can be expected. This could be achieved by such practices as mulching with crop residues and improved crop husbandry designed to provide the maximum crop cover as quickly as possible.

In a reforestation context the aim should be to keep to a minimum the area that has to be kept clear to reduce weed competition during tree seedling establishment. Also it is important to recognize when promoting tree planting as a conservation measure that it is the improved groundcover from litter below the trees rather than the tree canopy itself that provides the bulk of the protection against erosion.

Soil Erodibility

Soil erodibility is a measure of how vulnerable or susceptible the soil is to erosion. This will depend on the soil's structure and structural stability, texture, organic matter content, porosity, and permeability. Erodibility is initially an inherent property of the soil, but can change as a response to management. A soil's erodibility can be increased or decreased by changes in soil organic matter. Within upland areas, land that has been used for dryland annual crops (particularly shifting cultivation) typically has a low soil organic matter content. When such conditions are combined with coarse topsoil textures and weak surface structure it makes for highly erodible soils. A soil's erodibility can be reduced by management practices designed to raise the organic matter content of the topsoil.

Slope Length and Angle

Slope length and angle in the geomorphological sense are unalterable, but their values with respect to erosion can be modified by conservation measures. Effective slope angle can be

¹ Research work in a number of tropical countries suggests that intensities of less than 30mm per hour are virtually non-erosive, with intensities of 30-60mm per hour, some 10% of rainfall will be erosive, once the intensity reaches 100mm per hour, all rain is erosive.

altered only by terracing. However, the cost of terrace construction and maintenance (especially the labour requirement) is high. A shortage of labour within the household can result in low quality terracing which may actually increase soil erosion, should runoff concentrate at low points. Also crop yields may be reduced if during terrace construction the original topsoil is removed or buried and crops end up being planted in less fertile subsoil.

Effective slope length can be reduced by conservation measures of the barrier type. These may be physical structures (e.g. earth banks, stone walls, storm drains and cutoff ditches) or biological barriers (e.g. grass strips, barrier hedges). When considering the use of barriers for erosion control a distinction should be drawn between impermeable and permeable barriers. Impermeable barriers are those, such as ditch and bank structures which check all runoff, either by diversion or by retaining it in situ until it can infiltrate into the soil. Permeable barriers are those which allow some proportion of runoff to pass through. Examples of the latter would be contour stone lines, hedges or grass strips.

By allowing some runoff to flow through them, at a greatly reduced velocity, permeable barriers have an automatic safety valve to cope with the occasional storms of very high intensity that would overtop and destroy earth banks. Hence contour grass strips and hedgerows may be technically suitable alternatives to earth banks in high rainfall areas. Grass strips and hedgerows can also contribute directly to on-farm production by providing fodder, green manure, fuel and mulch.

In semi arid areas crop production is limited by moisture availability. Production benefits may follow the adoption of measures that encourage the conservation and infiltration of rainwater, such as the construction of impermeable cross slope barriers, retention ditches, level and backward sloping bench terraces. However the risk of mass movement increases with increased slope angle, therefore caution should be exhibited in steeply sloping areas, when adopting conservation farming practices that increase infiltration and reduce runoff. Retaining more water in situ may actually accelerate land degradation by mass movement. It therefore must be remembered that not all slopes can be terraced safely, the critical factors being soil type and geological structure and stability. Efforts to introduce terracing on unsuitable slopes can result in catastrophic landslides and mud flows.

There are disadvantages to relying on structures alone to solve soil degradation problems because:

- conservation structures have high direct costs (especially labour) for both initial construction and annual maintenance;
- they may involve foregone costs by taking strips of land - the width of the bank, channel and/or terrace riser - out of crop production, without necessarily producing any immediate benefit to compensate for the reduction in cropped area;
- they can counter only the effects of runoff - they have no effect against rainfall itself (raindrop impact);
- they can prevent gully formation - but have no effect on declining soil fertility as a result of continuous cropping in the inter-bank areas.

Conservation structures provide a means of dealing with excess storm runoff, but on their own cannot substitute for improved conditions of soil structure and cover in the inter-bank areas. They can be used safely and effectively only in support of other improved crop/plant, soil and rainwater management practices.

Ground Cover

Ground cover is the factor that has the greatest impact on the rate of erosion by protecting the soil surface from the impact of erosive rains. It is also easily modified by changes in land and crop management practice. Cover may be provided by the leaves and other parts of plants growing above the surface (the canopy) or the dead materials deposited on the soil surface below the plants (litter). In a natural system the litter would be composed of leaves, stems, twigs, branches, seeds, fruits etc. In cropping and agroforestry systems the canopy will be provided by the growing crop and the leaves of any woody perennials, while the litter may consist of deliberately applied mulch and/or crop residues.

Perennial tree crops with cover crops beneath have the potential to reduce erosion to a fraction of its rate on bare soil. Hence when planting perennial tree crops, as an alternative to annual crops, consideration should be given to interplanting cover crops. Cover crops should not only be conservation effective, but also offer productive benefits. For perennial cover crops to be accepted by farmers they must be easily propagated, require little management, be shade tolerant (so they will continue to provide surface cover as the tree canopy expands) and have some economic value as a food crop, green manure and/or fodder.

Wind Erosion Control

Strong horizontal winds can cause both damage to vegetation and soil erosion. Such winds are a feature of many arid and semiarid climatic zones. They are also a feature of coastal areas that lie within the hurricane and typhoon belts. Wind erosion can be expected when the following conditions occur:

- the soil is loose, dry, and finely divided;
- the soil surface is relatively smooth and plant cover is sparse;
- fields are large and open; and
- the wind velocity is high enough and turbulent enough to move soil particles.

In addition to the problems of wind erosion, the strong dry winds, combined with low humidity, that are a feature of the climate in arid and semi arid climatic zones can adversely affect crop production by:

- reducing the effectiveness of rainfall by evaporation from the soil surface;
- increasing evapotranspiration from the leaf area of growing crops, increasing the risk of moisture stress; and
- causing high evaporation losses from the surface of dams, rivers and irrigation canals.

Wind erosion is restricted to dry soils, and the amount is dependent upon wind velocity and ground roughness. Control measures can therefore be directed towards changing one or more of these factors, that is by maintaining soil moisture, reducing the wind velocity, or increasing soil roughness.

The planting of windbreaks would assist in reducing wind velocity, which in turn would reduce the ability of the wind to dry out the topsoil. Not only would windbreaks serve as a wind erosion control measure, but they would also improve the microclimate for crop production. In addition should there be any risk that irrigation would lead to waterlogging and salinization of the upper soil layers, then the planting of trees, in the form of windbreaks, would provide a means of counteracting this. The roots of mature trees can pump water at depth and thus would help in re-establishing a downwards water circulation in the soil.

For shelter belts or windbreaks with a height of less than some 10 m, a velocity reduction of more than 20% can be obtained up to heights of half the height of the belt and up to distances 15-20 times the height of the belt. Higher belts have relatively less effect. A key requirement of a windbreak is that it must not block the wind velocity. If the wind is blocked it causes serious turbulence just behind the belt. Hence a porous belt (one that the wind can flow through) has much more effect than a very dense one (one that wind has to go round or over). The best effect is obtained with a belt of medium density and a dynamic porosity of about 40-50%.

Shelter belts require good care and maintenance as openings in a belt give rise to higher wind speeds. This can be the case in old belts with heavy trees and a lack of undergrowth. The adverse effect of openings in dense belts is still worse (jet formation). These streams cause locally increased wind erosion or damage to vegetation. The same applies to both ends of a shelter belt. A belt should therefore not be ended abruptly, neither should part of a dense shelter belt be cut off; instead, porous ends should be maintained.

When deciding on the location and extent of shelter belt planting it should be borne in mind that; a) a second belt gives less protection than the first most windward one; and b) shelter belts have the disadvantage of contributing to an irregular windspeed pattern over the field. When a regular decrease in wind velocity is required trees and bushes (for fruit, green manure, fodder, fuel etc) in a variety of agroforestry systems, could be spread evenly and in small groups across the land. An increasing surface roughness and, consequently, a decrease in wind velocity will then result.

Rain Water Management

In arid and semi-arid areas rain water management calls for techniques that will harvest, store and/or spread water with the aim of concentrating moisture locally within a catchment, for the purpose of crop production (e.g. earth and rock bunds, graded channels, rock weirs etc). In slightly higher rainfall areas where moisture may still limit crop production the need is for techniques that will hold rainfall in situ, reduce the velocity of any runoff, and promote infiltration (e.g. hill side ditches, retention terraces, stone lines, tied ridges, planting pits, earth basins, vegetative strips, conservation tillage etc). In humid high rainfall areas the need is for techniques that can utilize the available water (e.g. level paddy rice terraces), control and safely dispose of excess rainfall (e.g. graded terraces and waterways) and drain soils that would otherwise be prone to waterlogging and possible mass movement (e.g. graded hillside ditches and drainage channels).

SOIL AND WATER CONSERVATION TECHNOLOGIES

A soil and water conservation technology consists of one or more of the following complementary measures (agronomic, vegetative, structural and management) that when used in the field would make a positive contribution to soil and water conservation (WOCAT 1998):

- **agronomic:** i.e. measures undertaken within the cropping area for primarily crop production purposes and include practices such as intercropping, contour cultivation, minimum tillage, mulching, manuring etc which are:
 - are usually associated with annual crops;
 - are repeated routinely each season or in a rotational sequence;
 - are of short duration and not permanent;
 - do not lead to changes in slope profile;

- are not zoned; and
- are independent of slope.
- **vegetative**: i.e. measures involving the deliberate planting of trees, shrubs, grasses etc, or retention of areas of natural vegetation (eg. reforestation, windbreaks, contour hedgerows, natural vegetative strips) which:
 - involve the use of perennial grasses/pasture legumes, shrubs or trees;
 - are of long duration;
 - often lead to a change in slope profile;
 - are often zoned on the contour or at right angles to wind direction; and
 - are often spaced according to slope.
- **structural**: i.e. measures involving the construction of physical structures (e.g. graded banks or bunds, contour stone lines, level bench terraces, artificial waterways and drop structures) which:
 - lead to a change in slope profile;
 - are of long duration or permanent;
 - are carried out primarily to control runoff and erosion;
 - require substantial inputs of labour or money when first installed;
 - are zoned on the contour; and
 - are spaced according to slope.
- **management**: i.e. measures arising from deliberate managerial decisions taken with the intention of protecting land from erosion/improving production etc, (eg. land use changes, area closure, rotational grazing) which:
 - involve a fundamental change in land use;
 - involve no agronomic and structural measures;
 - often result in improved vegetative cover; and
 - often reduce the intensity of use.
- **combination**: i.e. measures that combine two or more agronomic, vegetative, structural and management measures (in conditions where one measure does not work effectively without the other), e.g:
 - structural: an outward sloping terrace with
 - vegetative: grass and trees planted on the riser with
 - agronomic: crops grown on contour soil ridges

Appropriate soil and water conservation technologies for ISM are those which offer for a given production situation an optimal solution for using the land for sustainable and productive agricultural purposes. Appropriate technologies are not necessarily “simple” technologies. However, in the context of many developing countries, the appropriate technologies will be ones which are not capital-intensive and which use local resources and the existing labour force in an optimal way.

It should be emphasized that before introducing a new technology it is necessary to check whether local soil and water conservation measures already exist and why and how farmers apply these indigenous technologies. If such technologies exist and continue to be applied by farmers, then, providing they have not been introduced and maintained by legal force and state

authority, they can be considered successful and on investigation will be found to provide the adopters with tangible benefits. Understanding the reasons why farmers use such technologies, i.e. the production and conservation benefits they get from them, is the key to the successful introduction of any “new” technology, which must at least match and preferably improve on the benefits to be obtained from the existing ones.

By May 1998 some 113 soil and water conservation technologies had already been entered into the WOCAT database². It is thus impractical to include, in these guidelines, detailed specifications on the range of soil and water conservation technologies that could be investigated as part of an ISM FFS. However there exists a growing number of technical publications (published at the international, regional or national levels) that provide technical guidelines on alternative soil and water conservation and integrated soil management practices (see appendix 2 for a list of some of these). These should be consulted by those responsible for the preparation of the curricula for individual ISM FFS as reference sources when preparing locally appropriate FFS guidelines.

Normally, farmers recognize the occurrence of erosion processes in their fields. Crucial for the farmer’s decision to take action against erosion is their judgement on importance of the resulting damage. Some criteria for the selection (see also Box 3) of soil and water conservation technologies by farmers are the following (van Keer *et al.* 1996):

- The required labour input should be low.
- The technology should provide short-term benefits.
- The technology should be easy to implement, to maintain and to change.
- There should be no (or minimal) competition for area, light, moisture and nutrients between the soil and water conservation technology and the crop.

BOX 3: List of criteria for screening alternative soil and water conservation technologies

Feasibility under given socio-economic circumstances:

- Does the technology correspond with farmers’ skills?
- Are input and produce markets available?
- Do the farmers have sufficient resources?

Correspondence with farmers’ goals and preferences:

- Is the technology compatible with the cropping pattern and cropping calendar?
- Does the technology conflict with farmers’ preferences?
- Are there interactions between crop and livestock to be considered?

Feasibility under given natural conditions:

- Expected production as compared to present situation?
- Expected stability of production?
- Expected production risks?

Ecological viability:

- Expected effects on the natural environment?
- Expected effects on the long-term productivity?
- Expected effects on diversity of agro-ecosystems?

Economic viability:

- Profitability as compared to present situation?
- Expected effects on produce markets?

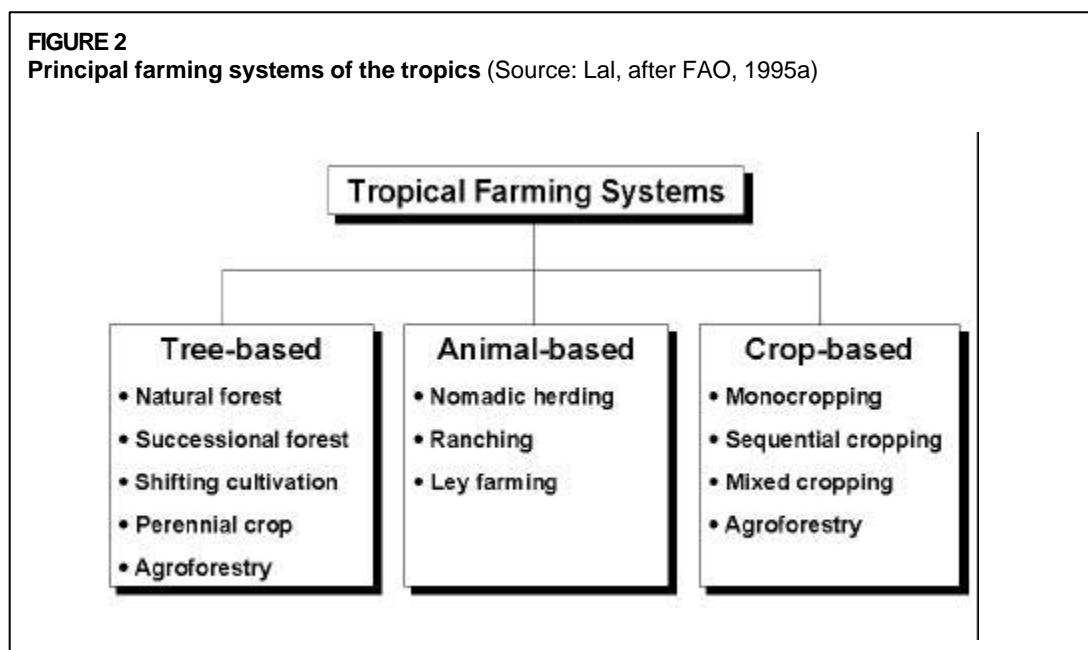
Further Criteria (such as cultural suitability, etc.)

(Source: Werner 1993)

² Database of the World Overview of Conservation Approaches and Technologies (WOCAT) programme of the World Association of Soil and Water Conservation coordinated by the Centre for development and Environment (CDE) of the University of Berne Switzerland.

The selection of technologies depends also on the predominant farming system. In principal there are three main groups of farming systems practices by small-scale farmers in the tropics: tree based, animal-based and crop-based farming systems (see Figure 2). Most ISM farmer field schools will be focused on improving crop-based farming systems, although appropriate ISM FFS curricula could be developed for the other two systems.

FIGURE 2
Principal farming systems of the tropics (Source: Lal, after FAO, 1995a)



Annex 3, Appendix 1

Guidelines for qualitatively assessing the status, type and severity of soil erosion by means of visual indicators

A qualitative estimate of the severity of existing erosion can be obtained through the use of simple visual indicators that can be observed during field inspection of both farm and forest land. The following notes provide examples of some visual parameters that it is believed could be used for assessing qualitatively the state and severity of soil erosion in the course of a transect walk undertaken as part of an ISM FFS. Such visual parameters call for the observer to make a subjective visual assessment based on his/her past experience and local knowledge. It is not possible to give quantitative or precise definitions of what constitutes slight, moderate or severe erosion. There is therefore an element of imprecision in this approach, in that it is possible for different observers to arrive at different classifications for the same area. However it is believed that a degree of uniformity can be achieved by the FFS participants through shared learning and field experience.

STATE OF EROSION

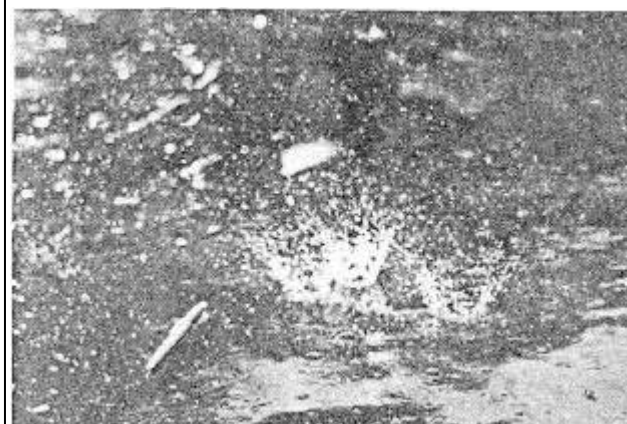
<i>Active</i>	one or both of the following conditions apply: evidence of sediment movement; sides and/or floors of erosion form(s) [e.g. rills, gullies] are relatively bare of vegetation.
<i>Stabilized</i>	one or both of the following conditions apply: no evidence of sediment movement; sides and/or floors of erosion form(s) are revegetated.
<i>Partly Stabilized</i>	evidence of some active erosion but also some evidence of stabilization.

SPLASH EROSION

Splash erosion commonly initiates water erosion and occurs when rain drops fall onto the bare soil surface (Figure 1). Rain drop impact breaks up the surface soil aggregates and splashes particles into the air. On sloping land relatively more of these will fall downslope resulting in a net downhill movement of soil. Some of the soil particles may fall into the voids between the surface aggregates thereby reducing the amount of rain water than can infiltrate into the soil and increasing runoff.

FIGURE 1

In a high-intensity storm, the raindrops hit the ground with great force, compacting the surface and splashing water and soil particles for considerable distances
(Source: Shaxson *et al.*, 1977)



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

SHEET EROSION

Sheet erosion is the relatively uniform removal of soil from an area without the development of conspicuous channels. Indicators of sheet erosion include pedestalling³ (Figure 2), root exposure (Figure 3), exposure of subsoils, and soil deposits against field boundaries, hedge rows and conservation structures down slope.

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

RILL EROSION

A rill is a small channel less than 300 mm deep (Figure 3) which can be completely smoothed out by cultivation with animal or machine drawn implements, although traces (depression lines within the field) may remain where all cultivation is done by hand.

³ Pedestalling occurs when an easily eroded soil is protected from splash erosion by a stone or tree root, isolated pedestals capped by the resistant material are left standing up from the surrounding ground. Providing there is little or no undercutting at the base of the pedestal then the removal of the surrounding soil is the result of splash erosion rather than by surface flow.

No rill erosion	
Slight	A few shallow (< 100mm depth) rills affecting no more than 5% of the surface area.
Moderate	Presence of shallow to moderately deep rills (<200mm depth) and/or rills affecting up to 25% of the surface area.
Severe	Presence of deep rills (up to 300mm depth) and/or rills affecting more than 25% of the surface area.

GULLY EROSION

A gully is a channel 300 mm or more deep (figure 3). It will provide a physical impediment to the movement, across the slope, of animal or machine drawn farm implements. It cannot be smoothed out in the course of normal cultivation.

No gully erosion	No gullies present within the field.
Slight	A few shallow (<0.5m depth) gullies affecting no more than 5% of the surface area.
Moderate	Presence of shallow to moderately deep gullies (0.5-1.0 m depth) and/or gullies affecting 5 - 25% of the surface area.
Severe	Presence of deep gullies (>1m depth) and/or gullies affecting more than 25% of the surface area.

STREAM BANK EROSION

Occurs along the side of banks of rivers and streams and contributes directly to the sediment load of the river system. Can be severe during floods when a considerable volume of water is flowing at great speed.

No stream bank erosion	Stream bank with close to 100% vegetative cover and no active erosion (rill and/or gully erosion) on the bank. Little if any signs of undercutting on the outer bends of meanders and little active deposition of sediment on the inside.
Slight	Limited loss of vegetative cover (>80% cover remaining) and no worse than slight erosion on the mid to upper portion of the stream bank. <5% of the meanders over a 1km stretch with active undercutting of only the lower portion of the bank on the outer bends of meanders and some deposition of sediment on the inside.
Moderate	Moderate loss of vegetative cover (50-80% cover remaining) and slight to moderate erosion on the mid to upper portion of the stream bank. 5-15% of the meanders over a 1km stretch with active undercutting that may extend into the mid portion of the bank on the outer bends of meanders and moderate deposition of sediment on the inside.
Severe	Severe loss of vegetative cover (<50% cover remaining) and moderate to severe erosion on the mid to upper portion of the stream bank. >15% of the meanders over a 1km stretch with active undercutting extending up to the upper portion of the bank on the outer bends of meanders and heavy deposition of sediment on the inside.

MASS MOVEMENT

This includes all relatively large down-slope movement of soil, rock or mixture of both, e.g. landslides, slumps, earth flows and debris avalanches. This category of land degradation would be described for relatively large land units, such as watersheds, rather than for individual fields.

Status

<i>Active</i>	Landslide scars clearly visible with sharp boundaries and less than 10% vegetation cover within the landslide area.
<i>Stabilized /Inactive</i>	Landslide scars still detectable but no longer with sharp boundaries and with greater than 50% vegetation cover within the land slide area.
<i>Partly Stabilized</i>	Landslide scars clearly visible with vegetation cover between 10-50% of the area of landslide.

Severity

No mass movement	None	No evidence of mass movement (no visual signs of land slides, or mass slumping)
Present	Slight	Isolated examples of mass movement. Individual events small in size and/or affecting less than 0.1% of the total area.
	Moderate	A moderate number of mass movement events. Individual events small to moderate in size and/or affecting 0.1-1.0% of the total area.
	Severe	Significant number of mass movement events. Individual events may be large in size and/or affecting over 1% of the total area.

WIND EROSION

Wind erosion involves both the removal and deposition of soil particles by wind action and the abrasive effects of moving particles as they are transported. It occurs when soil is left bare of vegetation as a result of cultivation, and/or overgrazing following overstocking. Not only can the wind remove topsoil from good farm land but can result in additional damage by burying land, buildings, machinery and fences with unwanted soil.

Strong horizontal winds can cause both damage to vegetation and soil erosion. Wind erosion can be expected when the following conditions occur:

- the soil is loose, dry, and finely divided;
- the soil surface is relatively smooth and plant cover is sparse;
- fields are large and open; and
- the wind velocity is high enough and turbulent enough to move soil particles.

Not apparent	No obvious signs of wind erosion but evidence of minor wind erosion may have been masked by for instance recent tillage.
None	No visual indicators of wind erosion.
Slight	Some visual evidence of the movement by wind of soil particles within individual fields; no evidence of wind scouring with only a few superficial roots exposed; deposits of wind blown soil at field margins or where the winds progress has been obstructed under 2 cm thickness; little accumulation of wind blown soil in drainage ditches.
Moderate	Clear signs of the transportation and deposition of soil particles by wind, some scouring but no more than 5 cm in depth; some tree and crop roots exposed within the topsoil; deposits of wind blown soil at field margins or where the winds progress has been obstructed 2-5 cm thickness; moderate accumulation of wind blown soil in drainage ditches.
Severe	Clear evidence of the wholesale transportation and deposition of soil particles by wind; extensive scouring with individual scours over 5 cm in depth; extensive exposure of tree and crop roots; subsoil horizons exposed at or close to the soil surface; drainage ditches filled with wind blown soil; elsewhere original soil surface buried beneath at least 5 cm of wind blown soil.

FIGURE 2

Soil that is not protected from the raindrops' force is splashed and carried away. Pedestals of soil are left standing where more resistant materials provide a protective cover(Source: Shaxson *et al.*, 1977)

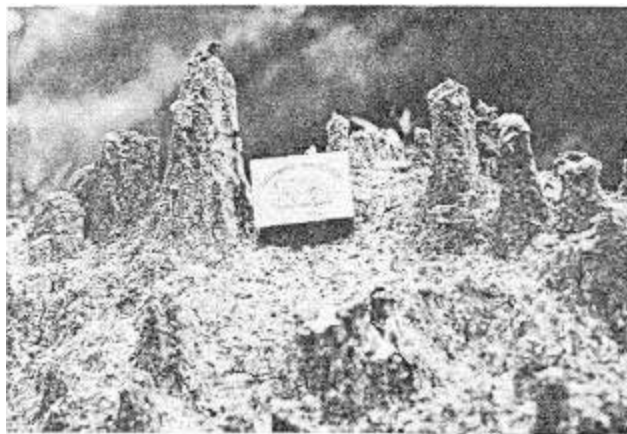
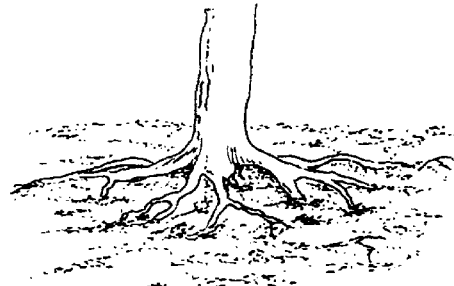
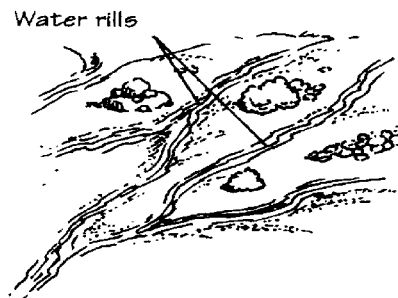


FIGURE 3
Different erosion processes (Source Vukasin *et al.*, 1995)



SHEET EROSION



RILL EROSION



GULLY EROSION

Annex 3, Appendix 2

Sources of information on soil and water conservation technologies

In 1992 a world wide programme known as the World Overview of Conservation Approaches and Technologies (WOCAT) was launched by the World Association of Soil and Water Conservation (WASWC) with the aim of systematically collecting and sharing information, between countries, about different soil and water conservation technologies and approaches. The WOCAT programme has to date worked with a number of collaborating institutions, at the national and international levels, to gather data from a large part of Africa and in some countries in Asia notably Thailand, China (Fujian Province) and the Philippines.

In May 1998 WOCAT produced its first major output in the form of a CD-ROM, released as FAO Land and Water Digital Media series No. 3. This CD-ROM contains not only the WOCAT database software, but also the available results from the collaborative documentation exercises conducted over the last few years. To date some 113 technologies and 75 approaches have been documented, by being entered into the WOCAT database.

Information on the availability of the CD-ROM, and the individual technologies and approaches contained in the WOCAT database, can be obtained from:

CDE WOCAT
Hallerstrasse 12
CH - 3012 Berne
Switzerland
Tel +44 31 631 88 22
Fax +44 31 631 85 44
E-mail: wocat@giub.unibe.ch

FAO
Chief AGLL
Viale delle Terme di Caracalla
00100 Rome
Italy
Fax +39 06 570 56275
E-mail: land-and-water@fao.org
Internet: <http://www.fao.org>

In addition to the WOCAT database a number of soil and water conservation/integrated soil management technologies and approaches are documented in a growing range of publications produced by international, regional, national and local agencies. The following are just some of those that are available:

International/Global Coverage

FAO 1984. *Tillage systems for soil and water conservation*. Soils Bulletin 54.

FAO 1985. *Watershed Management Field Manual - Vegetative and Soil Treatment Measures*. FAO Conservation Guide No. 13/1

FAO 1986. *Watershed Management Field Manual - Gully Control*. FAO Conservation Guide No. 13/2

- FAO 1987. *Soil and Water Conservation in Semi-arid Areas*. Soils Bulletin No. 57
- FAO 1988. *Watershed Management Field Manual - Slope Treatment Measures and Practices*. FAO Conservation Guide No. 13/3
- FAO 1988. *Watershed Management Field Manual - Landslide Prevention Measures*. FAO Conservation Guide No. 13/4
- FAO 1989. *Soil Conservation for Small Farmers in the Humid Tropics*. Soils Bulletin No. 60
- FAO 1991. *Water Harvesting - a Manual for the Design and Construction of Water Harvesting Schemes for Plant Production*. AGL/MISC/17/91
- FAO 1995. *Tillage Systems in the Tropics - management options and sustainability implications*. Soils Bulletin No. 71. FAO Rome
- FAO 1995. *Sustainable Dryland Farming in Relation to Soil Productivity*. Soils Bulletin No. 72 FAO Rome
- FAO 1996. *Land Husbandry Components and Strategy*. Soils Bulletin No. 70 FAO Rome
- FAO 1999. *Integrated soil management for sustainable agriculture and food security*. AG"/MISC/23/99 FAO Rome
- Herweg K. 1996. *Field Manual for Assessment of Current Erosion Damage*. Soil Conservation Research Programme Ethiopia and Centre for Development and Environment, Institute of Geography, University of Berne, Quartiergasse 12, CH-3012 Berne, Switzerland.
- Ingram J. 1990. *The Role of Trees in Maintaining and Improving Soil Productivity - A Review of the Literature*. Series No. CSC(90)AGR-15 Technical Paper 279 Commonwealth Science Council London.
- Vukasin H.L. [ed.] 1988. *Guidelines for Planning Environmentally Small-scale Agricultural Projects*. Arlington CODEL/VITA
- Wijewardene R & Waidyanatha P. 1984. *Systems, Techniques & Tools - Conservation Farming for Small Farmers in the Humid Tropics*. Commonwealth Secretariat Marlborough House London.
- World Neighbours 1985. *Introduction to Soil and Water Conservation Practices*. Oklahoma City USA.
- World Neighbours 1988. *Integrated Farm Management*. Oklahoma City USA.
- Young A. 1989. *Agroforestry for Soil Conservation*. Science and Practice of Agroforestry No 4. ICRAF Nairobi Kenya/CAB International Wallingford UK.

Asia Regional Coverage

- APAN 1996. *Asia-Pacific Agroforestry Profiles: Second Edition*. Asia-Pacific Agroforestry Network Field Doc. No. 4/RAP Publication 1996/20. FAO Regional Office for Asia and the Pacific, Bangkok.
- FAO & IIRR 1995. *Resource Management for Upland Areas in Southeast Asia - An Information Kit*. FARM Field Document 2. FAO RAP Bangkok Thailand, IIRR Cavite the Philippines.

Hafeez S. 1998. *Appropriate Farm Technologies for Cold and Dry Zones of the Hindu Kush-Himalayas*. ICIMOD, Kathmandu Nepal

Partap T & Watson H.R. 1994. *Sloping Agricultural Land Technology (SALT) a Regenerative Option for sustainable Mountain Farming*. ICIMOD Occasional Paper No. 23. Kathmandu Nepal

Africa Regional Coverage

Chinene V.R.N, Shaxson T.F., Molumeli P.R., Segerros M. and Douglas M.G. 1996. *Guidelines to Better Land Husbandry in the Southern African Region*. Environment and Land Management Sector SADC Maseru Lesotho

Critchley W. 1991. *Looking After Our Land New Approaches to Soil & Water Conservation in Dryland Africa*. IIED/OXFAM Oxford.

Hai M.T. 1998. *Water Harvesting: An Illustrative Manual for Development of Micro-catchment Techniques for Crop Production in Dry Areas*. Regional Land Management Unit RELMA/SIDA Nairobi Kenya.

Rocheleau D., Weber F. & Field-Juma A. 1988. *Agroforestry in Dryland Africa*. ICRAF Nairobi Kenya.

Caribbean Regional Coverage

Gumbs F.A. 1987. *Soil and Water Conservation Methods for the Caribbean*. Department of Agricultural Extension, University of West Indies, Trinidad

Country Specific Examples

1. China

MWR. 1989. *Terraces in China* Ministry of Water Resources, Beijing, People's Republic of China.

2. Ethiopia

CFSCD 1986. *Guidelines for Development Agents on Soil Conservation in Ethiopia*. Community Forests and Soil Conservation Development Department, Ministry of Agriculture Addis Ababa, Ethiopia.

3. India

Kerr J & Sanghi N,K. 1992. *Indigenous Soil and Water Conservation in India's Semi-Arid Tropics*. Gatekeeper Series No. 34 Sustainable Agriculture Programme International Institute for Environment and Development (IIED) London.

4. Kenya

Thomas D. 1997 *Soil and Water Conservation Manual for Kenya*. published by the Soil and Water Conservation Branch, Ministry of Agriculture, Livestock & Marketing, Nairobi.

5. Malawi

Shaxson T.F., Hunter N.D., Jackson T.R., & Alder J.R. 1977. *A Land Husbandry Manual*. Government Printer Zomba Malawi.

6. South Africa

Philip D et al. 1995. *People's Farming Workbook*. Environmental & Development Agency Trust, Capetown & Jo'burg ISBN 0 86486 112 5.

7. Philippines

Agroforestry Technology Information Kit. DENR, IRRI and the Ford Foundation.

Agroforestry Species for the Philippines. US Peace Corps, Technology Support Center, 2139 Fidal A. Reyes St. Malate, Manila 1004.

Ipil-Ipil Hedgerows For Soil Erosion Control in Hillylands. Celestino A.F. 1985. FSSRI College of Agriculture UPLB Laguna.

Resource Book - On Sustainable Agriculture for the Uplands. IRRI, Mindanao Baptist Rural Life Centre, Mag-uugmad Foundation, World Neighbours.

Sloping Agricultural Lands Technology. PCARRD Technology Series.

Soil Erosion Control Measures for the Uplands. Philippines Uplands Resources Center, de la Salle University Research Center, 2401 Taft Avenue, Manila 1004.

Annex 4

Farm and community level problem analysis methods

A. USE OF CAUSAL DIAGRAMS

Unless the causes of a problem are clearly understood inappropriate interventions may be proposed for solving field level soil management problems. Causal diagramming is a valuable technique for determining and explaining the complex relationships between different causes and how their effects, individually or combined lead to a particular problem. By clearly demonstrating these interrelationships the technique can help avoid or resolve differences between the participants of an ISM FFS as to which of their list of identified problems are the key ones, which are in reality causes, and how the various causes and constraints identified are linked.

In causal diagramming a potential cause or constraint that contributes to a particular problem is known as a causal factor. Not all causal factors are equal or have a direct effect on the problem. Some will be more distantly related to it than others and yet still be a contributory factor to it. This can be demonstrated through the use of causal chains linking the various causal factors in a logical sequence to the problem. The causal chain below shows that the causal factor of low soil fertility has the effect of producing low crop yields which in turn is the ultimate cause of the farm households key problem namely food shortage.



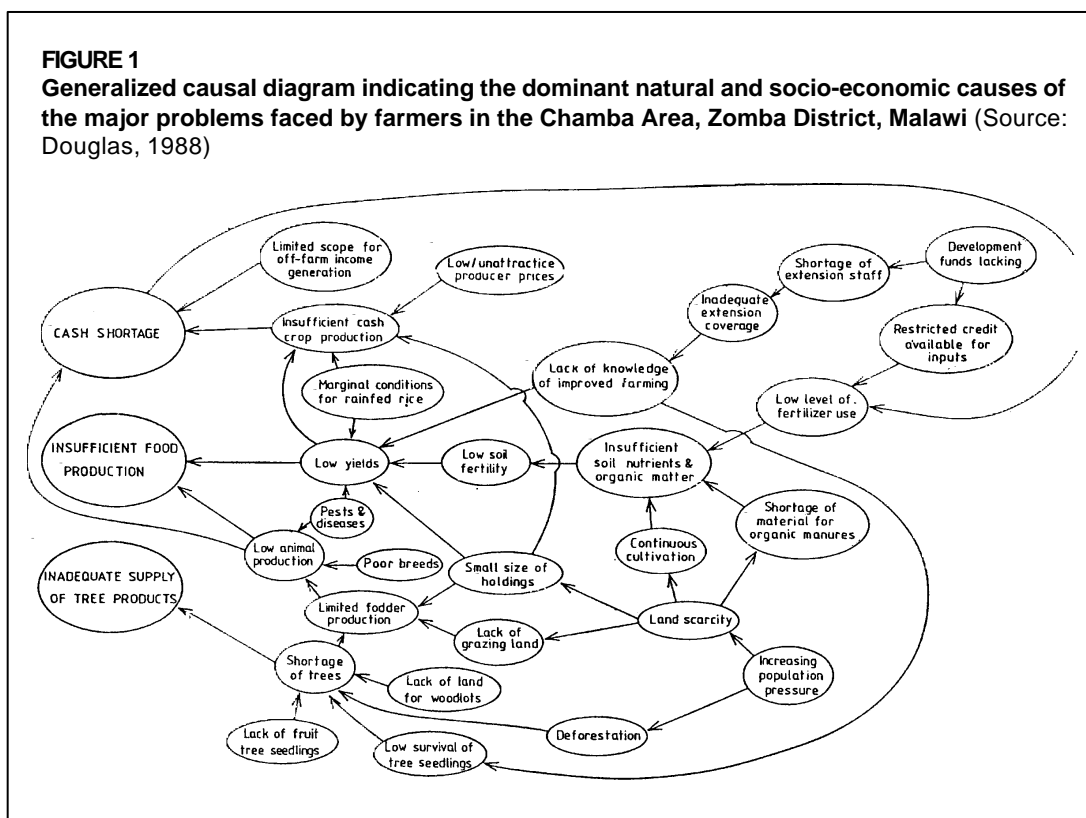
Developing a Causal Diagram

The procedure for developing a causal diagram is as follows:

- Identify the problem(s) to be explained.
- Identify the causal factors involved in the generation of each problem.
- Decide on a word, short phrase or symbol to describe the problem and enter on the left-hand side of the diagram and draw an oval around it.
- Decide on words, short phrases or symbols for the causal factors related to the problems. Starting with the most significant factors enter these in ovals to the right of the problem.
- Examine the various factors and draw arrows between the ovals to show the cause and effect relationships between them. The arrows pointing from the cause to the effect and resulting in a series of chains linking the various causal factors in a logical sequence to the problem.
- Clean up the first draft of the diagram resulting from the previous step. Make any necessary modifications to improve its consistency and clarity. Rearrange the position of the ovals as needed so as to produce an orderly progression from right to left in the diagram.

Identification of Intervention Points

Causal diagrams can be used to identify points within the system where there could be scope for intervention at the field and/or policy level with the aim of tackling a particular problem by combating the causes or removing the constraints to increasing production on a sustainable basis. The diagram is likely to reveal a number of possible points for intervention and the FFS participants will need to determine which have the most potential to make an impact on the problem and which constraints have to be overcome before other potential interventions can have any effect. The diagram can also reveal which causes are, for all intents and purposes, fixed constraints i.e. those that cannot at the present time be overcome by means of a technical or policy intervention for one or more bio-physical, social, economic or political reasons.



B. PROBLEM TREE ANALYSIS

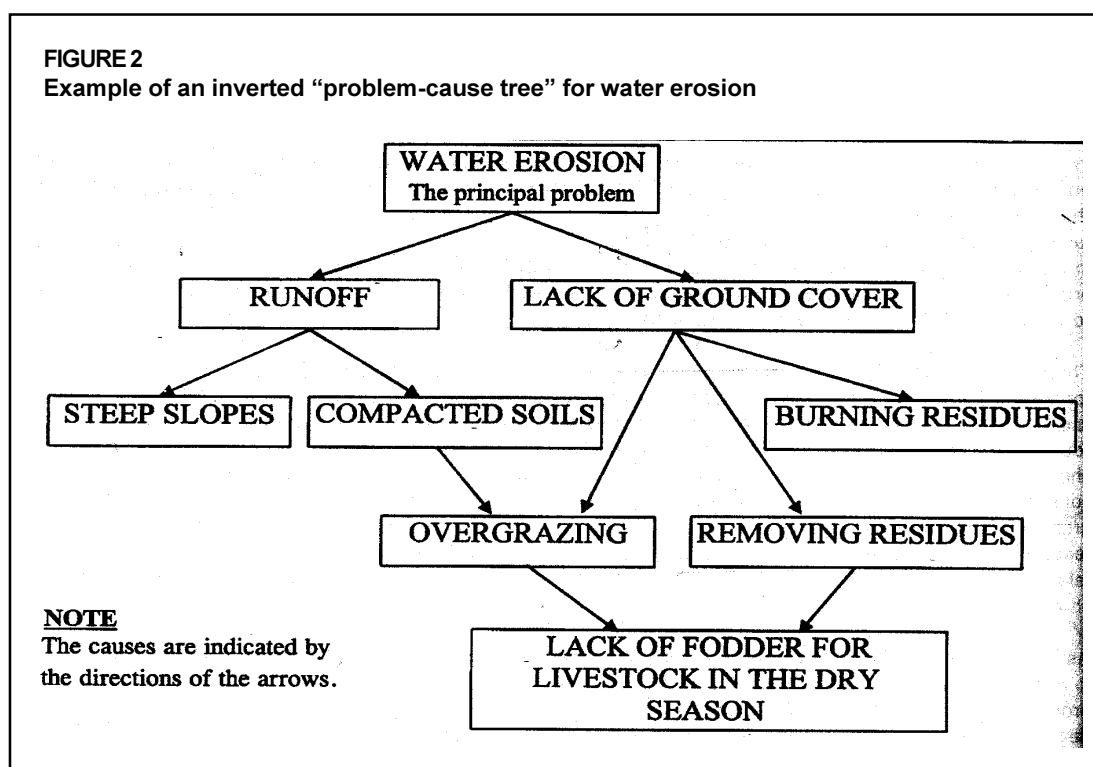
In this method, the major problems contributing to each of the identified constraints is analyzed on the basis of available information. The main causal relationships between the problems are then visualized in a problem tree. A problem tree consists of a diagram illustrating a set of relationships amongst problems, by fitting them in a hierarchy of cause and effect relationships. In such a diagram the causes are presented at lower levels and the effects at upper level. The organization of problems in a logical sequence should lead to logical conclusions and eventually to the identification of effective solutions.

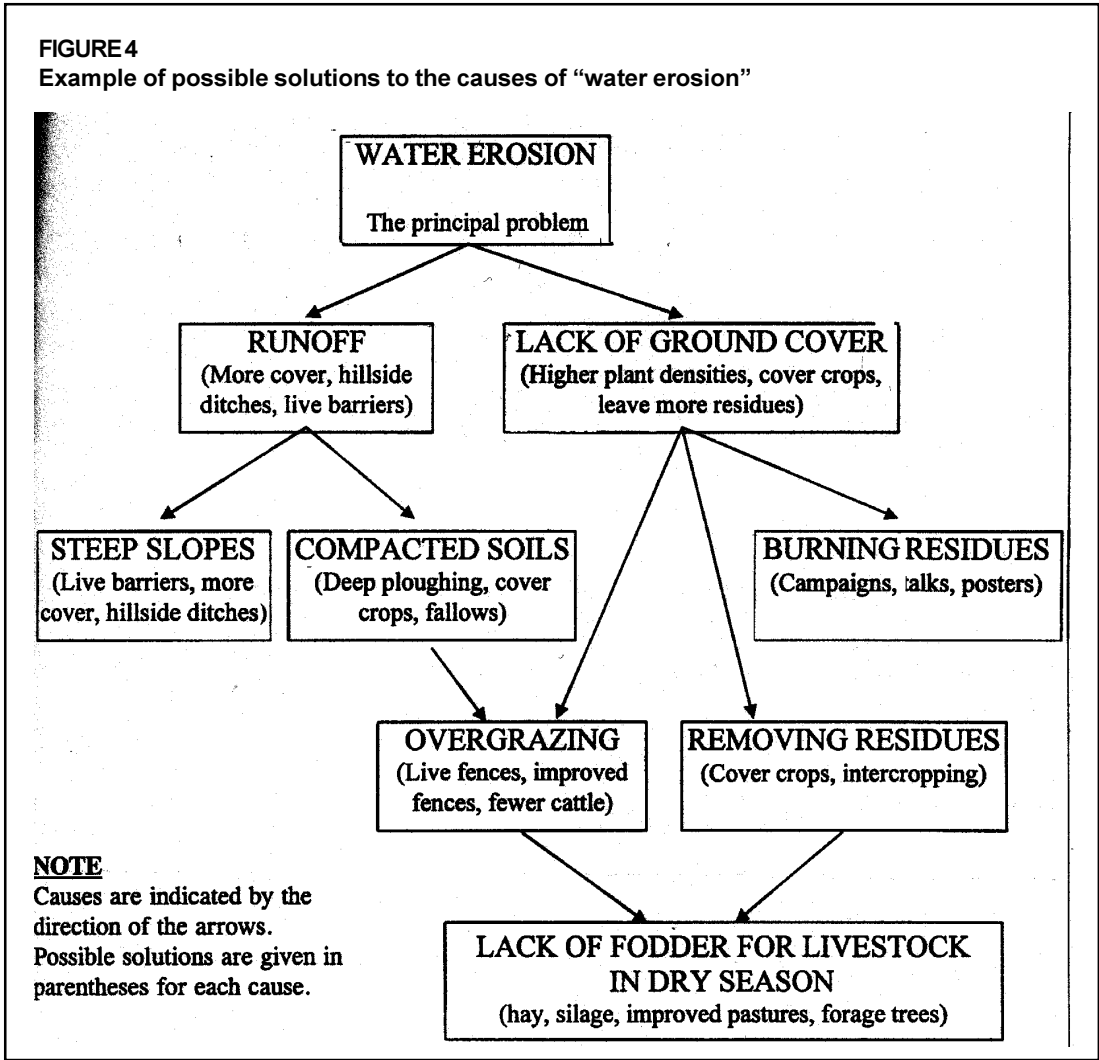
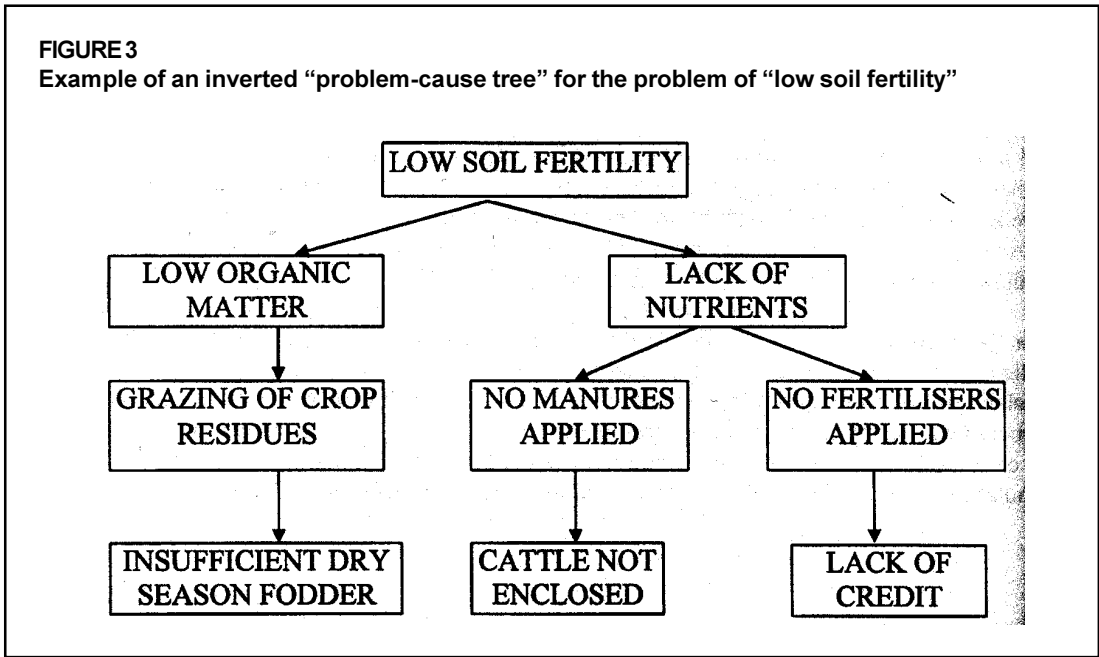
The starting point for constructing a problem tree is the identification of major existing problems (or focal problems) based on brainstorming and using available information. 'Mobile Cards' are used for this purpose, with each participant writing down (or using a symbol) a suggestion for a

focal problem (which he or she considers to be the central point of the over all problem). It should be kept in mind that a focal problem is an existing negative state but not the absence of solution. For example sodicity of soil is a problem, but non-availability of gypsum is not. The group should discuss each proposal and try to agree on one focal problem. If agreement is not reached, the proposed problems are arranged in a problem tree, according to casual relationships between them, and on the basis of the overview achieved in this way, the group should try again to agree on the focal problem

As the next activity, substantial and direct causes of the focal problem are identified and placed in parallel on the line directly underneath. Similarly, substantial and direct effects of the focal problem are identified and placed in parallel on the line above. Causes and effects are further developed along the same principle, at several levels, to form the problem tree. The process can be concluded when the participants are convinced that all essential information has been included in the network, in order to explain the main cause-effect relationships characterizing the problem. Care should be taken that it is not stopped until the root or underlying causes are clearly specified. The location of the problem in a tree diagram does not necessarily indicate its level of importance, but simply its position in a logical sequence of cause-effect relationships. As there are likely to be many changes to the problem structure during the course of the exercise, the use of pin boards or magnetic boards with problem boxes represented on small pieces of paper or cardboard (mobile cards) is recommended. These could be moved around regrouped or rearranged during the discussions.

After the construction of the tree is completed, it is reviewed, its validity and completeness verified, and necessary adjustments made. At this stage, working from the bottom upwards, all the elements of the tree are reformulated into positive desirable conditions. Each problem is examined systematically, to determine which could be solved by interventions at the household and community levels and which ones could not. This should provide one basis on which to formulate options for solving the identified problems. (See figures 2-4).





Annex 5

Forms for use during the farmer field school evaluation

TABLE 1
Form for recording data and calculating gross margins

Inputs			Costs		Other Cost
Amount (kg, l)	Cost	Hired labour (Days, hours)	Cost		
Seed					Equipment
Fertilizer					Medicine
Pesticides					for animals
Water					Spare parts
Bags					Threshing
Transport					
Petrol					
Total costs		Total costs		Total costs	
Total cash costs		<input style="width: 100px; height: 20px;" type="text"/>			

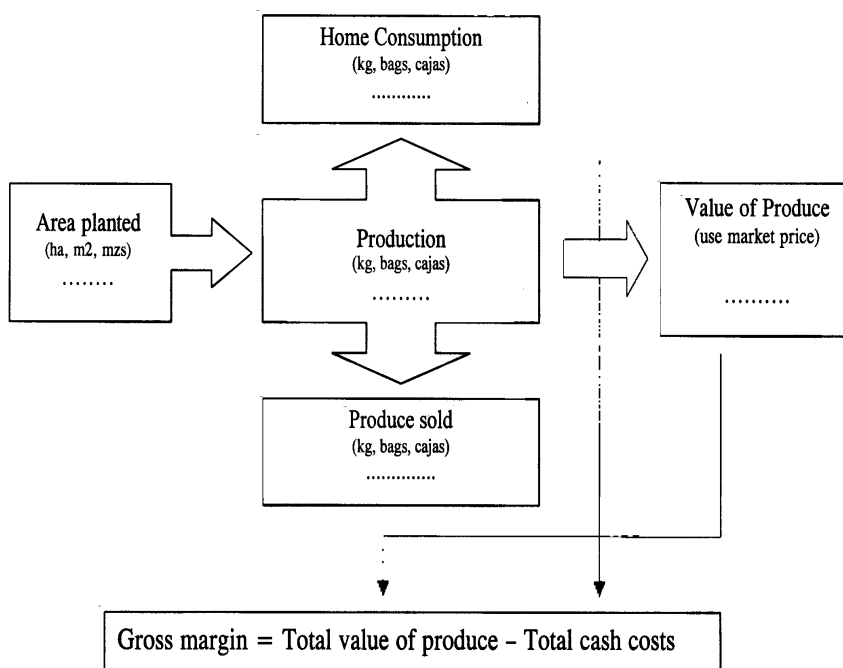


TABLE 2
Evaluation form for soil productivity changes

	Column A	Column B	Column C
	Increased	Decreased	Not changed
Part 1 Positive factors			
Crop yields have ...?			
Crop growth vigour has ...?			
Overall impression is that soil fertility has ...?			
Dark colour of the topsoil has ...?			
Frequency of including legumes has ...?			
Use of manures has ...?			
Use of composts has ...?			
Use of mulches has ...?			
Use of green manures has ...?			
Use of cover crops has ...?			
Use of crop rotations has ...?			
Use of zero or minimum tillage has ...?			
Use of intercropping and relay crops has ...?			
Plant density has ...?			
Quantity of surface residues has ...?			
Activity of worms has ...?			
Numbers of biopores have ...?			
Ease of tillage has ...?			
Total number of checks (+)			

Part 2 Negative factors			
	Column A	Column B	Column C
	Increased	Decreased	Not changed
Nutrient deficiency symptoms have ...?			
Weed incidence has ...?			
Numbers of grass weeds have ...?			
Frequency of crop water stress has ...?			
Frequency of crusting/sealing has ...?			
Frequency of low emergence rates has ...?			
Frequency of surface ponding has ...?			
Frequency of restricted rooting has ...?			
Need for subsoiling has ...?			
Frequency of waterlogging has ...?			
Frequency of runoff from rainstorms has ...?			
Frequency of rilling has ...?			
Frequency of gullies has ...?			
Frequency of wind erosion has ...?			
Total number of checks (+)			

Positive changes = Total No. of (+) Part 1, column A + Part 2, column B =	(X)
Negative changes = Total No. of (+) Part 1, column B + Part 2, column A =	(Y)
No changes = Total No. of (+) Part 1, column C + Part 2, column C =	(Z)
Overall change in soil health = (X) - (Y) - (Z) =	(J)

TABLE 3
Evaluation form of ISNM course modules

Evaluation of the usefulness, quality and level of understanding of the ISNM course modules, principles and skills.

Rating	Module/Principle/Skill				
	1	2	3	4	5
<i>Usefulness</i>					
Very beneficial					
Beneficial					
Not beneficial					
<i>Quality</i>					
Acceptable as is					
Needs to be improved					
Needs less time					
Needs more time					
<i>Level of understanding</i>					
Well understood					
Moderately understood					
Poorly understood					

TABLE 4
Evaluation form for FFS organization and facilitator

Evaluation of FFS organization and the facilitator's ability

	Good	Acceptable	Needs Improvement
<i>FFS organization</i>			
Duration			
Timing of sessions			
Length of sessions			
Locations			
Suitability for women			
Visits			
Exercises			
Skills			
Field testing of possible solutions			
<i>Facilitator's ability</i>			
Knowledge			
Ability to communicate			
Understanding of farmers problems			
Willingness to listen to farmers			
Receptivity to farmers suggestions			

TABLE 5
Form for suggestions

Suggestions on improvements

<i>General suggestions</i>	
Should there be more/less/same time devoted to:	
exercises?	
discussions?	
field tests?	
talks?	
visits?	
<i>Specific suggestions</i>	
Which new topics/skills should be:	
included?	
excluded?	
given less time?	
more time?	
How can the organisation of the FFS be improved?	

Annex 6

Foliar nutrient deficiency symptoms

COLOUR CHANGES IN LOWER LEAVES

Nitrogen: Appearance of a light green to pale yellow colour on the older leaves, starting from the tips. This is followed by death and/or by dropping of the older leaves depending on the degree of deficiency.

Phosphorus: The mature leaves have characteristic dark green to blue green colouration. In acute deficiency occasional purple colours may be seen on the leaves and stems. Also restricted root development, delayed maturity and poor seed and fruit development.

Potassium: Loss of green colour along the leaf margins followed by scorching and browning of the tips of older leaves. These symptoms then gradually progress inwards. Also slow and stunted growth, weak stalks and plants lodge easily.

Magnesium: Symptoms often appear in seedlings, the area between the veins becomes yellow to white, mainly on older leaves, producing a streaked or patchy effect. With acute deficiency the affected leaf may become reddish-purple from the edge inwards, then dries up and dies.

Zinc: Deficiency symptoms generally appear on the second or third fully mature leaves from the top of the plant. In maize the symptom is a light yellow striping to a broad band of white or yellow tissue with reddish purple veins between the midrib and the leaf edges, occurring mainly in the lower half of the leaf. In rice after 15-20 days from transplanting, small scattered light yellow spots appear on the older leaves, which later enlarge, coalesce and turn deep brown. The entire leaf becomes rust brown and dries out within a month.

COLOUR CHANGES IN UPPER LEAVES AND THE TERMINAL BUD DIES

Calcium: Calcium deficiencies are seldom seen because the secondary effects due to high acidity often dominate. The young leaves of new plants are first affected, they are often distorted, small and abnormally dark green. Leaves may be cup-shaped and crinkled. Terminal buds may die under severe deficiency, and root growth impaired or rotting of roots.

Boron: Leaves near growing point become light green to yellow, growth buds appear as white or light brown dead tissue.

COLOUR CHANGES IN UPPER LEAVES AND THE TERMINAL BUD REMAINS ALIVE

Sulphur: Younger leaves including the veins turn uniformly yellowish-green to yellow.

Iron: Interveneal areas of youngest leaves yellow to almost white, the points and margins of the leaves keep their green colour longest.

Copper: In cereals young leaves become uniformly pale yellow, or may wilt and wither without losing its green colour.

Manganese: Young leaves show pale green to yellow colour with dead spots between the veins. Greyish areas appear near the base of younger leaves and become yellow to yellow-orange.

PLATE 1
Nitrogen deficiency in maize (FAO 1984)



PLATE 2
Phosphorus deficiency in maize (FAO 1984)



PLATE 3
Potassium deficiency in soybean (FAO 1984)



PLATE 4
Magnesium deficiency in maize
(FAO 1984)



PLATE 5
Zinc deficiency in maize (Loué 1993)



PLATE 6
Copper deficiency in wheat (Loué 1993)



PLATE 7
Calcium deficiency in Banana (Belger *et al.*)



PLATE 8
Sulphur deficiency in rice (FAO 1984)



PLATE 9
Manganese deficiency in wheat
(Loué 1993)



PLATE 10
Manganese deficiency in banana (Loué 1993)

